UMC Utrecht
Wilhelmina Kinderziekenhuis

Jan 31st - Febr 1st
2025

Cath interventions in PA branch stenosis after ASO

Gianfranco Butera

Ospedale Pediatrico Bambino Gesu'

Bambino Gesù
OSPEDALE PEDIATRICO

Bambino Gesù
OSPEDALE PEDIATRICO

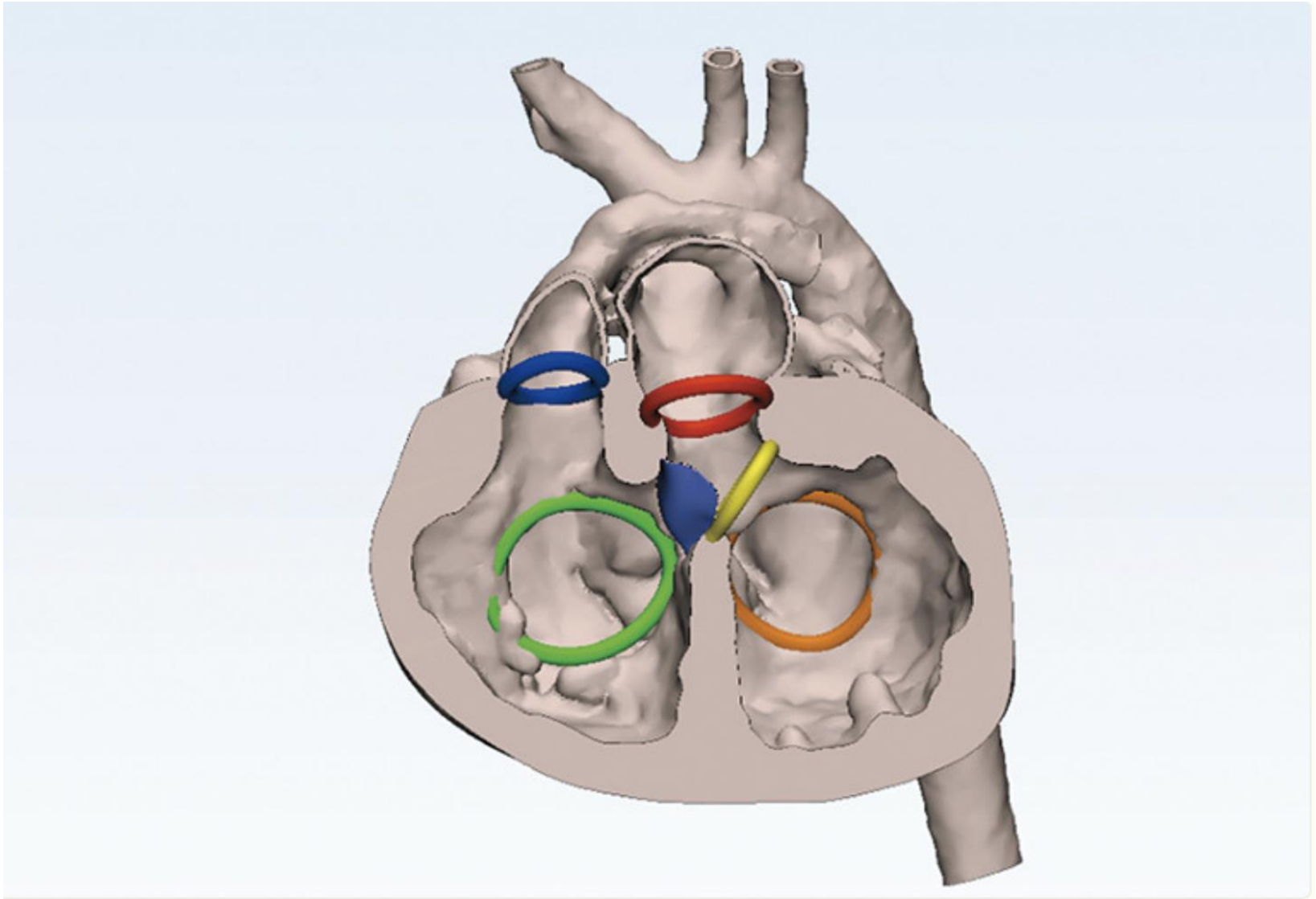
Ground-breaking and mid-blowing thoughts among Interventionalists

As an interventional cardiologist what do you think about the "ballooning" theory proposed today by Prof Antoon Mormoon about DORV embriology?

