



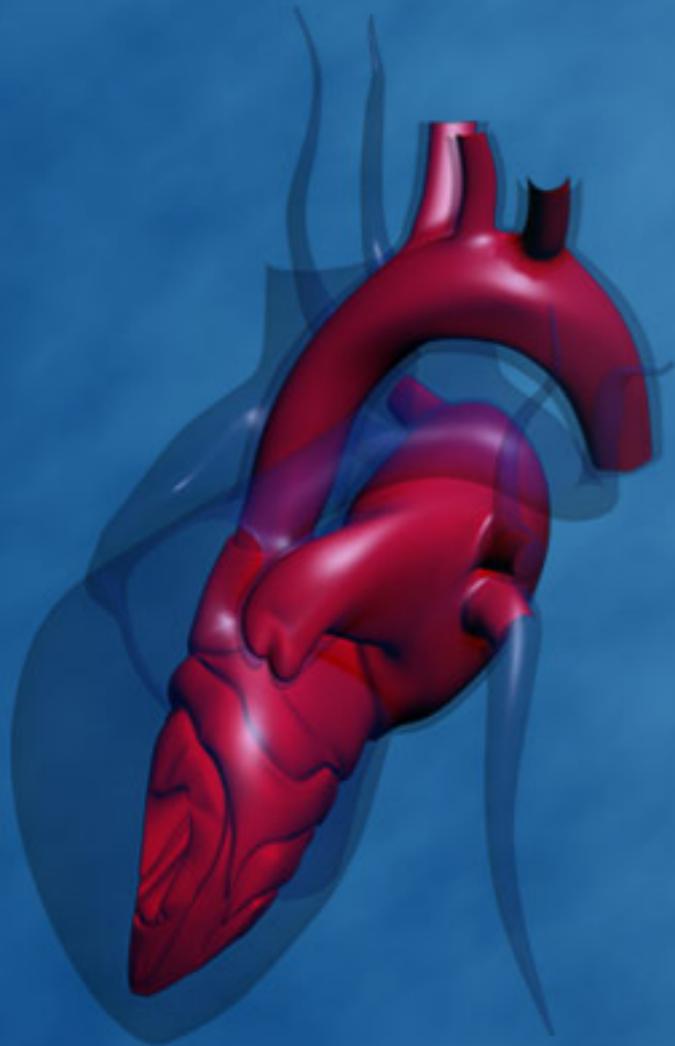
Where's Cardiac surgery going ?

Gino Gerosa

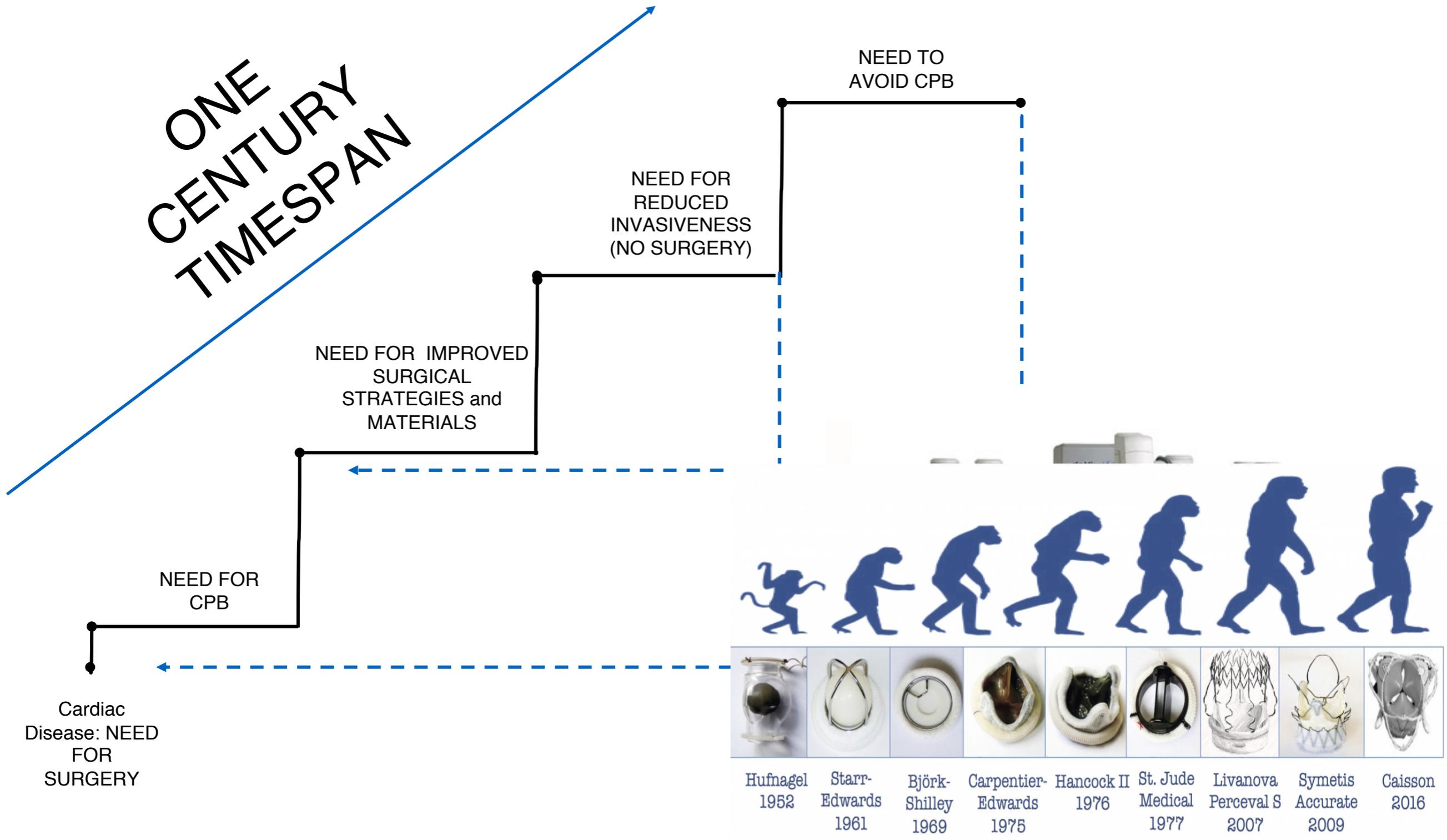
Department of Cardiac, Thoracic and Vascular Sciences,
University of Padua, Italy

*«you can't connect the dots
looking forward; you can only
connect them looking
backwards. So you have to trust
the dots will somehow connect
you in your future»*

Steve Jobs



Innovation in Conventional Cardiac Surgery: Back to the Future!



“The Miracle” 22 Maggio 1989

–Freddie Mercury–

*“Every drop of rain that falls in Sahara Desert say it all, it’s a miracle.
All God's creations great and small, the Golden Gate and the Taj Mahal,
That's a miracle,
Test tube babies being born, mothers, fathers dead and gone,
It's a miracle..”*

*Open-heart and surgery, Sunday mornings with a cup of tea,
Super powers always fighting,
But Mona Lisa just keeps on smiling, it’s a miracle
The wonders of this world go on, the hanging Gardens of Babylon,
Captain Cook and Cain and Able, Jimi Hendrix to the Tower of Babel
It's a miracle, it's a miracle, it's a miracle, it's a miracle..”*





The Past 50 Years of Cardiovascular Surgery

and the Future

Denton A. Cooley and O. H. Frazier

Originally published 22 Mar 2018 | Circulation. 2018;102:lv-87–lv-93



Early operating room scene, showing the cumbersome pump oxygenator equipment and the 14 units of freshly drawn blood needed to repair a simple atrial septal defect. Reprinted with permission of the Texas Heart Institute

**“Any ape can reach for a banana,
but only humans can reach the stars”**

V.S. Ramachandran

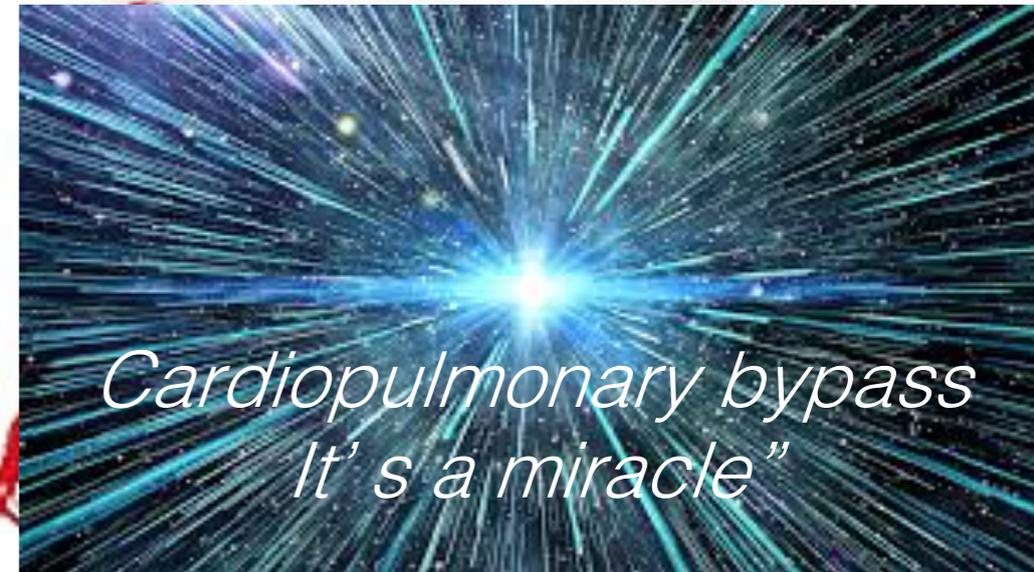
(Indian [neuroscientist](#) known primarily for his work in the fields of [behavioral neurology](#) and visual [psychophysics](#).)

Currently a Professor in the Department of Psychology and the Graduate Program in Neurosciences at the [University of California, San Diego](#))



**The origin:
Open-heart surgery**

**BACK
TO THE FUTURE
THE
Micro-Invasive Cardiac Surgery**



**Mini-invasive
Cardiac surgery
Futurisme?**

Cardiac Surgery: (R)evolution

Conventional
Cardiac Surgery

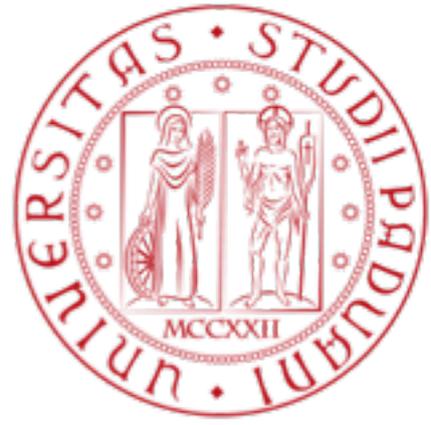


Minimally Invasive
Cardiac Surgery



Over time there has been a trend in reducing the invasiveness of cardiac surgery, moving from full sternotomy to minithoracotomy to robotic approach .

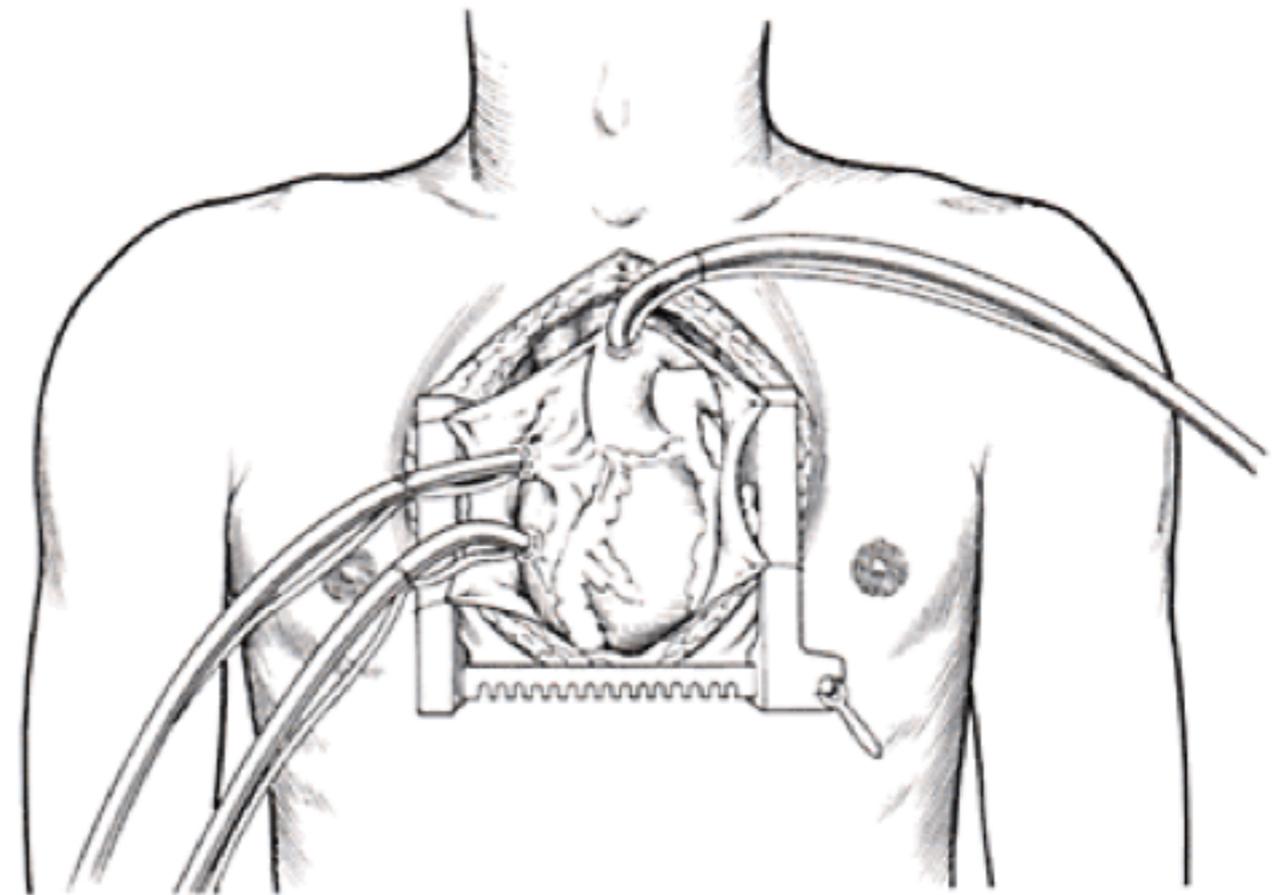
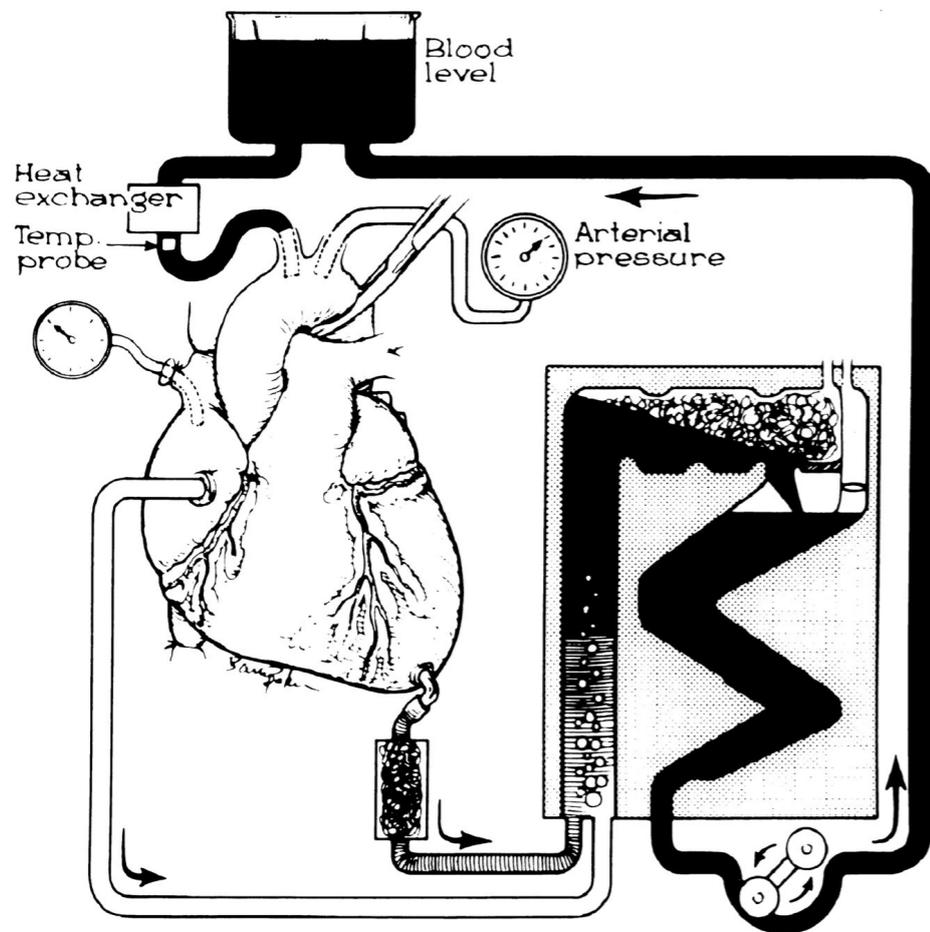
Regardless of the selected technique, however, these approaches all still require the use of cardiopulmonary bypass and cardioplegic arrest of the heart.



