REV PROCEDURE*

FOR

DORV-TGA TYPE WITH PS

and TRANSPOSITION VSD PS

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Necker Hospital, Paris

** Réparation à l'étage ventriculaire*

UTRECHT, 1ST February, 2025

CURRENT SITUATION

Rastelli and Nikaidoh procedures are the most commonly performed

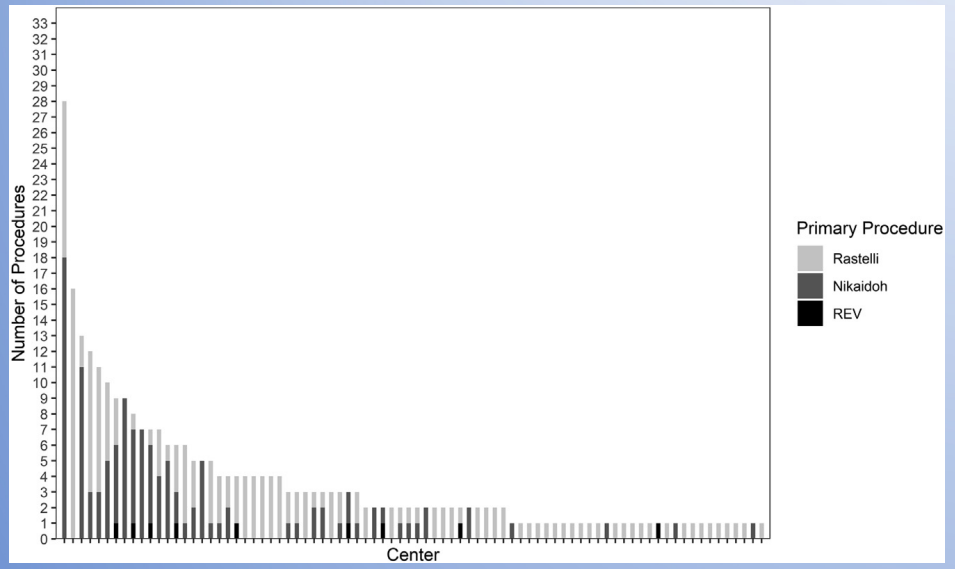

FIGURE 2 Bar graph demonstrating the utilization of Nikaidoh, Rastelli, and réparation à l'etage ventriculaire (REV) operations stratified by center.

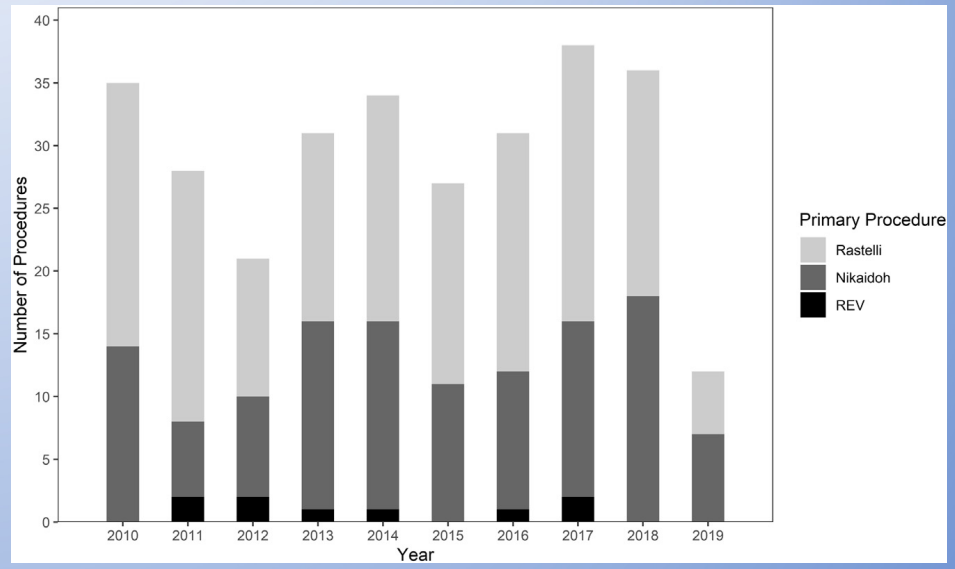

FIGURE 3 Bar graph demonstrating the volume of Nikaidoh, Rastelli, and réparation à l'etage ventriculaire (REV) operations by year.

RESULTS A total of 293 patients underwent repair at 82 centers (January 2010 to June 2019). Most patients underwent a Rastelli (n = 165, 56.3%) or a Nikaidoh (n = 119, 40.6%) operation; only 3.1% (n = 9) underwent a REV. High-volume

2022. Seese. Analysis of the STS congenital heart surgery database

JOURNAL ARTICLE

Long-term results after the réparation à l'étage ventriculaire procedure for transposition of the great arteries and double-outlet right ventricle with pulmonary stenosis FREE

Margaux Pontailler ✉, Alexander Moiroux-Sahraoui, Ségolène Bernheim, Régis Gaudin, Lucile Houyel, Damien Bonnet, Pascal Vouhé, Olivier Raisky

European Journal of Cardio-Thoracic Surgery, Volume 64, Issue 6, December 2023, ezad409, https://doi.org/10.1093/ejcts/ezad409

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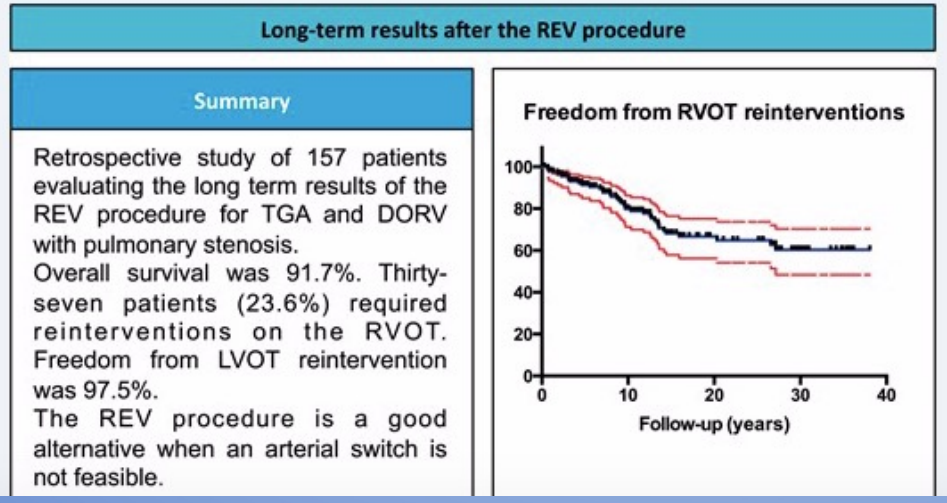
Abstract



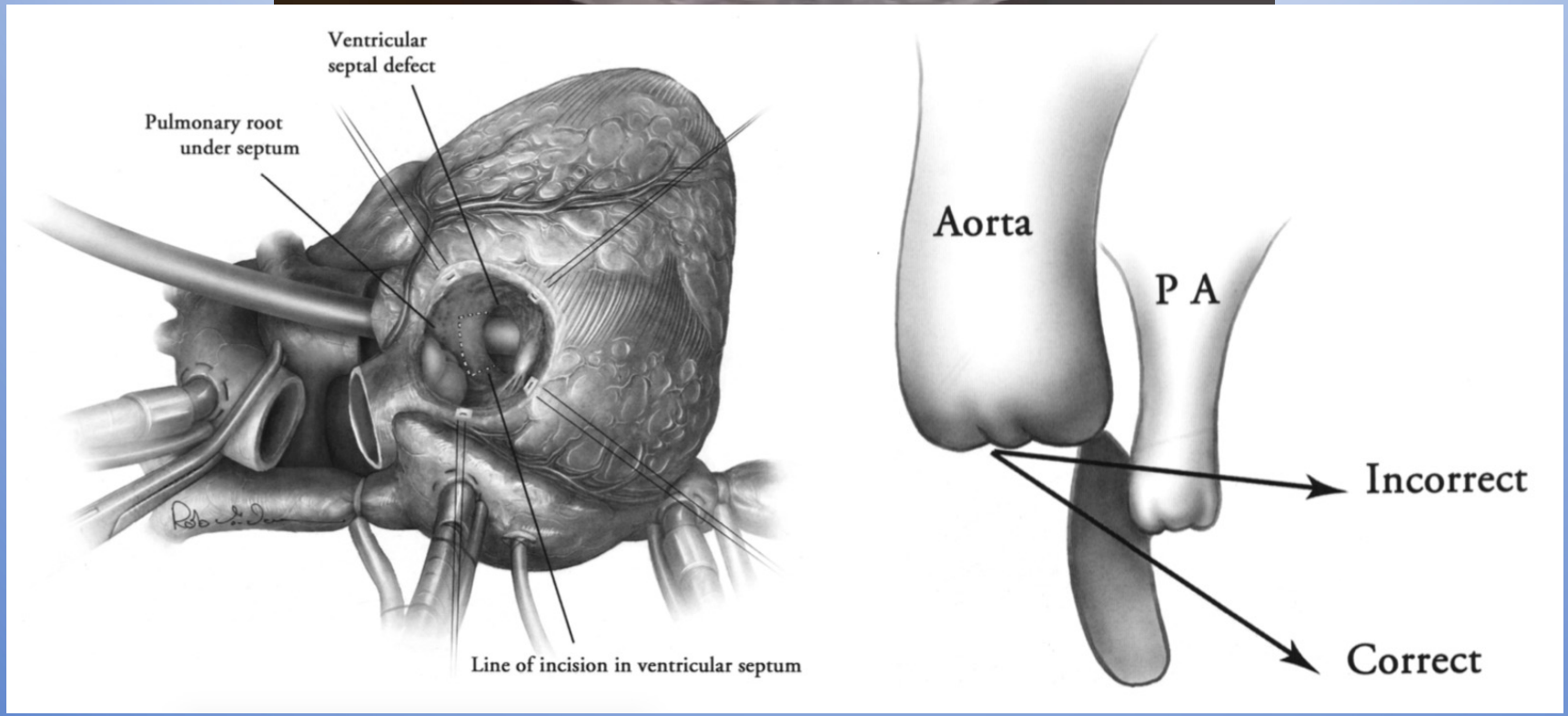
Réparation à l'Etage Ventriculaire (REV Procedure): Not a Rastelli Procedure Without Conduit

Yves Lecompte and Pascal Vouhé

Since 1980, we have been using a procedure, which we call Réparation à l'Etage Ventriculaire ([REV] procedure), for the repair of transposition of the great arteries associated with ventricular septal defect (VSD) and pulmonary outflow tract (POT) obstruction. The object of this procedure is to overcome some of the limitations and drawbacks of the Rastelli operation, which is the most common choice worldwide for this type of defect. One of these drawbacks is the use of a circular conduit for the repair of the POT. However, the most serious limitations of the Rastelli procedure relate to the construction of the left ventricle (LV) to aorta tunnel. The REV procedure allows some of the anatomic contraindications to biventricular repair to be overcome and, much more importantly, to decrease the incidence of the late complications associated with classical repair (i.e., deterioration of LV function) and the development of subaortic stenosis.[1,2] The final advantage of avoiding the use of a circular conduit for reconstructing the POT is, in our experience, of secondary importance. For this reason, the intracardiac step of the REV procedure will be described in great detail in this article. Although the REV procedure can be indicated in many types of anomalies of ventriculo-arterial connection, the description will be limited to the most frequent anatomy: "classical" transposition of the great arteries, with fibrous continuity between the atrioventricular valves and the pulmonary artery, and a well-developed subaortic infundibulum.