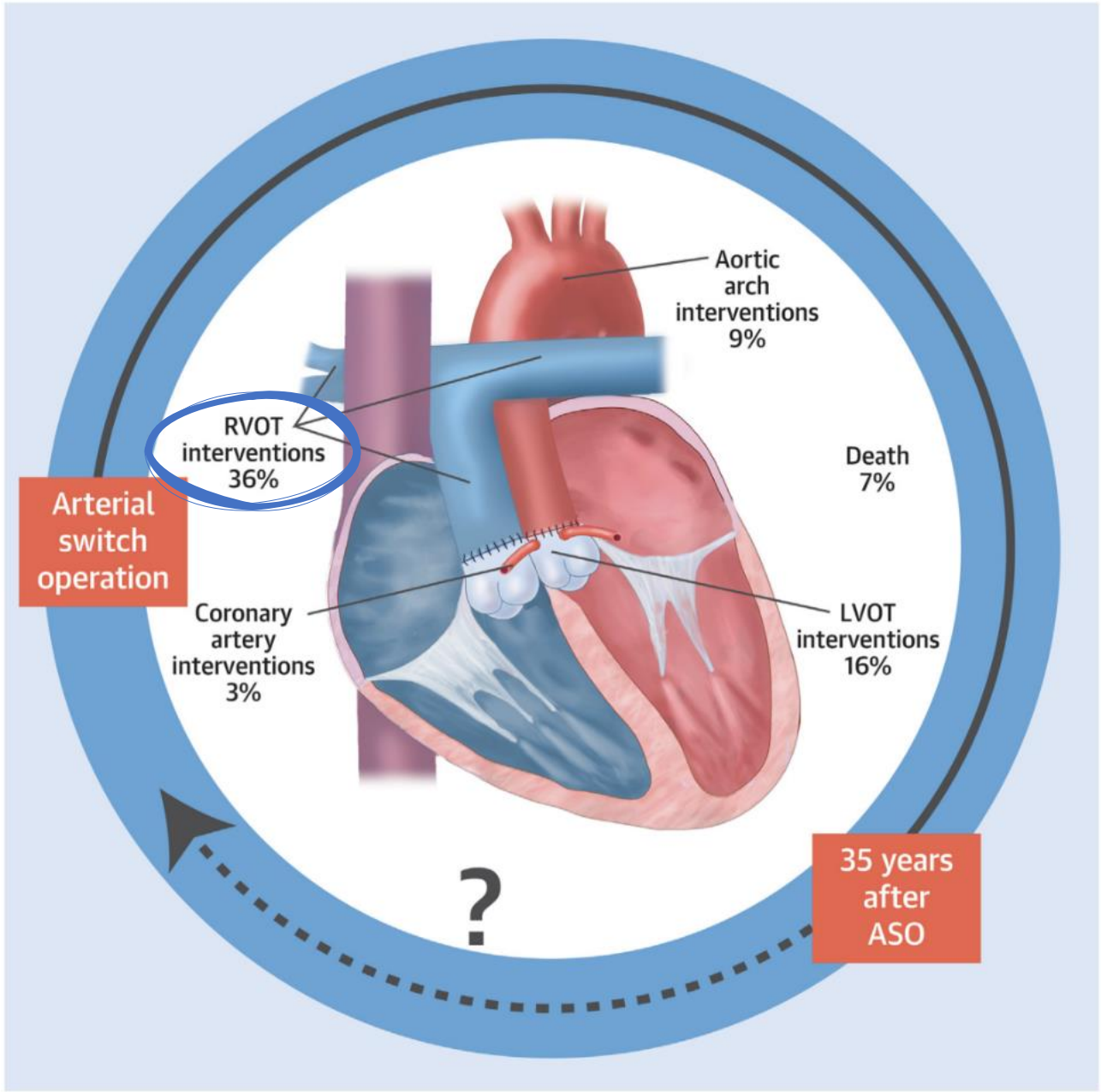
Dear Friend,
This is an interesting approach however …….

Ground-breaking and mid-blowing thoughts among Interventionalists

As you heard today
during my talk i'm
more prone
to consider
the **stenting approach**
as my preferred one



ASO for DORV correction: *Dark Blue, pulmonary valvar orifice; Red, aortic valvar orifice; Orange, mitral valvar orifice; Green, tricuspid valvar orifice; Yellow, outline of the interventricular communication.*



Engele LJ, et al. JACC Adv. 2024;3(2):100772.

- **RVOTO:** most common indication for catheterization after ASO-LeCompte [1,2]
- **Branch PA stenosis** is the most common indication for intervention: incidence of 4-28% [2,3]
- **LPA is most commonly affected**, requiring intervention x1.5 times compared to the RPA [3]

(1) Engele LJ, van der Palen RLF, Joosen RS, Sieswerda GT, Schoof PH, van Melle JP, Berger RMF, Accord RE, Rammeloo LAJ, Konings TC, Helbing WA, Roos-Hesselink JW, van de Woestijne PC, Frerich S, van Dijk APJ, Kuipers IM, Hazekamp MGH, Mulder BJM, Breur JMPJ, Blom N, Jongbloed MRM, Bouma BJ. **Clinical Course of TGA After Arterial Switch Operation in the Current Era. JACC Adv. 2023** Dec 27;3(2):100772. doi: 10.1016/j.jacadv.2023.100772. PMID: 38939383; PMCID: PMC11198364.

(2) Gritti MN, Farid P, Hassan A, Marshall AC. **Cardiac Catheterization Interventions in the Right Ventricular Outflow Tract and Branch Pulmonary Arteries Following the Arterial Switch Operation. Pediatr Cardiol. 2024** Feb 10. doi: 10.1007/s00246-024-03408-w. Epub ahead of print. PMID: 38341390.

(3) Joosen, R, van der Palen, R, Udink ten Cate, F. et al. **30 Years' Experience in Percutaneous Pulmonary Artery Interventions in Transposition of the Great Arteries. JACC Adv. 2024** Nov, 3 (11)https://doi.org/10.1016/j.jacadv.2024.101327

Indications for catheterization

- Symptoms
- Severe PS or PR (with increased RVEDV)
- RV/LV systolic pressure ratio > 2/3
- Significant PA stenosis (gradient echo >20mmHg)
- Significant differential split net flow ratio MRI
- Significant differential PA branch size/ narrowing

(1) Gritti MN, Farid P, Hassan A, Marshall AC. **Cardiac Catheterization Interventions in the Right Ventricular Outflow Tract and Branch Pulmonary Arteries Following the Arterial Switch Operation. Pediatr Cardiol. 2024** Feb 10. doi: 10.1007/s00246-024-03408-w. Epub ahead of print. PMID: 38341390.