Minimally invasive cardiac surgery procedures

- Mitral valve repair and replacement
- Tricuspid valve repair and replacement
- Aortic valve replacement
- Atrial septal defect and patent foramen ovale closure
- Atrioventricular septal defect surgery
- Maze procedure for atrial fibrillation
- Coronary artery bypass surgery
- Saphenous vein harvest for coronary artery bypass surgery

Conventional Cardiac Surgery

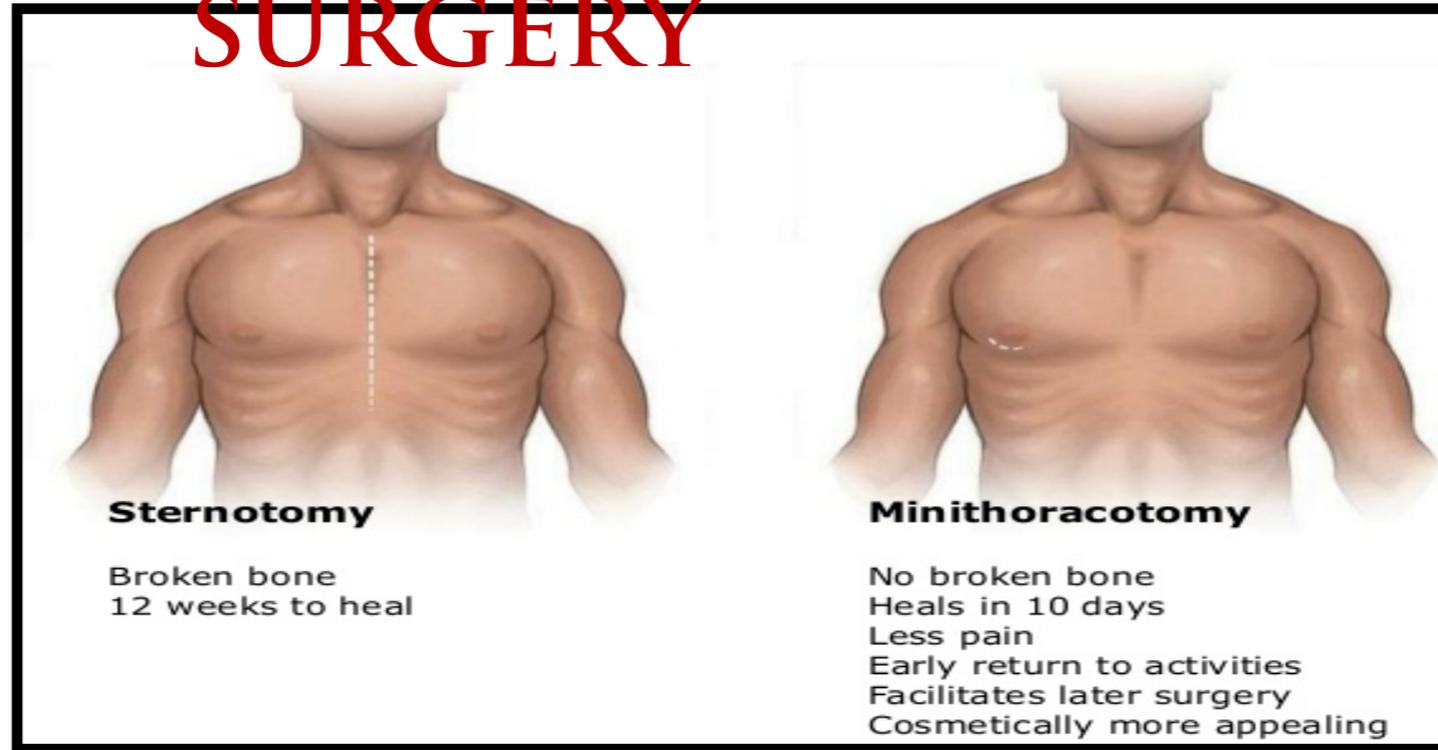


- **Cardiopulmonary bypass;**
- **Aortic Cross Clamp;**
- **Cold Cardioplegic Arrest.**

Full-Sternotomy approach

(Drawing of Heart-lung machine of the 1960s; Reprinted with permission of the Texas Heart Institute.)

MINI-THORACOTOMY ACCESS FOR CARDIAC SURGERY



Benefits of minimally invasive cardiac surgery may include:

- Reduced pain
- Reduced blood loss
- Reduced risk of infection
- Faster recovery and shorter hospital stay
- Less scarring and better cosmetic appearance.

Minimally invasive mitral valve surgery provides excellent outcomes without increased cost: A multi-institutional analysis equivalent

Emily A. Downs, MD¹, Lily Johnston, MD, MPH¹, Damien J. LaPar, MD, MSc¹, Ravi K. Ghanta, MD¹, Irving L. Kron, MD¹, Alan M. Speir, MD², Clifford E. Fonner, BA³, John A. Kern, MD¹, and Gorav Ailawadi, MD¹

¹University of Virginia, Department of Surgery, Division of Thoracic and Cardiovascular Surgery, Michael A. Acker, MD, and W. Clark Hargrove, MD, n Y. Szeto, MD,

The Journal of Thoracic and Cardiovascular Surgery • Volume 151, Number 2

(Ann Thorac Surg 2016;■:■-■)

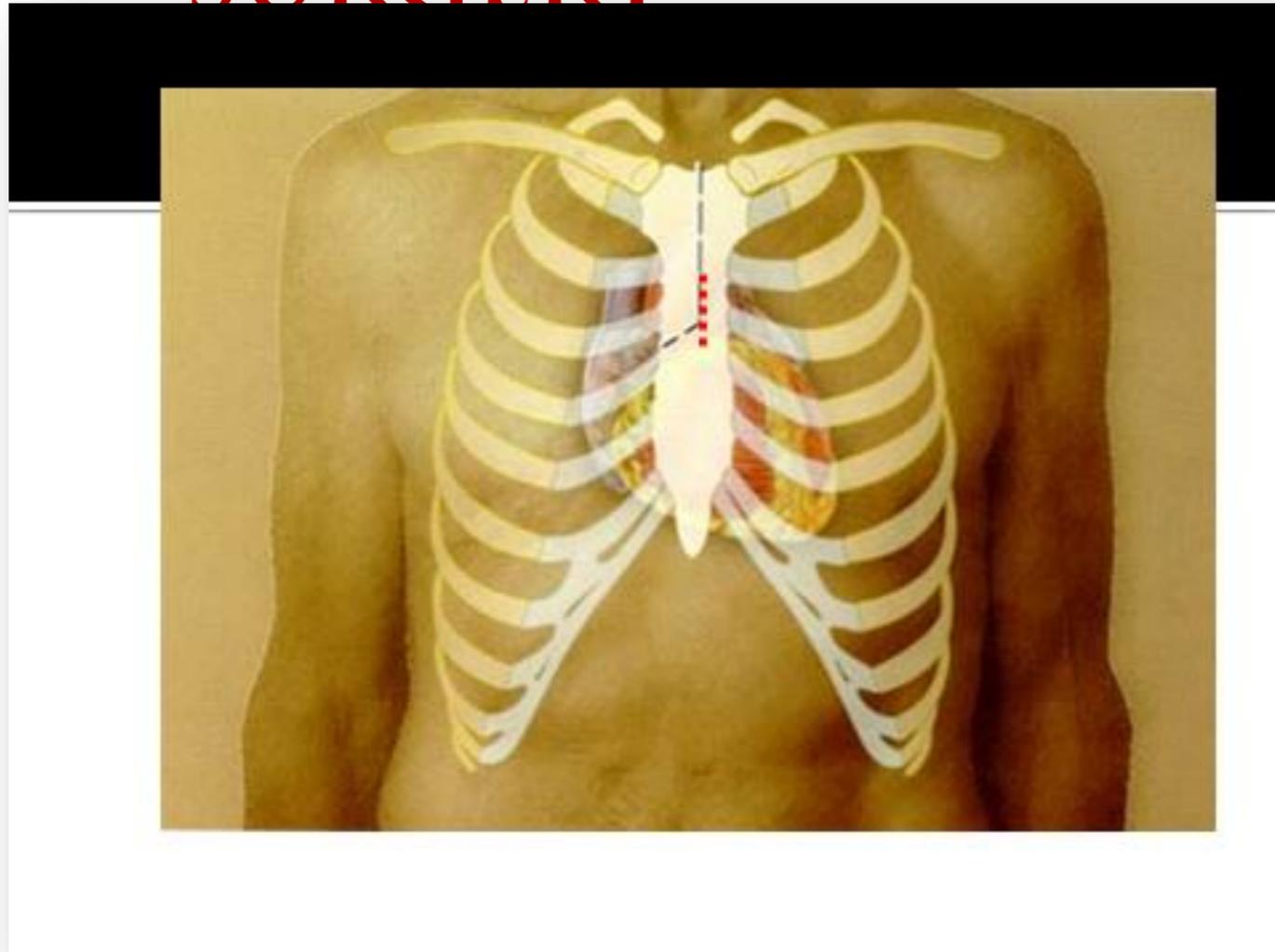
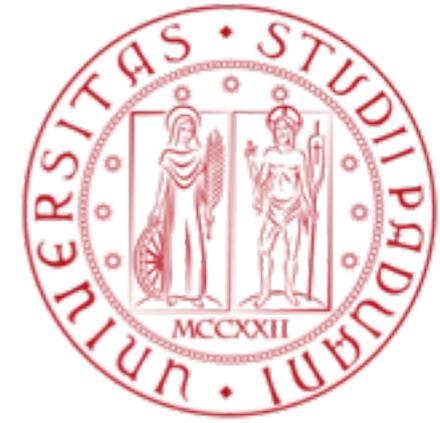
© 2016 by The Society of Thoracic Surgeons

| Variables | Conventional Sternotomy (n = 355) | Mini-MVR (n = 355) | p Value |
|---|--------------------------------------|-----------------------|---------|
| Concomitant atrial fibrillation procedure | 128 (36%) | 66 (18.6%) | <0.001 |
| Mitral repair | 258 (72.7%) | 295 (83.1%) | <0.001 |
| Femoral arterial cannulation | 39 (11%) | 331 (93%) | <0.001 |
| Cardiopulmonary bypass time, minutes | 112 [90–153] | 137 [116–168] | <0.001 |
| Cross-clamp time, minutes | 75 [63–104] | 107.5 [83–125] | <0.001 |
| Operative death | 4 (1.1%) | 4 (1.1%) | 1.0 |
| Stroke | 3 (0.9%) | 3 (0.9%) | 1.0 |
| Renal failure | 2 (0.6%) | 4 (1.1%) | 0.41 |
| Prolonged ventilation | 15 (4.2%) | 25 (7%) | 0.1 |
| Total postoperative ventilation time, hours | 5.2 [3.6–6.7] | 4.2 [3.2–6.4] | 0.003 |
| Deep sternal wound infection | 0 (0%) | 0 (0%) | 1.0 |
| Reoperation | 12 (3.4%) | 15 (4.2%) | 0.56 |
| Atrial fibrillation | 65 (18.3%) | 55 (15.5%) | 0.32 |
| Any postoperative transfusion | 99 (28%) | 41 (11.6%) | <0.001 |
| Red blood cell units | 0.69 ± 2.4 | 0.27 ± 1.2 | 0.004 |
| Blood product units, total | 1.41 ± 5.4 | 0.55 ± 2.3 | 0.006 |
| ICU length of stay, hours | 29.3 [23–70] | 24 [10.9–47] | 0.006 |
| Postoperative length of stay, days | 5 [4–8] | 4 [3–6] | <0.001 |

Continuous variables are expressed as median [Interquartile range] or mean ± SD. Categorical variables are expressed as n (%).

ICU = intensive care unit; Mini-MVR = minimally invasive mitral valve repair or replacement.

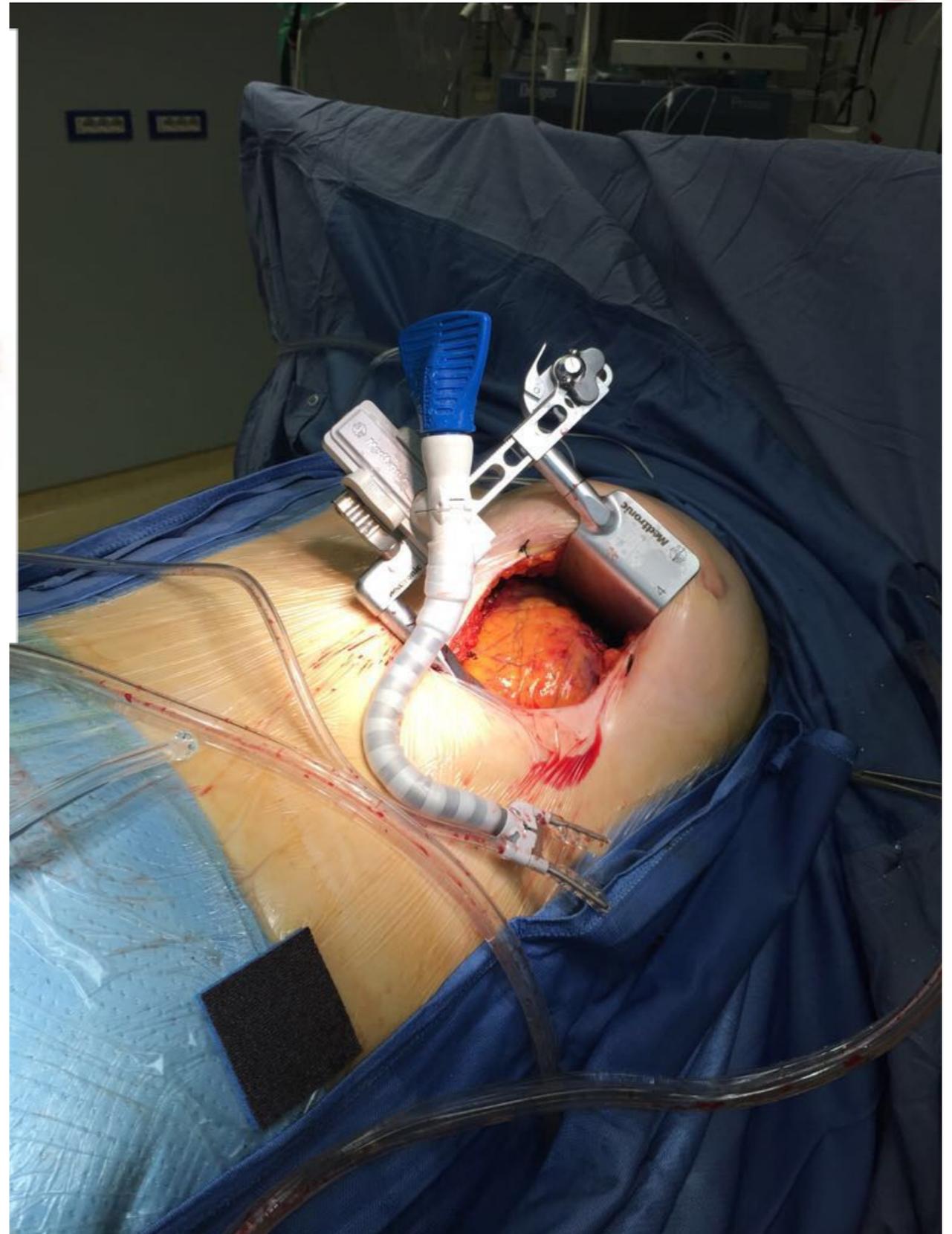
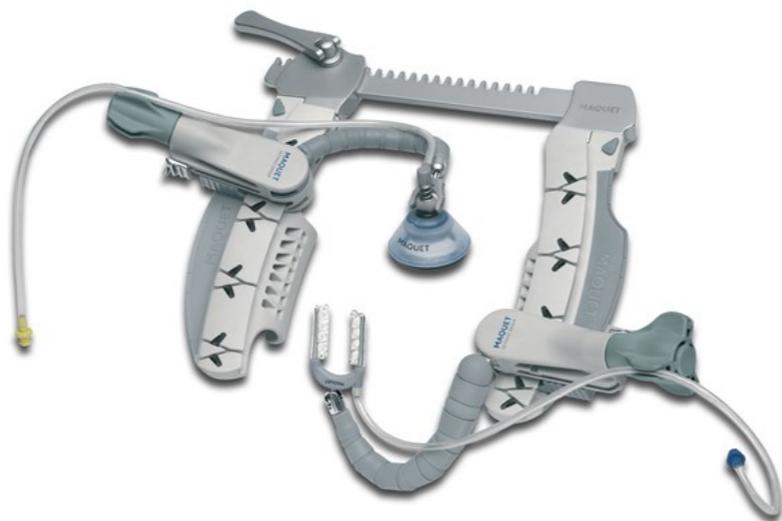
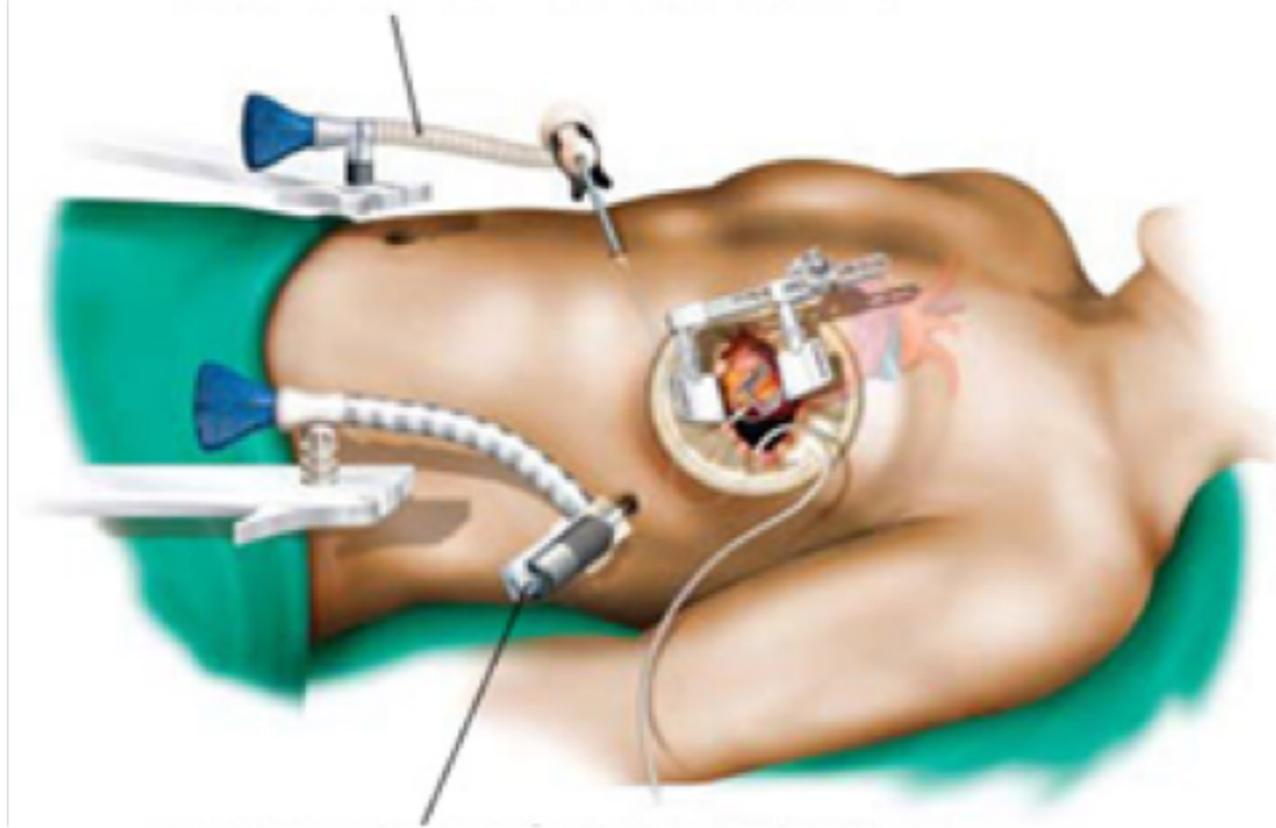
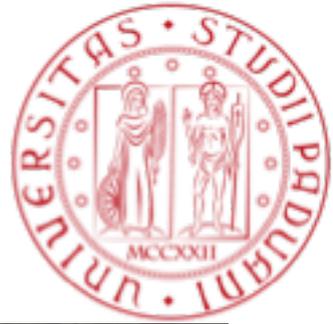
MINISTERNOTOMY FOR AORTIC VALVE SURGERY



