ADVANCES IN CARDIAC ARRHYTHMIAS AND GREAT INNOVATIONS IN CARDIOLOGY

XXVII GIORNATE CARDIOLOGICHE TORINESI

ActisDato RobertoBosio artificial heart

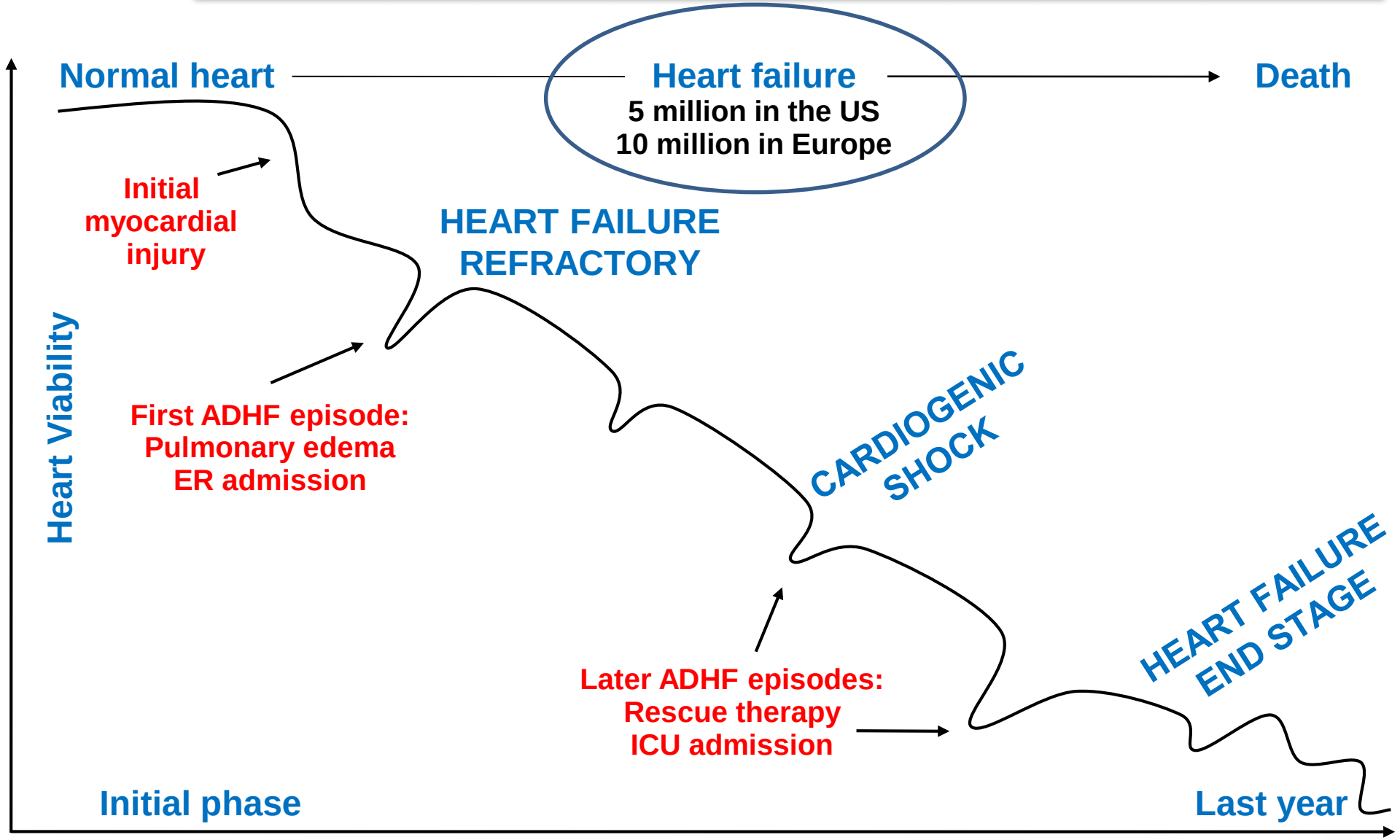
Torino, 23-24 ottobre 2015

TURIN and The First Artificial heart

Sebastiano MARRA, *FESC*

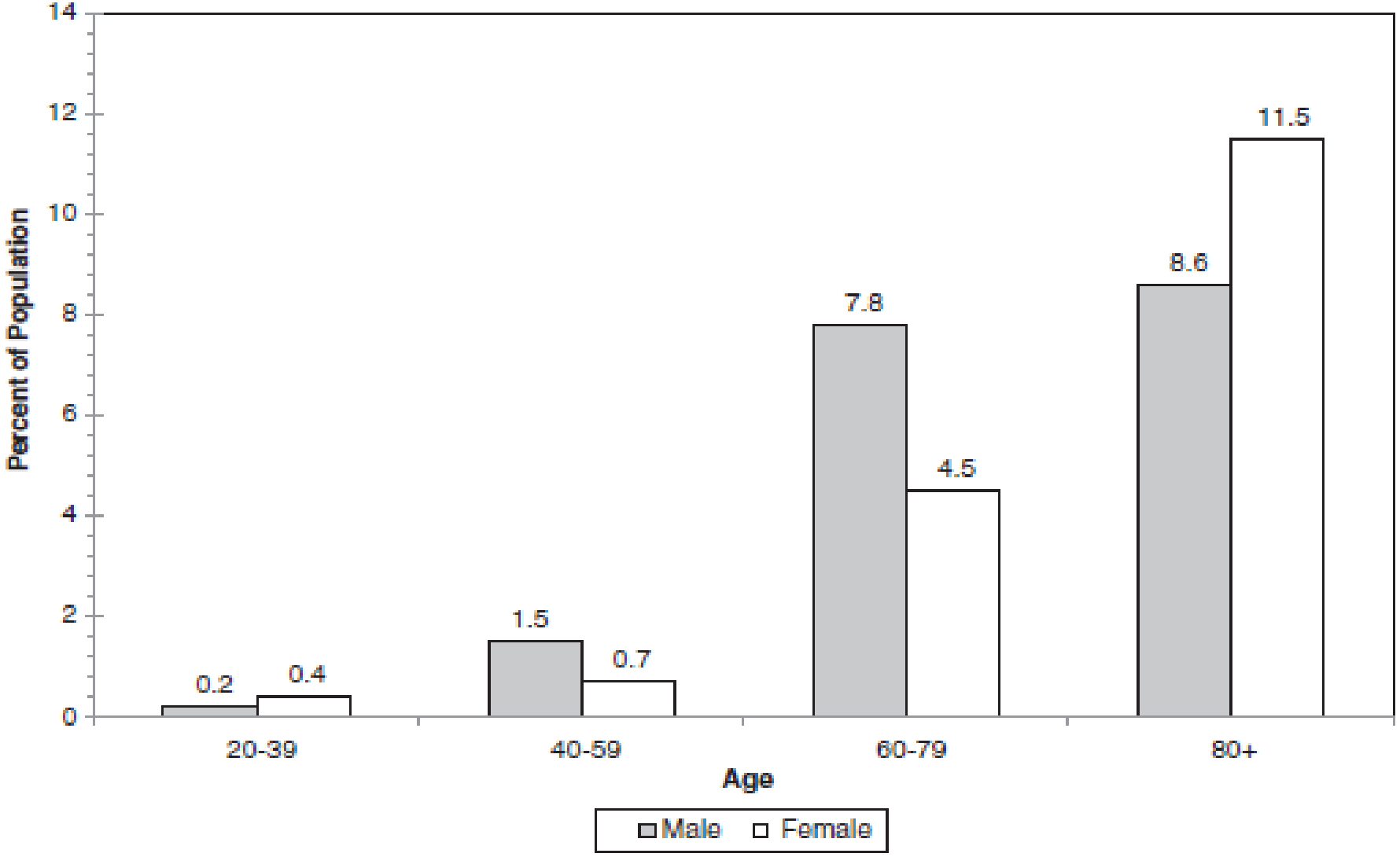
Luca CHECCO, *MD*

Heart Failure evolution



Gheorghiade M, et al. Circulation 2007;112:3958-68

Heart Failure population



Circulation
JOURNAL OF THE AMERICAN HEART ASSOCIATION

2013;127:e6-e245

Beyond the NYHA IV: INTERMACS risk profiles

INTERMACS Levels of Limitation at the Time of Implantation and the Time Frame of Need for Consideration of MCS

INTERMACS Profile Level	Status	Time Frame
1	Critical cardiogenic shock	Hours
2	Progressive decline	Days to week
3	Stable but inotrope dependent	Weeks
4	Recurrent advanced HF	Weeks to few months if baseline restored
5	Exertion intolerant	Weeks to months
6	Exertion limited	Months, if nutrition and activity maintained
7	Advanced NYHA class III	

NYHA indicates New York Heart Association. Adapted with permission from Stevenson et al.[11] Copyright © 2009, Elsevier.

LW Stevenson, FD Pagani, JB Young et al.

INTERMACS profiles of advanced heart failure: the current practice, J Heart Lung Transpl. 2009;28:535-41

HOW Heart Failure population?

European Heart Journal (2006) 27, 1207–1215
doi:10.1093/eurheartj/ehl845

Clinical research
Heart failure

Nationwide survey on acute heart failure in cardiology ward services in Italy

Luigi Tavazzi[1*], Aldo P. Maggioni[2], Donata Lucci[2], Giuseppe Cacciatore[3], Gerardo Ansalone[4], Fabrizio Oliva[5], and Maurizio Porcu[6] on behalf of the Italian survey on Acute Heart Failure Investigators

Nationwide, prospective, observational study setting 206 cardiology centres with intensive cardiac care units. During 3 months, 2807 patients were enrolled with de novo acute HF (44%) or worsening chronic HF (56%)

The HF profiles were classified by the investigators as:

- **Cardiogenic shock in** **7.7% patients**
- **Acute pulmonary oedema in** **49.6% patients**
- **Worsened NYHA functional class (III and IV) in** **42.7% patients**

INTM 1

INTM 2-3-4

INTM 5-6-7

Heart Transplant is for all?