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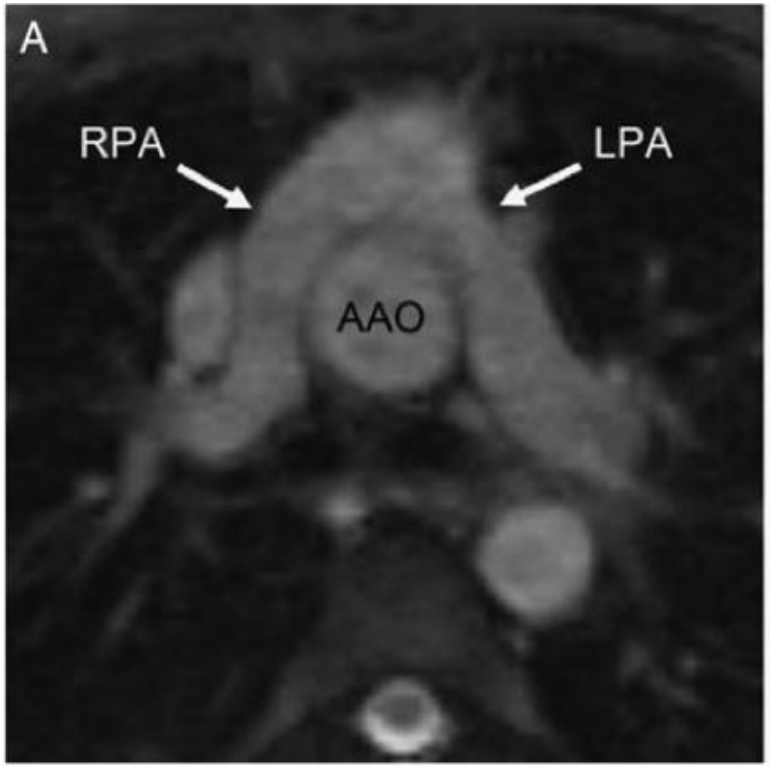
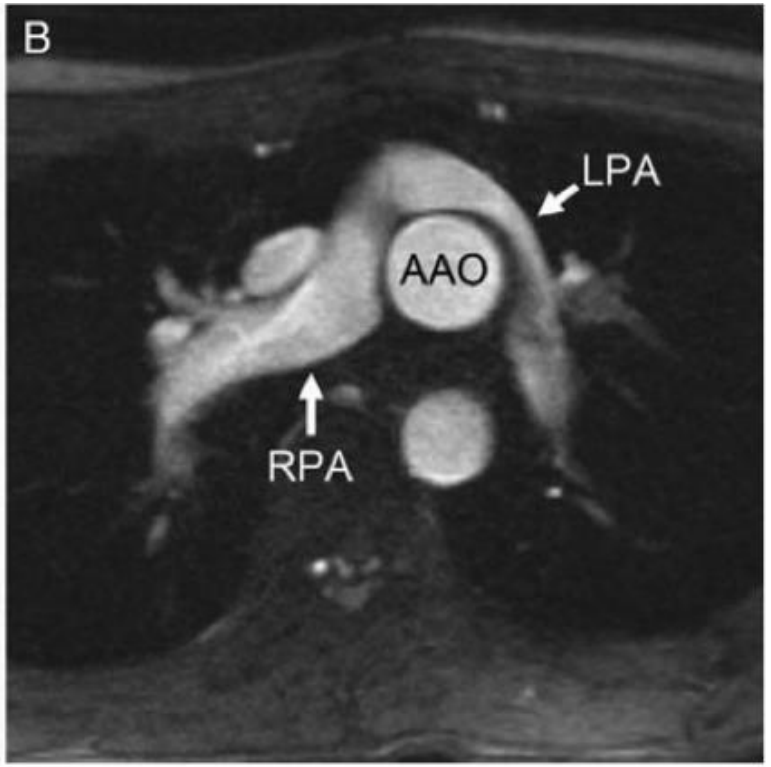
Pathophysiology of LPA stenosis: (4)

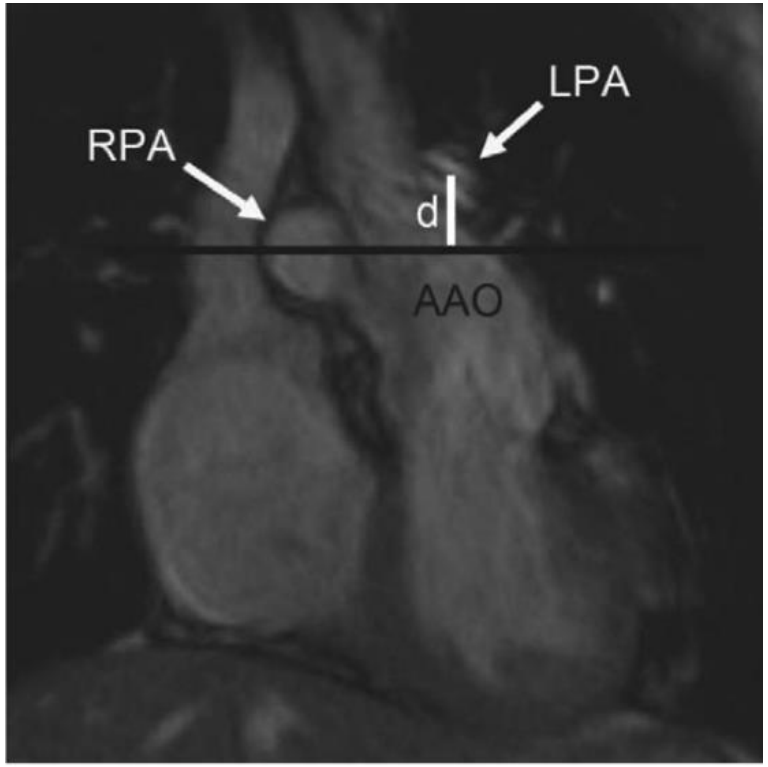
-Multifactorial. Aortic root enlargement and rightward neo-pulmonary position -> stretching and elongation of the LPA over the aorta (rather than a discrete stenosis)

-Reduced left pulmonary blood flow -> imbalanced LPA: RPA split net flow ratio

(4) Morgan CT, Mertens L, Grotenhuis H, Yoo SJ, Seed M, Grosse-Wortmann L. **Understanding the mechanism for branch pulmonary artery stenosis after the arterial switch operation for transposition of the great arteries. Eur Heart J Cardiovasc Imaging. 2017** Feb;18(2):180-185. doi: 10.1093/ehjci/jew046. Epub 2016 Mar 29. PMID: 27025515.