Minimally invasive aortic valve replacement (AVR) through ministernotomy has been developed as an alternative to conventional AVR to reduce surgical trauma and has demonstrated favorable postoperative outcomes.

- Murtuza B, Pepper JR, Stanbridge RD, et al. Minimal access aortic valve replacement: is it worth it? *Ann Thorac Surg* 2008;85:1121–31.
- Brown ML, McKellar SH, Sundt TM, Schaff HV. Ministernotomy versus conventional sternotomy for aortic valve replacement: a systematic review and meta-analysis. *J Thorac Cardiovasc Surg* 2009;137:670–9.
- Gilmanov D, Bevilacqua S, Murzi M, et al. Minimally invasive and conventional aortic valve replacement: a propensity score analysis. *Ann Thorac Surg* 2013;96:837–43.
- Furukawa N, Kuss O, Aboud A, et al. Ministernotomy versus conventional sternotomy for aortic valve replacement: matched propensity score analysis of 808 patients. *Eur J Cardiothorac Surg* 2014;46:221–6.

Minimally invasive cardiac surgery (MICS) CABG

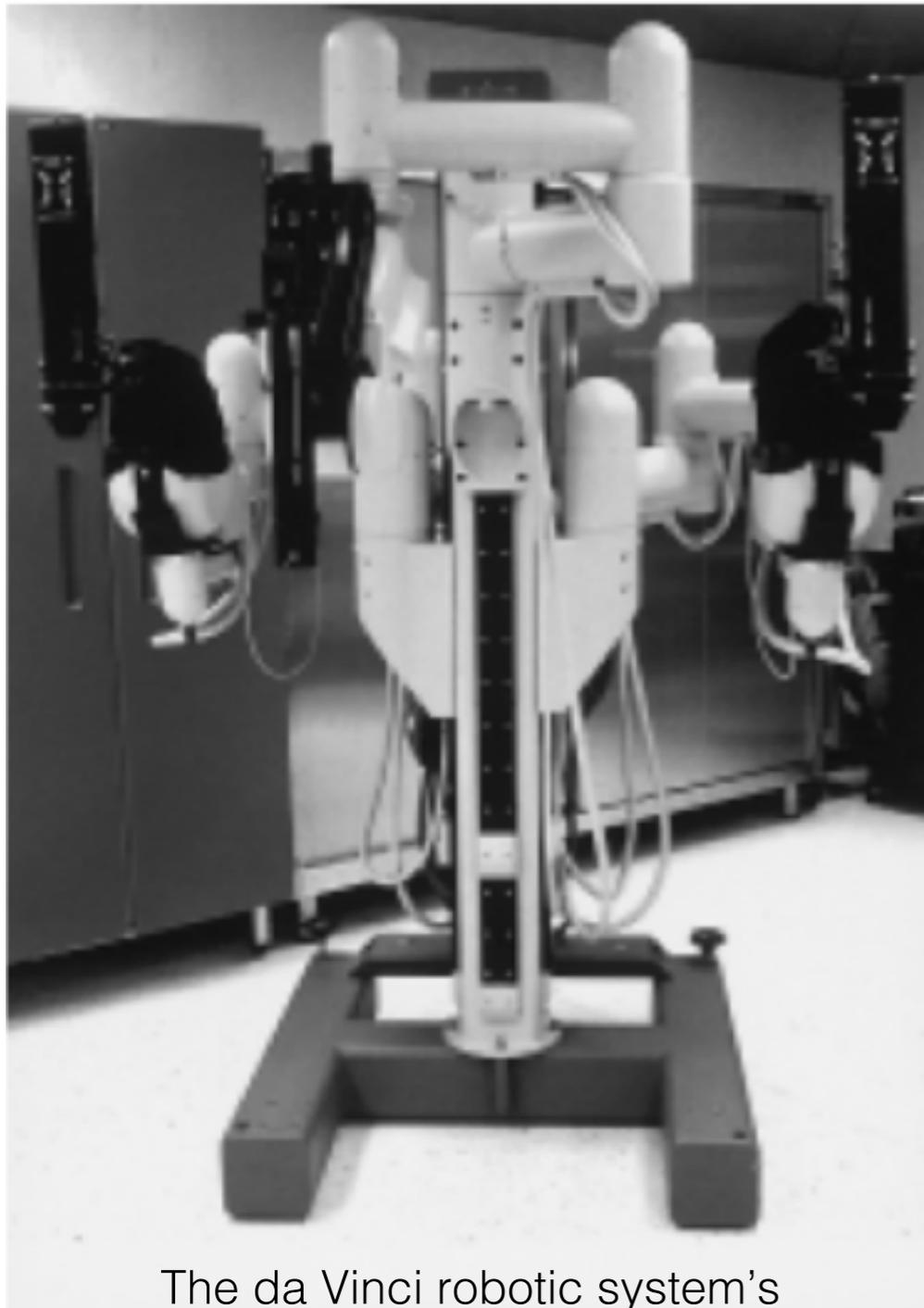


First Italian robot-enhanced coronary bypass

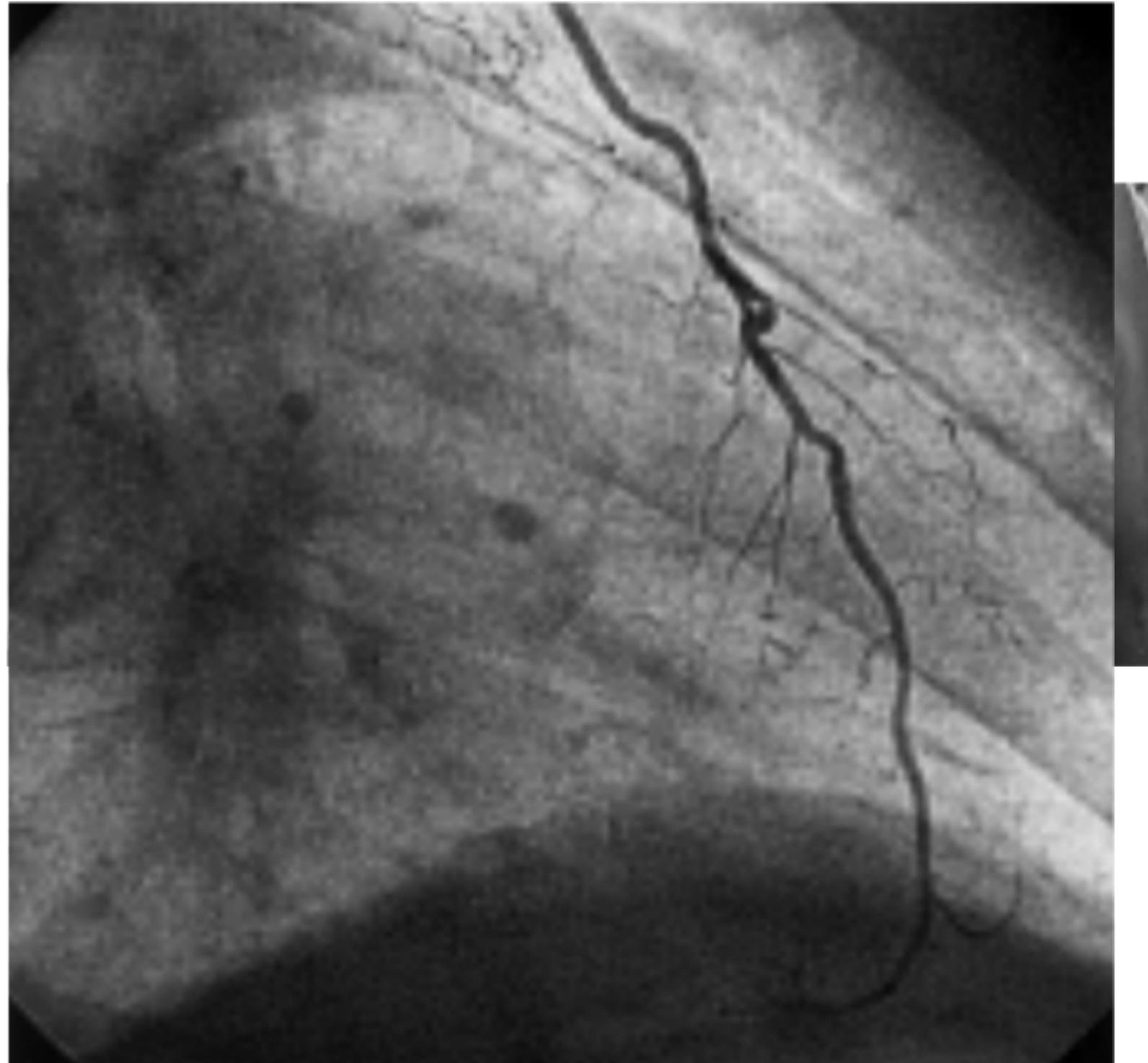
(Ital Heart J 2004; 5 (6): 475-478)

Gino Gerosa, Francesca di Marco, Roberto Bianco, Igor Vendramin, Dino Casarotto

Department of Cardiovascular Surgery, University of Padua, Padua, Italy



The da Vinci robotic system's slave unit



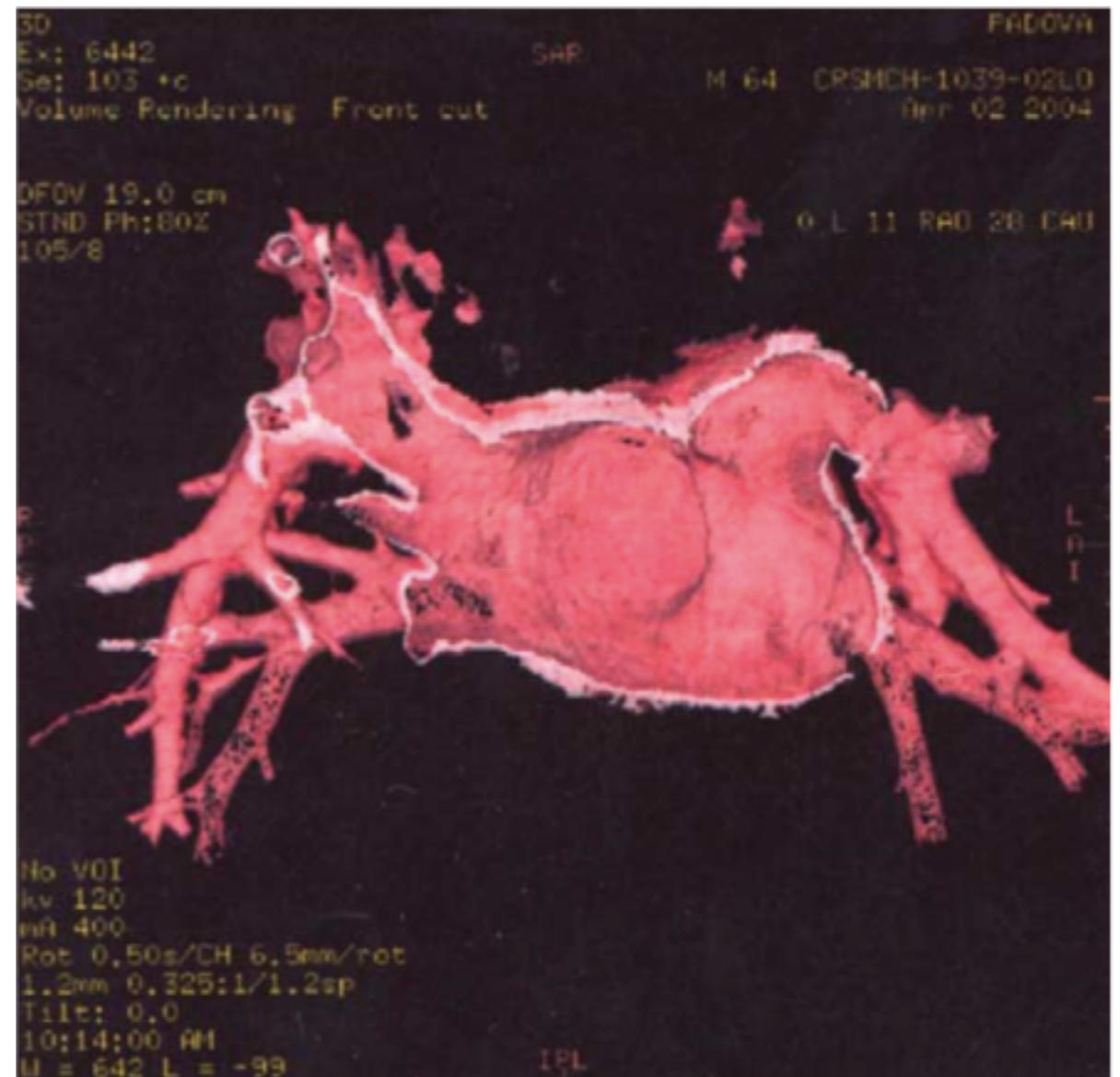
On day 5 postoperatively

Totally endoscopic robotic-guided pulmonary veins ablation: an alternative method for the treatment of atrial fibrillation[☆]

Gino Gerosa^{a,*}, Roberto Bianco^a, Gianfranco Buja^b, Francesca di Marco^a

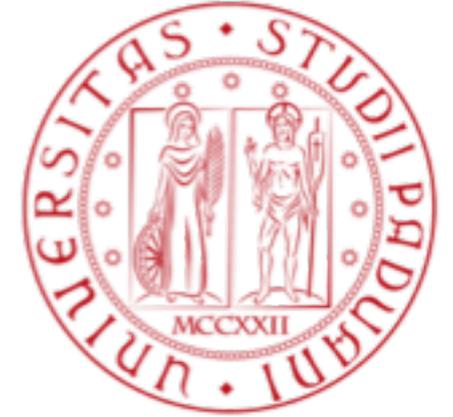
^a*Istituto di Chirurgia Cardiovascolare, Università degli Studi di Padova, 35128 Padova, Italy*

European Journal of Cardio-thoracic Surgery 26 (2004) 450–452



Three-month follow up: angio-TC excluding any stenosis of pulmonary veins' orifices.

