Cardiocirculatory Assistance and Total Artificial Heart

Historical Review

Abstract

* Domingo Liotta, Michael DeBakey, Denton Cooley and Stanley Crawford created the Cardiocirculatory Assistance —*Left Ventricular Assist Systems*— at Baylor University College of Medicine, Houston, Texas, USA (1962) and started the clinical application.

* Domingo Liotta and Denton Cooley developed the clinical use prosthesis for the total replacement of the heart in orthotopic position at Baylor University College of Medicine and the Texas Heart Institute and started its clinical application (1969.)

* Domingo Liotta started the development of Cardiocirculatory Assistance in Argentina (1971 – work in progress.)

* Today, new possibilities for the treatment of advanced heart failure are arising on the horizon of cardiocirculatory assistance and the total artificial heart♠. Cardiac transplantation is not a solution regarding the real epidemic of patients who have severe heart failure, basically due to the lack of donors and the gradual increase of the disease as it is observed in the clinical practice.

1. Introduction

Cardiocirculatory Assistance and the *Total Artificial Heart* are systems employed all over the world nowadays. The development and use of these systems have been diversified according to the type and models; however, the clinical origin of their use can be found in the pioneer works carried out by Domingo Liotta in the 60s.

The first models of electro-pneumatically driven pulsatile cardiocirculatory assist devices were implemented and today there exist pulsatile and continuous-flow devices, in a wide range of technology. Throughout 40 years their application, which was originally thought to be a bridge to recovery for patients in postcardiotomy shock (during the surgery), has been diversified: 1- as a bridge to cardiac transplantation; 2- myocardial recovery; and 3- permanent implantation.

2. Initial Development of Total Artificial Heart

Basic Laboratory Work

1- Université de Lyon (Lyon University) (France, 1959): Theoretical studies on hemodynamics maintained by means of mechanical devices, including their energy sources after total removal of the heart.

2- Universidad Nacional de Córdoba (Córdoba National University) (Argentina, 1960): Studies on the development of 3 systems- electrical, mechanical and pneumatic- and on their implantation in dogs, with survival observations after total removal of the heart, were carried out. In that year, 1960, an unprecedented one regarding the progress made, there appeared the dear and estimable figure of the old Engineer Tomasso Taliani; a gem at the dawn of bioengineering.[1, 2]

3- Cleveland Clinic (USA, 1961): At the beginning of the 1960s, Dr. Liotta was invited by Dr. William J. Kolff, the famous creator of the artificial kidney, to his Artificial Organ Department at the Cleveland Clinic in USA. In that Department Dr. T. Akutsu conducted experiments in the animal laboratory on the total replacement of the heart with mechanical circulation.

As of that moment, Dr. Liotta has acknowledged Dr. Kolff as the scientist and the most virtuous and noblest person he has ever met.♣

In the late 1960s, Dr. Kolff invited Dr. Liotta to the Conference of the American Society for Artificial Internal Organs (ASAIO) held in

♠ *Professor Alain F. Carpentier of the Hôpital Européen Georges Pompidou in Paris is actively working on the development of an orthotopic total artificial heart ready for clinical use by 2011 and for alternative to transplant in 2013.*

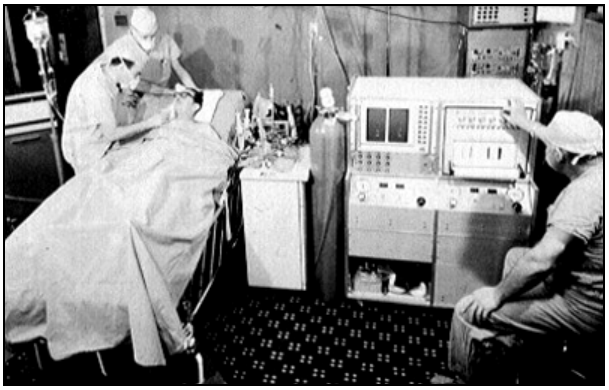
♣ *Extracted from the book: Domingo Liotta: AMAZING ADVENTURES OF A HEART SURGEON.The Artificial Heart: The Frontier of Human Life. iUniverse, 2007, chapter 27, page 225*

Atlantic City; thus he could communicate his experiences in Córdoba and their preliminary outcomes.

Among the relevant attendants to the Conference was Dr. Michael DeBakey, who offered Dr. Liotta a one-year fellowship in his Cardiovascular Surgery Service at the Baylor University College of Medicine, Houston, Texas.