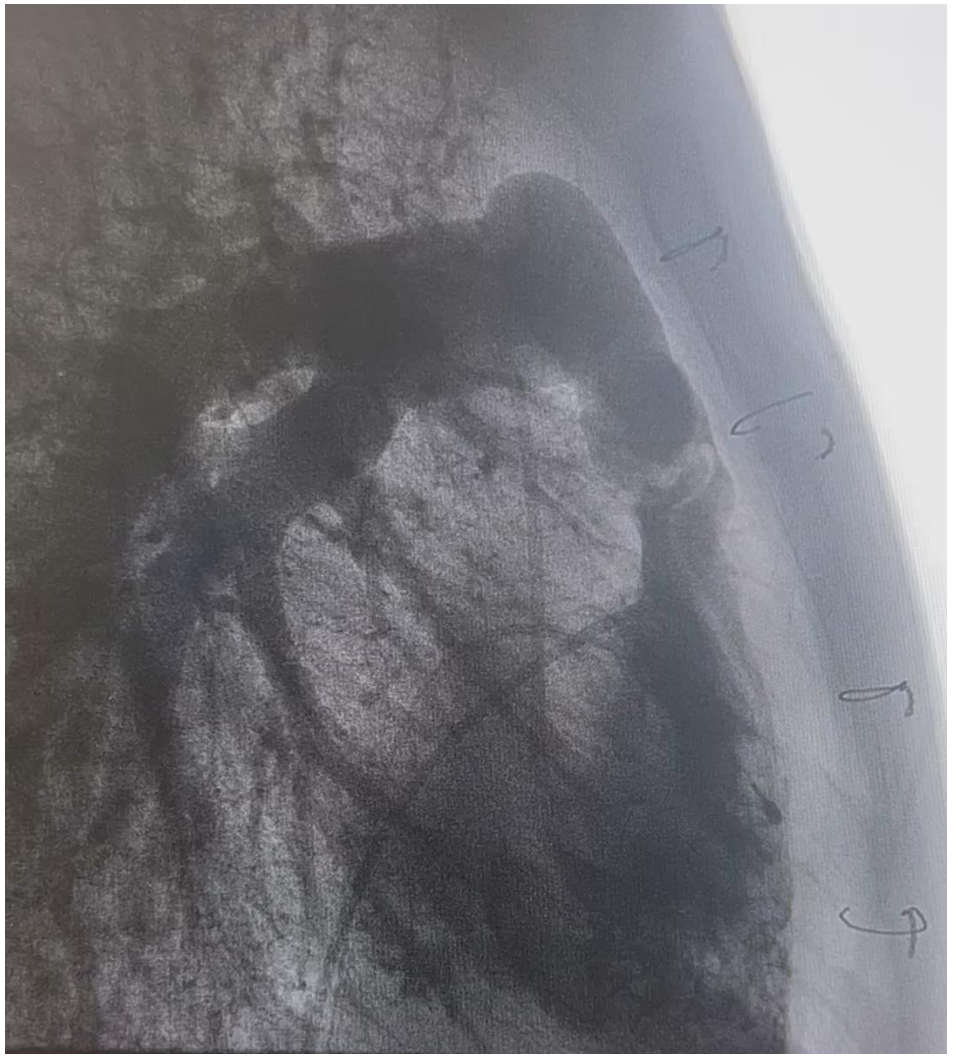
balanced PA embracing the A Ao

rightward neo-pulmonary -> stretching of LPA

enlargement of the neo-aortic root -> 'scoop up' of the LPA

(4) Morgan CT, Mertens L, Grotenhuis H, Yoo SJ, Seed M, Grosse-Wortmann L. ***Understanding the mechanism for branch pulmonary artery stenosis after the arterial switch operation for transposition of the great arteries. Eur Heart J Cardiovasc Imaging.*** *2017 Feb;18(2):180-185. doi: 10.1093/ehjci/jew046. Epub 2016 Mar 29. PMID: 27025515.*

Rotational angiography and 3D



Useful tool to evaluate the anatomy, mediastinal structures relationship (great vessels and bronchi)