- **100.000 European/years, suffering from severe CHF, need new hearts**
- **Only 2.000 patients/year receive heart transplant**

MANY PATIENTS DIE WAITING FOR A NEW HEART

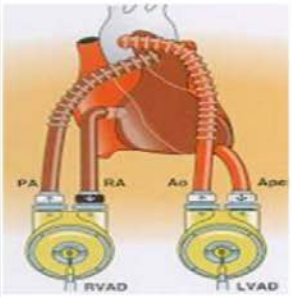
- **A suistable alternative to donor hearts could prolong thousands of lives**

MCS: TAH or VAD

The systems of mechanical assistance to the circle
MCS - Mechanical Circulatory Support
implantable type like, begin to be developed from the '60s

TAH: Total Artificial Heart
assistance systems completely replacing orthotopic native heart

VAD: Ventricular Assist Device
assistive devices only for the ventricles



- Paracorporeal
- Pneumatic
- Pulsatile
- Uni- or Biventricular

1150 g

- Implantable
- Electric
- Pulsatile
- Large
- Multiple moving parts

800 g

- Implantable
- Electric
- Continuous flow
- Axial design
- Smaller
- Single moving part

400 g

- Implantable
- Electric
- Continuous flow
- Centrifugal design
- Smaller
- Bearingless

200 g

- Implantable
- Electric
- Continuous flow
- Axial design
- Smaller
- Partial support

90 g

Henning LM, Mueller J, Spiegelsberger S et al , Long-term circulatory support as a bridge to transplantation, for recovery from cardiomyopathy, and for permanent replacement. Eur J Cardiothorac Surg 1997;11:S18-S24

MCS: why yes?

TAH or VAD

are used

As

bridge the time

to a heart transplant

or

As

a life extending

device

Heart Failure population

Circulation
JOURNAL OF THE AMERICAN HEART ASSOCIATION

American Heart Association.

2013 ACCF/AHA Guideline for the Management of Heart Failure: A Report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines

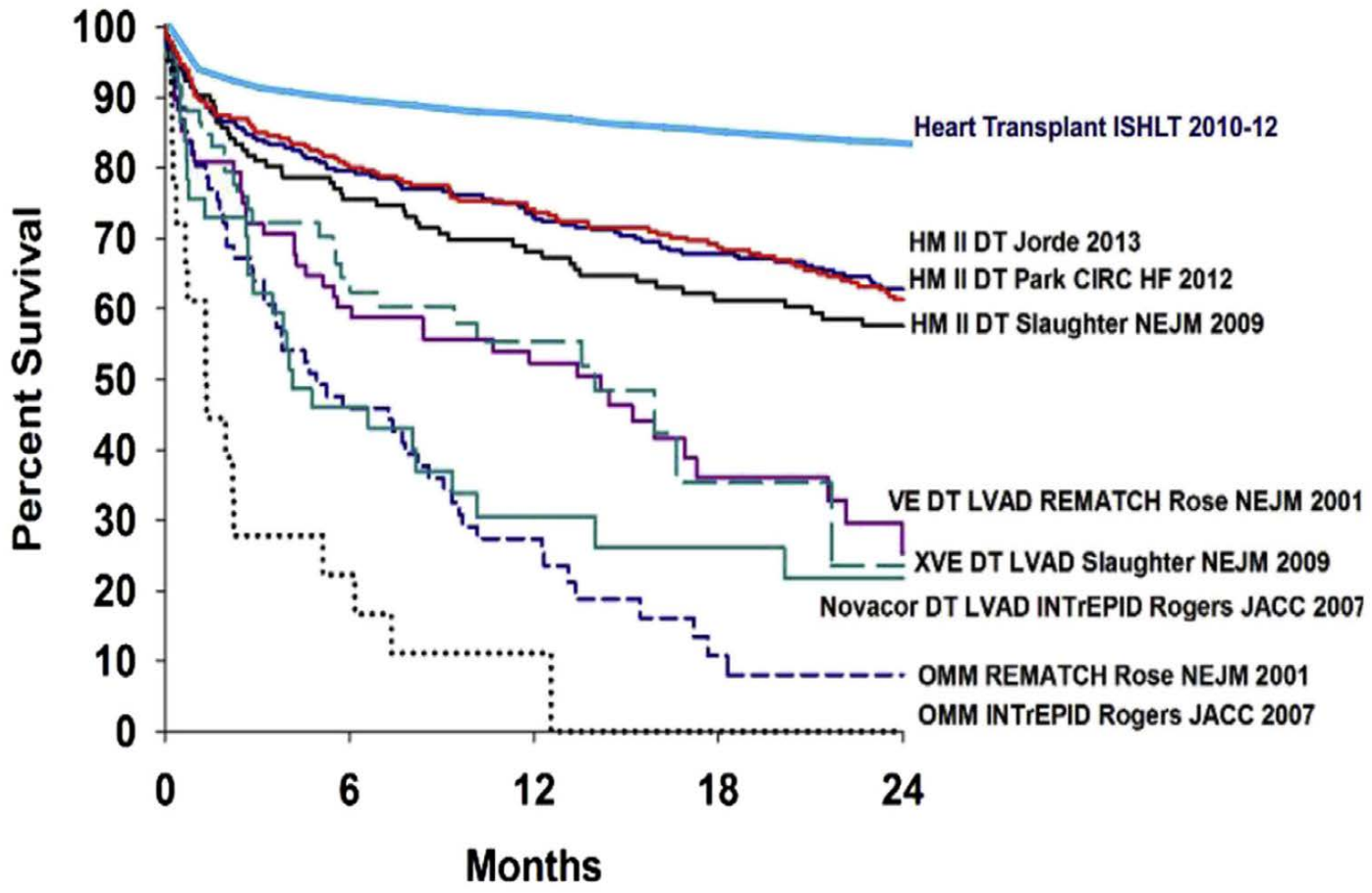
Clyde W. Yancy, Mariell Jessup, Biykem Bozkurt, Javed Butler, Donald E. Casey, Jr, Mark H. Drazner, Gregg C. Fonarow, Stephen A. Geraci, Tamara Horwich, James L. Januzzi, Maryl R. Johnson, Edward K. Kasper, Wayne C. Levy, Frederick A. Masoudi, Patrick E. McBride, John J.V. McMurray, Judith E. Mitchell, Pamela N. Peterson, Barbara Riegel, Flora Sam, Lynne W. Stevenson, W.H. Wilson Tang, Emily J. Tsai and Bruce L. Wilkoff

Circulation. 2013;128:e240-e327; originally published online June 5, 2013;

Best implanted MCS before

- **Impairment of the clinical condition, according to the INTERMACS Classification**
- **Impairment of renal function**
- **Occurrence of pulmonary hypertension**
- **Impairment of RV function**

MCS: why yes?



Survival Rates in Trials and Registry Reports of Heart Transplantation and Chronic Mechanical Circulatory Support Lifetime Therapy (DT)

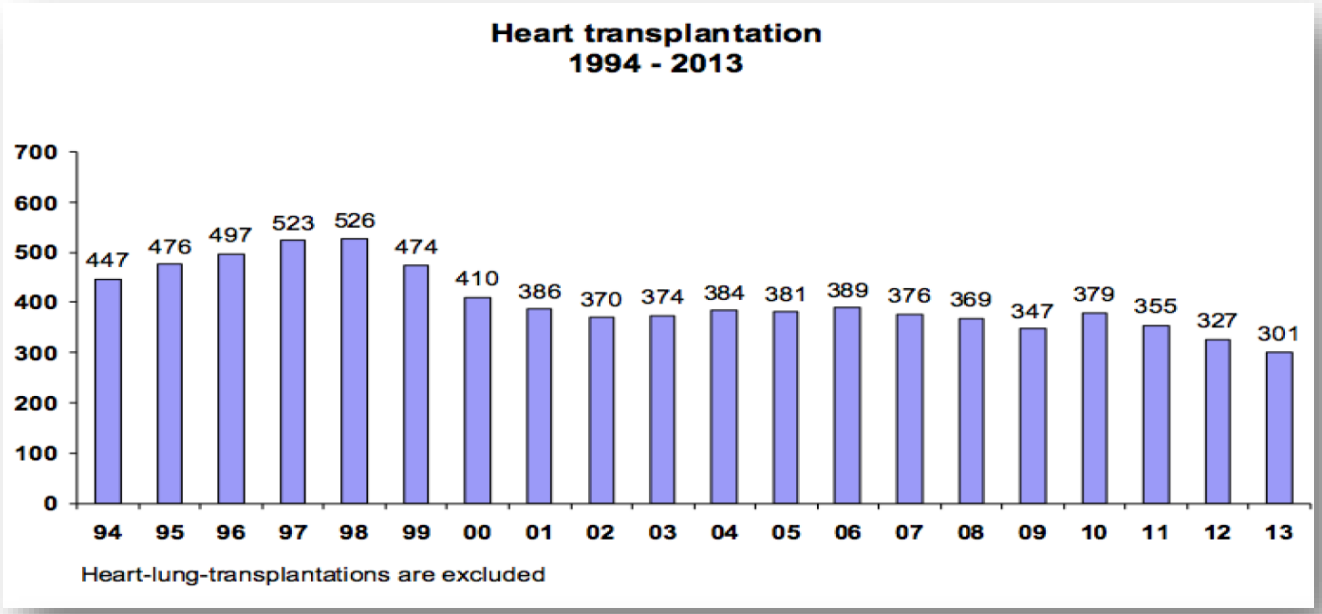
SG. Drakos et al, JACC 2014; 63 (17): 1758-62

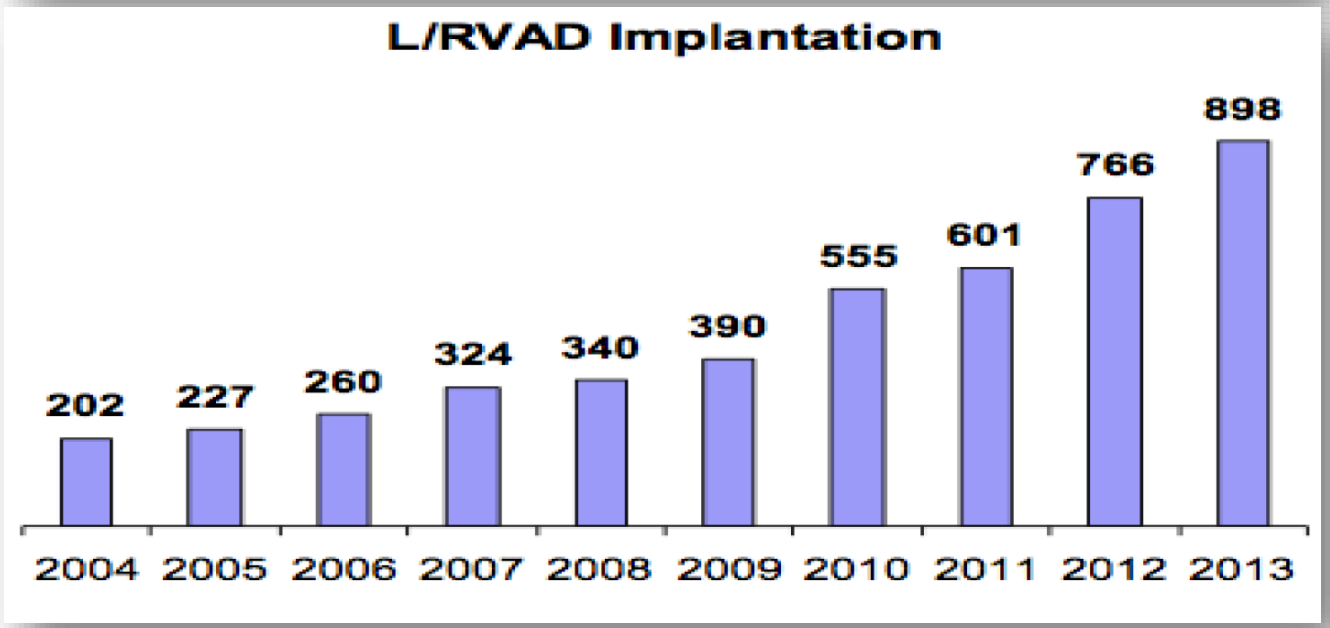
MCS: why yes?

