THESAURUS 54

Supporting Cardiac Function with Mechanical Devices

Part I - Assisted Circulation (LVASs) in the Medical Practice 50 years later. Historical Overview.

Domingo S. Liotta discovered Assisted Mechanical Circulation (**LVASs**) in 1961-62 for the Advanced Irreversible Cardiac Failure therapy; then the history of prolonged artificial blood circulation was forever changed. Moreover, in his saddlebag Liotta took to Houston his pioneering work on cardiac replacement with a Total Artificial Heart prosthesis conducted at the National University of Córdoba, Argentina in the year 1960, following his Thoracic Residency (Assistant Étranger) in Lyon and Paris, 1956-59. Actually, in France, he started discussing the hemodynamic basis of heart replacement with a small implantable pump. It was the beginning of the following experimental works carried out in 1960 at the National University of Córdoba:- Liotta D, Taliani T (1961) *Artificial heart in the chest: preliminary report*. Trans Am Soc Artif Int Organs, 7:318-322 and -Liotta D, Taliani T (1961) *Ablation Expérimentale and remplacement du Coeur par un Coeur artificiel intra-thoracique*. Lyon Chirurgical 57: 704-714.

Dr. Liotta did an extensive study of the physiopathology of cardiac failure from the surgical point of view, for 10 years—in the 60s—in the Department of surgery at Baylor College of Medicine in Houston, Texas, under the chairmanship of Michael E. DeBakey. Liotta arrived in Houston in July 1961, after a brief stay at the Cleveland Foundation.

In fact, in the area of modern surgical cardiology Liotta was the central protagonist of three medical breakthroughs to the advanced irreversible heart failure therapy in the 20th century:

1- Left ventricular assist system (LVASs) that he discovered in 1961-62 by means of an artificial incorporated left ventricle; first clinical implantation in medicine on July 19, 1963, together with E.Stanley Crawford, that is 50 years ago.

2- First successful use in medicine for postcardiotomy cardiogenic shock of the Liotta-DeBakey; a paracorporeal left cardiocirculatory assist device, on August 6 1966, together with Michael E. DeBakey.

3- First clinical use in medicine of Liotta-Cooley Total Artificial Heart: Implanted with resection of the native heart of the patient on April 4, 1969, together with Dr. Denton A. Cooley.

The cardiocirculatory assistance —with an incorporated left ventricle– preserves the patient's life until a donor is obtained for the final heart transplantation. Furthermore, the artificial ventricle may assist the patient definitively: destination therapy.

Today, 50 years later, the cardiocirculatory mechanical assistance is present in the medical practice all over the world.

In 2006 the Liotta-Cooley artificial heart original prototype used in Mr. Haskell Karp on April 4 1969 was selected to be displayed prominently in the new '*Smithsonian Treasures of American History'*. Curators selected the artificial heart from the collection of more than 3 million artifacts at the Smithsonian museum.

On said occasion Dr. Denton A. Cooley declared 'this *establishes it as a worthy part of humanity's history'*.

Part II - LVASs, the Novel III. Left Atrium- left axillary artery bypass. An Overview.

On July 1 1971, Dr. Liotta was appointed Chief of Cardiovascular Surgery of the Italian Hospital of Buenos Aires until 1990, when he reached 65 years old. Today, the Cardiovascular Service of the Italian Hospital is named "*Service of Cardiovascular Surgery Dr. Domingo S. Liotta Chief Surgeon 1971-1990*" after him.

During that period, Dr. Liotta was the State Secretary of Public Health—May 1973- July 1974—and was appointed chief medical doctor of President Juan Domingo Peron.

Furthermore, for 23 years (until 1996) he was officially appointed responsible for the training of Chinese physicians as specialists in Cardiology and Cardiovascular surgery by Premier Chou en-Lai and the Government of the Popular Republic of China either on Chinese soil or in the Italian Hospital in Buenos Aires.

Dr. Liotta was the founder of the School of Medicine of the University of Morón and its dean from 1997 to 2013; moreover, Secretary for Science and Technology (since 2005) and Emeritus Professor in the same University (since 2011).

On August 2013, he was appointed Vice-Rector of the University of Morón and Emeritus Dean of the School of Medicine of the same institution.

In the School of Medicine of the University of Morón Dr. Liotta continues working on cardiocirculatory assistance, mainly directed to either myocardial recovery or very strongly to permanent use of the assist system —destination therapy— in adult patients over 65 years old.

At present, the work is carried out with a small continuous-flow pump; the *Novel III*, with an inflow pump from the left atrium chamber, employing a 25-mm inside diameter atrial prosthesis sutured to the left atrial wall —with no cannula within the left atrial chamber— and an outflow connector with a 10-12 mm graft to the left axillary artery. The direction of the implanted system is like an ascending small arch of a vault from the left atrium at the fourth intercostal space to the axillary artery immediately under the left clavicle. The small pump is fixed at the opening thoracotomy, at the fourth left intercostal space.

The functional system is set with the following principles. The outflow of the continuous flow pump is set at approximately 3.5 to 4 liters of blood per minute and it is absolutely necessary to have the native heart output at least from 1.5 to 2 liters of blood per minute. Then, the total blood circulation is from 5 to 6 liters per minute.