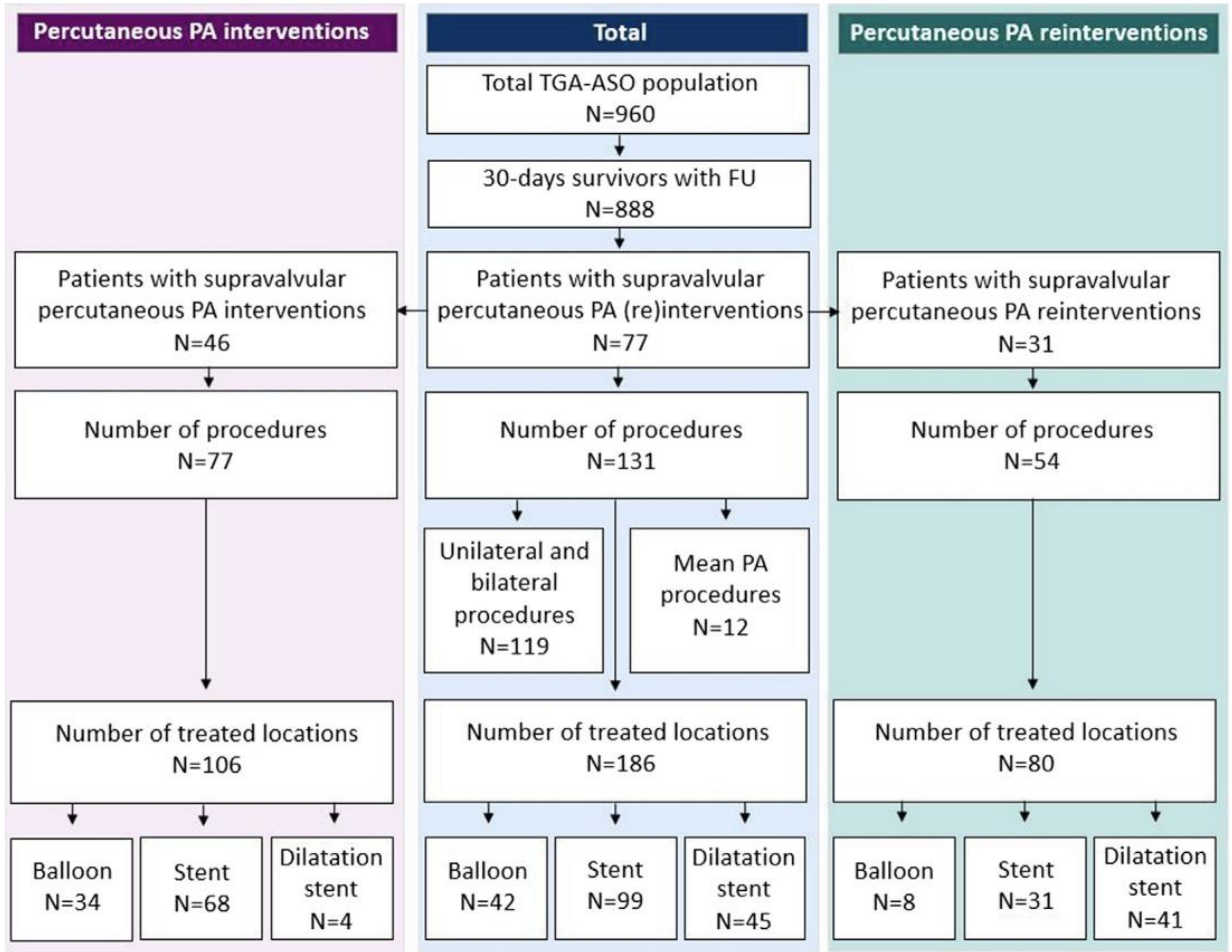
JACC: ADVANCES VOL. 3, NO. 11, 2024

ORIGINAL RESEARCH

30 Years' Experience in Percutaneous Pulmonary Artery Interventions in Transposition of the Great Arteries

Renée S. Joosen, MSc,[a] Roel L.F. van der Palen, MD, PhD,[b,c] Floris E.A. Udink ten Cate, MD, PhD,[d] Michiel Voskuil, MD, PhD,[e] Gregor J. Krings, MD, PhD,[a] Regina Bökenkamp, MD, PhD,[b,c] Mirella C. Molenschot, MD,[a] Nathan D. Hahurij, MD, PhD,[b,c] Michael G. Dickinson, MD, PhD,[e] Mark G. Hazekamp, MD, PhD,[c,f] Paul H. Schoof, MD, PhD,[g] Martijn G. Slieker, MD, PhD,[a] Bart Straver, MD, PhD,[b,c,h] Nico A. Blom, MD, PhD,[b,c,h,*] Johannes M.P.J. Breur, MD, PhD[a,*]

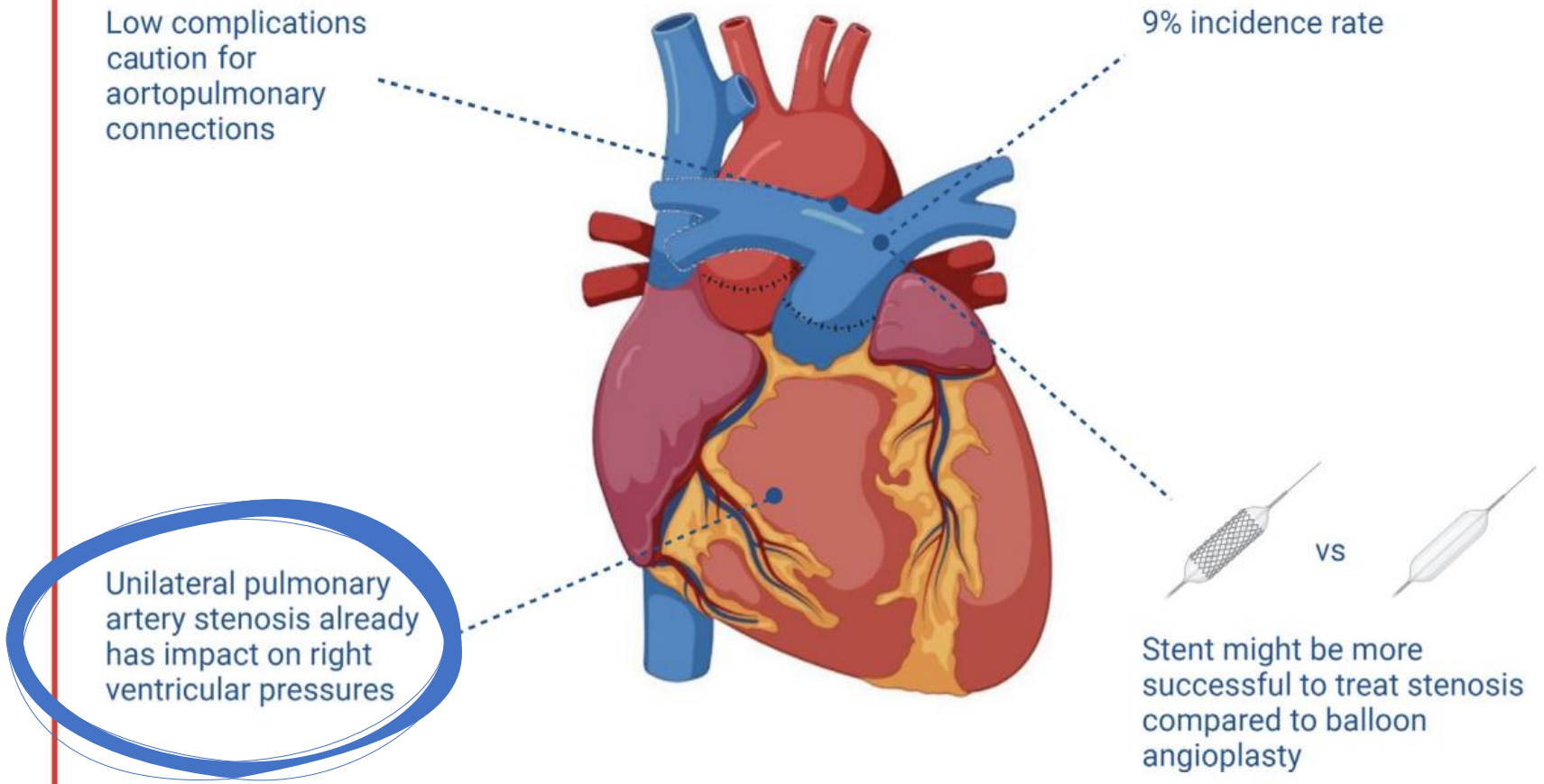
FIGURE 1 Flowchart Percutaneous PA (Re)intervention in TGA Patients After ASO