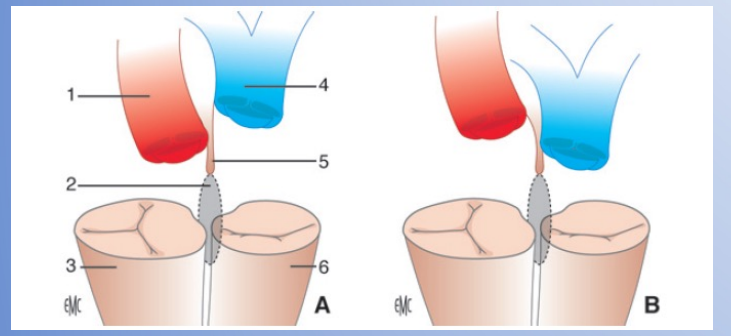
Operative Techniques in Thoracic and Cardiovascular Surgery, Vol 8, No 3 (August), 2003: pp 150-159

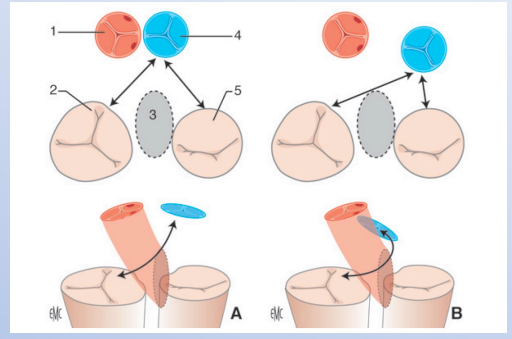

2
4
6
8

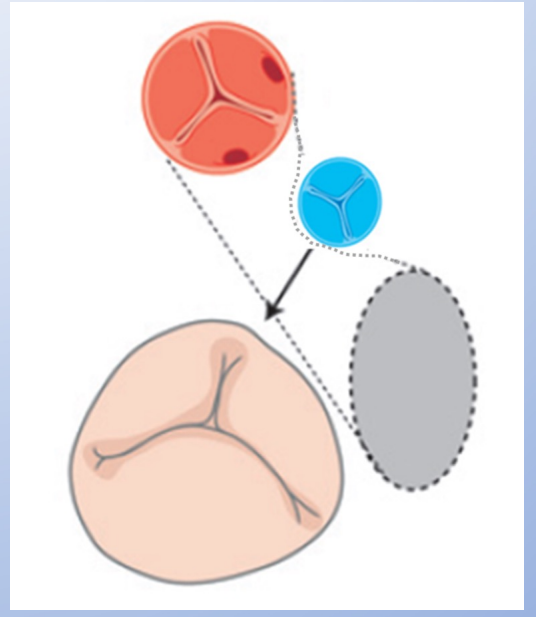

Ventricular septal defect
Pulmonary root under septum
Line of incision in ventricular septum
Aorta
P A
Incorrect
Correct

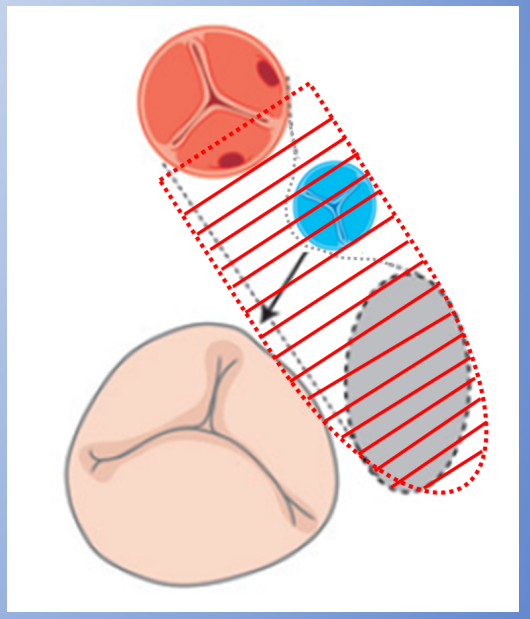
DORV: TGA-TYPE WITH PS

Sub Aortic Conus is long
Sub Pulmonary is short
= Sub Pumonary VSD

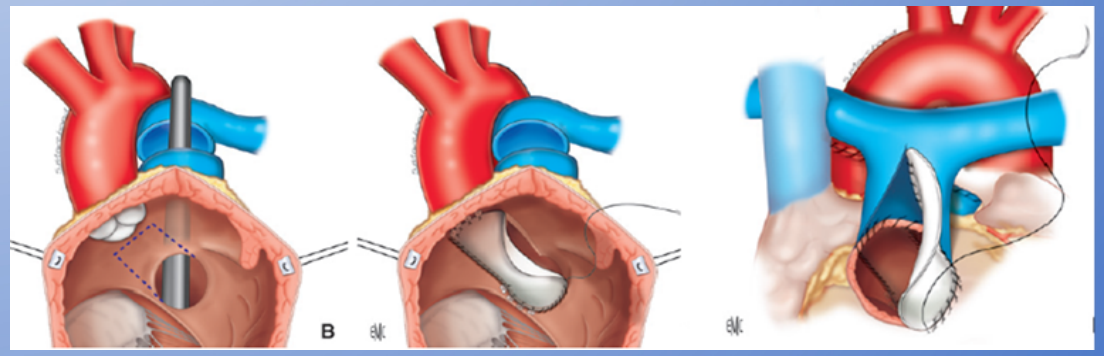






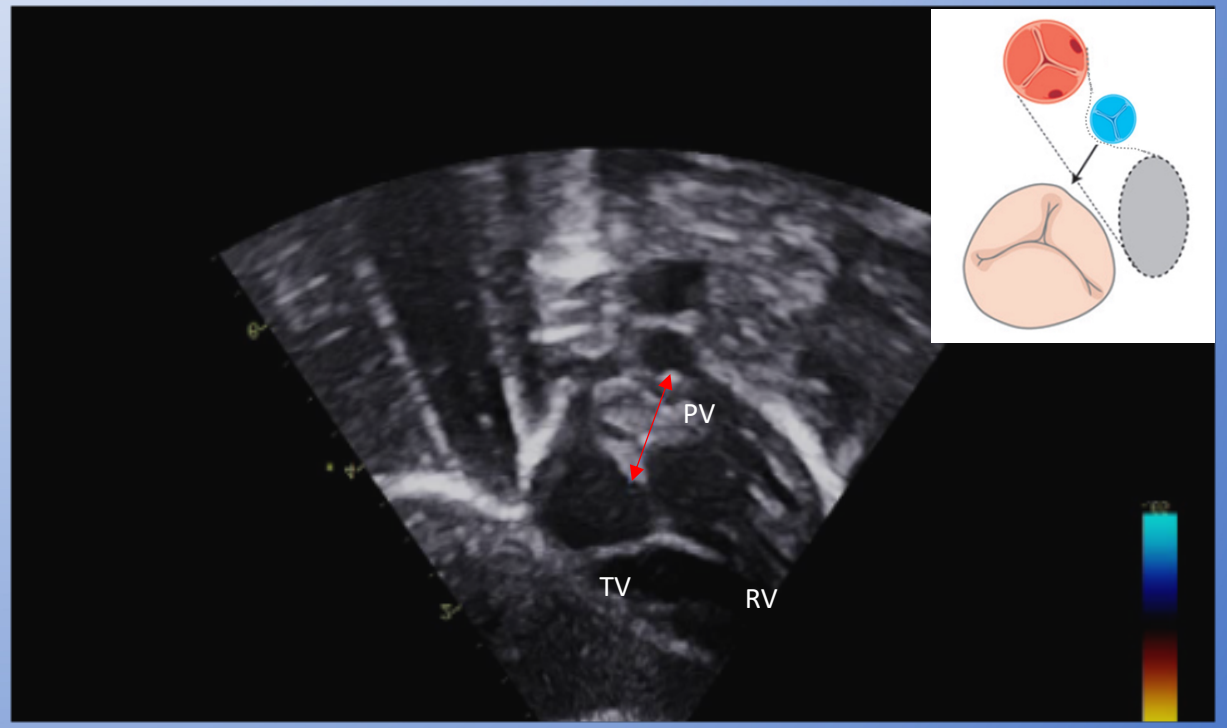


1. Tricuspide-pulmonary valve distance is inferior to aortic diameter
2. LV to Aorta connection is possible but the baffle incorporates the pulmonary outflow tract
3. Needs to relocate the pulmonary artery

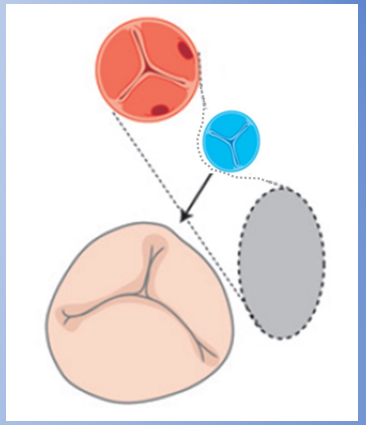


What do I want to see?

Precise plan before surgery



DORV REPAIR



Tricuspide-pulmonary valve distance

Sup or equal to the aortic annulus diameter

No RVOTO

IVR

RVOTO

Fallot-type Repair

Inferior to the aortic annulus diameter

RVOT Anatomy

Normal

Switch + LV to Ao

Stenotic

REV Rastelli

Bex-Nikaïdoh

Subnormal

Cono truncal rotation

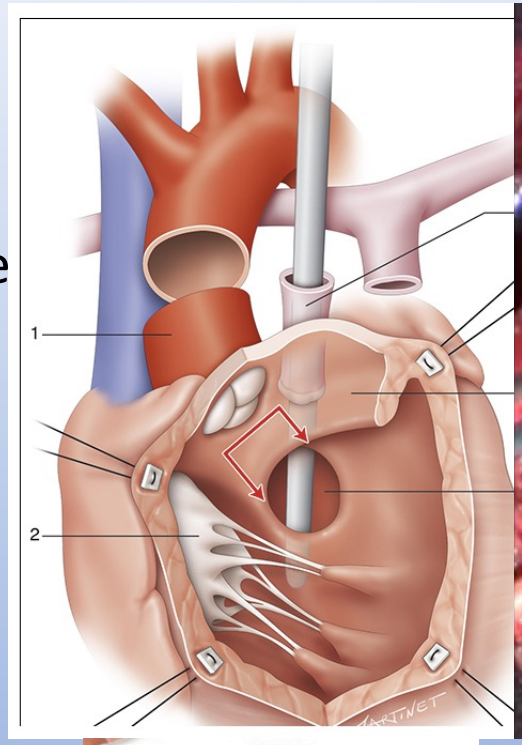
VSD can be connected to Aorta or Pulmonary valve

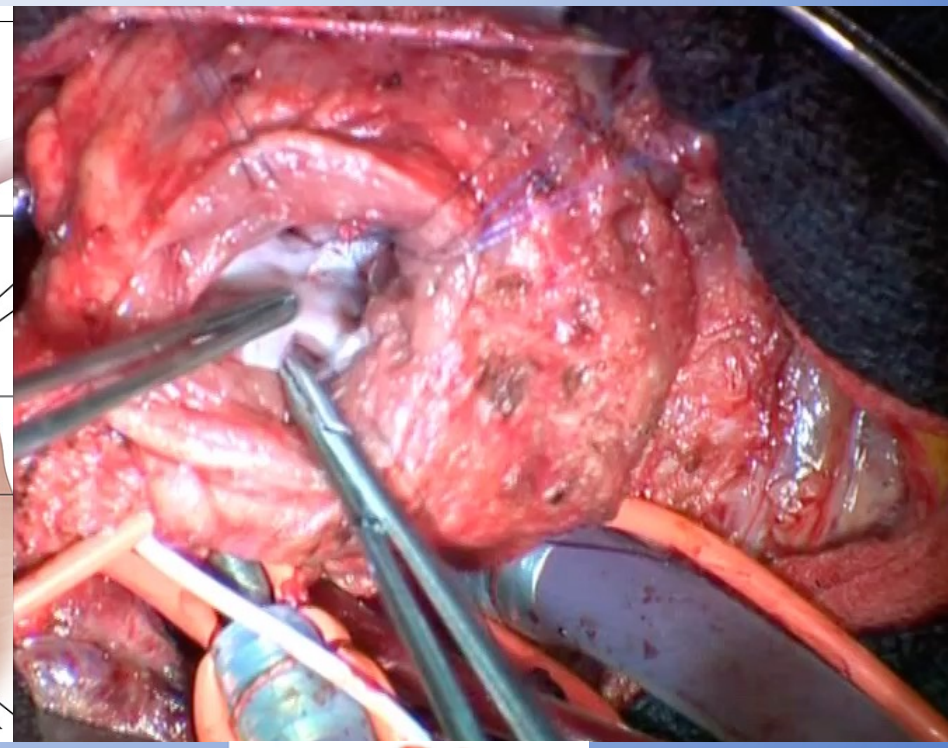
VSD can't be connected to the aorta (PV not suitable)

The Surgical Repair
Left Side

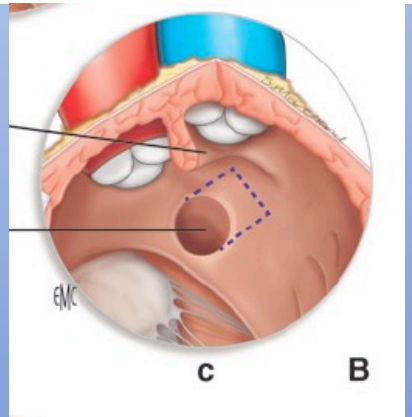
Tips and Tricks

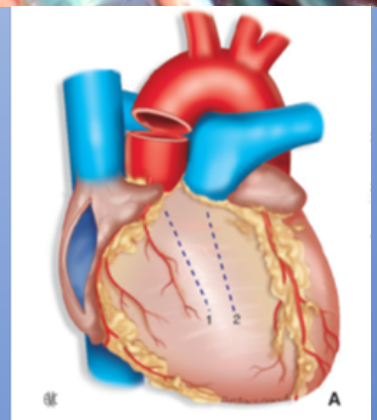
- Resection of the conal septum
  - Anterior to the baffle
  - Resection for the border line TGA type