Total Artificial Heart Clinical Application

Baylor University and Texas Heart Institute (Houston): Development of the Total Artificial Heart (TAH) as a bridge to heart transplantation and its first clinical application in the history of medicine. On April 4 1969, Denton Cooley and Domingo Liotta replaced the heart of a dying man with an Orthotopic Total Mechanical Heart (inside the pericardium sac) after removing the severely damaged native heart. This artificial heart kept the patient alive for 64 hours until the cardiac transplant was performed.[3,4]



Dr. Liotta is talking to Mr. Karp, receiver of the first artificial heart, and Dr. Cooley is observing (April 5, 1969).

The original clinical prototype of the Liotta-Cooley-TAH was selected in 2006 to be displayed prominently in the new Smithsonian ´*Treasures of American History*´ exhibit in Washington DC. In Dr. Cooley´s opinion:

"This establishes it as a worthy part of human history."

Press coverage in Houston and in Buenos Aires at the moment of the first replacement of a failing biological heart with a mechanical one.

3. Creation of Cardiocirculatory Assistance and its Clinical applications

Dr. Liotta's activity in the field of cardiocirculatory assistance may be divided in three key cycles, as follows:

Cycle 1: Milestones in the History of Medicine

1- Baylor University College of Medicine (Houston, 1961-1971): A ten-year intensive clinical, teaching and research activity, which led to the creation of Cardiocirculatory Assistance, its laboratory experimentation (1962), and its extension to clinical use.[5-9]

These works were selected by the American Society of Cardiology for the Young Investigators´ Annual Award and were presented by Dr. Liotta in the Society Conference in Denver in May 1962.

It is at the beginning of this cycle when the first clinical success of cardiocirculatory support systems took place; it was a key moment in the history of medicine: on August 6 1966, the Cardiocirculatory Assistance was applied in a paracorporeal position for the treatment of postcardiotomy cardiogenic shock.

The patient underwent a double mitro-aortic valve replacement, but could not be weaned off extracorporeal circulation. In that critical moment, a cardiocirculatory assistance device was implanted, thus maintaining the circulation for 10 days, with a blood flow of 1,200 mL/min. The patient recovered, being this the first successful use of an LVAS for the treatment of postcardiotomy shock in the history of medicine.[10-15]

Dr. DeBakey (in the foreground) and Dr. Liotta. <u>Historical cardiac surgery</u>*: implantation of the Liotta-DeBakey Left Ventricular Assist Device (LVAD) in a paracorporeal position at the Methodist Hospital, Houston (April 21, 1966).*

<u>Cycle 2: Development of Cardiocirculatory Assistance in Argentina (Stage I)</u>

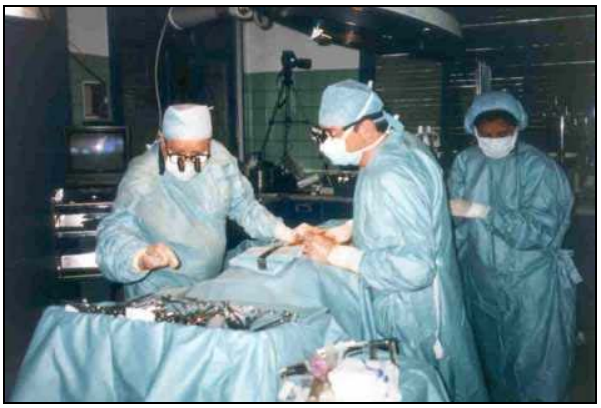
1- Hospital Italiano de Buenos Aires (Italian Hospital in Buenos Aires) (1971-1996): Continuity of experimental research works on Cardiocirculatory Assistance and its clinical use. Research works extended to cardiology and cardiovascular surgery professionals in the Popular Republic of China throughout 23 years (1973-1996.)

2- Development of a Univentricular Artificial Heart (1989): The aim of this research work was to explore the development of a bovine model of total heart replacement only with the implantation of a left ventricle. Surgeons and researchers from the Italian Hospital in Buenos Aires took part in this research, and the experiments were conducted in the Texas Heart Institute (Houston) and the Institute for Biomedical Engineering of the University of Utah (Salt Lake City). Pulmonary circulation was resolved with a direct and wide anastomosis between the right atrium and the pulmonary artery; a Fontan-type surgery for the treatment of congenital hypoplasia of the right ventricle. This research work was possible thanks to the financial support of Fortabat Foundation (Buenos Aires, Argentina) and a grant from the Presidency of Argentina, being Dr. Raúl R. Alfonsín the head of the National Government.[16]