Technique vs. technology

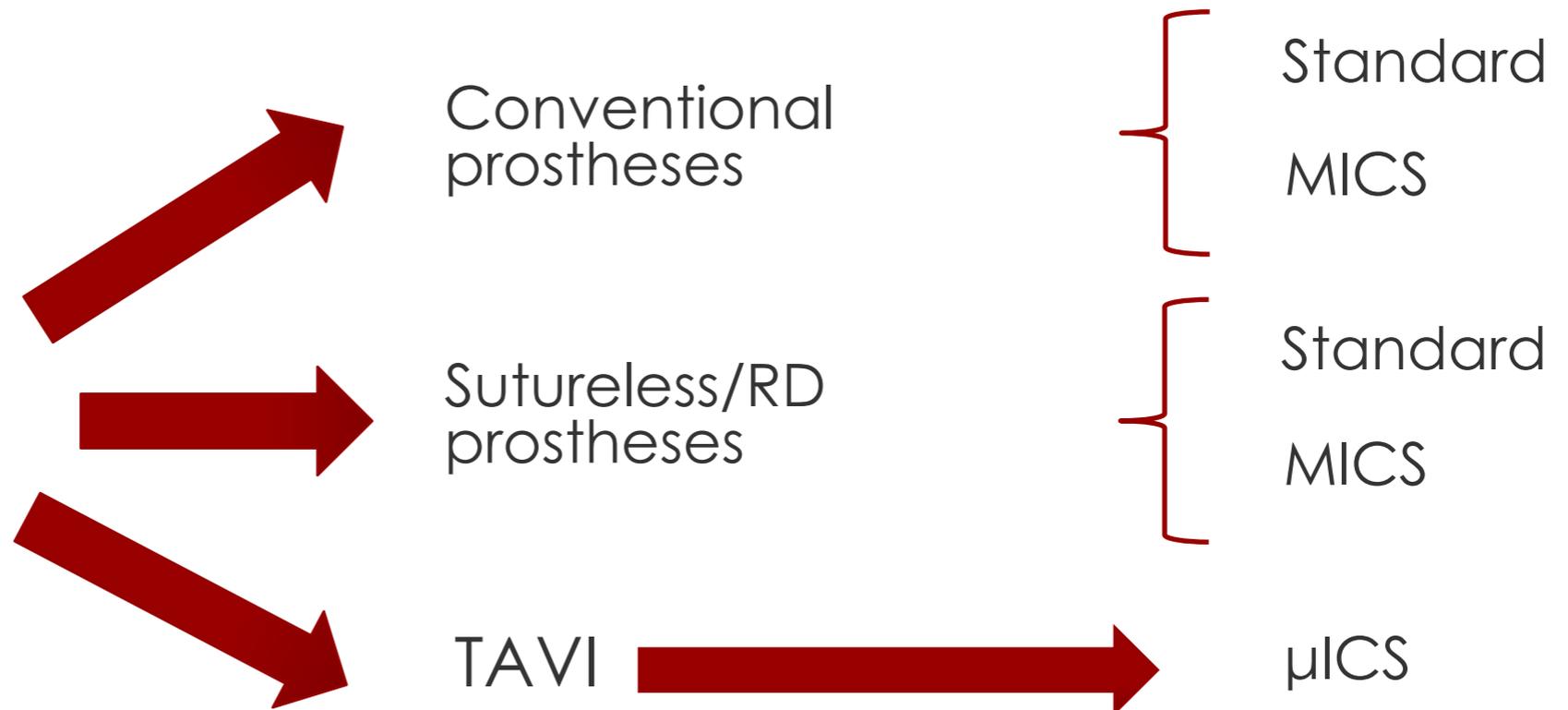


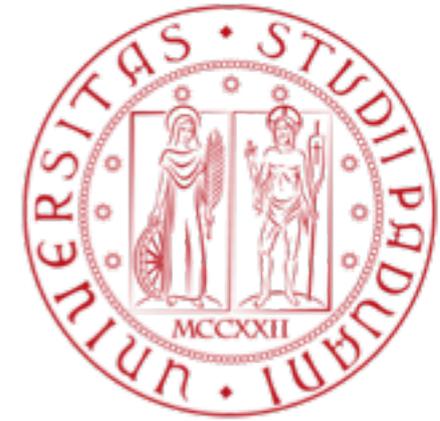
TECHNIQUE (STATIC)



- The treatment of severe aortic valve stenosis is the **IMPLANTATION** of a prosthesis in aortic position

TECHNOLOGY (DYNAMIC)





However, we have already evolved through technology

Conventional Valve Surgery



Minimally invasive valve Surgery (MICS)

Median sternotomy



Ministernotomy/Minithoracotomy

Central CPB



Peripheral CPB / Off-pump

Central cardioplegia



Percutaneous retrograde cardioplegia

Central cross clamp



Endoclamp

Conventional Instruments



Minimally invasive instruments

Standard prostheses



Sutureless/Rapid deployment prostheses

Just one more step....

We can do it

Minimally invasive valve Surgery



TAVI (μ ICS)

Ministernotomy/Minithoracotomy



Percutaneous/small incision

Peripheral CPB



No CPB

Percutaneous retrograde cardioplegia



No cardioplegia

Endoclamp



No cross clamp

Minimally invasive instruments



No Instruments

Sutureless/Rapid deployment prostheses



TAVI/TMVR

MI-AVR VS. TAVI

MI-AVR

Arrested heart

CPB

Often longer and more technically demanding than SAVR

Need for skin incision

Always general anesthesia

TAVI

Beating heart

No need for CPB

Shorter than

Total

Conscious sedation or anesthesia only

Multimodality imaging techniques

**Micro-invasive AVR
(μ I-AVR)**

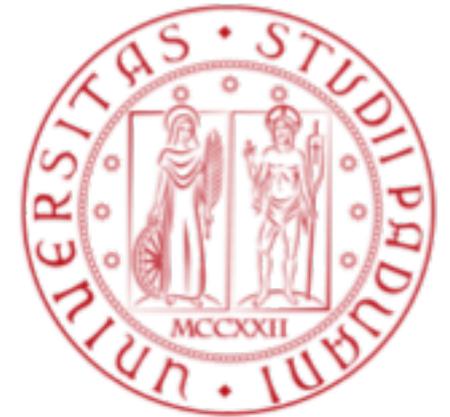
What is really “less invasive” ?

Editorial

Shifting a Paradigm of Cardiac Surgery: From Minimally Invasive to Micro-Invasive

Augusto D'Onofrio, Gino Gerosa

Division of Cardiac Surgery, University of Padova, Padova, Italy



It goes without saying...

- a) on the beating heart,
- b) with no need for CPB,
- c) in a totally percutaneous fashion or with a very small skin incision,
- d) after with local anesthesia
- e) using multimodality imaging techniques.

It is not a futuristic scenario. IT is REALITY.

μ ICS would NOT be just reserved to a restricted number of inoperable patients. Cardiac surgery needs to KEEP UP WITH TIMES!
We need to rethink our vision of cardiac surgery and be ready to reshape our mentality.

Cardiac Surgery: (R)evolution



Over time there has been a trend in reducing the invasiveness of cardiac surgery, moving from full sternotomy to minithoracotomy to robotic approach .

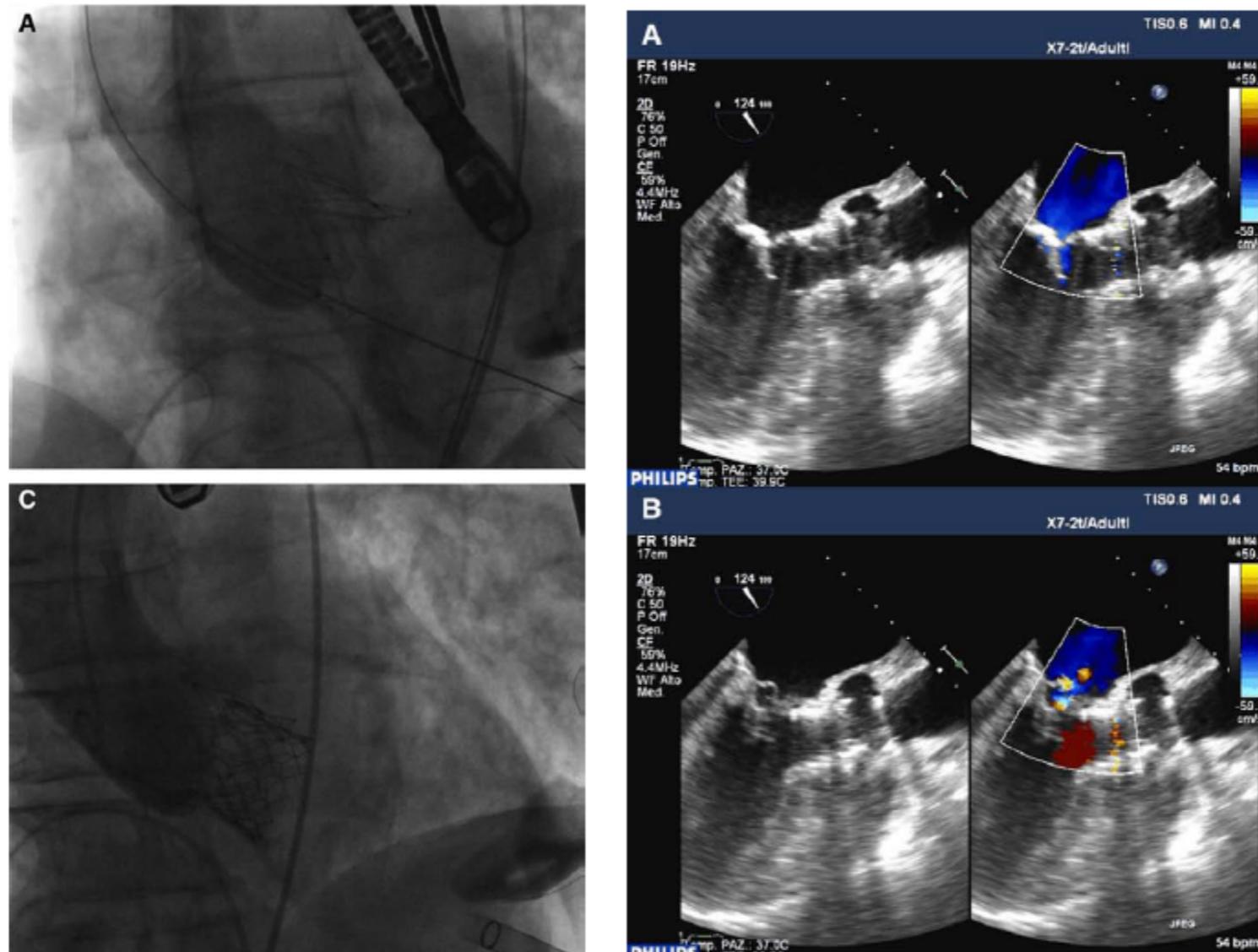
Regardless of the selected technique, however, these approaches all still require the use of cardiopulmonary bypass and cardioplegic arrest of the heart.

One-Stage Off-Pump Transapical Mitral Valve Repair and Aortic Valve Replacement

Gino Gerosa, MD; Augusto D'Onofrio, MD, PhD; Erica Manzan, MD; Laura Besola, MD; Eleonora Bizzotto, MD; Fabio Zucchetto, MD; Giuseppe Tarantini, MD, PhD; Demetrio Pittarello, MD; Andrea Colli, MD, PhD

Circulation, May 2015

TA-TAVI + NeoChord

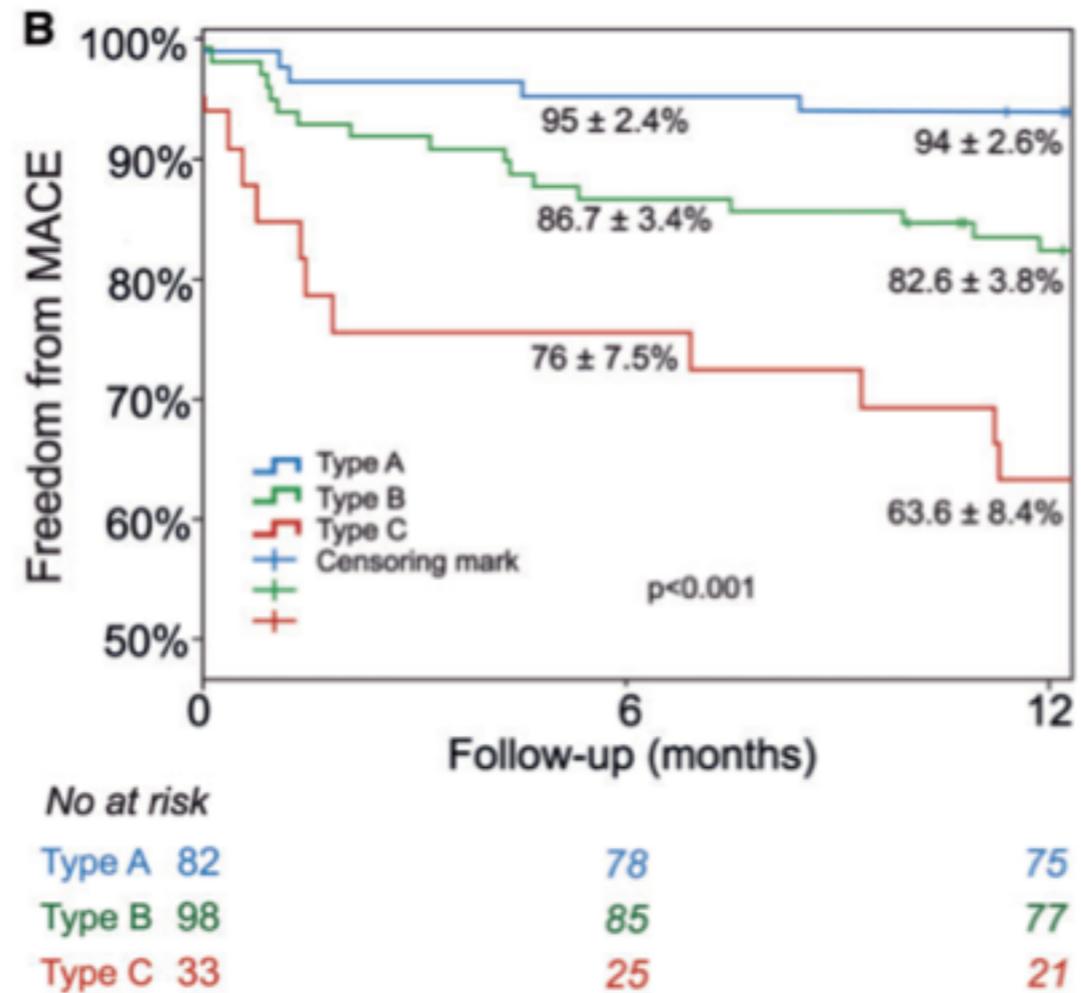
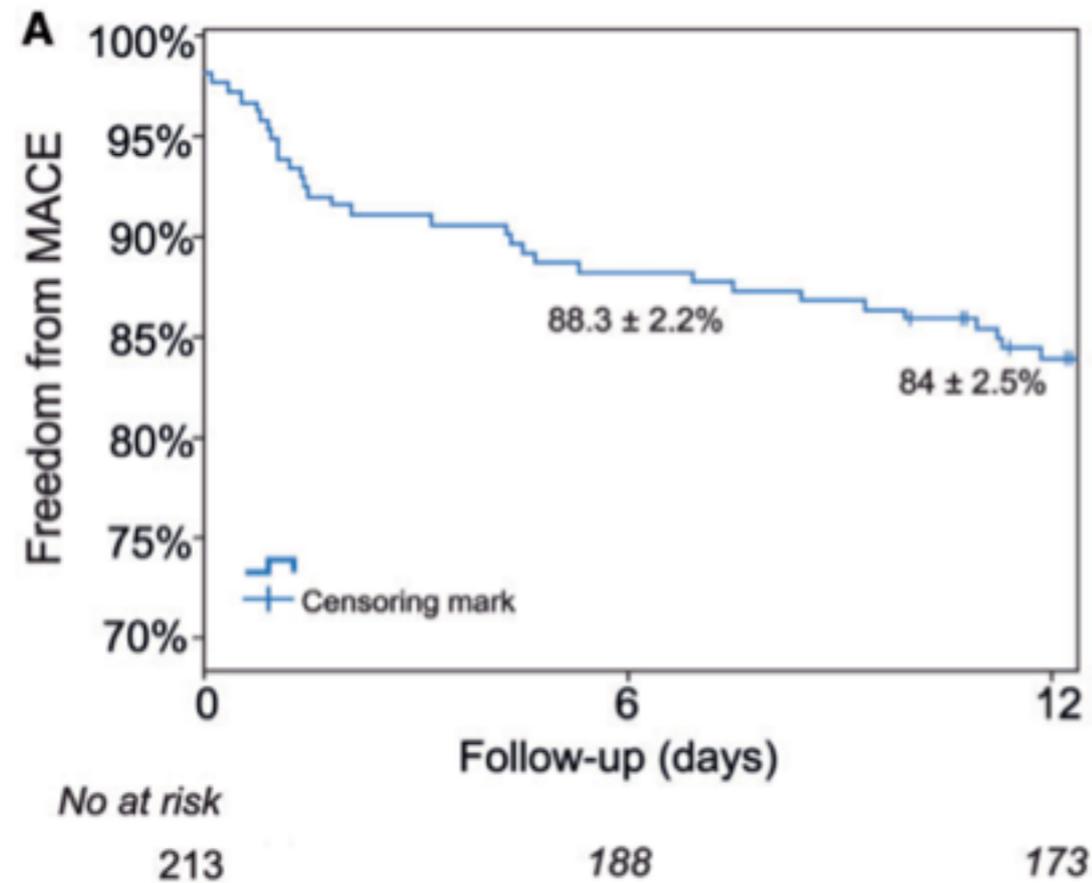


NeoChord Repair

Cite this article as: Colli A, Manzan E, Aidiets A, Rucinskas K, Bizzotto E, Besola L et al. An early European experience with transapical off-pump mitral valve repair with NeoChord implantation. Eur J Cardiothorac Surg 2018; doi:10.1093/ejcts/eyz064.