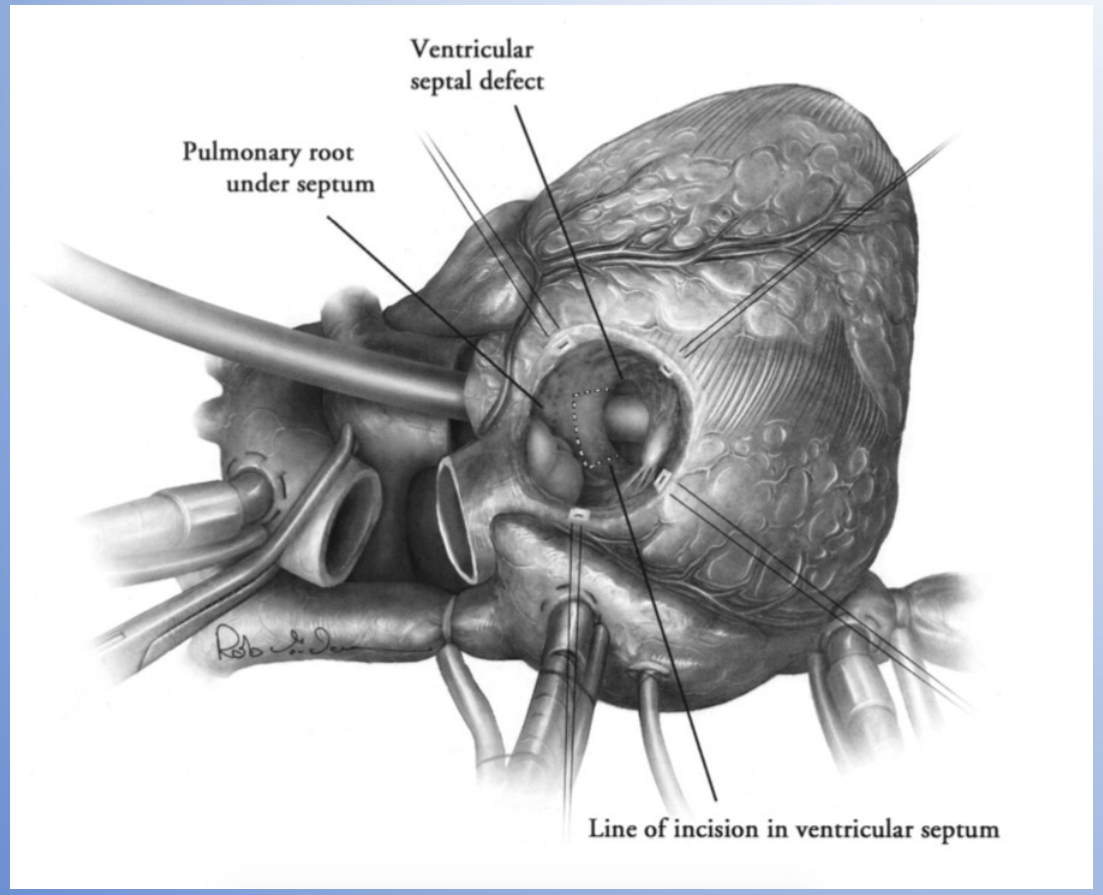


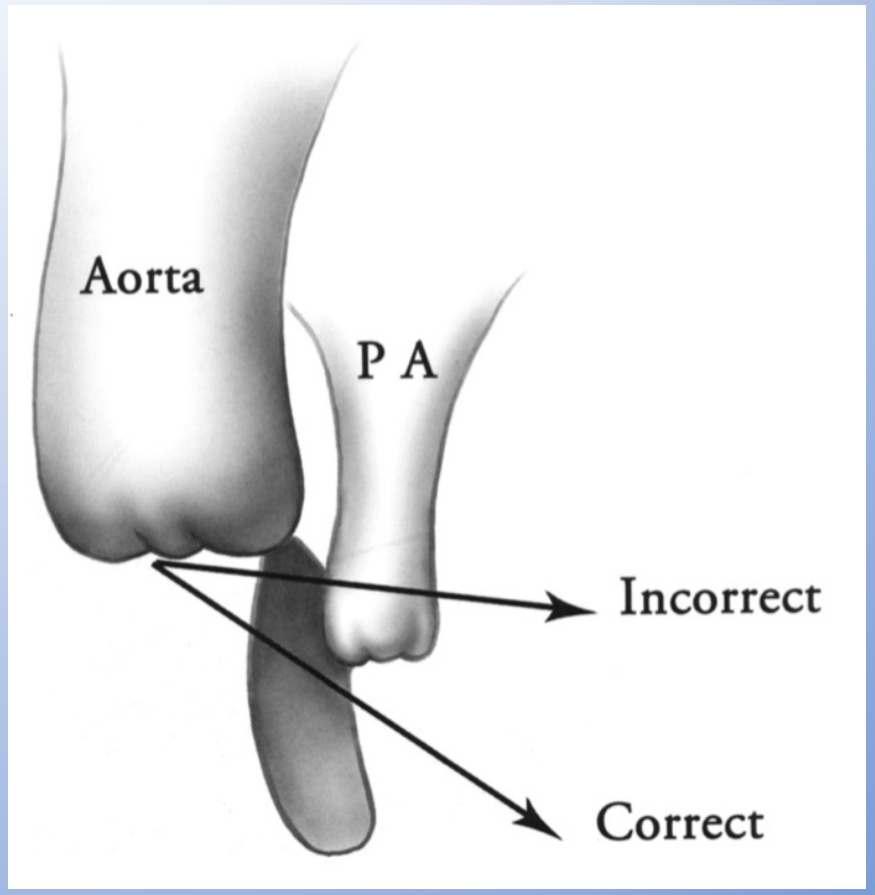


- VSD enlargement
  - Only when needed
  - Anterior enlargement
  - Create immediately a fragile area
  - Can provoque localised infarct and subsequent residual VSD
  - Mandatory for some patients
  - Increase AV block risk

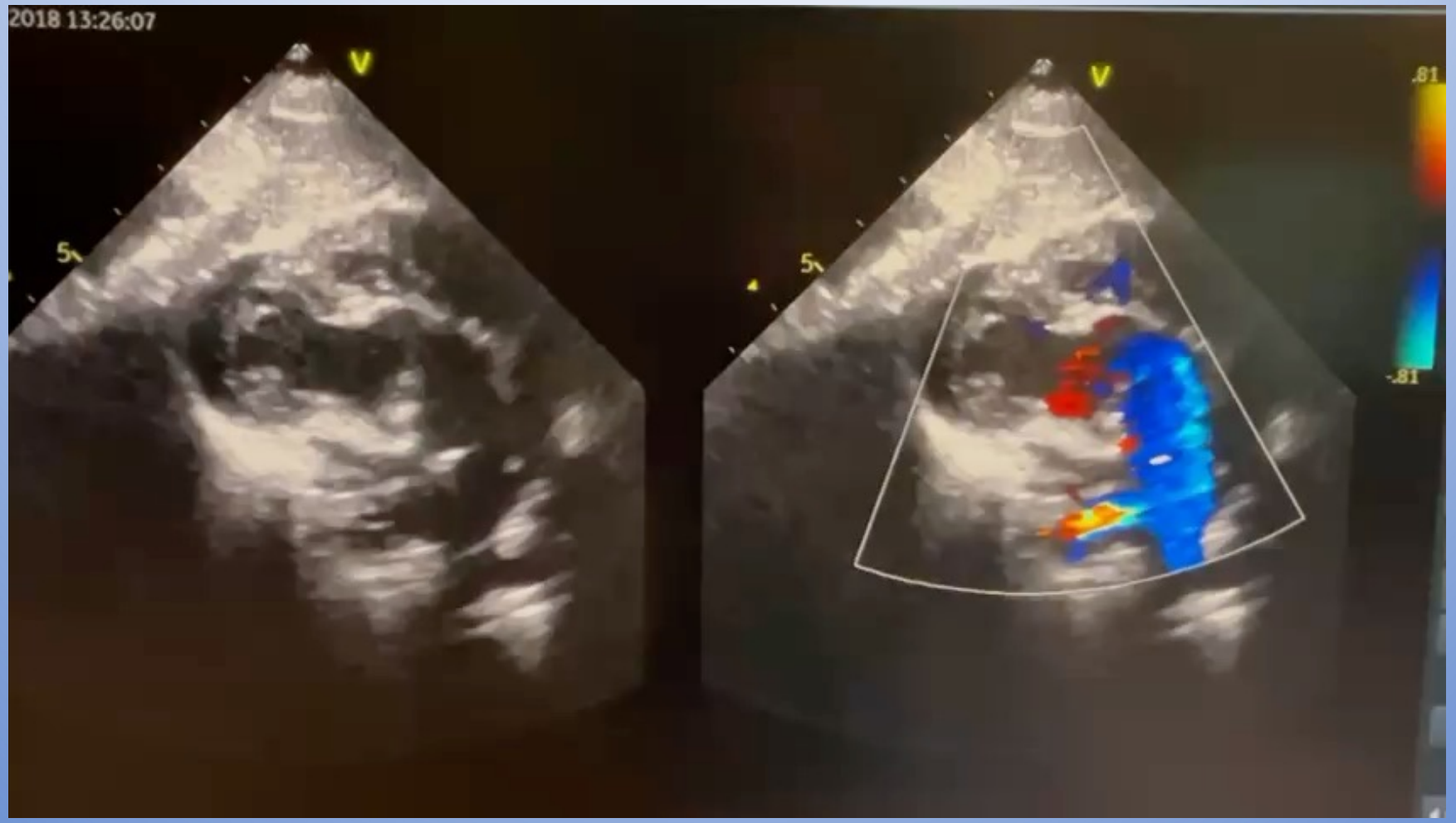





Ventricular
septal defect
Pulmonary root
under septum
Line of incision in ventricular septum


Aorta
P A
Incorrect
Correct

Conal resection and ideal baffle



The Surgical Repair
Left Side

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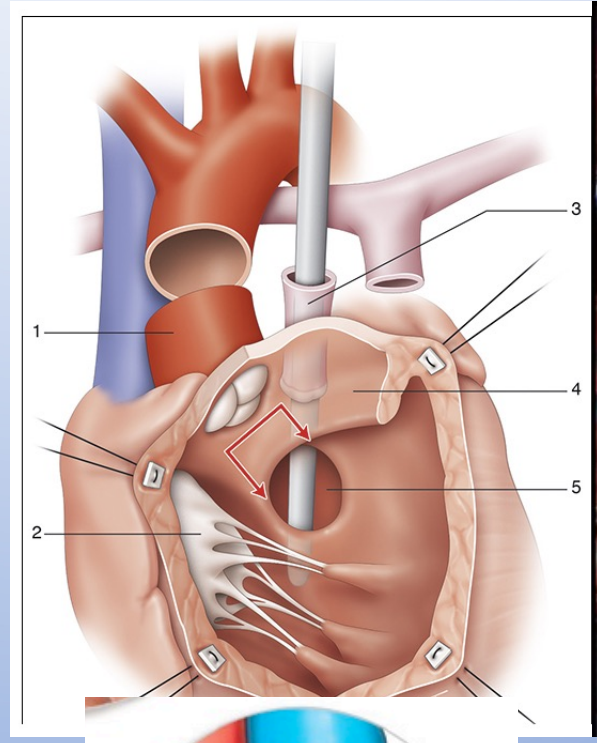