A flowchart of the number of procedures, the number of locations (LPA, RPA, or MPA) treated per procedure, and the type of procedure (Balloon, stent, dilatation of stent) during percutaneous PA (Re)interventions. ASO = arterial switch operation; FU = follow-up; LPA = left pulmonary artery; MPA = main pulmonary artery; PA = pulmonary artery; RPA = right pulmonary artery; TGA = transposition of the great arteries.

(3) Joosen, R, van der Palen, R, Udink ten Cate, F. et al. **30 Years' Experience in Percutaneous Pulmonary Artery Interventions in Transposition of the Great Arteries. JACC Adv. 2024** Nov, 3 (11)https://doi.org/10.1016/j.jacadv.2024.101327

CENTRAL ILLUSTRATION **Pulmonary Artery Stenosis in Transposition of the Great Arteries**



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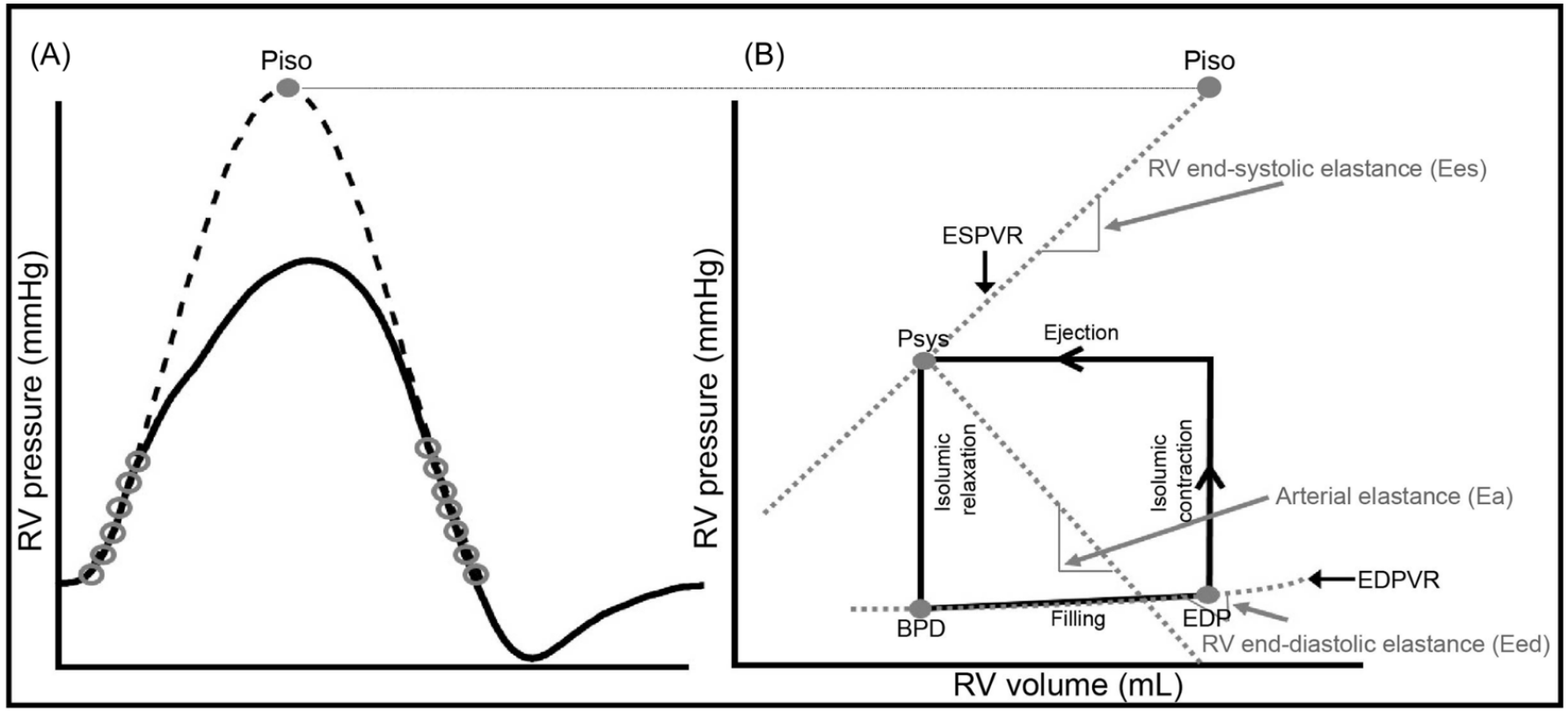