An early European experience with transapical off-pump mitral valve repair with NeoChord implantation†

Andrea Colli^a, Erica Manzan^a, Audrius Aidiets^b, Kestutis Rucinskas^b, Eleonora Bizzotto^a, Laura Besola^a, Nicola Pradegan^a, Demetrio Pittarello^a, Vilius Janusauskas^b, Diana Zakarkaite^b, Agne Drasutiene^b, Arturas Lipnevicius^b, Bernhard C. Danner^c, Horst Sievert^d, Laura Vaskelyte^d, Nalan Schnelle^d, Stefano Salizzoni^e, Massimo Marro^e, Mauro Rinaldi^e, Katarzyna Kurnicka^f, Kristof Wrobel^f, Mariano Ceffarelli^g, Carlo Savini^h, Davide Pacini^h and Gino Gerosa^a



TEE-Guided Transapical Beating-Heart Neochord Implantation in Mitral Regurgitation



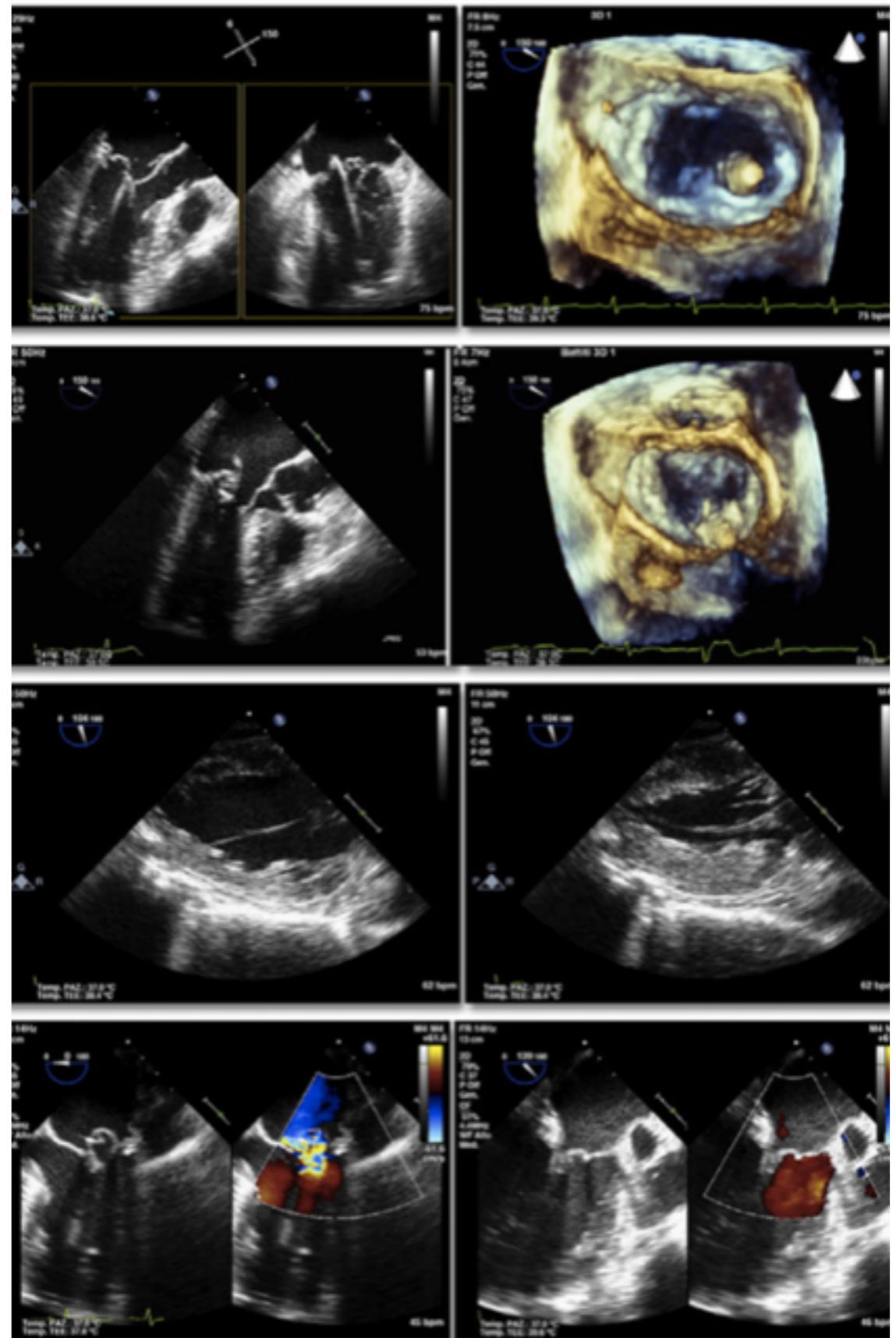
Andrea Colli, MD, PhD,* Erica Manzan, MD,
Fabio Zucchetta Fabio, MD, Cristiano Sarais, MD,
Demetrio Pittarello, MD, Giovanni Speziali, MD, Gino Gerosa, MD

*Department of Cardiology, Thoracic and Vascular Sciences, University of Padua, via Giustiniani 2, 35128 Padova, Italy. *E-mail:* colli.

The so-called “*surgical view*,” presents the view of the valve similar to that seen by the surgeon from a left atrial perspective.

For assessing mitral valve anatomy and guiding the device from the apex of the left ventricle across the mitral annulus, 2D TEE is preferred.

Once the mitral valve has been crossed, the view is changed to real-time 3D TEE. 3D TEE allows for optimal orientation of the tip of the device.

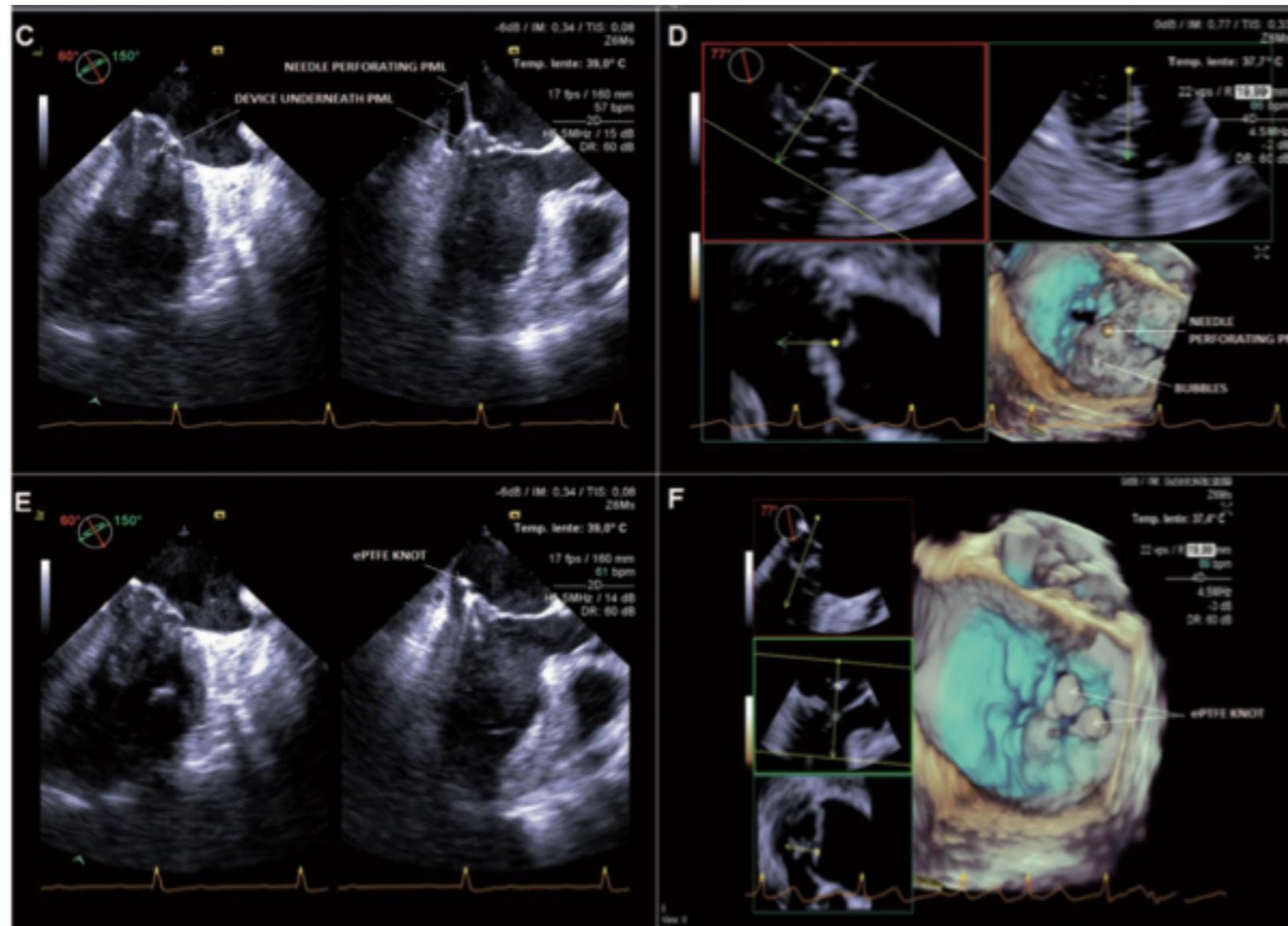


Transoesophageal echo-guided mitral valve repair using the Harpoon system

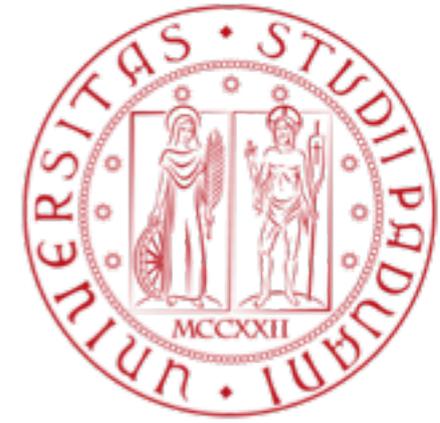
Gino Gerosa[†], Augusto D'Onofrio, Laura Besola[†] and Andrea Colli^{*†}

European Journal of Cardio-Thoracic Surgery 00 (2017) 1–3
doi:10.1093/ejcts/ezx365

Cardiac Surgery Unit, Department of Cardiac, Thoracic and Vascular Sciences, University of Padua, Padova, Italy

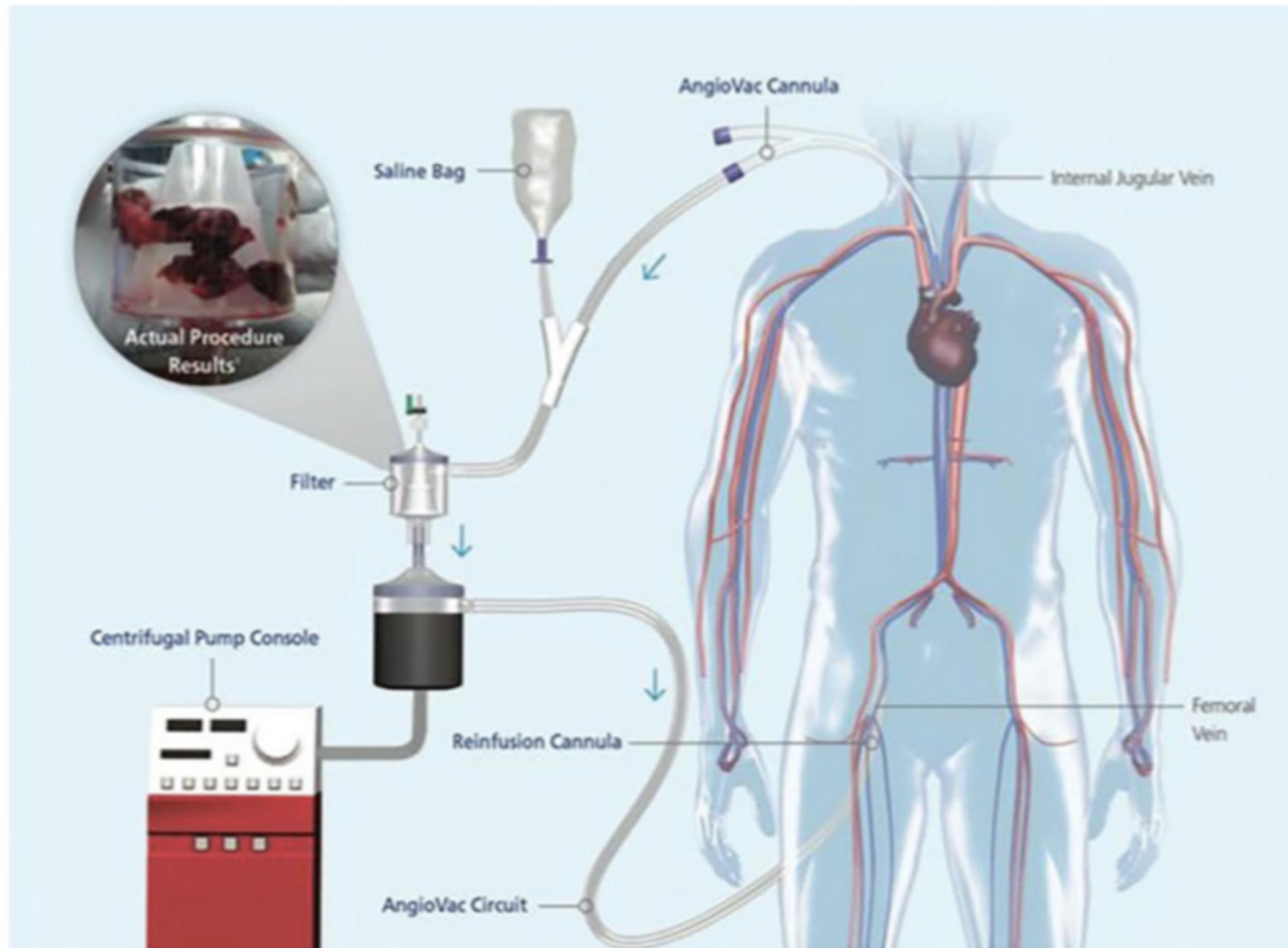


Transapical off-pump echo-guided mitral valve repair with implantation of artificial ePTFE chordae with the Harpoon device has been proposed to treat patients presenting with severe mitral regurgitation due to posterior leaflet prolapse. The device is inserted in the left ventricle and steered to the surface of the diseased portion of the leaflet.