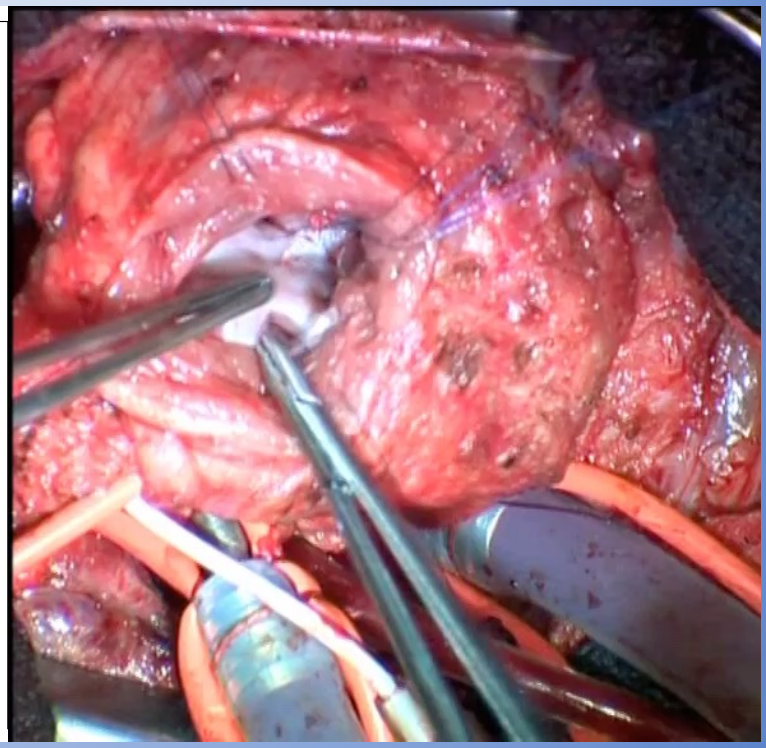

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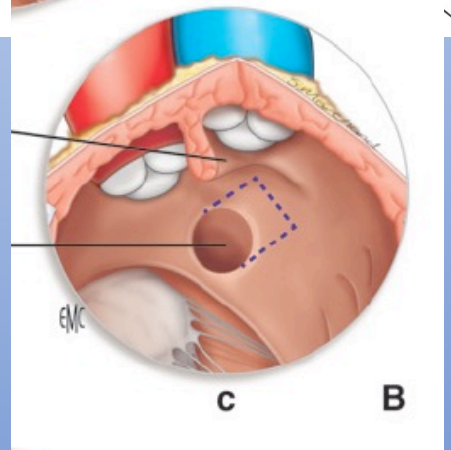
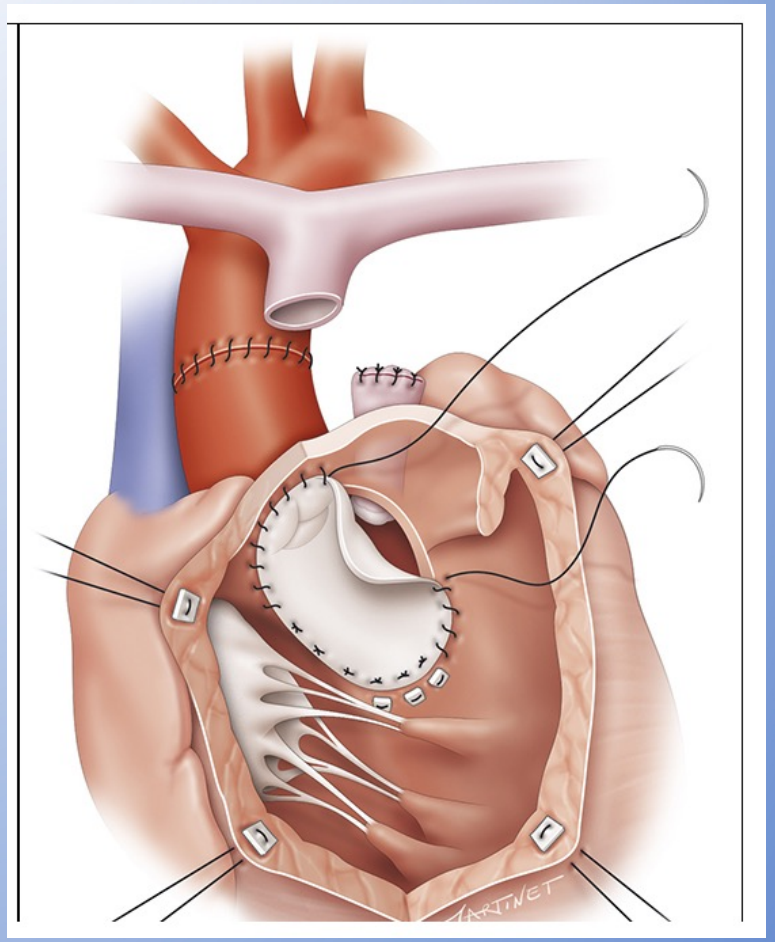


The Surgical Repair
Left Side

- LV to Aorta baffle:
  - 3 Accesses for VSD visualization : RA, Aorta and RV
  - Position of the Right Ventriculotomy
  - It's not a VSD closure: tailoring of the patch
  - Interposition within the reconstruction: tricuspid, muscular band

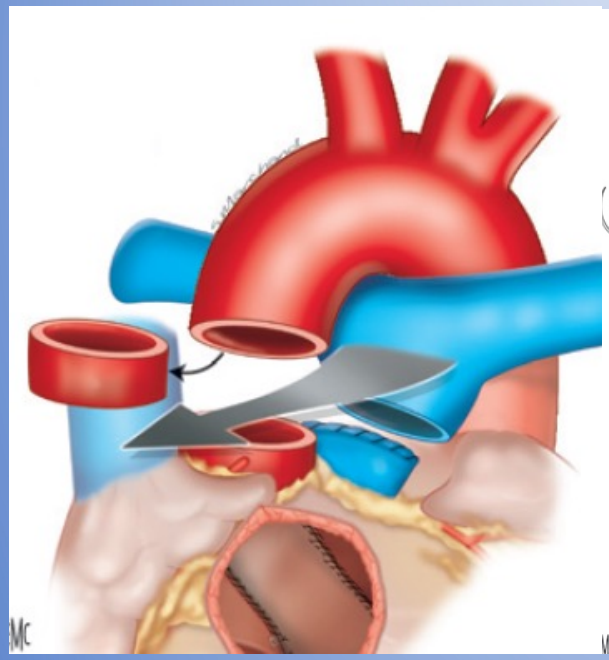
- Perfect baffle -> direct, short, unobstructed, without folding

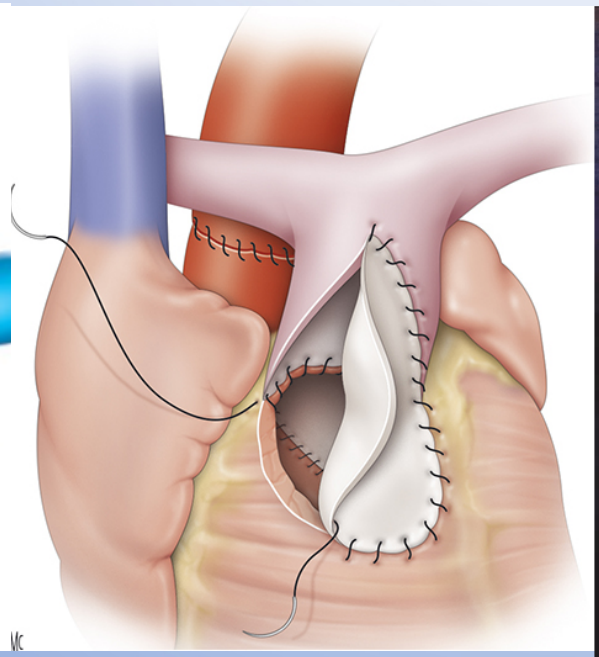
  Baffle checking through aortic transection

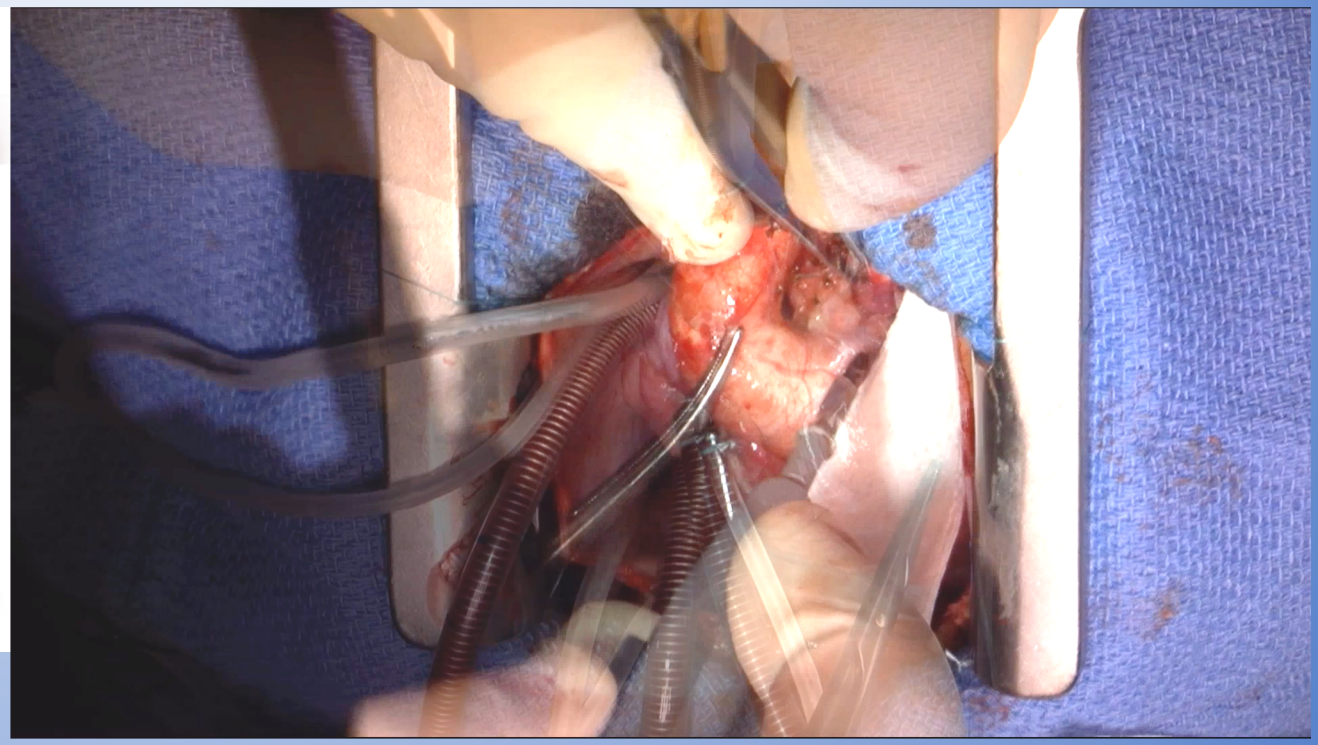


- SMALL PA ANNULUS = SHORT BAFFLE
- TAILORED PATCH: LENGH= DISTANCE BETWEEN THE POSTERIOR EDGE OF THE VSD AND THE AORTIC ANNULUS