- **Post MCS: 75% patients are able to walk and about 60% are able to walk 100ft long after two weeks following the implantation.**
- **The estimated amount ranges from a low $100,000 to a high $300,000 instead of $500,000 for medical cost of CHF**

JACC 2013

Heart Failure population





Hermann Reichenspurner
president ISHLT, 2014-15

AATS Annual Meeting
Toronto (CAN) 26-30/04/14

What's new?

JACC
JOURNAL OF THE AMERICAN COLLEGE OF CARDIOLOGY

Volume 65, Issue 23, June 2015 >

The Present And Future: State-of-the-Art Review | June 2015

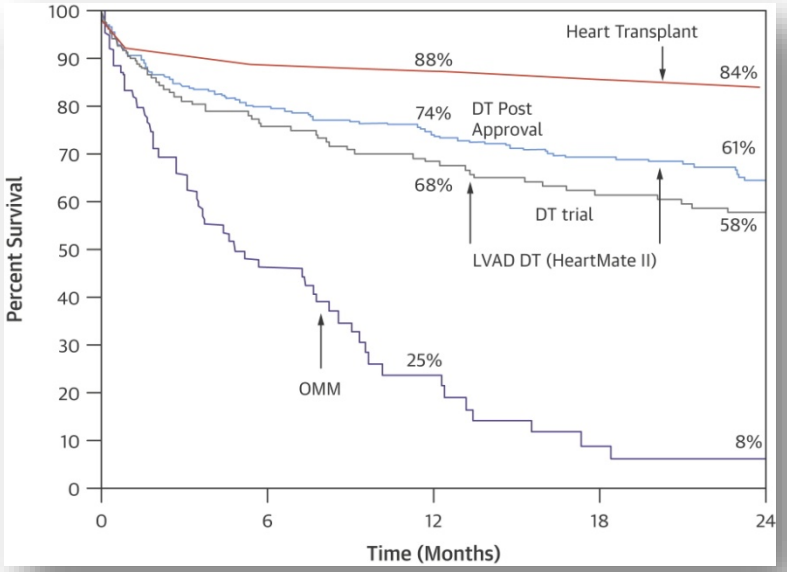
Left Ventricular Assist Devices

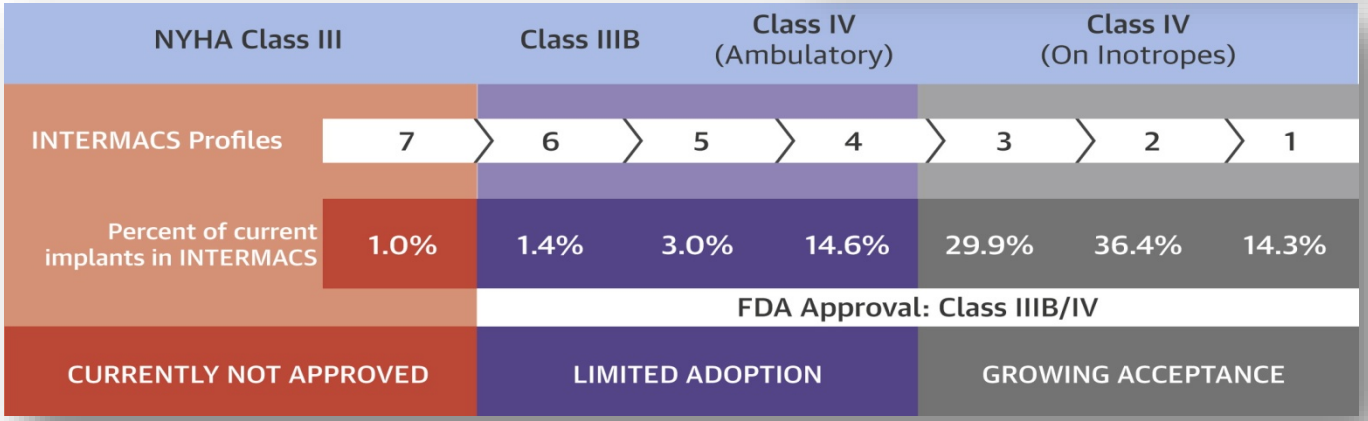
A Rapidly Evolving Alternative to Transplant

Commentary by Dr. Valentin Fuster

Donna Mancini, MD; Paolo C. Colombo, MD

J Am Coll Cardiol. 2015;65(23):2542-2555. doi:10.1016/j.jacc.2015.04.039





Piemonte CHF population

Ministero della Salute — Agenzia Nazionale per i Servizi Sanitari Regionali

Programma Nazionale Esiti – PNE

Edizione 2014

Piemonte population	**4,424 milions**
Prevalence of CHF	**2.54%**
Potential CHF patients INTERMACS 7 -> 1	**111.264**
Real CHF patients: INTERMACS 6 -> 1	**11.880**
Hospitalizations	**14.369**
Potential advance INTERMACS 3 -> 1	**700 ?**
INTERMACS 2 -> 1	**60-70 ?**

Piemonte Heart Transplant Program

Waiting List patients	58
Active list	38
Work-up list	20
mean years/waiting heart transplant:	*2.5*
Piemonte MCS implanted	**70**

Piemonte Hearts tranplant

	total	adult	pediat
2010	26	22	4
2011	28	26	2
2012	10	9	1
2013	19	16	1
2014	27	22	5
2015	12	9	3

1800: the beginning of cardiac artificial heart

EXPÉRIENCES

SUR

LE PRINCIPE DE LA VIE,

NOTAMMENT

SUR CELUI DES MOUVEMENS DU CŒUR,

ET SUR LE SIÉGE DE CE PRINCIPE ;

Suivies du Rapport fait à la première classe de l'Institut sur celles relatives aux mouvemens du cœur.

Par M. LE GALLOIS,

Docteur en médecine de la Faculté de Paris, membre adjoint de la société des professeurs de cette Faculté, membre de la société Philomatique, médecin du Bureau de bienfaisance de la division du Panthéon.

Unde anima atque animæ constet natura videndum.
Lucret. lib. I, v. 152.

Ornées d'une planche gravée en taille-douce.

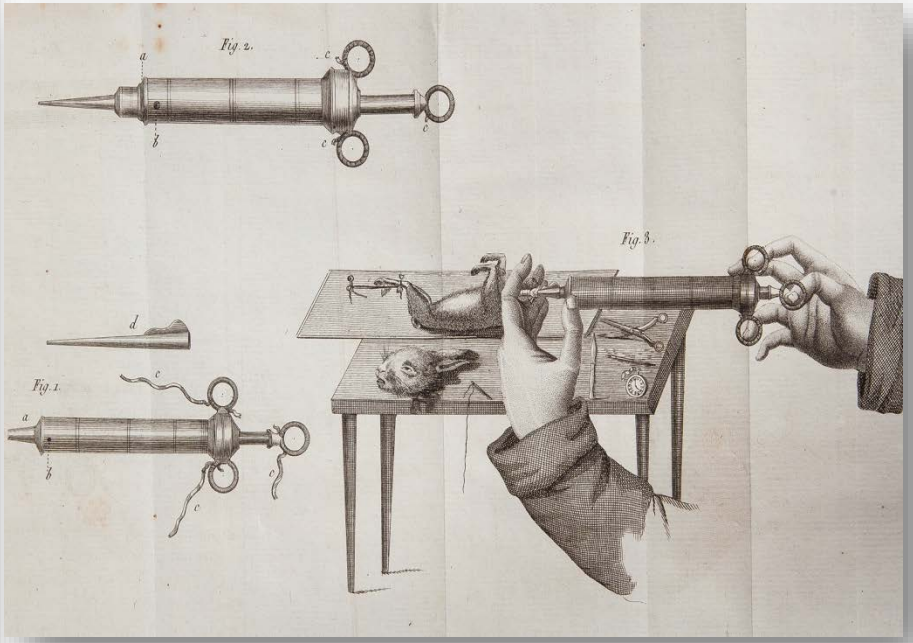
A PARIS,

Chez D'HAUTEL, libraire, rue de la Harpe, n° 80,
près le collége de Justice.