Unilateral branch stenosis can impact RV pressures. Increased RV afterload causes impaired RV diastolic stiffness and RV contractility leading to RV-PA uncoupling [5]

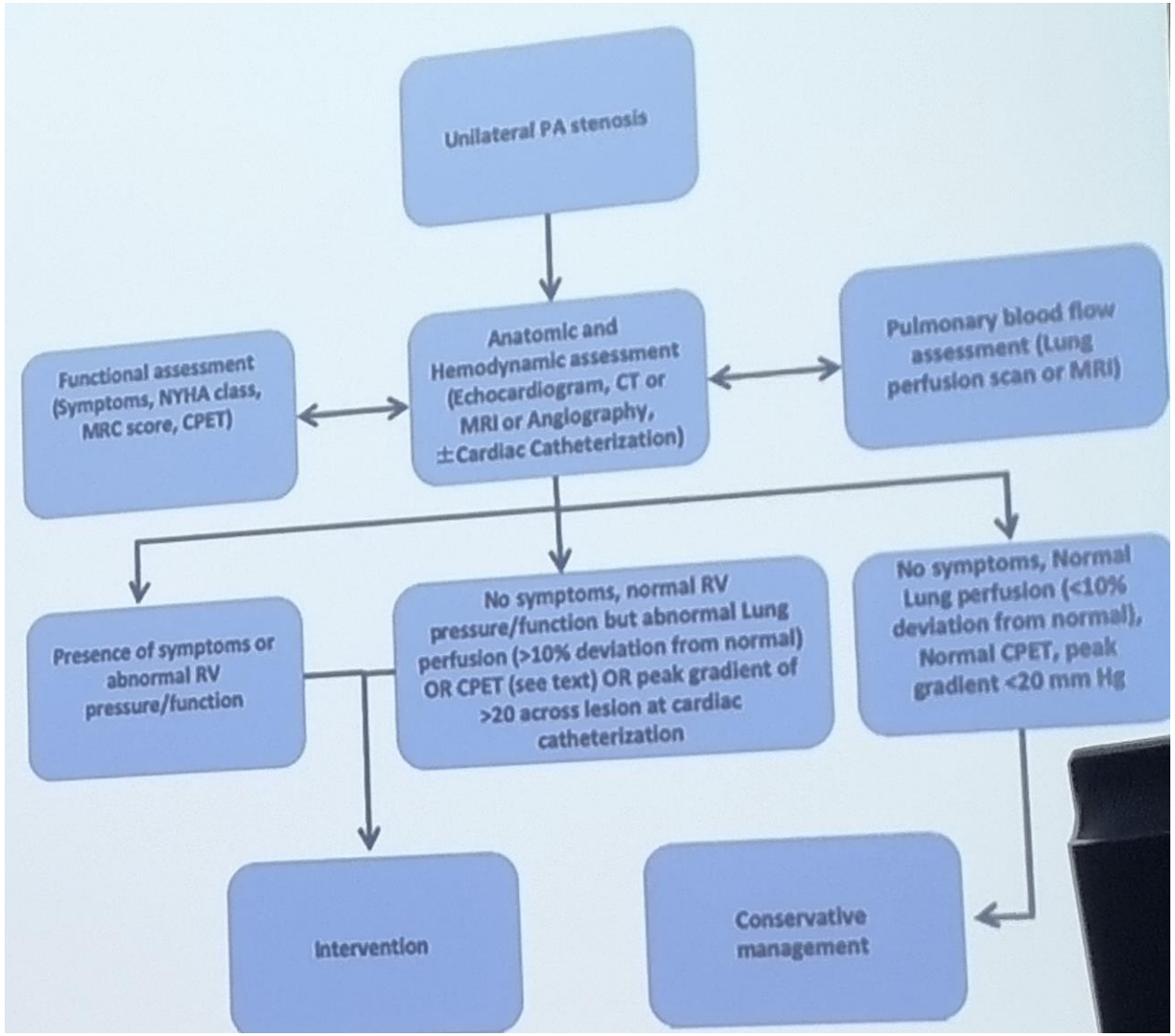
(5) Joosen RS, Voskuil M, Krings GJ, Handoko ML, Dickinson MG, van de Veerdonk MC, Breur JMPJ. **The impact of unilateral pulmonary artery stenosis on right ventricular to pulmonary arterial coupling in patients with transposition of the great arteries. Catheter Cardiovasc Interv. 2024** May;103(6):943-948. doi: 10.1002/ccd.31036. Epub 2024 Apr 5. PMID: 38577955.