RIGHT OUTFLOW RECONSTRUCTION



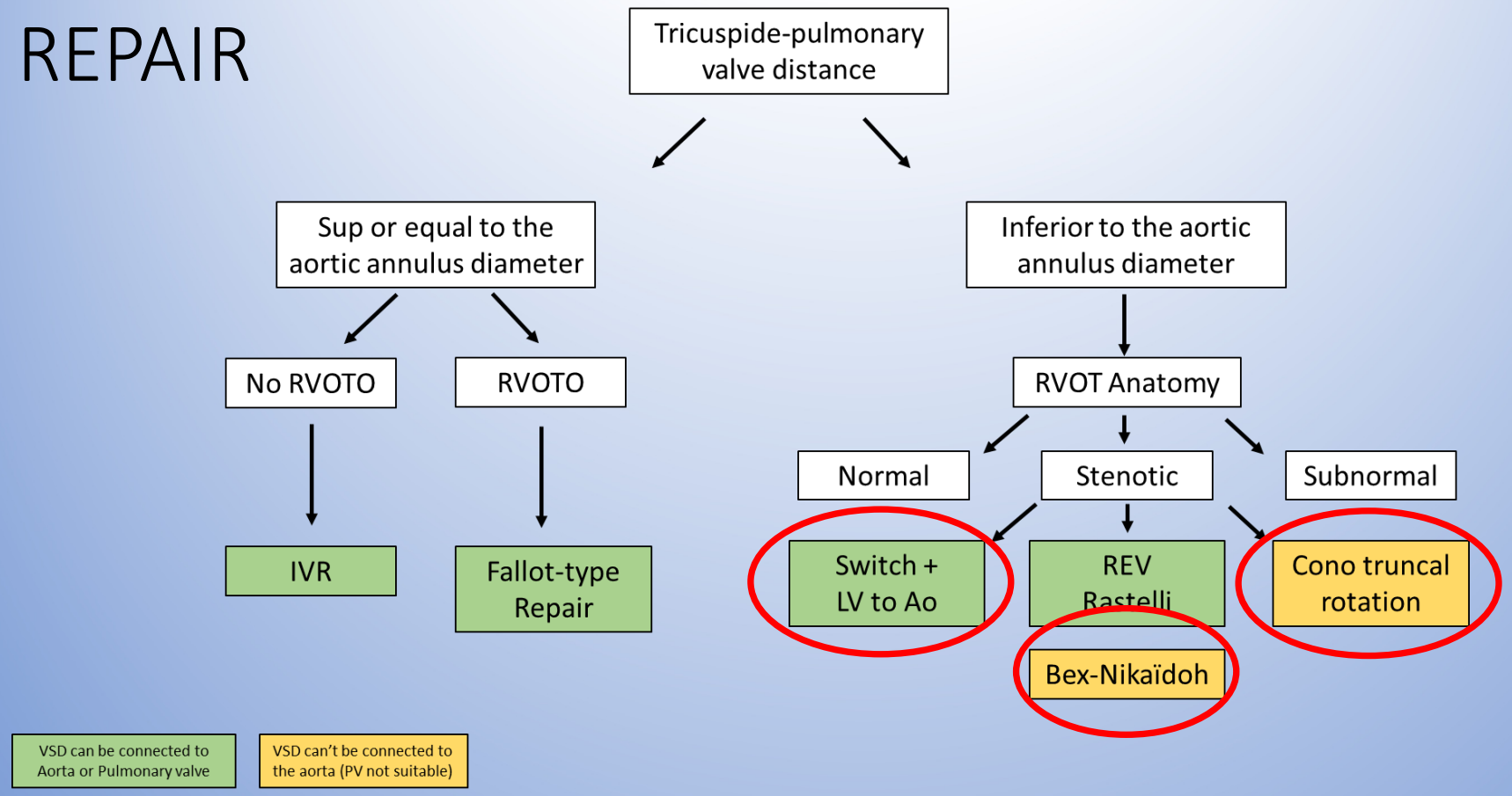




1. SIGNIFICANT SHORTENING OF THE ASCENDING AORTA
2. LECOMPTE MANEUVER
3. POSTERIOR ANASTOMOSIS BETWEEN THE OPEN TRUNCK AND VENTRICULOTOMY
4. ANTERIOR PATCH +/- PA BRANCH PLASTY

NO TENSION
NO DISTORSION OF THE PA OSTIA
NO CORONARY COMPRESSION

DORV REPAIR

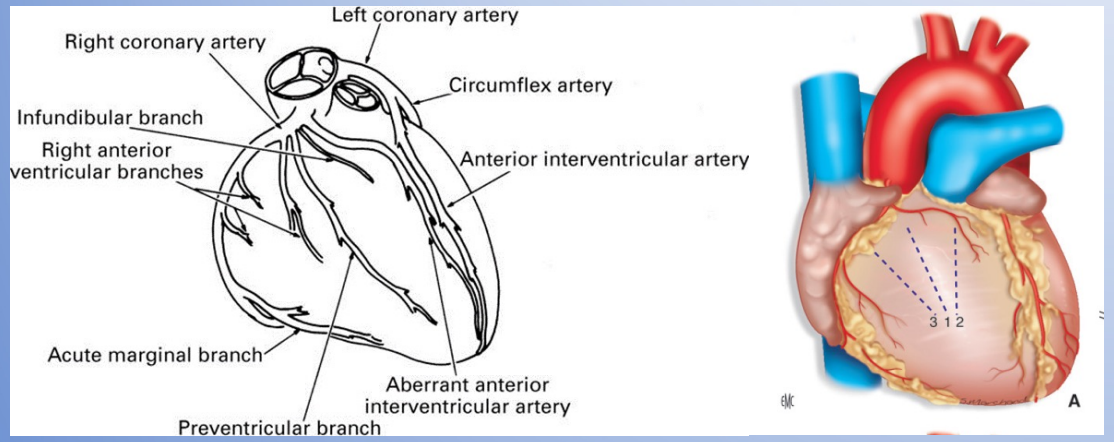


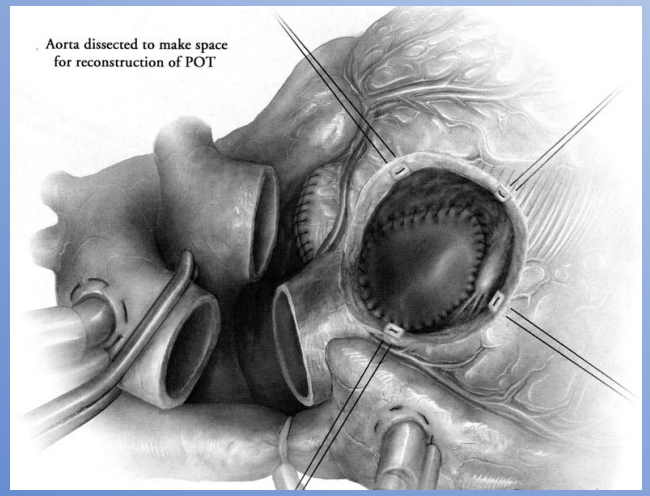
- without coronary transfer:
  IVR, Fallot type repair, Rastelli and REV

- with coronary transfer:
  Switch, Bex-Nikaidoh, Half turned cono truncal rotation

REV and Coronaries

Right ventriculotomy and Pulmonary artery closure

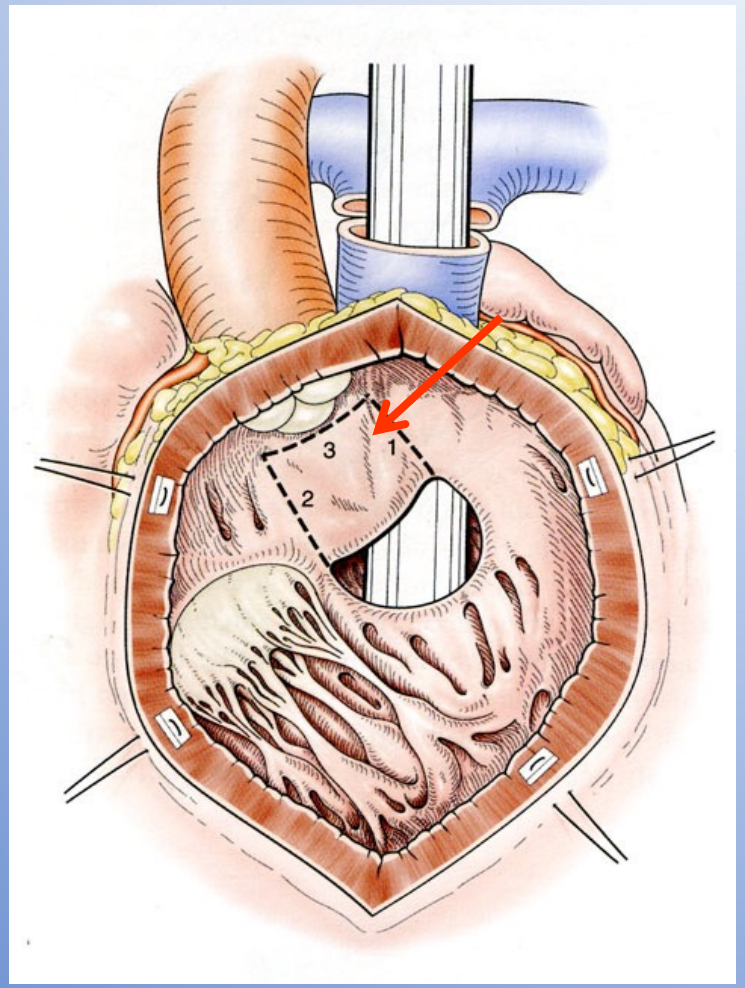


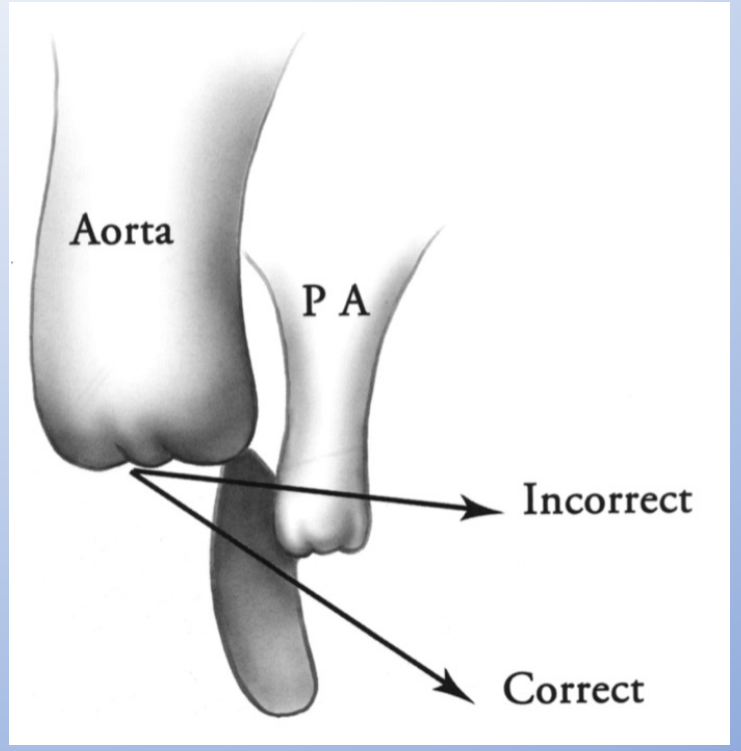


- Difficulties when lots of branches on the RV
- If no spot to reimplant the PA, consider Rastelli

- Mandatory to mobilize the pulmonary root at redo surgery
- Avoid big bites when it's bleeding on a beating heart

REV : Resection of the conal septum





- 1st septal branch
- Injury between the 2 vessels and subsequent desaster

REV

- Problem linked to the shortenning of the Aorta: stretching of the right coronary artery or rotation of a single CA

- Compression by the posterior wall of the reimplanted pulmonary artery
(infundibular branche or anterior loop)

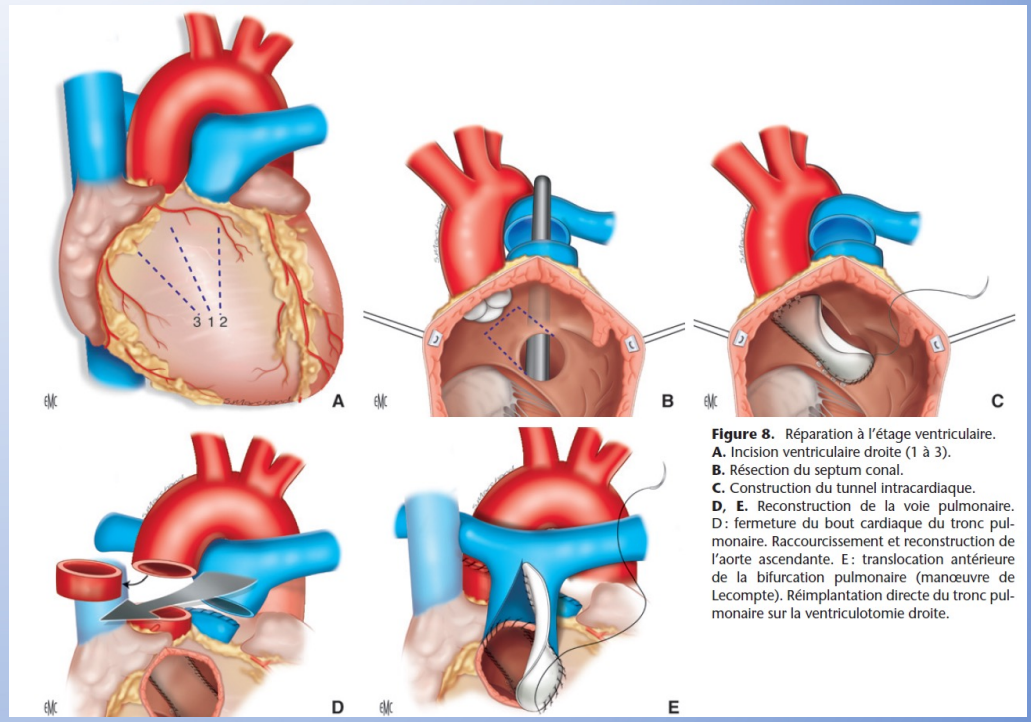


Figure 8. Réparation à l'étage ventriculaire.
A. Incision ventriculaire droite (1 à 3).
B. Résection du septum conal.
C. Construction du tunnel intracardiaque.
D, E. Reconstruction de la voie pulmonaire. D : fermeture du bout cardiaque du tronc pulmonaire. Raccourcissement et reconstruction de l'aorte ascendante. E : translocation antérieure de la bifurcation pulmonaire (manœuvre de Lecompte). Réimplantation directe du tronc pulmonaire sur la ventriculotomie droite.