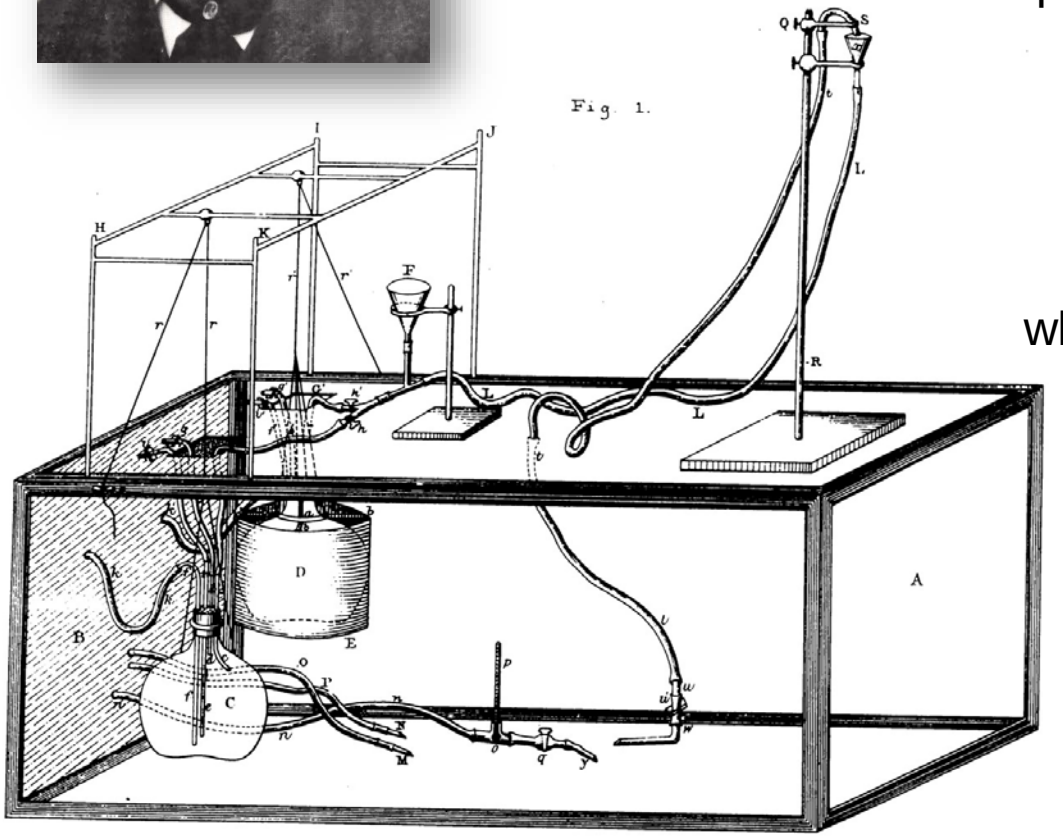
1812.

In 1812 **Julien-Jean Cesar Le Gallois** (1770-1814) said that

"…if we could replace the heart with a kind of injection of arterial blood, it would be possible to keep alive indefinitely any part of the body…"



1800: the beginning of cardiac artificial heart



In 1880, **Henry Martin** (1848-1896), first british professorship of physiology at John's Hopkins University (USA), introduced its own system of isolated perfusion of the heart and lungs, principles of which are still used today with the CEC (heart-lung machine).

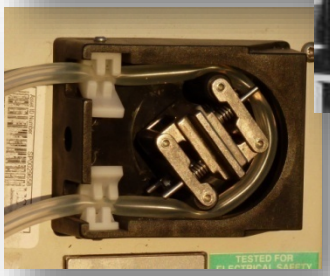
He developed the first isolated mammalian heart lung preparation which Starling later used to great effect

Martin's own scientific career was curtailed around 1893

1900's: the new era

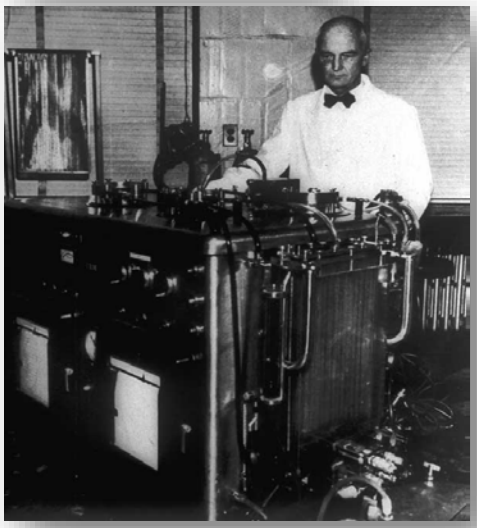
In 1928 **HH Dale** and **EHJ Schuster** in England planned their first diaphragm pump.
It had been studied in order to replace the function of the both cavity of the natural heart and to provide a complete circulation in an experimental animal.

In 1927 **C Lindbergh**, along with **A Carrel** developed a pump oxygenator .



In 1934 **M DeBakey** invented a rotary pump or "roller" yet still used in all heart-lung machines.

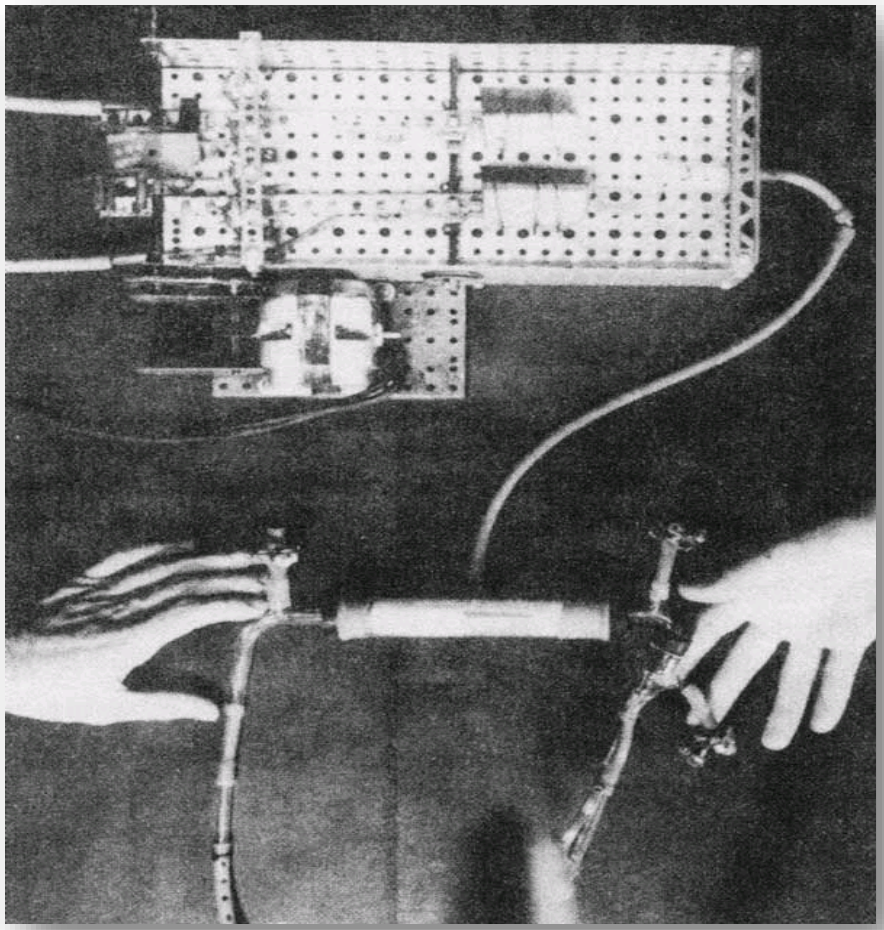
In 1935 **A Carrel** developed a pump oxygenator ; the pump for perfusion attracted the attention of journalists who called it " robots heart" or "heart of glass ".



In 1937 **J Gibbon** began working on his heart-lung machine that was introduced into clinical practice in 1953.

1940's: other projects became to go

In 1949, a precursor to the modern artificial heart pump was built by doctors **W Sewell** and **W Glenn** of the Yale School of Medicine using an Erector Set, assorted odds and ends, and dime-store toys.
The external pump successfully bypassed the heart of a dog for more than an hour.



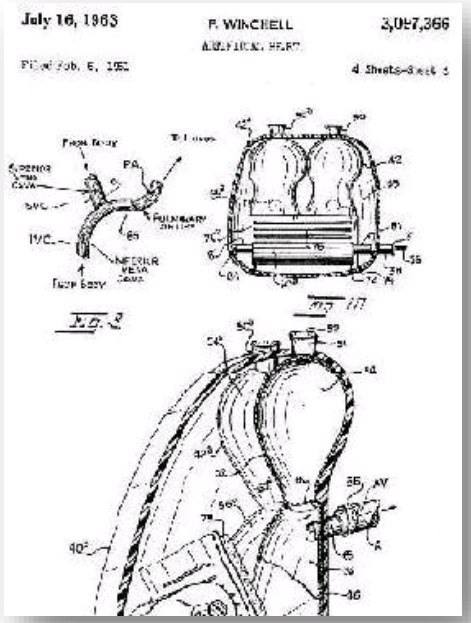
The assembled pump attached to the cam-lever unit driven by a small Erector™ set motor which opens the suction and pressure lines alternately, for the purpose of forcing blood through and out of the pumping chambers. The hand on the right supports the outflow end of the pump and attached pulmonary cannula while the hand on the left supports the inflow end of the pump and the single atrial cannula. In other experiments, the right atrium was isolated by removing the systemic venous return with a single venae cavae cannula.

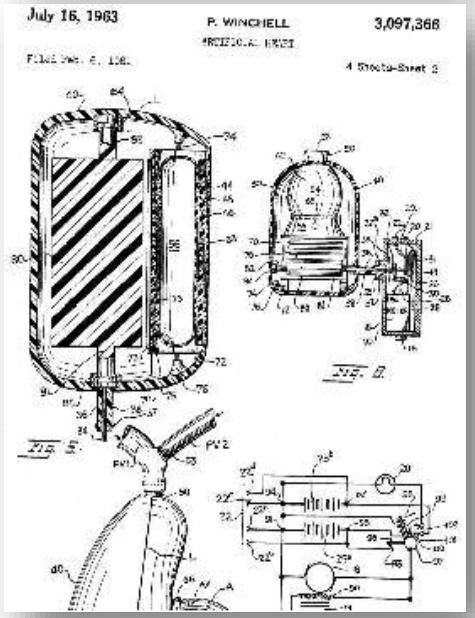
1940’s: other projects became to go

P Winchell invented an artificial heart with the assistance of **H Heimlich** (the inventor of the Heimlich maneuver) and held the first patent for such a device.

The University of Utah developed a similar apparatus around the same time, but when they tried to patent it, Winchell's heart was cited as prior art.

The university requested that Winchell donate the heart to the University of Utah, which he did. There is some debate as to how much of Winchell's design **R Jarvik** used in creating Jarvik's artificial heart.
The basic principle used in Winchell's heart and Jarvik's heart is exactly the same." Jarvik denies that any of Winchell's design elements were incorporated into the device he fabricated for humans which was successfully implanted.