The role of percutaneous vacuum-assisted thrombectomy for intracardiac and intravascular pathology

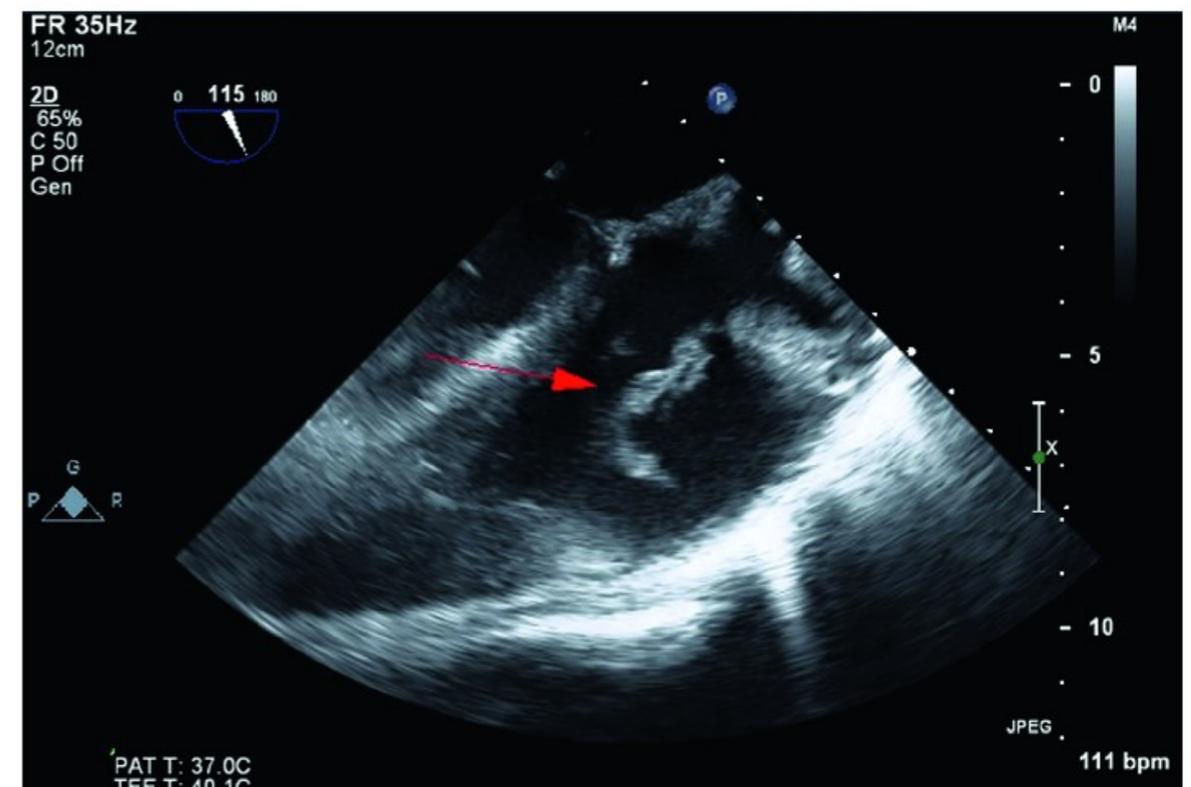
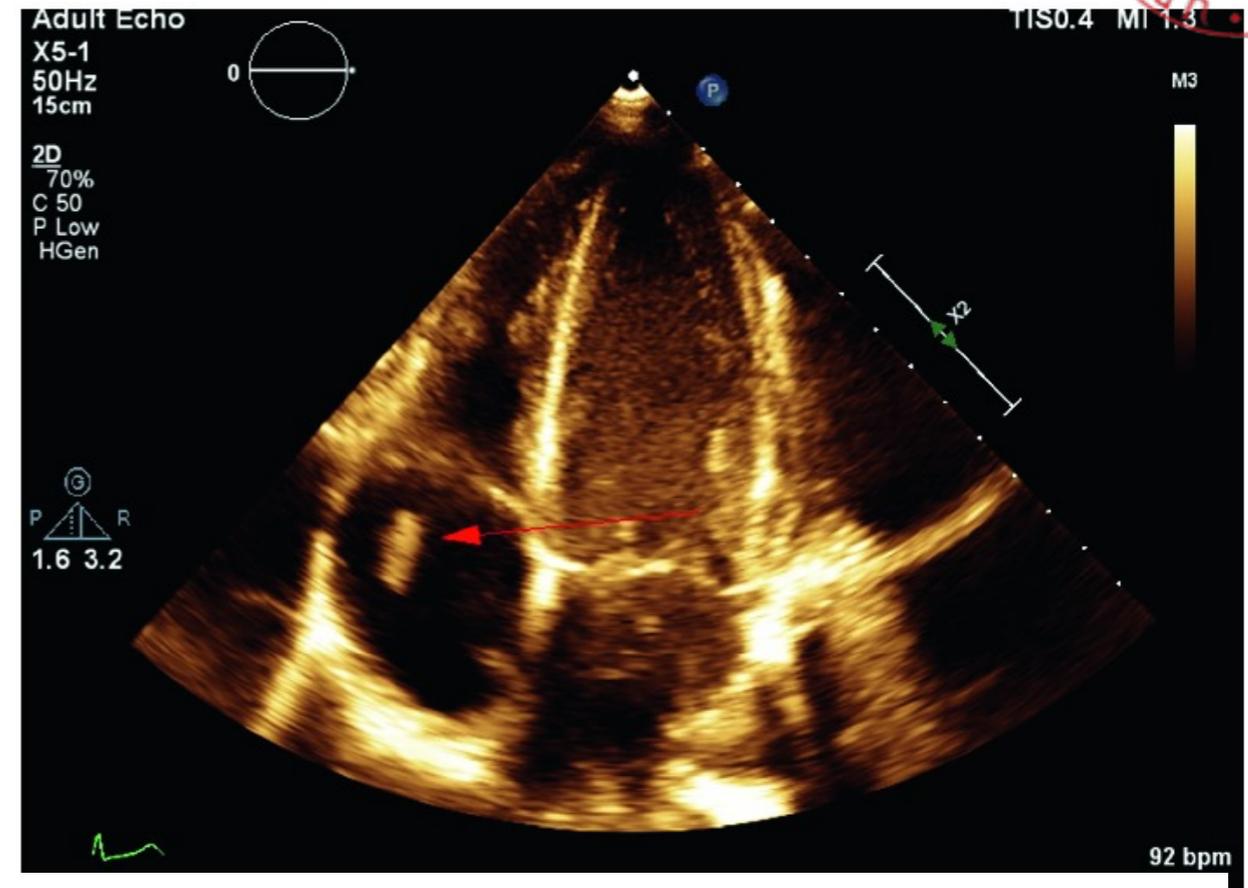
Craig Basman MD  | Umar Rashid MD | Yuvrajsinh J. Parmar MD |



VAT: Angio VAC system

A vacuum-based device approved in 2014 for percutaneous removal of undesirable materials from the intravascular system.

The use of the AngioVac device has been approved in aspiration of ilio caval, pulmonary, upper extremity, and right-sided heart chamber thrombi; we performed its use in treatment of right-sided endocarditis.



First-in-Human of Catheter-Delivered Annuloplasty Ring to Treat Functional Mitral Regurgitation

JACC: CARDIOVASCULAR INTERVENTIONS
© 2016 BY THE AMERICAN COLLEGE OF CARDIOLOGY FOUNDATION
PUBLISHED BY ELSEVIER

Gino Gerosa, MD,^a Laura Besola, MD,^a Erica Manzan, MD,^a Eleonora Bizzotto, MD,^a Fabio Zucchetta, MD,^a Demetrio Pittarello, MD,^b Giuseppe Tarantini, MD, PhD,^a David Meerkin, MD,^c Andrea Colli, MD, PhD^a

Implantation of the Amend transcatheter mitral valve repair system (ValCare Medical, Herzliya, Israel) to treat functional mitral incompetence under a compassionate use approval.

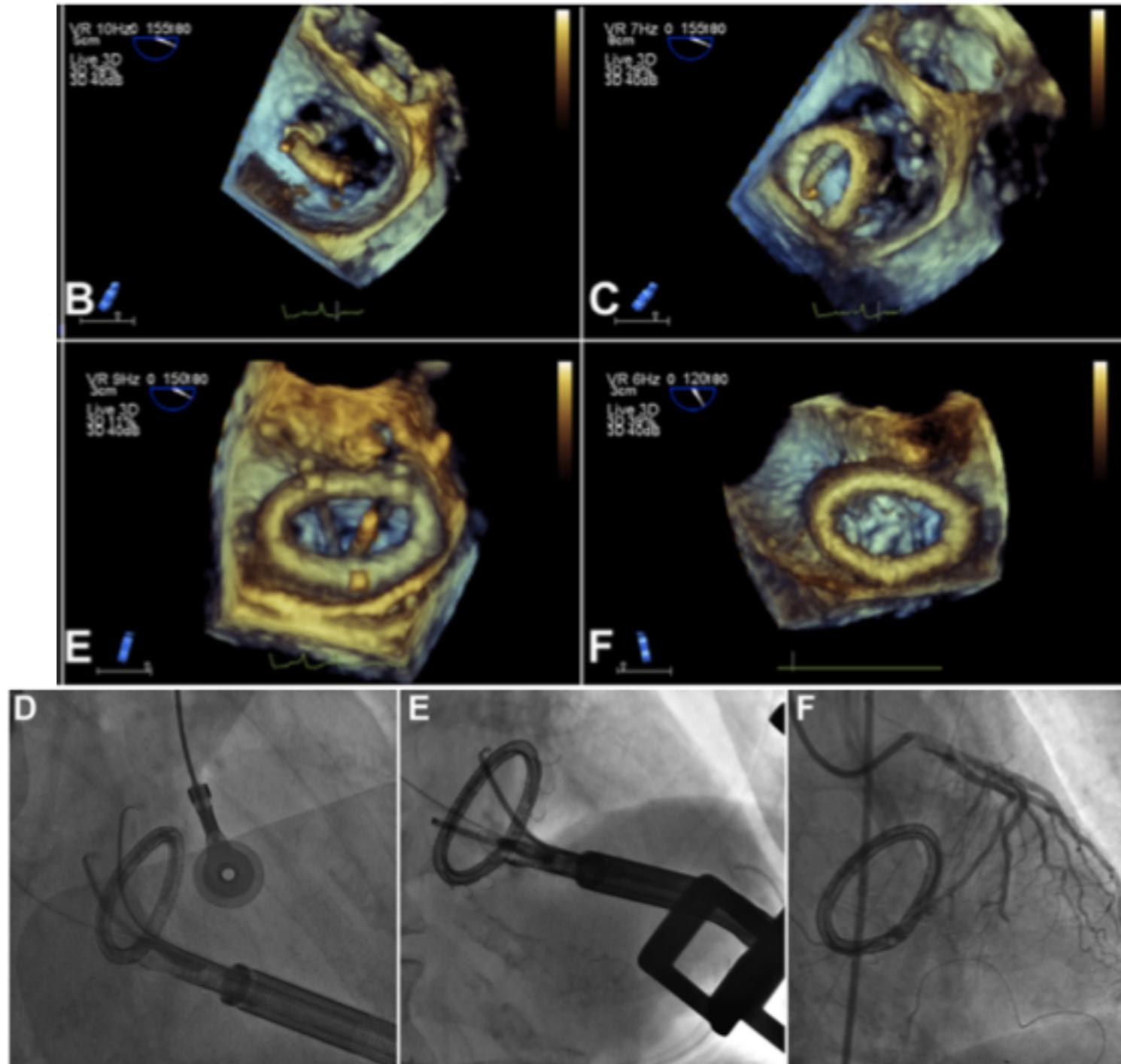
A standard transapical access the 28-F Amend system was advanced through the mitral valve over a wire to the left atrium and the ring was unsheathed, Gerosa et al.

The ring was then oriented appropriately to the annulus

The sheath was steered anteriorly toward the mitro-aortic continuity and again when good contact was achieved the anterior anchors were also deployed.

The device was then released from the delivery system and retracted from the heart.

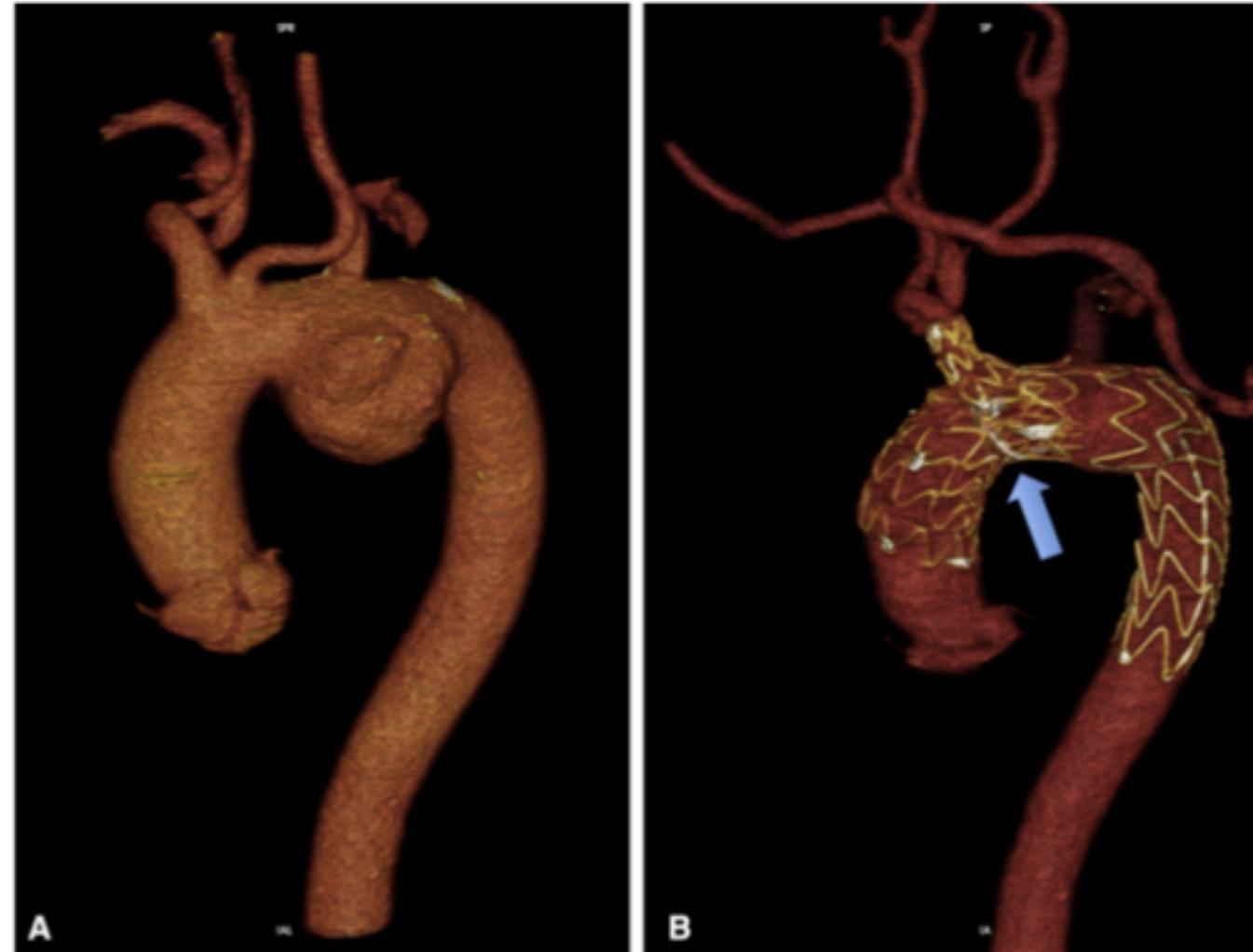
The patient was discharged home and at 3-month follow-up, she was asymptomatic (New York Heart Association functional class I) with mild MR, and stable ring position confirmed by multislice computed tomography.



Endovascular treatment of aortic arch aneurysm with a single-branched double-stage stent graft

J Thorac Cardiovasc Surg 2017; ■:e1-3
0022-5223/\$36.00

Augusto D'Onofrio, MD, PhD,^a Michele Antonello, MD, PhD,^b Mario Lachat, MD,^c David Planer, MD,^d Andrea Manfrin, BSc,^e Andrea Bagno, BSc,^e David Pakeliani, MD,^c Franco Grego, MD,^b and Gino Gerosa, MD,^a Padova, Italy; Zurich, Switzerland; and Jerusalem, Israel



Surgery for aortic arch pathologies such as aneurysms and chronic dissections requires invasive procedures.

For the first time we described the implantation of Nexus Endospan branched aortic arch stent graft
A new promising technique for the endovascular treatment of aortic arch pathologies, potentially having long- term migration resistance because of its landing in the BCA.
A next-generation configuration, incorporating a precannulated fenestration for the left common carotid artery, could avoid the supra-aortic surgical debranching procedure.



Who is the “owner” of the *technique*?