1980-2021, 157 patients
2 patients experienced a major coronary events
- 1 patient had a stretching of the LCA due to a twist of the ascending aorta after shortenning
- 1 patient with single CA had compression by a melody

SPECIFIC SITUATIONS
SOMETIMES THE REV IS NOT APPROPRIATE

- IMPOSSIBILITY TO OBTAIN A « GOOD » CHANNEL
- ANOMALOUS PULMONARY ARTERY TREE:

  DISTORTION, HYPOPLASIA, DISTAL STENOSIS, MULTIPLE BT SHUNTS, NO TRUNK
- CORONARY BRANCHES CROSSING THE VENTRICULOTOMY SPOT
- MITRAL CLEFT WITH THE NEED OF CONAL RESECTION,
- MITRAL APPARATUS CREATING VSD OBSTRUCTION
- PULMONARY VALVE SUITABLE FOR SWITCH OR CONO TRUNCAL ROTATION!

New tool for visualization of complex forms of DORV and planning of the intra cardiac baffle

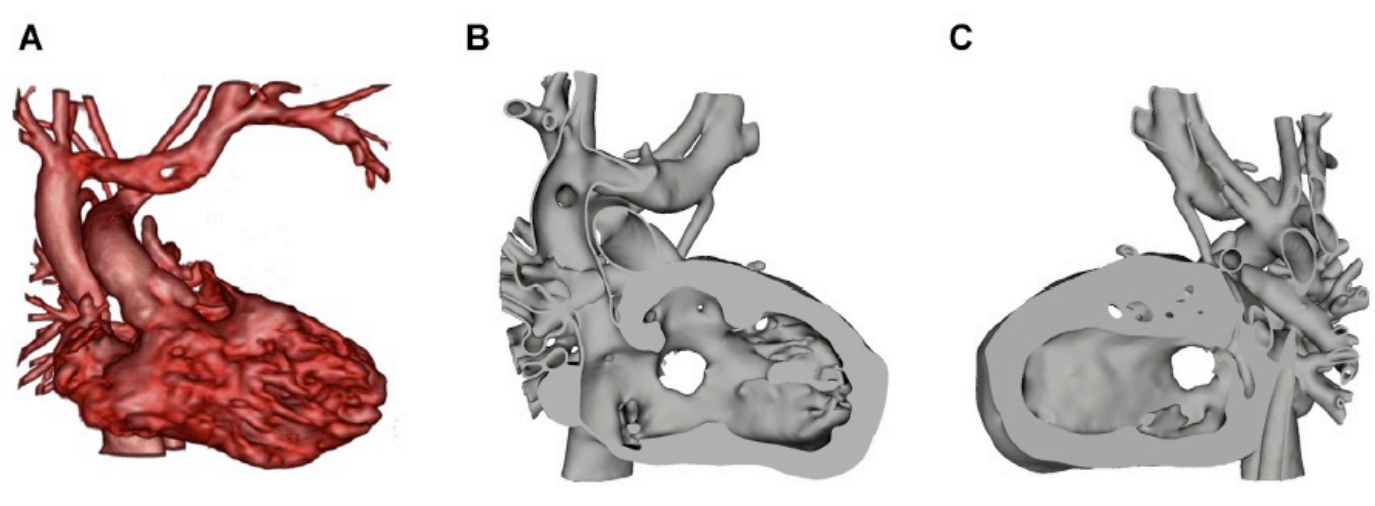


FIGURE 1 Model visualization. (A) Volume rendering of cardiac magnetic resonance of a patient with (S, D, D) double-outlet right ventricle and a subaortic ventricular septal defect. (B) Right ventricular view of a segmented model showing a ventricular septal defect. (C) Left ventricular view of a segmented model showing a ventricular septal defect. (S, D, D) = (Atrial solitus, D-ventricular loop, D-malposition of the semilunar valves).

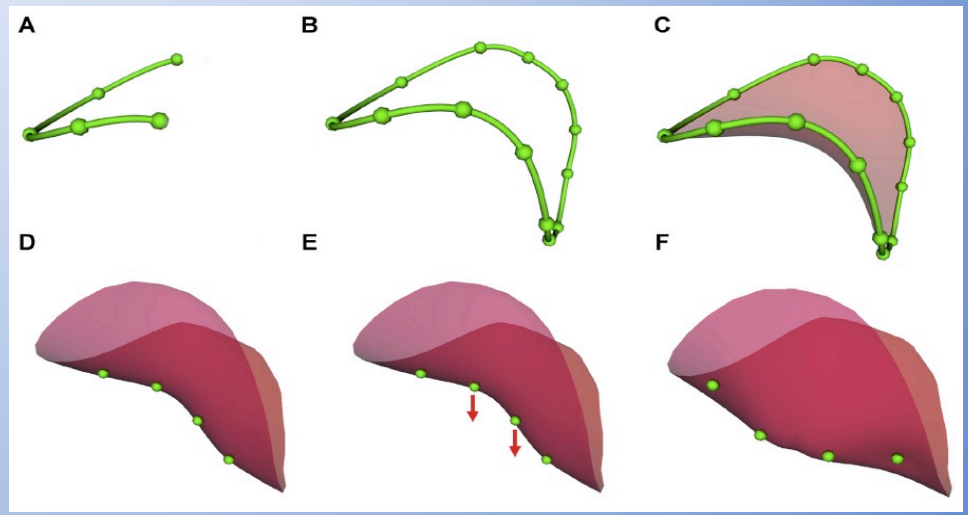


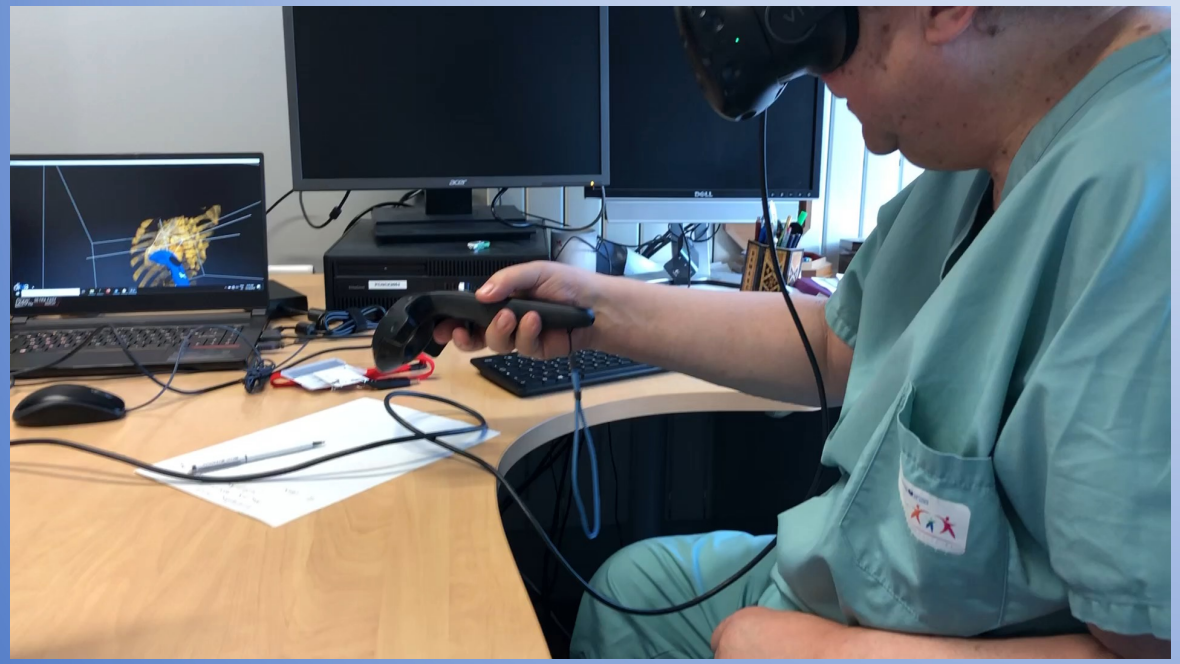
FIGURE 2 Baffle creation tool. (A) Placement of baffle perimeter contour points. (B) Completion of perimeter contour point placement. (C) Creation of baffle model from perimeter points. (D) Addition of surface points to baffle model. (E) Translation of baffle surface points inferiorly (as shown by red arrows) to modify the baffle. (F) Resulting baffle modification using surface point modification.

Modeling Tool for Rapid Virtual Planning of the Intracardiac Baffle in Double-Outlet Right Ventricle

(Ann Thorac Surg 2021;111:2078-83)

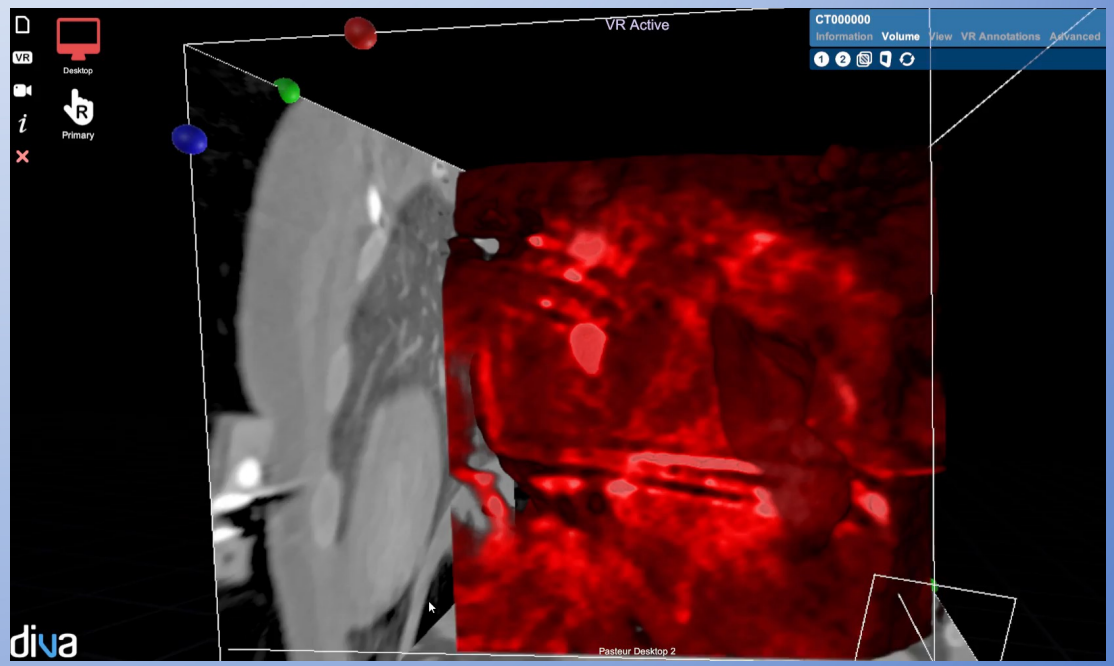
New tool for visualization of complex forms of DORV and planning of the intra cardiac baffle

Video of a game player – VR headset



El Beheiry M, Godard C, Caporal C, et al. DIVA: natural navigation inside 3D images using virtual reality. *J Mol Biol*. 2020;432: 4745-4749.

- Movie 3D from Pasteur DORV L-Malposition



Fast-track virtual reality for cardiac imaging in congenital heart disease Raimondi, J Card Surg 2021

SPECIFIC SITUATIONS
SOMETIMES THE REV IS NOT APPROPRIATE

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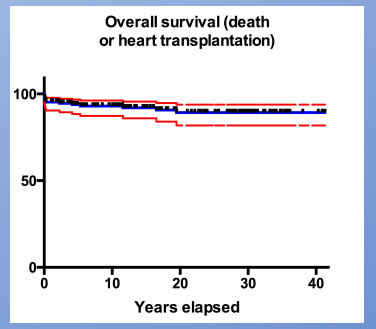
- MITRAL CLEFT WITH THE NEED OF CONAL RESECTION
- MITRAL APPARATUS CREATING VSD OBSTRUCTION
- PULMONARY VALVE SUITABLE FOR SWITCH OR CONO TRUNCAL ROTATION!