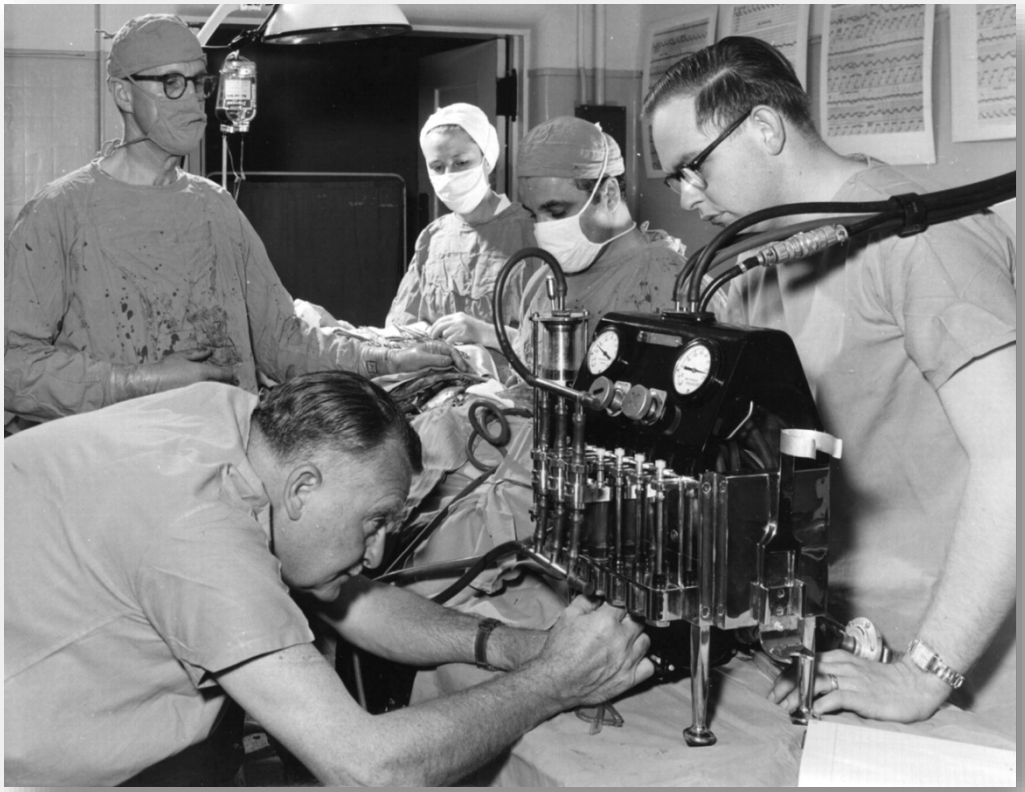




1950’s: come the Dodrill–General Motor machine

The Dodrill–GMR machine was the first operational mechanical heart successfully used while performing open heart surgery.

It was developed by **F.D. Dodrill**, a surgeon at Harper University Hospital in Detroit, and General Motors Research.



On July 3 1952,
Dodrill used the machine to bypass Henry Opitek’s left ventricle, a man 41yo suffering from shortness of breath at Harper University Hospital in Michigan, for 50 min. while he opened the patient's left atrium and worked to repair the mitral valve.

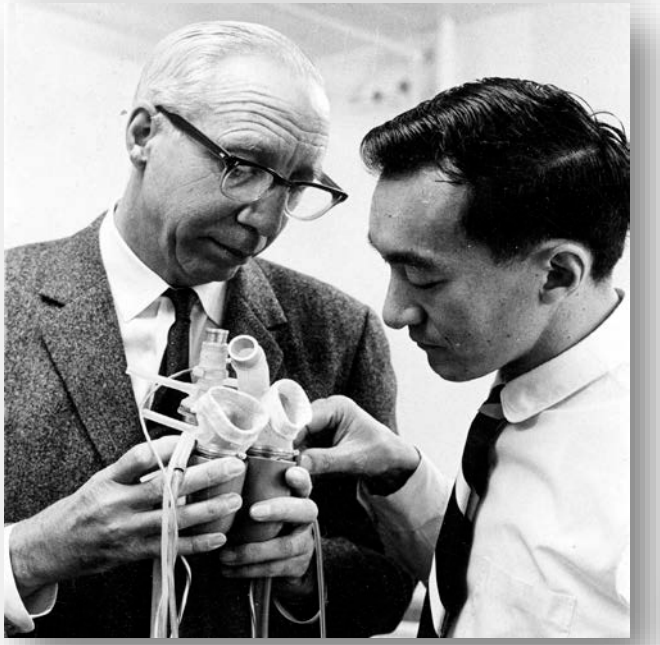
The Dodrill–GMR heart machine, considered by some to be the first operational mechanical heart was successfully used while performing heart surgery.

The machine performs the functions of the heart, allowing doctors to detour blood and stop the heart of a patient during an operation.
The machine is external of the body and is only used during an operation.

1950's: come the first experimental artifical heart

In 1957 **T Akutsu** (1922-2007) and **W Kolff** (1911-2009) at Cleveland Clinic, proposed for the first time a project of totally artificial heart by placing two compact pumps in the chest of a dog instead of the heart .

In the first experiment the artificial heart was made of polyvinyl chloride and was driven by an extracorporeal source of compressed air.



The dog survived for about 90 min.

In 1967 Kolff left Cleveland to Salt Lake City, founded the Division of Artificial Organs at the Utah University, where he was able to combine medical research to engineering disciplines .

Pioneer experience

Pioneering experiments conducted in the 60's by **Liotta**, **DeBakey**, **Cooley** and **Hall** lead to the emergence in the 70's to a line of medical research of systems for mechanical assistance into the general circulation, to support to the work of the native heart .


Domingo Liotta, MD

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

Liotta D, Hall CW, Henly WS, Beall AC, Cooley DA, DeBakey ME. Prolonged assisted circulation during or after cardiac and aortic surgery 1-Prolonged Left ventricular bypass by means of an intrathoracic circulatory pump. II-Diastolic pulsation of the descending thoracic aorta. Trans Am Soc Intern Organs ,1963; 9 :182-185.

Liotta D, Hall CW, Henly WS, Cooley DA, Crawford ES, DeBakey ME. Prolonged assisted circulation during and after cardiac or aortic surgery. Prolonged partial left ventricular bypass by means of intracorporeal circulation. Am J Cardiol, 1963; 12: 399-405.

Liotta D, Hall CW, Cooley DA, DeBakey ME. Prolonged ventricular bypass with intrathoracic pump. Trans Am Soc Intern Organs, 1964; 10: 154.

Liotta D, Maness JH, Bourland H, Podwell D, Hall CW, DeBakey ME. Recent modification in the implantable left ventricular bypass. Trans Am Soc Intern Organs, 1965; 11: 284.

DeBakey ME, Liotta D, Hall CW. Prospects for implications of the artificial heart and assistive devices. J Rehab;1966,32:106

Liotta D, Hall CW, Villanueva A, O'Neal RM, DeBakey ME. A pseudoendocardium for implantable blood pumps. Trans Am Soc Intern Organs,1966;12: 129.

1960's: first clinical application

First clinical application of an intrathoracic pump

On July 19 1963, **E S Crawford** and **D Liotta** implanted the first clinical Left Ventricular Assist Device (LVAD) at The Methodist Hospital in Houston, Texas, in a patient who had a cardiac arrest after surgery.
The patient survived for 4 days under mechanical support but did not recover from the complications of the cardiac arrest; finally the pump was discontinued and the patient died

First clinical application of a paracorporeal pump

On April 21 1966, **M DeBakey** and **D Liotta** implanted the first clinical LVAD in a paracorporeal position (where the external pump rests at the side of the patient) at The Methodist Hospital in Houston, in a patient experiencing cardiogenic shock after heart surgery.
The patient developed neurological and pulmonary complications and died after few days of LVAD mechanical support.

On October 10 1966, **DeBakey** and **Liotta** implanted the paracorporeal Liotta-DeBakey LVAD in a new patient who recovered well and was discharged from the hospital after 10 days of mechanical support, thus constituting the first successful use of an VAD for postcardiotomy shock

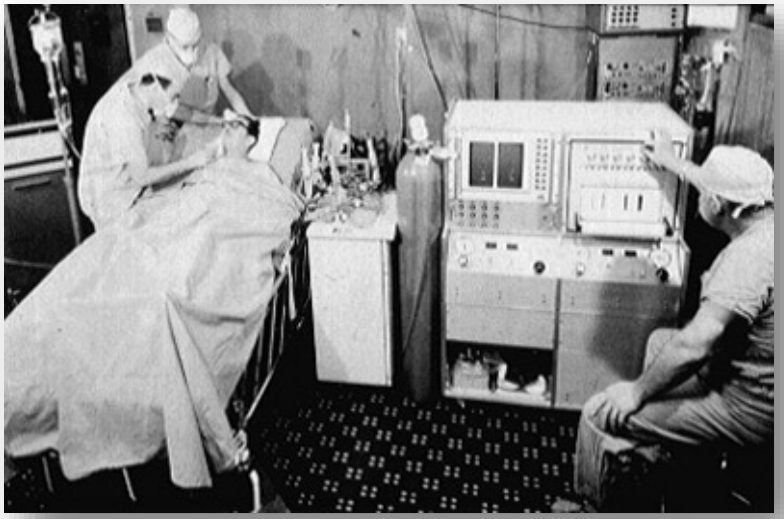
1969: the First uman implant

In 1969 **D Cooley** with a patient who was unable to wean from CEC after cardiac surgery, was forced to remove the patient's heart and to implant a full prosthesis of cardiac ventricles, operated by a pneumatic system.

This heart prosthesis, inserted it orthotopic, was designed and built by **D Liotta** and kept the patient alive for 64 hours, after which underwent a heart transplant.

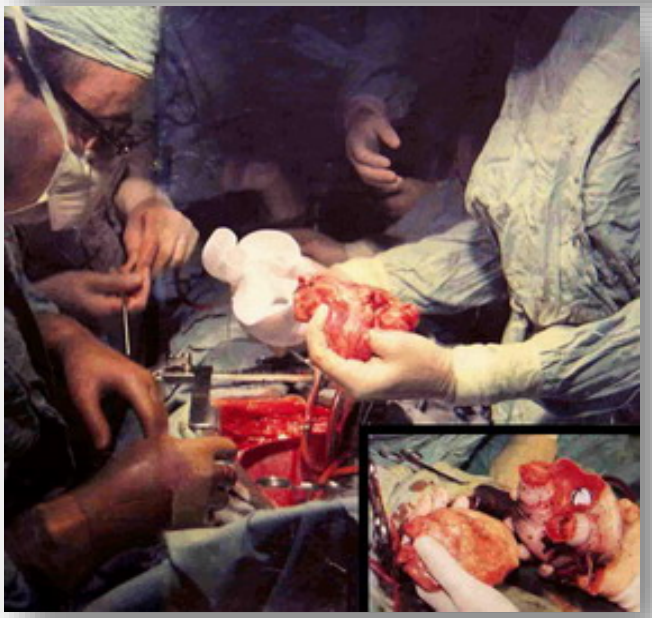
1969: the first uman implant

The artificial heart worked for 64 hours, before being replaced by a natural heart, but unfortunately patient died shortly after receiving the heart and Cooley was banned by the Food and Drug Administration (FDA) because his experiment was not previously authorized.