- Cardiac surgeons have been performing **IMPLANTATION** of prostheses in aortic position with many different **APPROACHES**:
 - Median sternotomy
 - Ministernotomy
 - Right thoracotomy
- Since evolving technologies have started to enable to **IMPLANT** a prosthesis in aortic position through a (simple) transcatheter (*transfemoral*) **APPROACH**, cardiac surgeons have been reluctant

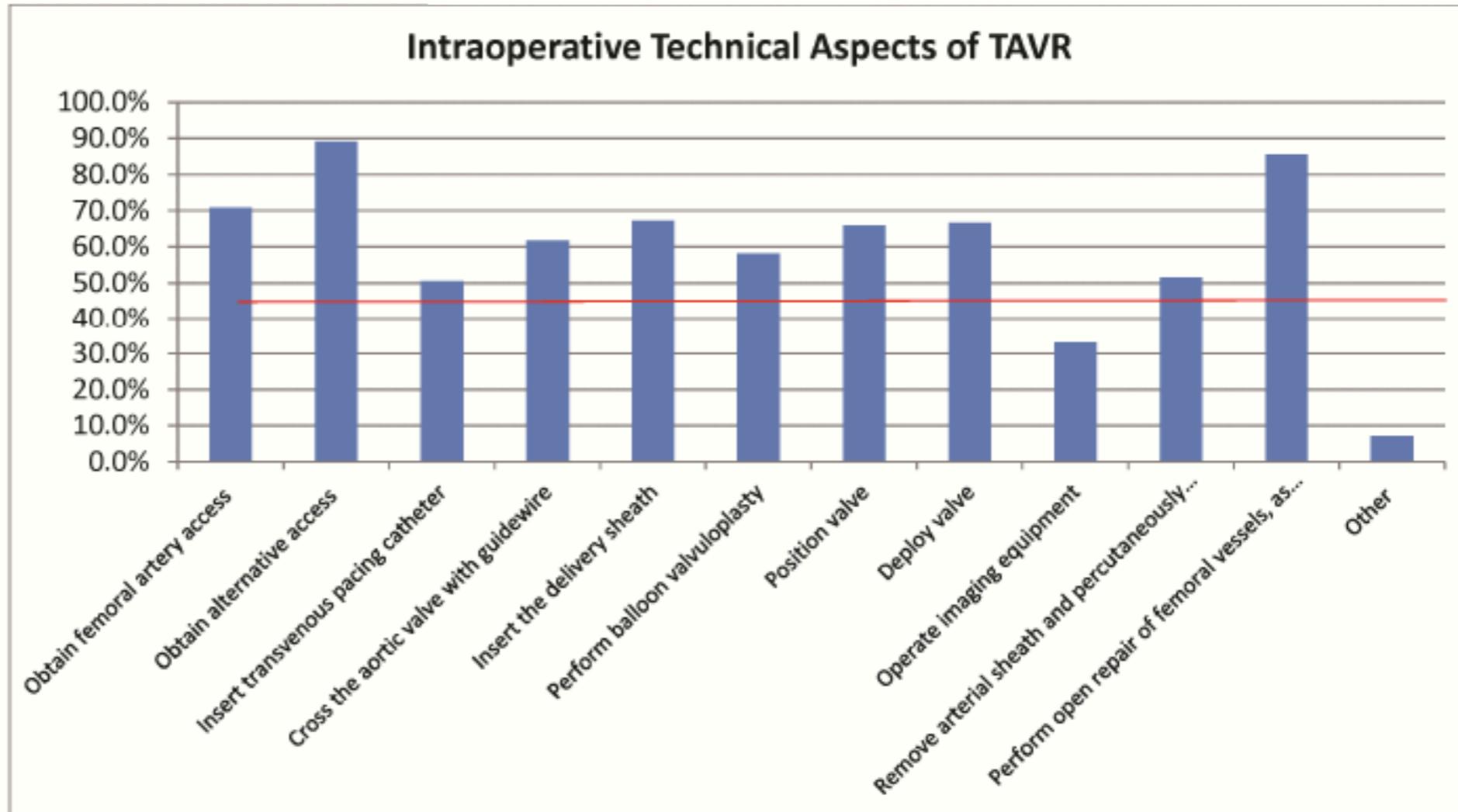
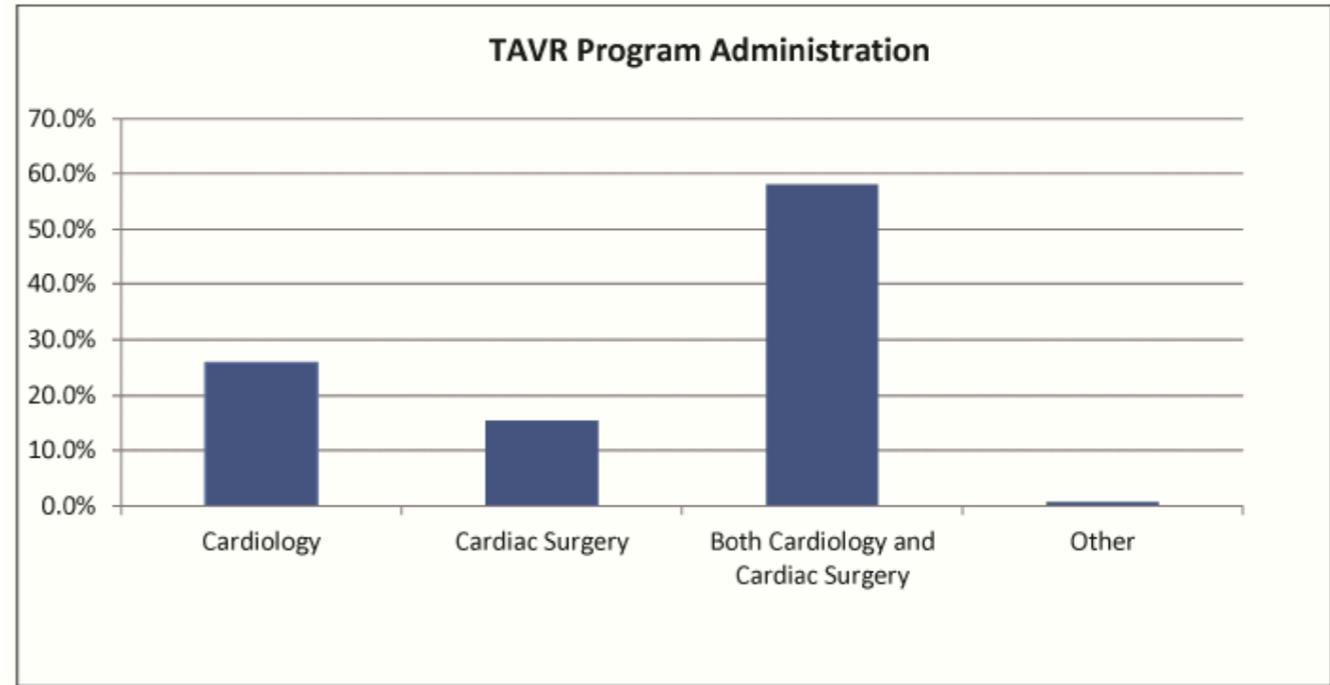


Surgeon Involvement in Transcatheter Aortic Valve Replacement in the United States: A 2016 Society of Thoracic Surgeons Survey



Joseph E. Bavaria, MD, Richard L. Prager, MD, Keith S. Naunheim, MD,

(Ann Thorac Surg 2017;104:1088-94)
 © 2017 by The Society of Thoracic Surgeons



Cardiac surgeons who perform transcatheter aortic valve replacement (TAVR) regularly participated in all aspects of intraoperative procedure, except operating imaging equipment.

American Board of Thoracic Surgery

Index Case Requirements Effective July 1, 2017

The Index Case Requirements for residents who start their thoracic surgery training on or after July 1, 2017 are listed below. This affects the following residents:

Residents in 2-year traditional programs starting PGY 6 on or after July 1, 2017

Residents in 3-year traditional programs starting PGY 6 on or after July 1, 2017

Residents in 6-year integrated programs starting PGY 4 on or after July 1, 2017

Residents in Joint Training programs starting PGY 4 on or after July 1, 2017

| Cardiothoracic Focused | | Requirements |
|------------------------|----------|--|
| Total | Subtotal | |
| | 15 | Mitral Valve Repair/ Replacement |
| | 5 | Tricuspid Valve Repair/Replacement, Annuloplasty |
| | 5 | TAVR as primary |
| | 10 | TAVR as assistant |
| | | |
| 80 | | Myocardial Revascularization |
| | | |
| | 15 | Re-Do Sternotomy** **Can be double-counted with any Cardiac procedure |
| | | |
| 15 | | Interventional Wire-based Procedures |
| | 5 | Left Heart Catheterization, PCI, TEVAR, Mitral Clip |
| | 10 | Intra-aortic Balloon Pump |
| | | |
| 5 | | Conduit Dissection and Preparation** Open or Endoscopic Saphenous/Radial Vein harvest and preparation **Can be double-counted with CABG |





Cardiac Surgery and the Future

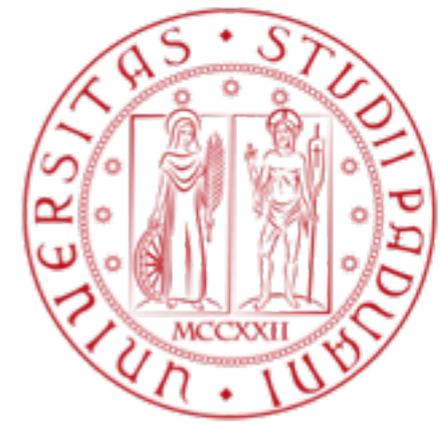
Sep 09, 2015 | David Yaffee, MD; Mathew Williams, MD, FACC

Expert Analysis

Cardiac surgery is a specialty in its adolescence adapting to the evolution of modern medicine.

The development of new technology has always shaped and driven the field of cardiac surgery aimed at minimizing the invasiveness of surgical intervention.

Patients continue to grow older and sicker, they require progressively more complex procedures and less invasive treatments of their disease;



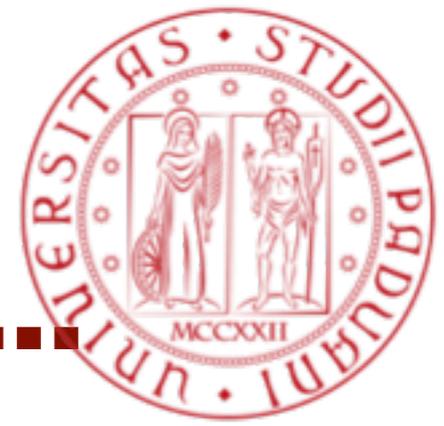
Adherence of Catheterization Laboratory Cardiologists to American College of Cardiology/American Heart Association Guidelines for Percutaneous Coronary Interventions and Coronary Artery Bypass Graft Surgery

What Happens in Actual Practice? (*Circulation*. 2010;121:267-275.)

Edward L. Hannan, PhD; Michael J. Racz, PhD; Jeffrey Gold, MD; Kimberly Cozzens, MA;
Nicholas J. Stamato, MD; Tia Powell, MD; Mary Hibberd, MD; Gary Walford, MD

- Indications for CABG (According to guidelines)
 - CABG recommended in 53%
 - PCI recommended in 34%
 - Medical therapy recommended in 12%
- Indications for PCI (According to guidelines)
 - PCI recommended in 94%
 - CABG recommended in 4%
 - Medical therapy recommended in 2%

Conclusions—Patients with coronary artery disease receive more recommendations for PCI and fewer recommendations for CABG surgery than indicated in the American College of Cardiology/American Heart Association guidelines. (*Circulation*. 2010;121:267-275.)



However this may not be enough...

Cardiac surgeons must not simply adapt to change;

they have to partner with industry, participate in prospective clinical trials, and lead with innovation to guide the future of cardiac diseases .

The cardiac surgeon's job will be to ensure that suboptimal treatments are not allowed to be justified by their less invasive methods.

As cardiac surgery becomes isolated from the diagnostic process, the line between what is necessary and what is available becomes blurred, as exemplified by the fact that up to **30% of ad hoc percutaneous coronary interventions** are performed in patients who would have benefitted from coronary artery bypass.



The NEW ENGLAND JOURNAL *of* MEDICINE

What Is Value in Health Care?

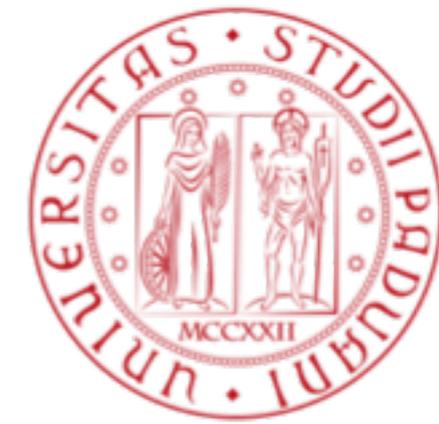
Michael E. Porter, Ph.D.

The concept of value in health care, has been circulating for decades. In 2010, Porter declared that value was neither an “abstract ideal nor a code word for cost reduction”

It should define the framework for performance improvement in health care. He also stressed that value should always be defined around the customer, and in a well-functioning health care system the creation of value for patients should determine the rewards for all other actors in the system.

“Value” is a word that has long aroused skepticism among physicians, who suspect it of being code for “cost reduction.”

Nowadays “enhancement of value” for patients is a fundamental goal



Value in cardiac surgery: The price of saving

Robbin G. Cohen, MD, MMM

In 2007, the Institute of Medicine prepared a statement outlining the 6 requirements for effective healthcare

Kolarczyk LM, et al. (2017), <http://dx.doi.org/10.1053/j.jvca.2017.09.043>

2007 Institute of Medicine Requirements for Effective Health Care

1. No needless deaths
 2. No needless pain or suffering
 3. No helplessness in those served or serving
 4. No unwanted waiting
 5. No waste
 6. No one left out
-

$$\text{Value} = \frac{(\text{Clinical Outcomes} + \text{Patient Experience})}{\text{Total Cost per Capita}}$$

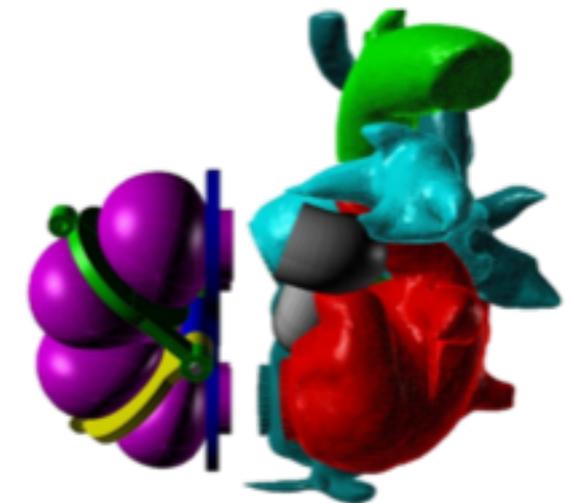
$$\text{Value} = \frac{\text{Quality}}{\text{Cost}}$$

Medicare is the customer in the cardiac surgery value equation, patients the benefactors.

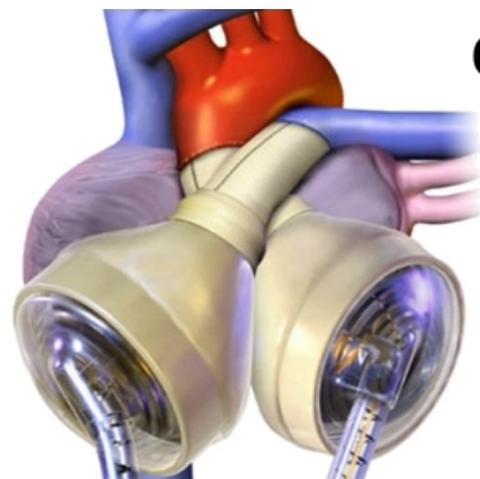
Central Message

Clinical and financial strategies that satisfy the demands of the Affordable Care Act to provide cost-effective care must result in a value equation that benefits patients.

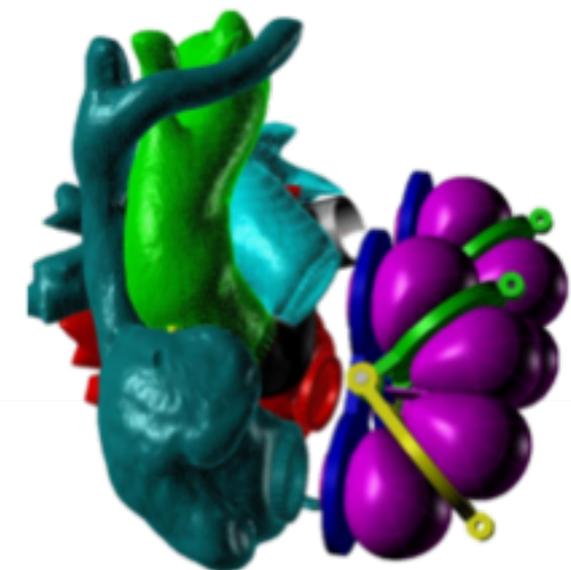
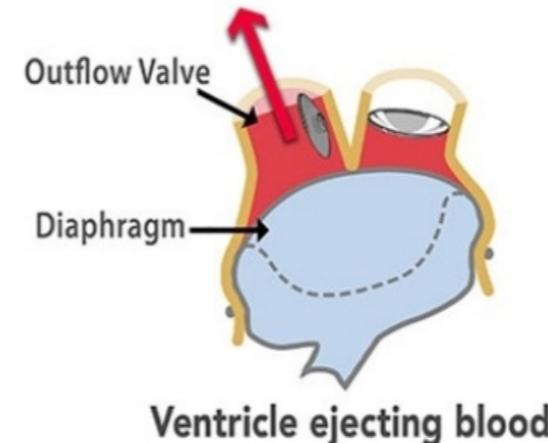
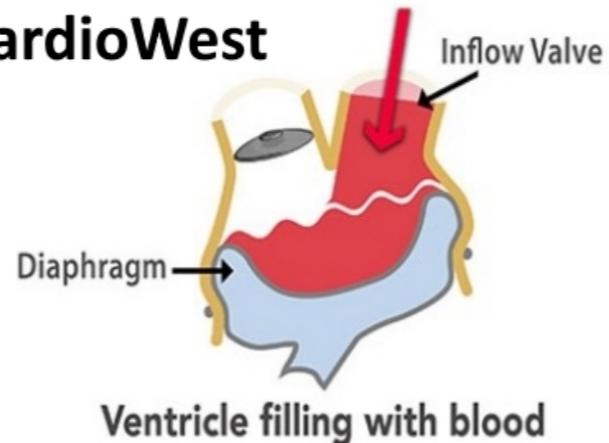
- Eccellente biocompatibilità grazie all'utilizzo della medicina rigenerativa
- Bassa rumorosità grazie all'utilizzo di un motore elettrico miniaturizzato
- Dimensioni ridotte grazie al meccanismo di movimentazione dei volumi di sangue



Utilizzo efficace dell'intero volume del device
(contrariamente a quanto avviene per esempio nel TAH CardioWest)



CardioWest



A landscape photograph with a blue sky, a dark mountain range, and a white foreground. The text "Building the future..." is overlaid on the sky.