Long-term results of the REV procedure

(réparation à l'étage ventriculaire) - NECKER

- 40 years, 1980 and 2021
- 157 patients underwent a REV procedure
- DORV (Fallot or TGA type): 30% , TGA VSD LVOTO (65%)
- NO DIFFERENCE BETWEEN THE 2 GROUPS
- Median age and weight were 10 months and 8 kg
- 43% had a prior surgical palliation (BT shunt: 95%)
- Resection of the conal septum and/or VSD enlargement was performed in 36%
- Twelve patients (7.6%) died, including 4 (2.5%) during the first postoperative month
- Overall survival at 40 years was 89%



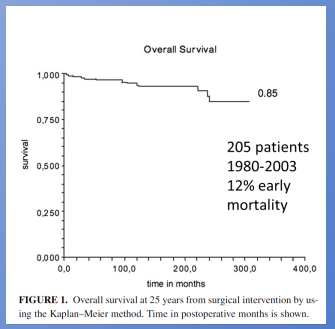
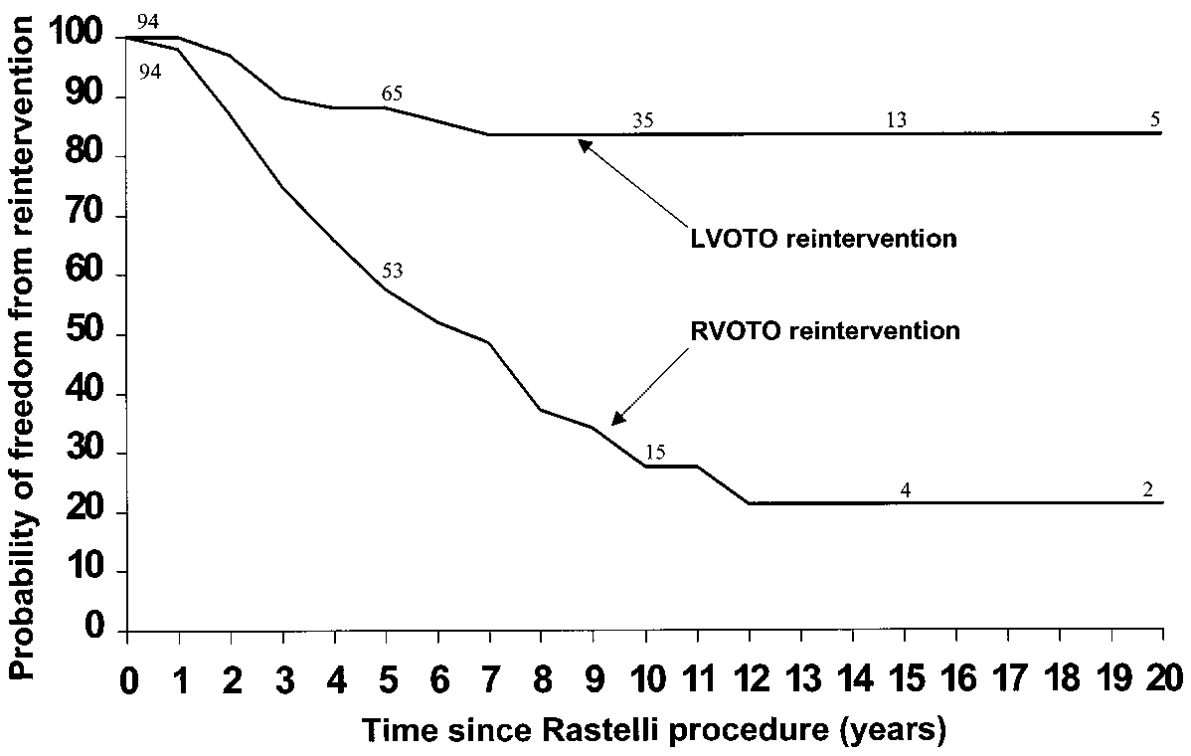


FIGURE 1. Overall survival at 25 years from surgical intervention by using the Kaplan–Meier method. Time in postoperative months is shown.

Di Carlo, Cohen, Vouhé
Lecompte, JTCS, 2011

Background & Objectives



2000. JTCS. Kreutzer

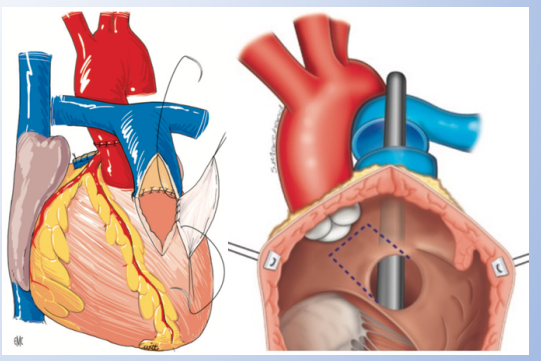
Nikaidoh vs REV vs Rastelli

Table 1 Outcomes of Nikaidoh, Rastelli, REV, and En Bloc Rotation Operations

Author	Number of Patients	Mortality		Reoperations	
		Early	Late	LVOT	RVOT
Nikaidoh					
Yeh et al[10]	18	1/18	0/17	0/17	5/17
Morell et al[11]	12	1/12	0/11	0/11	2/11
Raju et al[17]	17	0/17	0/17	0/17	4/17
Hu et al[21]	9	0/9	0/9	0/9	0/9
Leiden (unpublished data)	13	0/13	0/13	0/13	1/13
Kramer et al[18]	14	2/14	1/12	0/12	2/12
Honjo et al[22]	8	0/8	0/8	0/8	0/8
Rastelli					
Brown et al[19]	40	0/40	3/40	2/37	16/37
Hu et al[21]	6	1/6	0/5	0/5	0/5
Hazekamp et al[23]	82	5/82	8/77	4/77	29/77
Kreutzer et al[15]	101	7/101	17/94	11/94	44/94
Hörer et al[20]	39	0/39	4/39	1/35	17/35
REV					
Hu et al[21]	3	1/3	0/2	0/2	0/2
Hazekamp et al[23]	31	2/31	3/29	5/29	3/29
Di Carlo et al[24]	142	2/142	13/140	3/140	36/140
En bloc rotation/double-root translocation					
Mair et al[16]	13	0/13	0/13	0/13	0/13
Yamagishi et al[8]	2	0/2	0/2	0/2	0/2

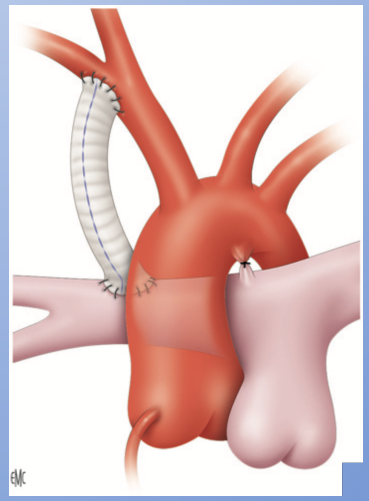
2018. Ped Card Surg. Hazekamp

Patients



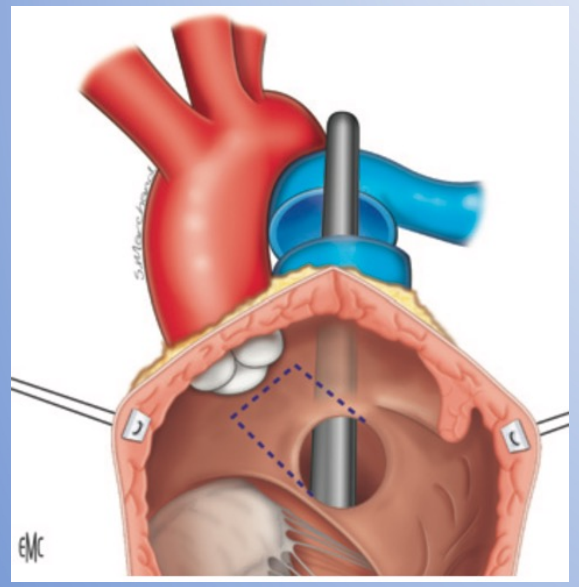
- 1980 => 2022, 157 REV procedure
- Follow up 18 years (2m - 41.3y)
- Median age 10 months (2.1m -13.7y) and weight 8.2 kg (4.2-25)

TGA VSD PS	**113 (72%)**
DORV TGA-like	**27 (17.2%)**
DORV TOF-like	9 (5.7%)
DOLV	6 (3.8%)
ccTGA	2 (1.3%)

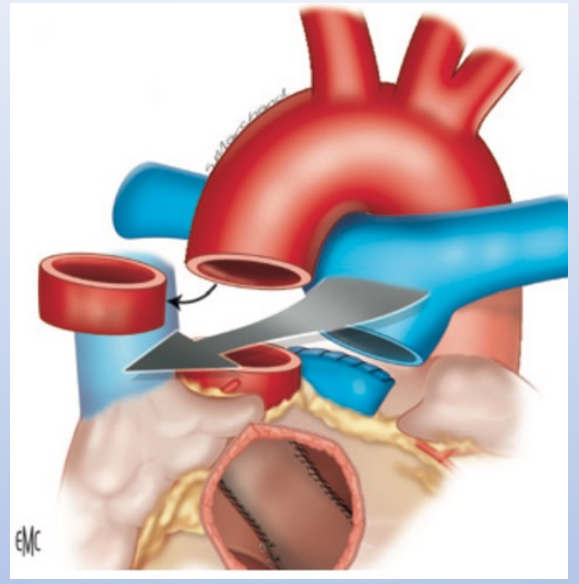


62 (39.5%)

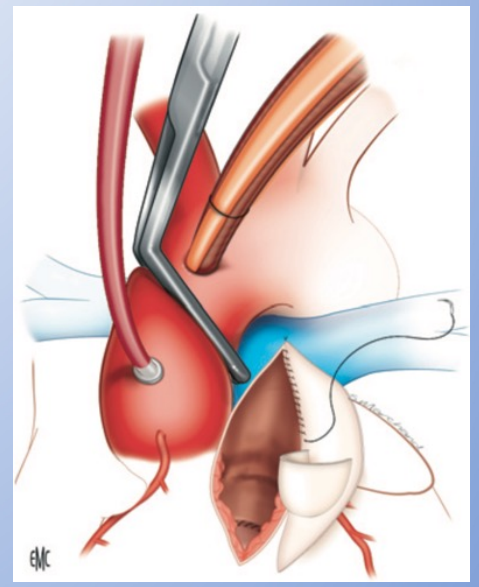
Surgical procedure



Resection of conal septum / VSD enlargment
n = 135 (88.4%)



Lecompte maneuver
n = 146 (93%)



Monocusp implantation
n = 105 (66.9%)
=> 2008

Survival

Overall survival (death or Tx) was 89.3% (95CI : 81.8-93.8%) at 20 and 40 years

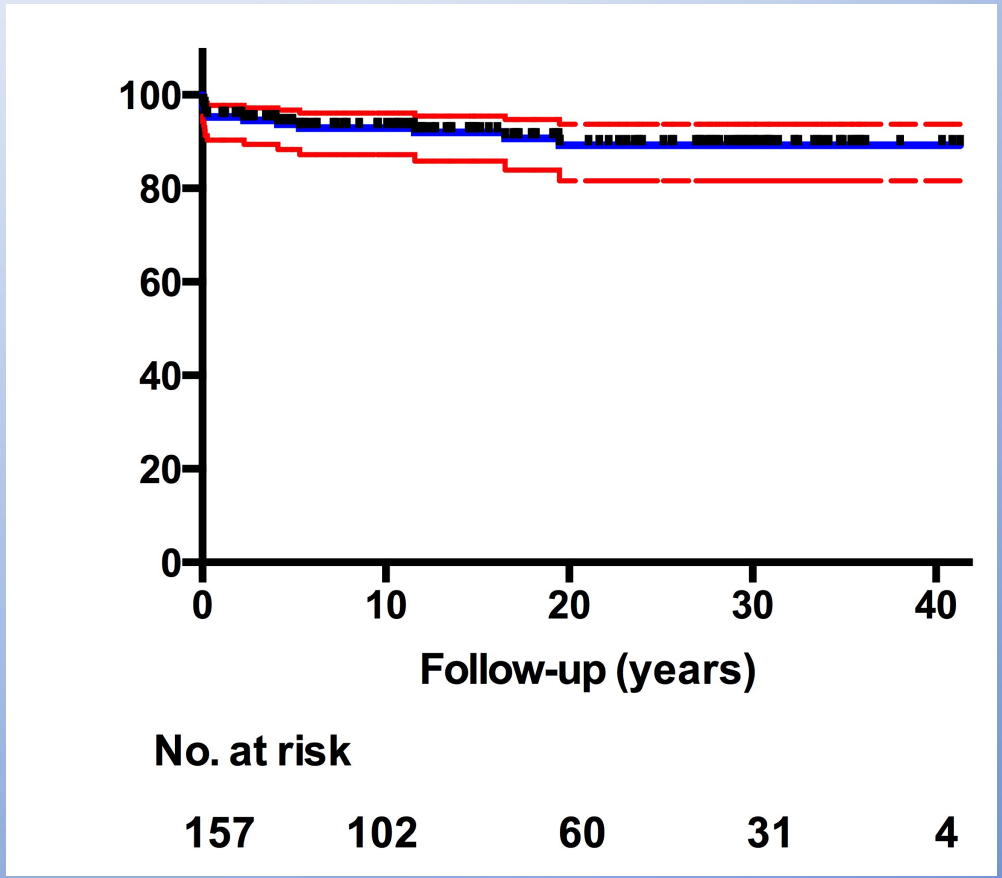
- Early death, n=4 (2.5%)
- Late death, n=9 (5.7%)