3- PROCOAR Program, supported by the CONICET-National Council on Scientific and Technical Research, Argentina (1993-1998): Development of a left ventricular assist device with endogenous energy source. Both the latissimus dorsi and the teres major muscles were detached from the humerus and stimulated with a special pacemaker to power a circulation assist device. This project was technically and financially supported by the CONICET through the PROCOAR program, and some institutions like the Institute of Cardiovascular Clinics in Buenos Aires. The masterly work of Engineer Laureano Nava from the CONICET was acknowledged.[17, 18]

<u>Cycle 3: Development of Cardiocirculatory Assistance in Argentina (Stage II)</u>

School of Medicine- Universidad de Morón (From 1998 to present): Continuity of the Research work on Cardiocirculatory Assistance. Development and *in vitro* and *in vivo* assays of a new model of Left Ventricular Assist Device: the Novel- LVAS.[19-21]



Dr. Liotta and his collaborators while performing in-vivo assays in calves (INTA-Castelar). Assays in calves with the use of the Novel-LVAS devices, in the School of Medicine, University of Morón (2002).

At this stage, Dr. Liotta has carried out the experimental development of the **Left Atriostomy** approach as a source of inflow blood drainage from the left atrium (atriostomy diameter: 25-30 mm) to the implantable artificial ventricle. This has avoided further damage because of the cannulation of the heart chambers, particularly the introduction of cannulas through the apex of the left ventricle, which is already severely damaged in the case of patients who

have heart failure. In addition, normal contraction of the myocardium helical shape has been preserved.[19, 20]

4. Discussion

Throughout the history of the development and the first clinical application of the Cardiocirculatory Assistance and the Total Artificial Heart, not only is the work of the pioneers in the development of said systems acknowledged, but other consequences, which might have been unexpected at the moment they took place, can be analyzed as well.

The Cardiocirculatory Assistance was conceived at the beginning with the purpose of assisting the heart in cardiogenic shock in order to keep an adequate blood flow and arterial pressure. Later, it meant to keep the patient who is at risk of dying alive, as a "bridge" to cardiac transplantation.

It can be inferred from Dr. Liotta´s works carried out in the early years that the medium-term application of the Cardiocirculatory Assistance allowed a severely damaged and dilated heart to improve its contractility when its dilated chambers were "unloaded" from the excessive blood volume through the assistance of prolonged mechanical circulation. This could be interpreted as a form of regression -from the depressed contractile states- of the Frank-Starling flat and descending curve of the dilated heart subjected to an excess of diastolic volume. It means the regression to the initial ascending segment of the Frank-Starling curve. The fact that the patient's heart resumed the size and shape it had before the pathology, even after being weaned off the assistance system, gave origin to the possibility of *functional myocardial recovery*, which is today widely accepted. Liotta proved a remarkable and permanent improvement of the heart function after weaning the patient off the circulatory assistance. The **mechanical blood unloading of the left ventricle in a prolonged way** by means of the Cardiocirculatory Assistance resulted in a real myocardial recovery.[5-14]

And this consequence opened up new horizons in the treatment of advanced heart failure, since it admitted the assessment of the possibility of avoiding heart transplantation or the use of a total artificial heart, as the Cardiocirculatory Assistance allows the native heart myocardium to recover. And, again, this entailed another meaningful fact: the conception of Cardiocirculatory Assistance as a "platform" for other pharmacological and cellular (stem cells) treatments.

In this way, the initial objective of Cardiocirculatory Assistance developed by Liotta, DeBakey and Cooley for supporting the failing heart function has been enlarged since its original conception. By contributing to the circulatory function of the native heart, new continuous-flow implantable small pumps employing left atriostomy blood drainage, with combined management strategies, have options of a permanent assistance.

Hopefully, the limited daily life of patients in advanced cardiac failure would be truly changed.

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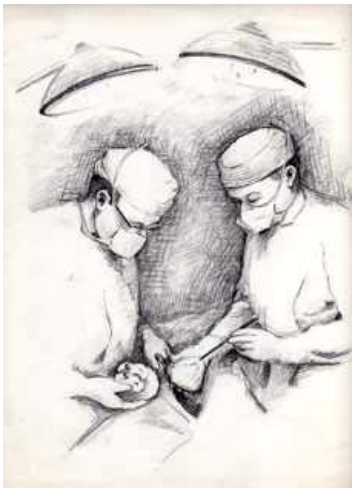

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