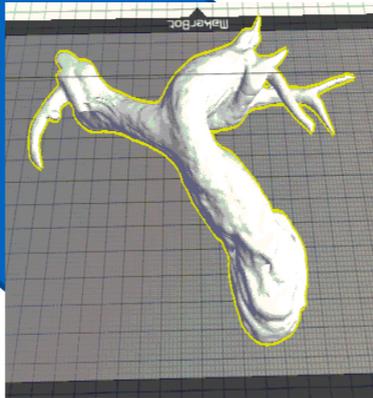
Building the future...

Perspectives and challenges



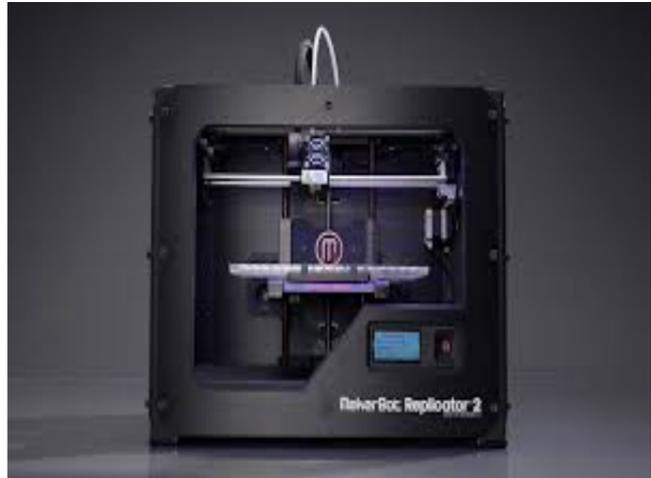
CT SCAN

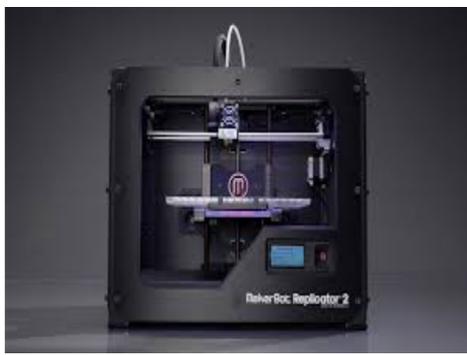
Volume Rendering



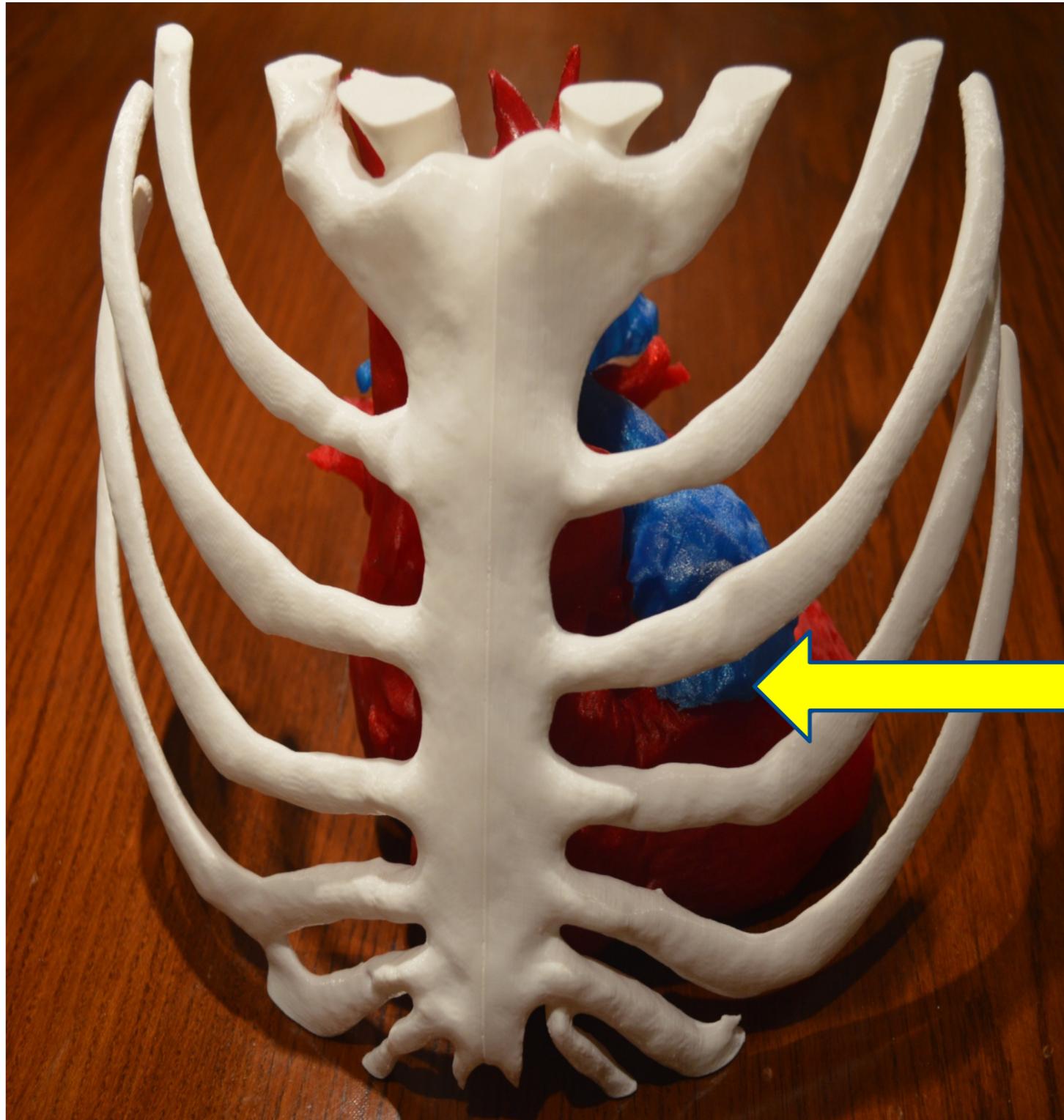
Patient Specific Surgery

3D Printing

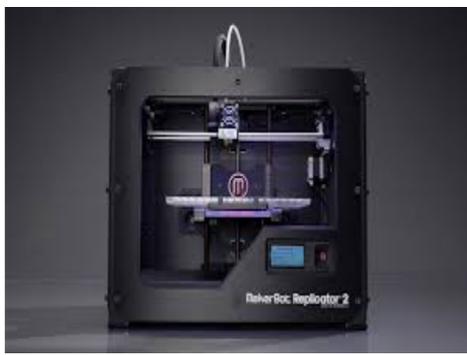




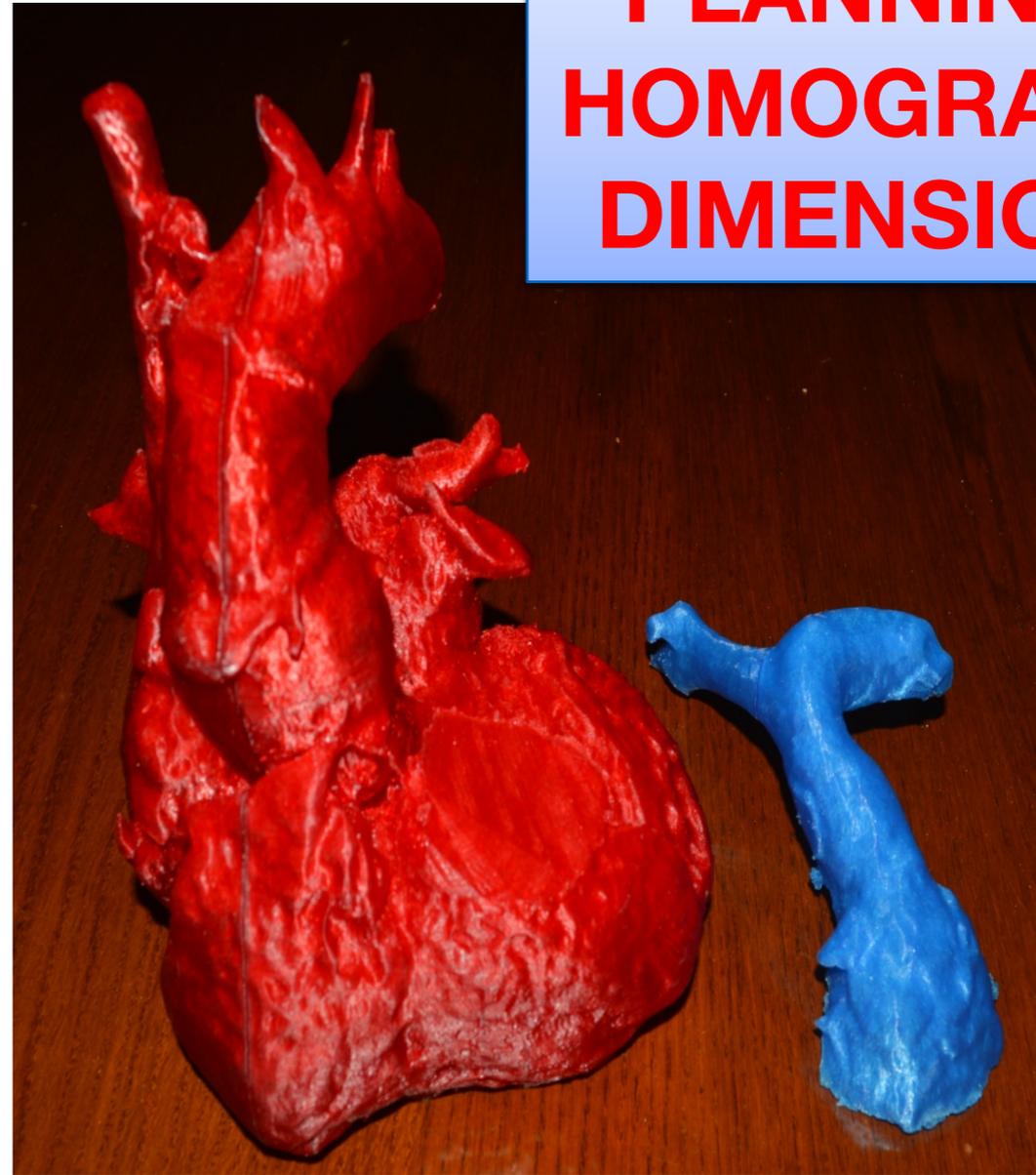
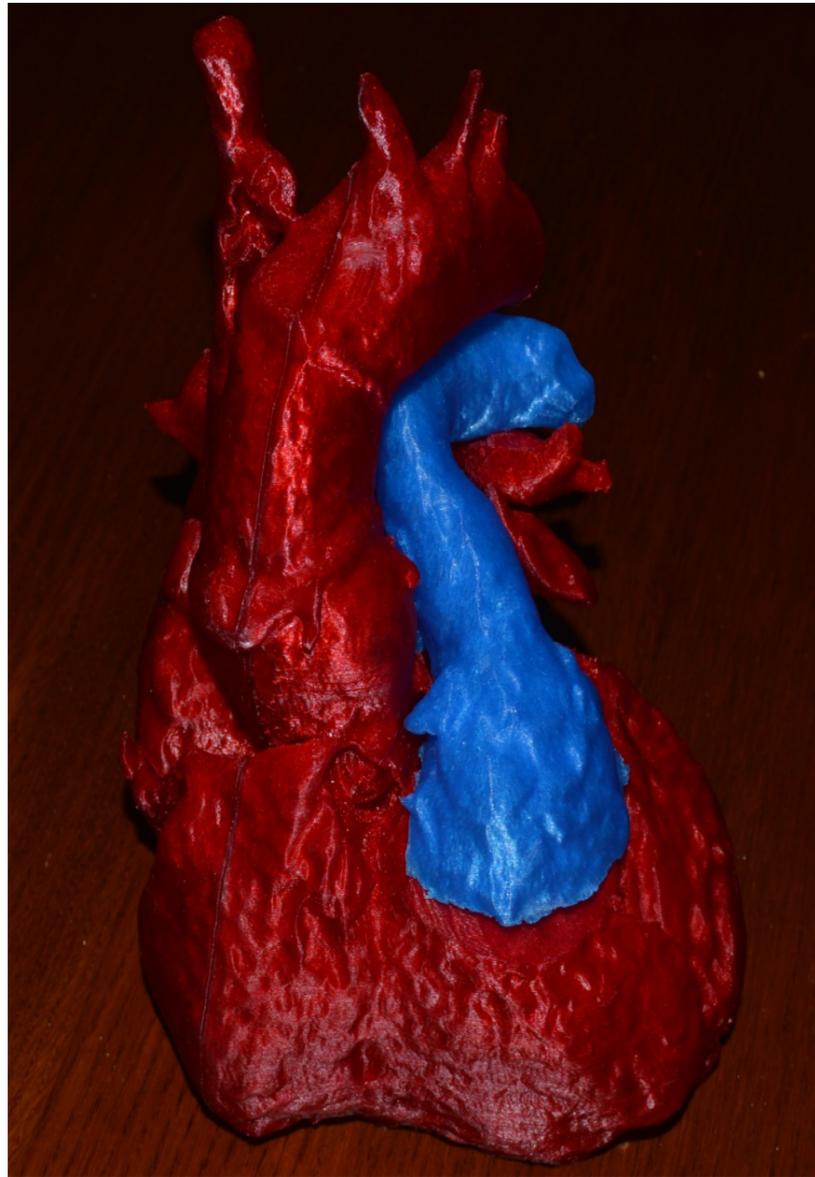
3D Printing



**PLANNING
BETTER
SURGICAL
ACCESS**



3D Printing

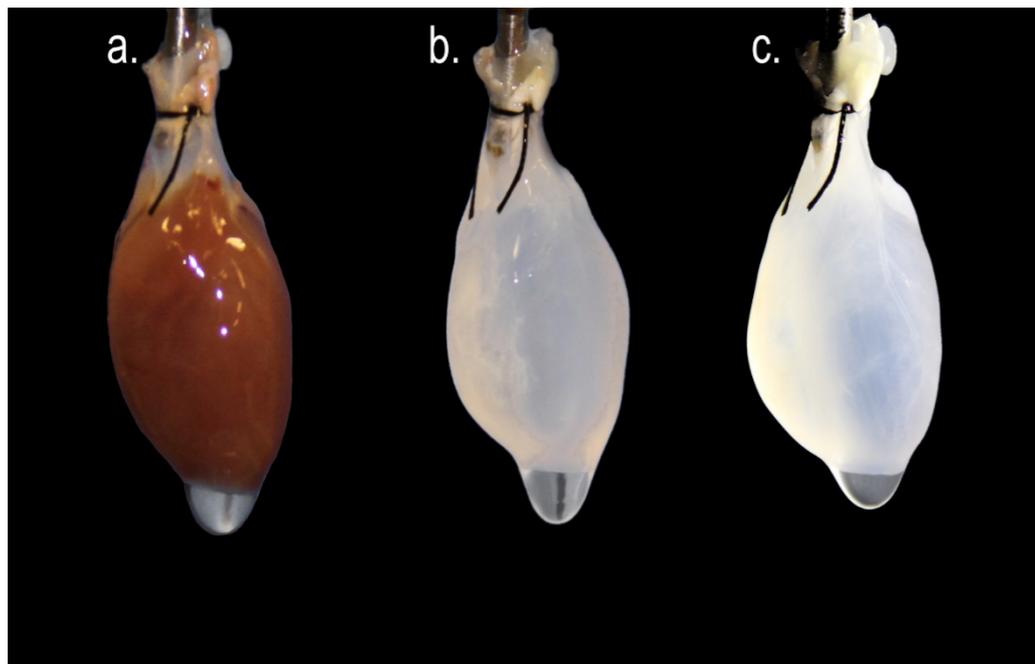


**PLANNING
HOMOGRAFT
DIMENSION**

The Challenge

Bioengineering Human Tissues and Organs *in vitro*,
accurately Reproducing their Natural Tridimensional
Architecture
and Cellular Physiology
as Ultimate Solution for End-Stage All Organ Failure

LA NUOVA FRONTIERA PER IL TRAPIANTO D'ORGANO: RegenHEART, il cuore totalmente bioingegnerizzato



lop et al,
unpublished
data



**DON'T
STOP
ME
NOW**

'CAUSE I'M HAVING A GOOD TIME HAVING A GOOD TIME