Among those opposed to the intervention of Cooley, there was also **C. Barnard** who put it this way:

"I do not believe in artificial heart, a successful transplant is always better than an artificial device . The mechanical devices fail and will never guarantee a good quality of life for the patient, who should remain the main objective of any medical intervention."



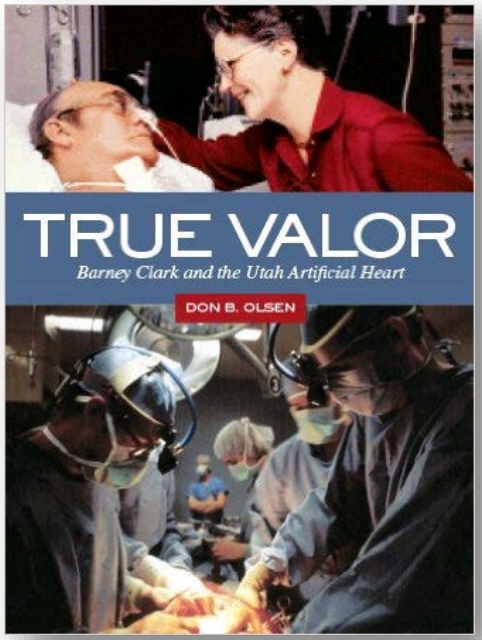
1982: first time in a man

In 1981, **W DeVries** submitted a request to the FDA for permission to implant the Jarvik 7 into a human being.

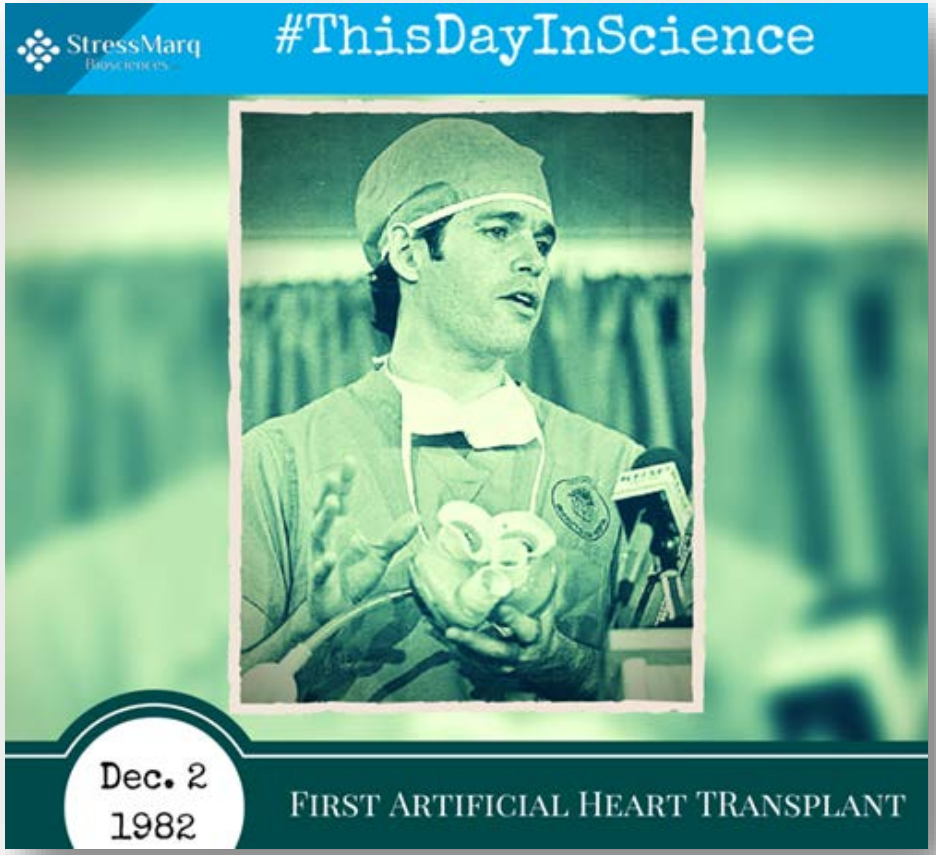
On December 2, 1982, Kolff implanted the Jarvik 7 artificial heart into **B Clark**, a dentist from Seattle who was suffering from severe congestive heart failure.

Clark lived for 112 days tethered to an external pneumatic compressor, a device weighing some 400 pounds (180 kg)

B Schroeder became the second recipient and lived for a record 620 days.



1982: first time in a man



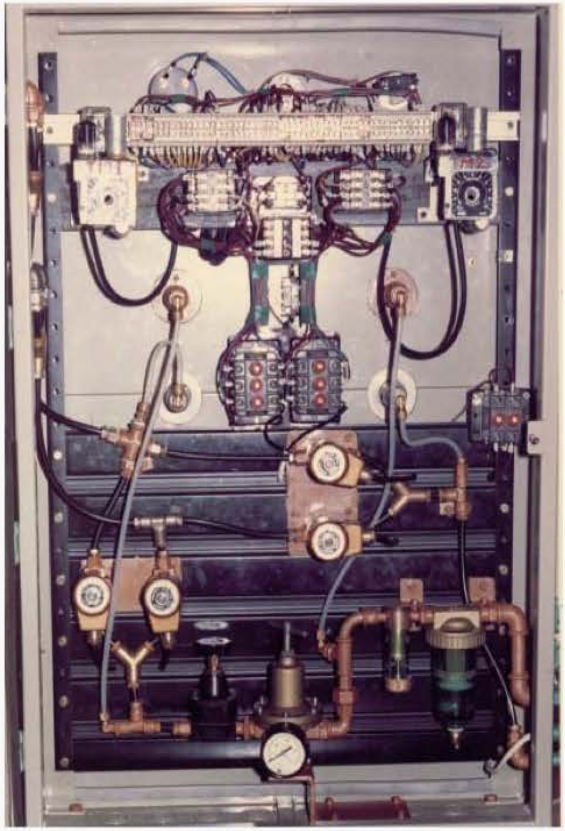
Jarvik-7 was designed by R Jarvik as a temporary replacement device for patients awaiting heart transplants.

It was used as a permanent heart transplant for only four other patients, but was used by many people temporarily as they waited for heart transplants.

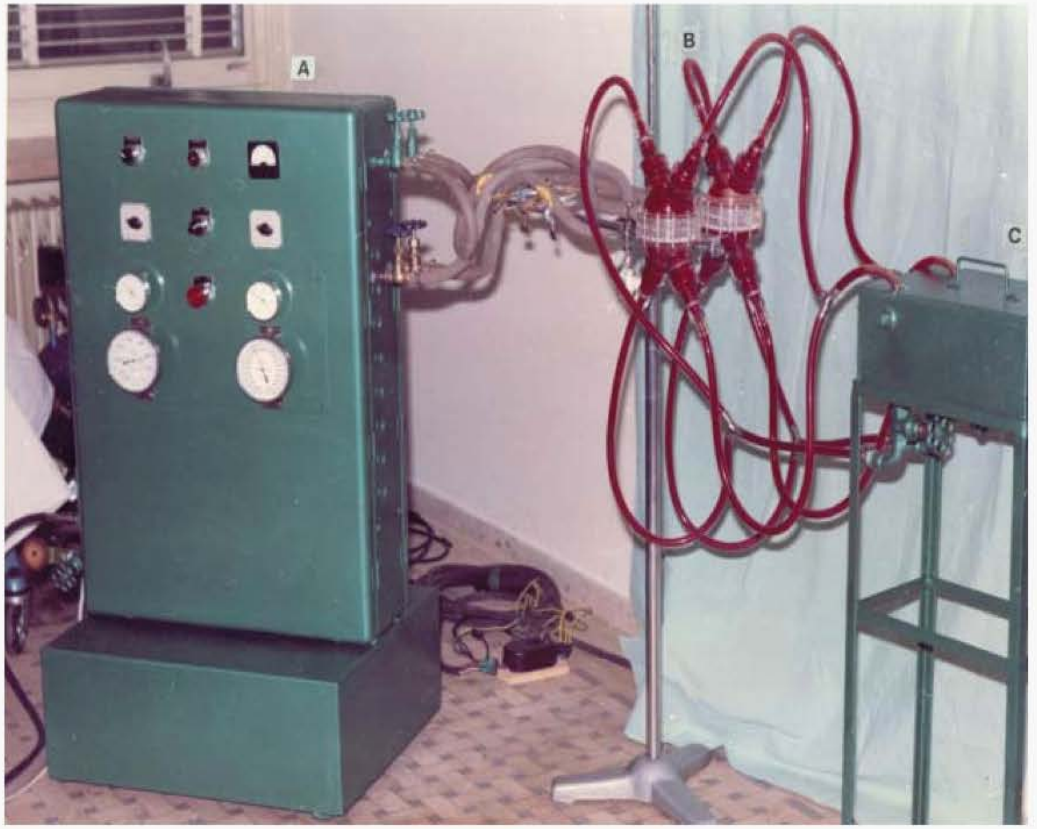
BEGINS MCS's ERA

IL PROGETTO ITALIANO
di
ROBERTO BOSIO

In a context of extreme international scientific research, also in Italy were studied systems not only to repair the heart muscle but also to replace it.



Schema di comando e regolazione elettromeccanica.



Ventricoli artificiali in funzione al banco di prova.

The Bosio family

In Turin, Cavalier Guido Bosio, owner of a mechanical industry, had 2 sons both worked as engineers in the industry family : Felice and Roberto.

Roberto Bosio was born in Turin in 1933 and graduated on 1960 at the Turin Polytechnic in industrial and electrical engineering.