It is mandatory to see that the aortic valve is open on each contraction of the heart to avoid thromboembolism at the outflow tract of left ventricle and at the aortic valve itself.

Long time ago, Dr. Liotta performed some interesting experiments[1]. It was necessary to remove from the left atrium a volume of blood reaching almost 60 % of the total blood volume and injecting back to the circulation with a DeBakey roller continuous flow pump to observe then a gradual disappearance of the pulsatile flow from the native heart. This demonstration is extremely important, because it is possible to have even a weaker pulsatile flow in all central organs, including the body's periphery, when a continuous flow pump is interposed in the general circulation and the native heart is ejecting a reduced stroke volume in each beat.

Part III - LVASs applied on the overstretched myocardium. The first publication on LVASs in Medicine.

Physiopathology of Cardiocirculatory Mechanical Assistance

In the seminal studies the functional recovery of advanced myocardial failure is possible with the prolonged assistance of an incorporated artificial left ventricle (LVAS), which has been the outstanding finding.

In extreme dilation in advanced heart failure the left ventricular chamber keeps permanently an excess of blood that is irreversible to eject— *left ventricular chamber overloaded by a 'parasitic'' volume of blood.*

Unloading the excess of blood for a prolonged time —weeks or months— makes it possible myocardial recovery by means of an implantable left ventricle. Throughout the assistance it was shown —oxygen consumption studies— that cardiac metabolism decreases and so does the left ventricular wall tension when the radius of left ventricle is reduced too, according to Laplace's law; at the same time, coronary circulation increases.

There is an interaction between the overstretched myocardial fibers and the result of cardiac assistance causing their shortening within normal values when the excess of blood retained —*parasitic*— is unloaded —*unloading of the overloaded left ventricular chamber.* The Frank-Starling mechanism has been definitely superseded regarding its functional recovery in overstretched myocardial fibers.

First Publication in Medicine on Cardiocirculatory Assistance (LVASs), 1962

Liotta D, Crawford ES, Cooley DA, DeBakey ME, De Urquia M, Feldman L. (1962**).** ***Prolonged partial Left ventricular bypass by means of an intrathoracic pump implanted in the left chest.*** Trans Am Soc Artif Intern Organs 8: 90-99.

As stated in this publication, the blood was drained from the left atrium and was injected either in the descending or in the ascending thoracic aorta. The following parameters were evaluated with the ventricular prosthesis on or off:

1- Pressures: Systemic arterial; left ventricular chamber; left atrial chamber; artificial ventricle chamber.

2- Blood Flow: Total native heart output; artificial ventricle output.

3- Coronary flow with the prosthesis on and off.

4- P_{O2} and P_{CO2} in arterial and venous coronary blood.

5- The myocardial oxygen consumption and CO_2 production were calculated.

6- The left ventricular work was calculated.

7- The external cardiac efficiency was calculated.

8- A severe myocardial lesion was provoked and studied with the pump on and off.

In the section Discussion, it is stated, *"The bypass decreases the heart's work by diminishing the left ventricular output";…"the left ventricular wall tension ('wall stress') also decreases because it is dependent on the intraventricular decreased pressure and the blood volume per stroke which also decreases. The latter was measured with accuracy according to the duration of ventricular systole".*

"This bypass reduces the volume per stroke and consequently reduces the volume of the left ventricular chamber and the wall tension also decreases according to Laplace's law: P=T/R; where the pressure ,P, developed at a particular level of the ventricular wall tension ,T, it is inversely proportional the radius ,R, of the ventricular chamber. In other words, the myocardial fibers must develop higher tension to produce the same level of intra-ventricular pressure when the ventricular chamber diameter is larger; that is when the heart is excessively dilated (the underlining is not in the original paper of 1962).

"So, the ventricular wall tension (wall stress) is considered to be a primary factor in myocardial oxygen consumption[(11)].The LVAD is surely more effective when the ventricular chamber is more dilated"…"with the shortening of myocardial fibers the reduction in the end-diastolic pressure is caused".

In the conclusion it is stated, *"the left ventricular bypass-LVAD- as herein described reduces the work of the left ventricle and the tension of the ventricular wall while the coronary circulation increases".*

The above-cited bibliographic reference [(11)] corresponds to a celebrated publication: Sarnoff ST, Braunwald E et al. (1958) *Hemodynamic determinants of oxygen consumption of the heart with special reference of Tension-Time-Index.* Am J Physiol 192 (1): 148-156.

It is remarkable that the physiopathology finding in the first publication of Assisted Circulation more than 50 years ago (1962) is in force regarding its conception on medical practice today: *"The unloading of 'parasitic' blood volume from the dilated blood chamber decreases its diameter and the ventricular wall stress. Consequently, myocardial oxygen consumption decreases while the coronary flow increases"*

Today, among the cumbersome lengthy publications, very rarely can we see a short sentence on the seminal research work that introduced Assistance circulation in medical practice.

Thesaurus series intended to stimulate vocational research in medical students in basic and clinical integration and general instruction and culture

Domingo S. LIOTTA, MD
Vice-Rector,
University of Morón, Morón, Buenos Aires, Argentina

Reference:

1- Liotta D. *Persistence of pulsatile flow when a continuous-flow pump is incorporated in the arterial circulation*, submitted at the National University of Córdoba, for the Enrique Finochietto Award, 1965.

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