Sudden death, n=3

Heart Tx, n=2

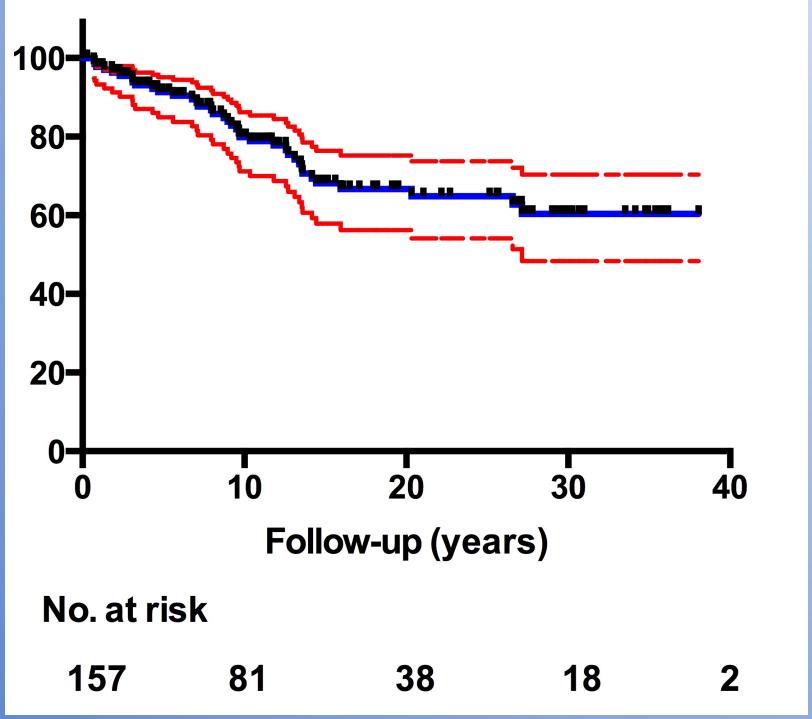
Arrhythmias, n=2

Redo surgery, n=1



Fate of the RVOT

- Thirty-eight patients (24.2%) required 68 reinterventions on the RVOT, including 49 reoperations in 34 patients (21.7%)
- Median delay of 9 years after the REV (8 months - 27 years)



- Implantation of a monocusp
  - RVOT reintervention (p=0.0099)
  - RVOT reoperation (p=0.0026)
  - Pulmonary valvulation (p=0.2132)

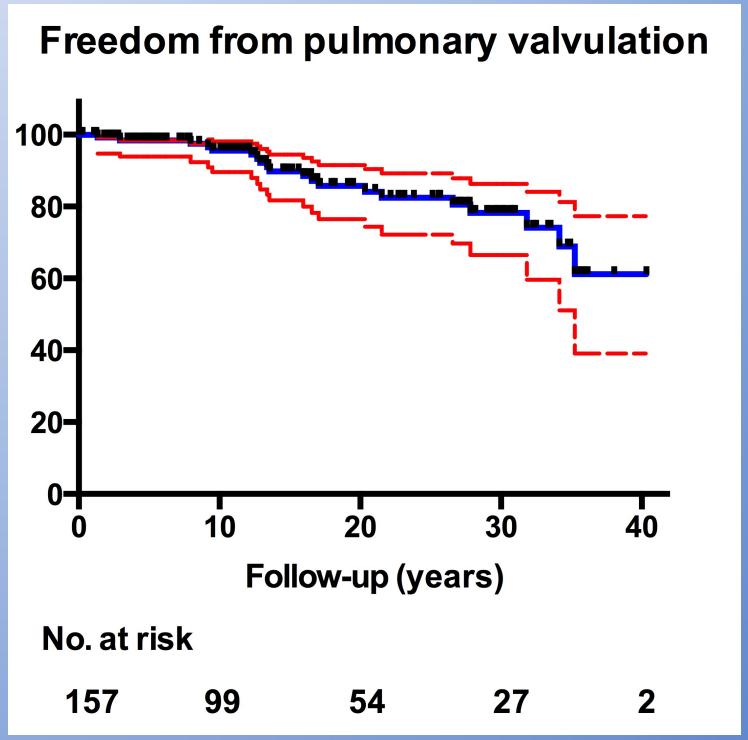
USE OF MONOCUSP = INDEPENDANT RISK FOR SUBSEQUENT STENOSIS

70% FREEDOM OF REINTERVENTION AT 20 YEARS

Fate of the RVOT

Indications for RVOT reinterventions = MAINLY STENOSIS

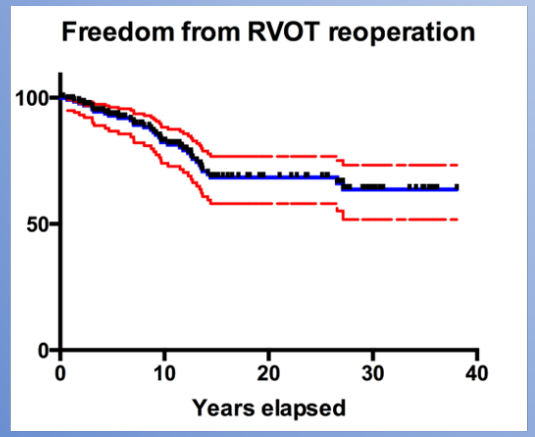
- RVOT obstruction, n=61, mean gradient 65mmHg (40-105mmHg)
  - Annular, n=41
  - Supravalvular, n=13
  - Both annular and supravalvular, n=5
  - Subpulmonar, n=2
- Pulmonary regurgitation, n=7
- Pulmonary valvulation in 20 patients (13%)
  - ¾ surgery, ¼ PPVI



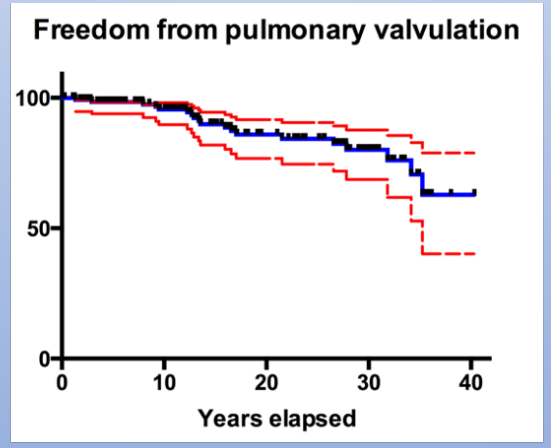
82% FREEDOM FROM PULMONARY VALVULATION AT 20 YEARS

REV : very long term outcome

- 23% required reinterventions for RVOTO (median delay: 9 years => 8 months - 27 years)
- 13% underwent pulmonary valvulation (15 surgical and 5 interventional).
- Freedom from RVOT obstruction reintervention was 90% at 5 years, 76% at 10 years, 55% at 20 years and 42% at 40 years.



Freedom from RVOT reoperation
99.3% at 1 year, 92.9% at 5 years,
82.4% at 10 years and 63.6% at 40 years



Freedom from pulmonary valvulation
88.4% at 5 years, 85.6% at 10 years and
62.8% at 40 years

RASTELLI - REINTERVENTIONS

Left: 20% of reinterventions at 5 years

Right: reinterventions
45% à 5 years
75% à 10 years
80% à 15 years

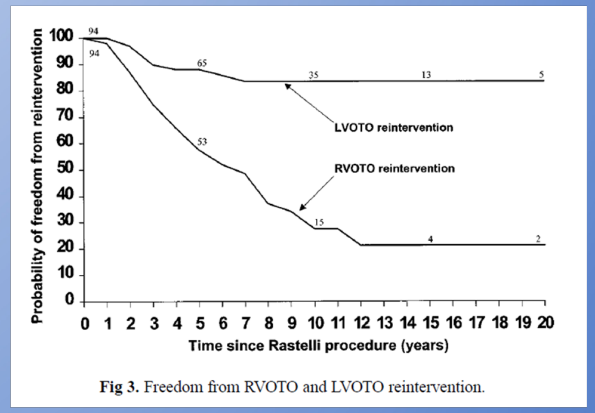
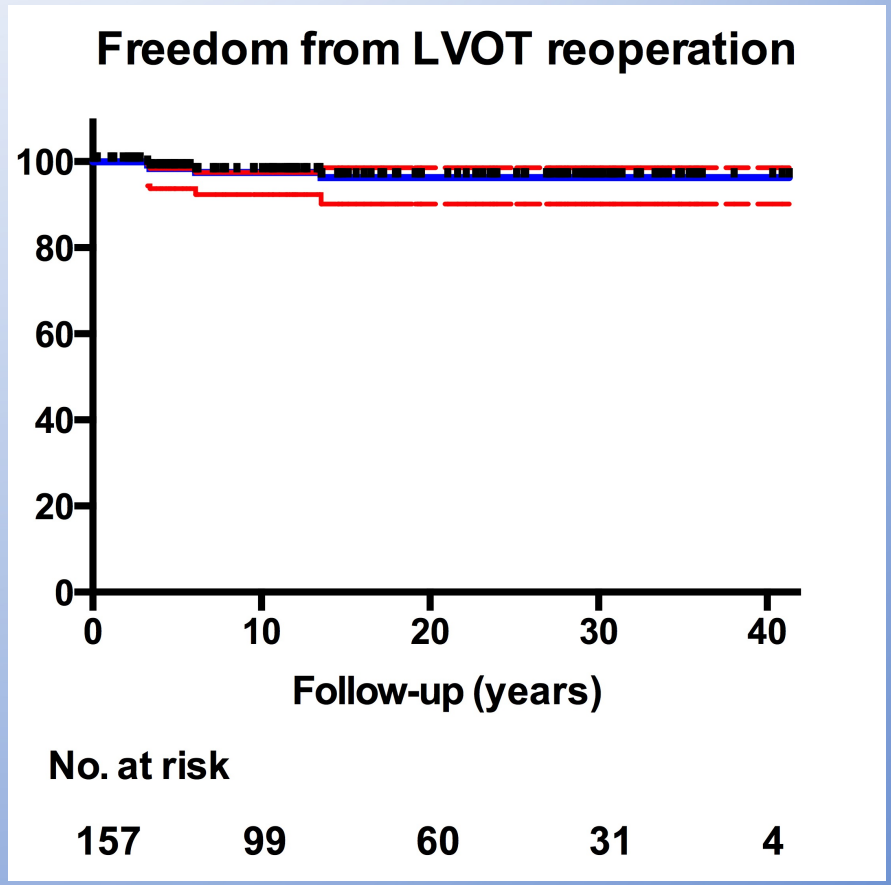


Fig 3. Freedom from RVOTO and LVOTO reintervention.

Kreutzer, JTCS, 2000 (Boston)

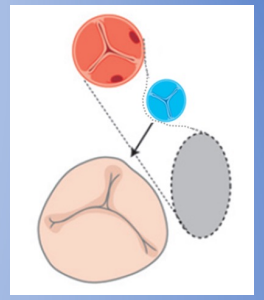
Fate of the LVOT

- LVOT reoperation are scarce: 2.5% required reoperation for LVOTO
- Median delay of 5 years (range 3.2-13.5 years)
- Confirmed by other series (2 to 5%)



An K, pediat Cardiol, 2021
Lim HG, JTCVS, 2014
Hu, JTCVS, 2008

REV



- STRONG ALTERNATIVE TO THE RASTELLI (long term outcome: survival, RVOT, LVOT)
- INDICATIONS: DORV TGA-type and TGA VSD PS when pulmonary valve not suitable for Switch or for the RVOT (Cono truncal rotation)
- CONCERNS:
  - Arrythmias: ventricular scar
  - No pulmonary valve – dilatation of the RV?
  - LV to aorta channel: realignement?

} currently under evaluation

CONCLUSIONS

- The REV (means dream in French) is not a nightmare
- Probably better a REV than a Rastelli
- But no nice REV without efficient LV to aorta channel
- So, probably room for other surgical options…