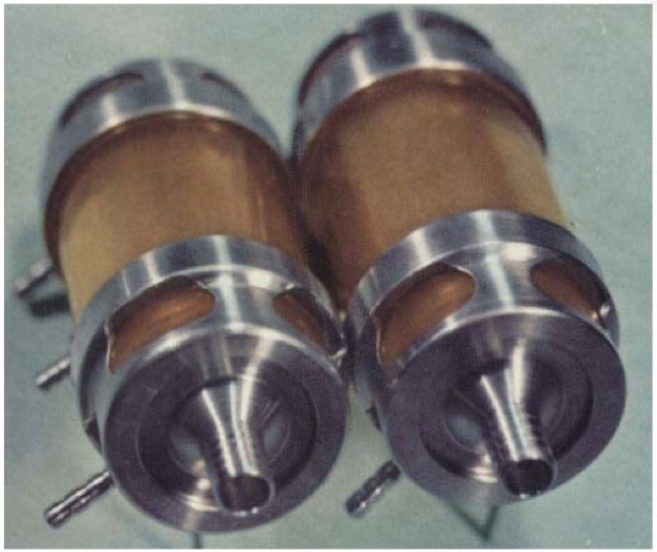
Since early 60's, his work focused on the implementation of bioengineering equipment for the treatment of cardiovascular diseases, becoming at the time one of the top experts in biomechanics and cardiovascular bioengineering .

This passion will accompany him throughout his life, bringing it to teaching a nascent discipline at the Polytechnic of Turin: bio and molecular engineering.

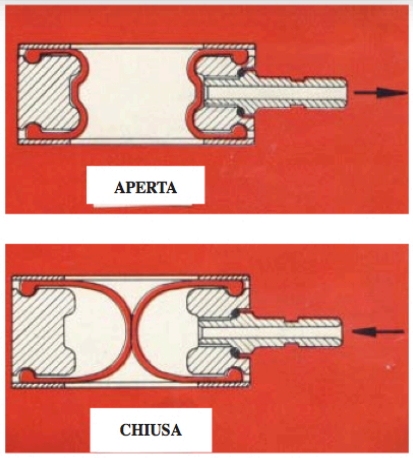
The Actis Dato-Bosio heart

1963 : the engineer **Roberto Bosio**
meet
A Actis Dato a young heart surgeon.

The meeting between a heart surgeon who had very clear concepts of pathophysiology circulatory and an engineer on the other hand had experience and expertise in hydraulics and fluid mechanics allowed to start a fascinating journey of design and testing, even with the use of technical solutions absolutely innovative and original as fluidic valves to reduce turbulence and hemolysis during operation of the ventricles tires



I due ventricoli del cuore artificiale esterno.

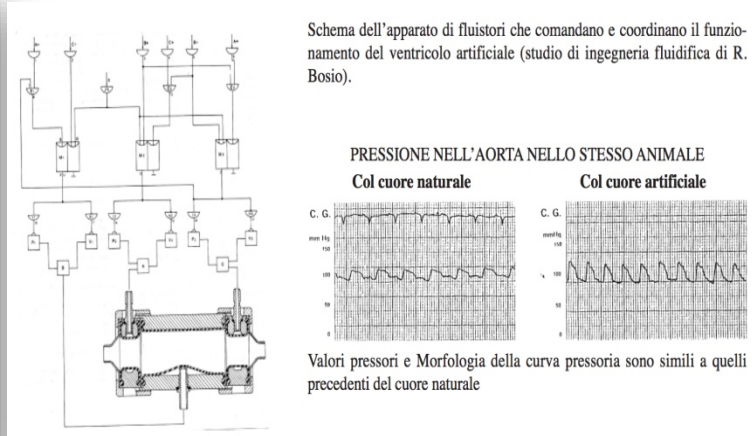


Sezione schematica del ventricolo artificiale in polimetilmetacrilato ed elastomero di silicone.Valvole fluidiche (R. Bosio).

courtesy of Actis Dato family

The Actis Dato-Bosio heart

Prof Angelo Actis Dato e il perfusionista Gino Lavista durante un impianto su animale



Schema dell'apparato di fluistori che comandano e coordinano il funzionamento del ventricolo artificiale (studio di ingegneria fluidifica di R. Bosio).

PRESSIONE NELL'AORTA NELLO STESSO ANIMALE

Col cuore naturale — Col cuore artificiale

Valori pressori e Morfologia della curva pressoria sono simili a quelli precedenti del cuore naturale

Primo prototipo di cuore artificiale a campana con i due ventricoli contrapposti

That device caused the immediate attention of prof. A Senning, director of Clinical Surgery in Zurich Cantonal Hospital, and introduced A Actis Dato e F Bosio in the international medical-scientific board.

courtesy of Actis Dato family

The Actis Dato-Bosio heart

1968: after years of study and design with use of innovative and original technical solutions as the fluidic valves to reduce turbulence and hemolysis during the contractile activity of the artificial ventricles, there has been recording in the Patent Office of the first artificial heart Italian:

Actis Dato-Bosio fluidic pump control for artificial circulation


UFFICIO CENTRALE BREVETTI

BREVETTO PER INVENZIONE INDUSTRIALE

N. 820372

Il presente brevetto viene concesso per l'invenzione oggetto della domanda sotto specificata:

TORINO

11901

TITOLARE ACTIS DATO ANGELO
A TORINO
BOSIO ROBERTO
A CASTIGLIONE TORINESE, TORINO

RAPPR.TE Ing. JACOBACCI CASETTA
via ALFIERI N. 17 TORINO

TITOLO POMPA ATTA A REALIZZARE UNA CIRCOLAZIONE SANGUIGNA ARTIFICIALE

ROMA, li 15 LUG. 1968

IL DIRETTORE


STUDIO TECNICO
Ing. JACOBACCI-CASETTA
BREVETTI - MARCHI

Via Alfieri, 17 — TORINO (Italia)

Stato Italia

Titolare ACTIS-DATO Angelo

Invenzione "Pompa atta a realizzare una circolazione,ecc."

Privativa N. 820372

Depositata 16 Ottobre 1967

Rilasciata 15 luglio 1968

Durata 15 anni dal 16 Ottobre 196

Annualità da pagare prima del 31 Ottobre

Pratica attuazione: la 1ª volta prima del 15.7.1971

e in seguito ogni 3 anni a datare dalla precedente.

Priorità

Marcatura articoli brevettati facoltativa

Abbiamo diritto all'Ufficio di, per adempimento, curare delle pratiche da fare per mantenere la validità della Privativa.
Tuttavia si declina qualsiasi responsabilità sul caso in cui, per qualsiasi motivo, il Cliente non riceverà un tale avviso.

courtesy of Actis Dato family

The Actis Dato-Bosio heart

The first experimental installation took place in Zurich University Hospital in Switzerland, by M Turina M and C Scherf of a german shepherd female dog of 8 years and 30 kg weight called Bless.

From the newspapers of the time:
"*…after an operation that lasted about 4 hours, under the personal control of the engineer Bosio, the artificial heart has finally begun to beat . The emodinamic parameters was perfect…*"

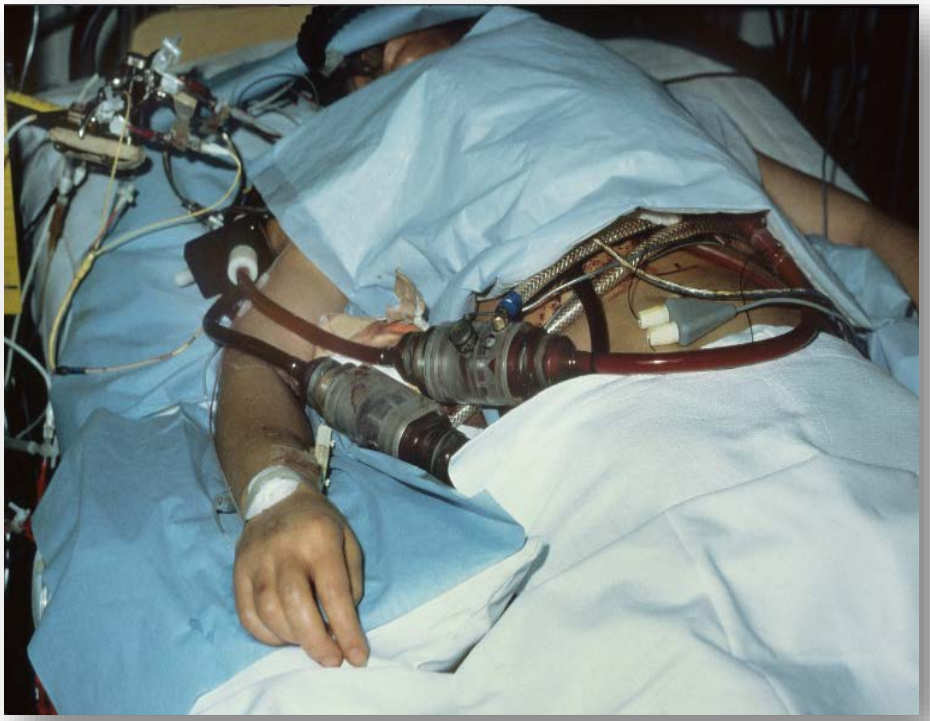
At 48 hours following implantation the animal was suppressed because the experiment was scheduled to last a number of hours.

M Turina said : "*The artificial heart of R Bosio can be considered perfect . We can keep alive an animal what we want and until now we know that 24 hours of a dog corresponding to 5 days of a man. Today we can put an artificial heart in a patient suffered a heart attack and we can keep him alive at least ten days waiting for a transplant. We are on a wonderful road.*"

The Actis Dato-Bosio heart

Device consisting in 2 artificial ventricles each comprising a hollow body with one-way valves of inlet and outlet whose inner cavity was divided into 2 compartments by a membrane of elastically deformable material

The weight and size were very low

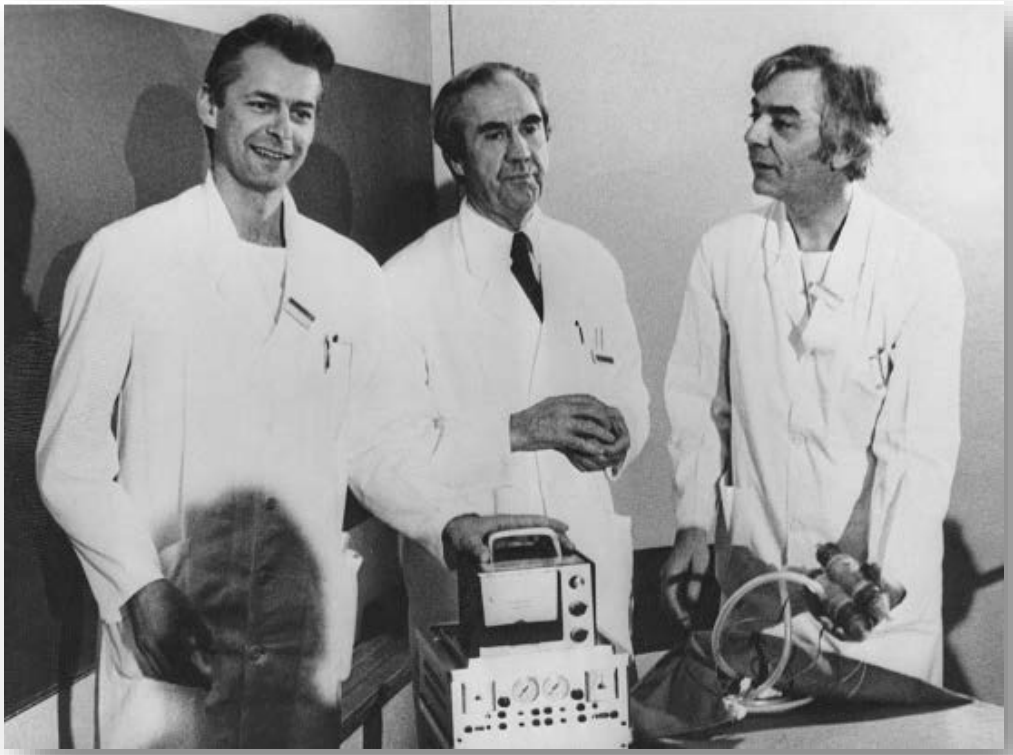


For reasons of lack of validation and authorization by the italian ministry of Health, this device was never implanted in Italy

courtesy of Actis Dato family

1977 Switzerland experience

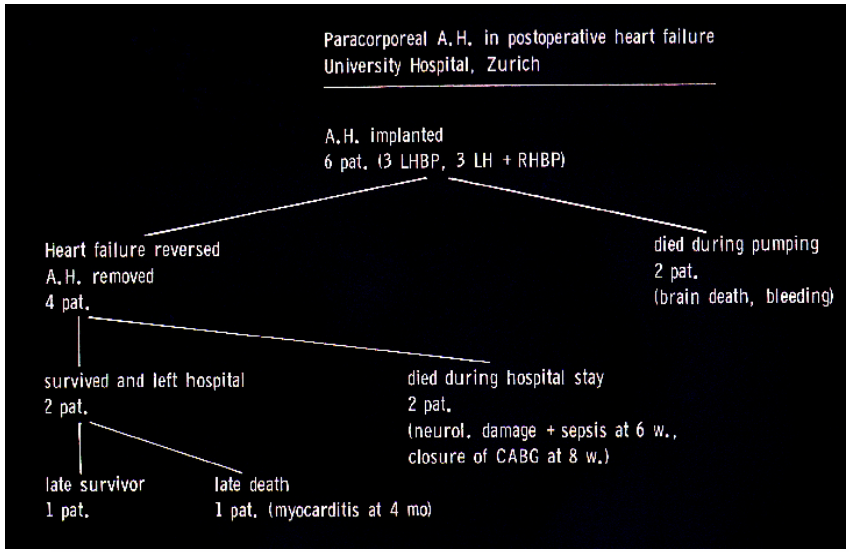
from 1977 as “bridge to recovery” in Zurich University Hospital implanted in 6 patients not wean by CEC after cardiac surgery .

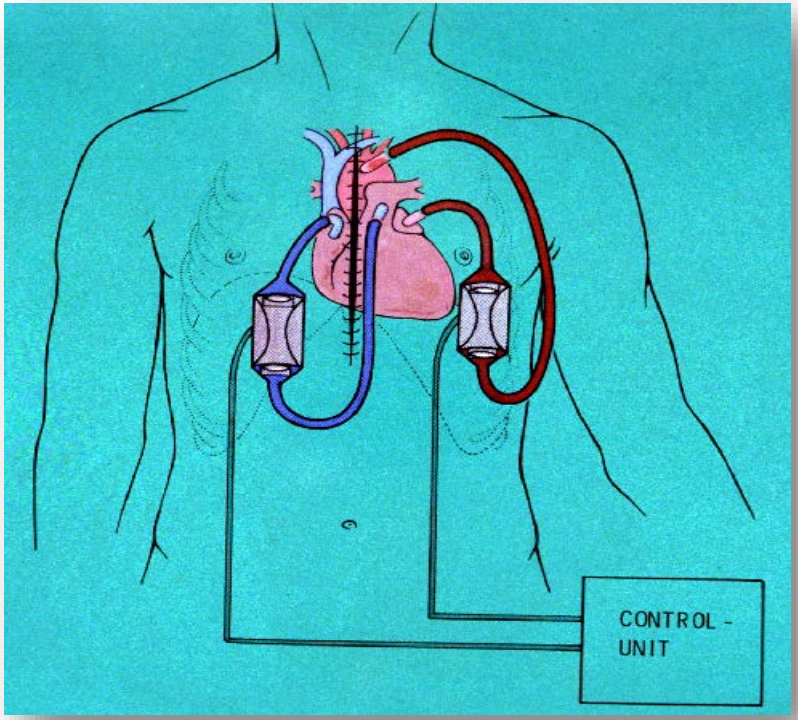


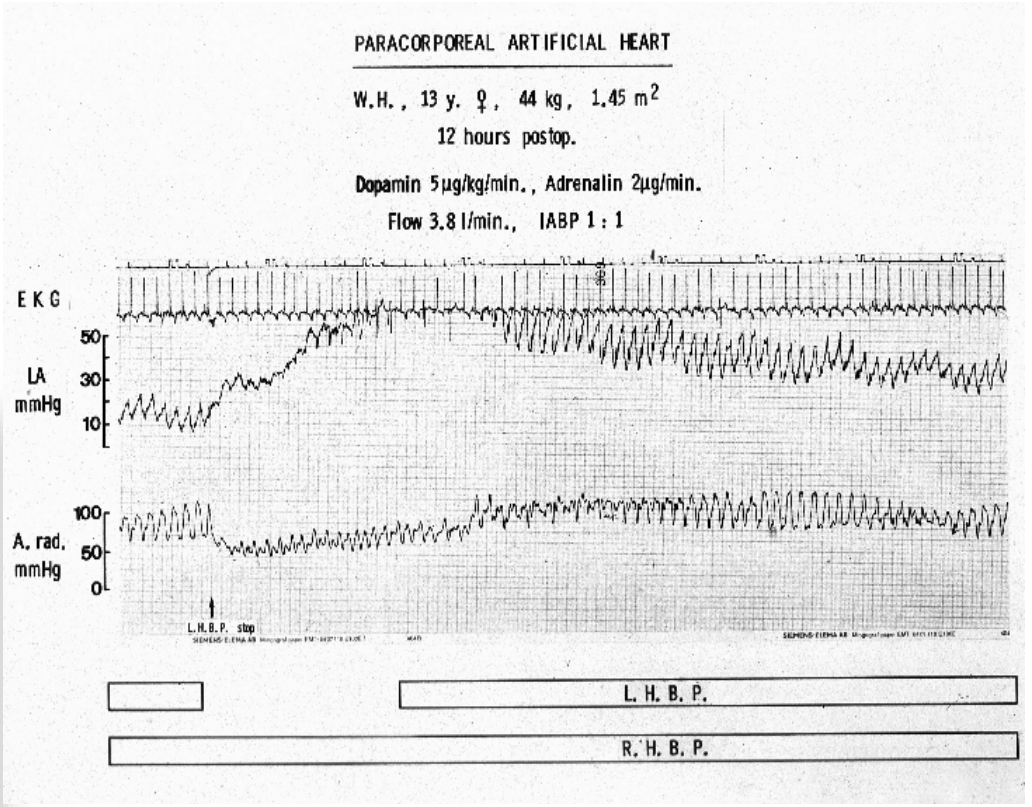
A team of surgeons who saved the life of a heart attack victim, at the Zurich University Hospital in Switzerland, using an artificial heart, 20th December 1977.

from left to right, croatian cardiac surgeon Marko Turina, swedish cardiac surgeon Ake Senning and italian engineer Roberto Bosio, who developed the technology.

Switzerland experience







Actis Dato-Bosio heart System Schematics (courtesy of M. Turina)

The Actis Dato-Bosio heart

VAD in Italy

In Italy it took another 20 years to get permission from the Ministry of Health for the implanting of VAD in a man.

The first implant took place almost simultaneously in Pavia and Bergamo between late 1987 and early 1988.

On the night of december 24 1987, **M Viganò** in Pavia planted the first VAD in a patient, which a week after was transplanted an heart.

Simultaneously in january 4 1988, **L Parenzan** in Bergamo put in L-VAD a young man of 17 years suffering from dilated cardiomyopathy . The patient was subjected after 45 days to cardiac transplant with a donor of Turin.

INTERNO

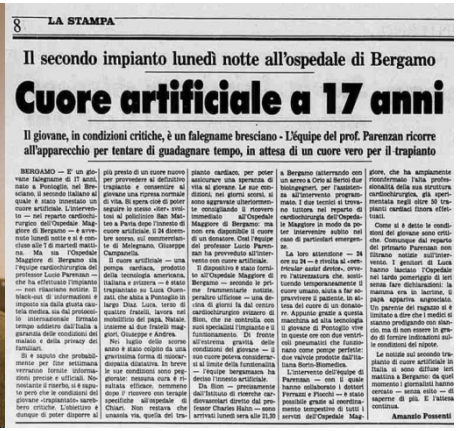
Dalla Francia a Pavia l'organo che ha sostituito la prima macchina impiantata in Italia

Dopo quello artificiale, il cuore vero

Alle 18 di giovedì la segnalazione dal Centro di Sion a quelli di Lione e Milano - Il cuore trasportato in jet a Linate e di lì al San Matteo dove è stato trapiantato su Giuseppe Campanella - «Ha ricominciato a battere da solo» dice il prof. Viganò

Resta segreto il nome del donatore: 24 anni, era in coma da 4 giorni per un colpo di pistola

Il dono d'un ragazzo che rifiutava la vita



LA STAMPA

Il secondo impianto lunedì notte all'ospedale di Bergamo

Cuore artificiale a 17 anni

Il giovane, in condizioni critiche, è un falegname bresciano - L'équipe del prof. Parenzan ricorre all'apparecchio per tentare di guadagnare tempo, in attesa di un cuore vero per il trapianto

VAD in Italy

The first bi-VAD support was implanted in Italy march 13 1988, to Niguarda by A Pellegrini on a patient of 41 years with a biventricular paracorporeal Pierce-Donachy as a bridge to transplant.

The patient was transplanted 31 days after bi-VAD implantation.

Il Prof Pellegrini - Il VAD impiantato a Milano nel 1988

MCS: sunrise of new era?