Trends in Cardiovascular Medicine
Volume 31, Issue 3, April 2021, Pages 179-184

Treatment approach to unilateral branch pulmonary artery stenosis ☆

Gurumurthy Hiremath [a], Athar M. Qureshi [b], Jeffery Meadows [c], Varun Aggarwal [a]

Show more



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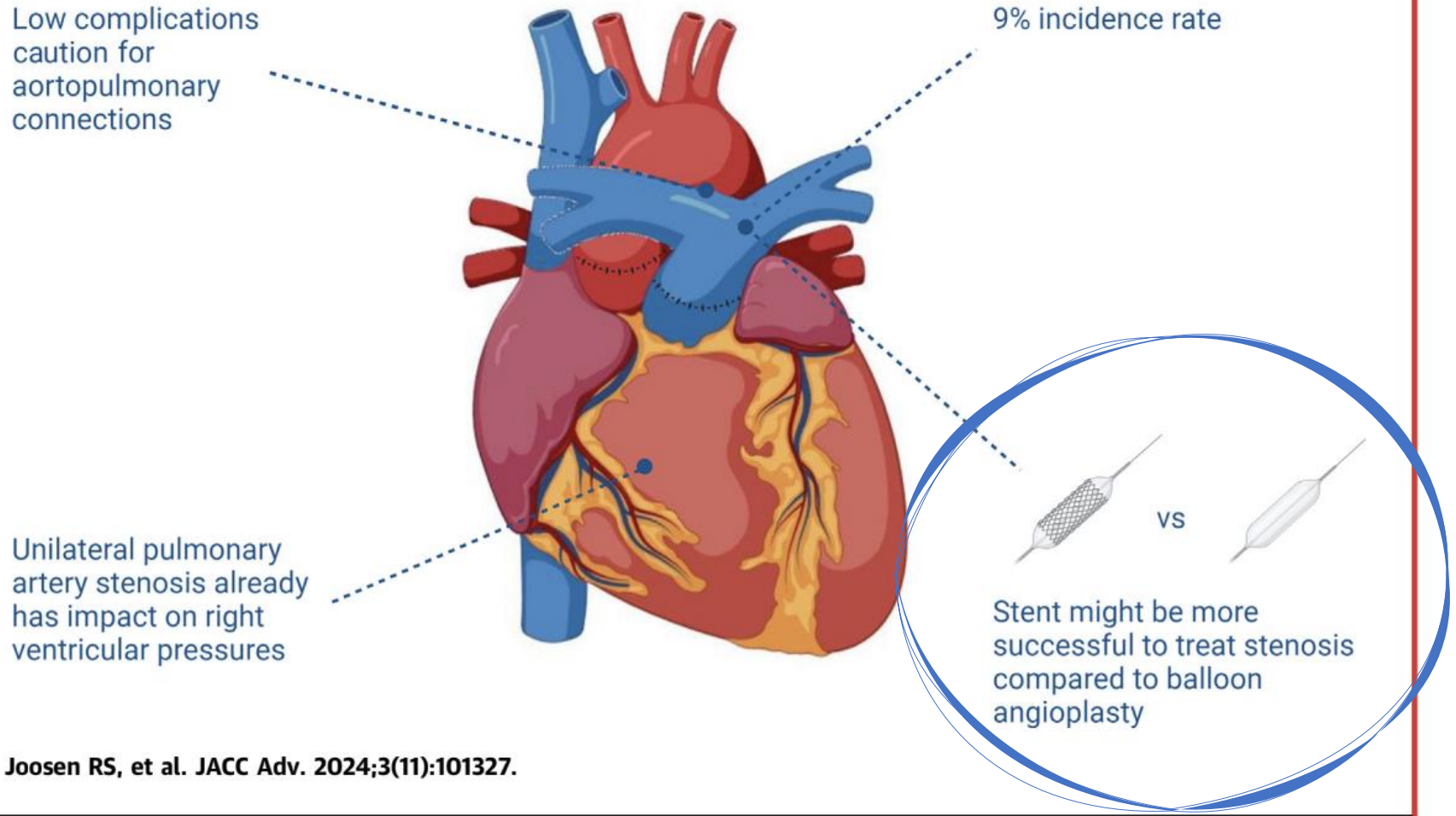

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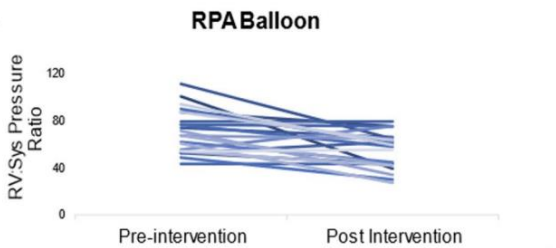
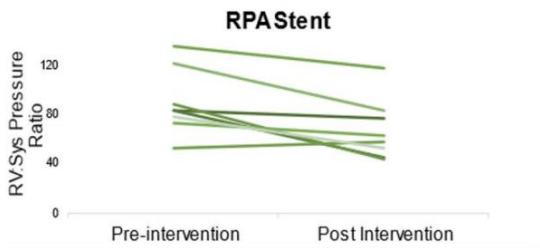


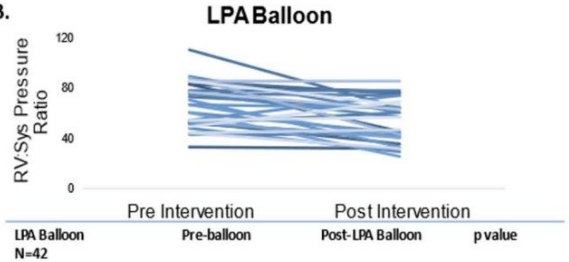
RPA Balloon N=27	Pre-balloon	Post-RPA Balloon	p value
RV:SysRatio	0.69 ± 0.17	0.54 ± 0.15	p<0.001
RPA Gradient (mmHg)	22 ± 15	10 ± 9	p<0.02

C.



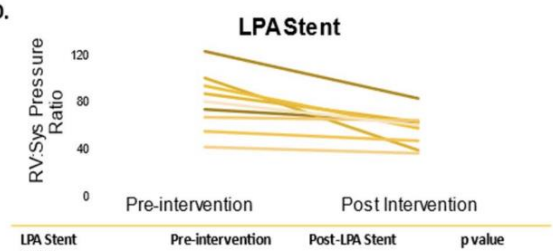
RPA Stent N=15	Pre-intervention	Post-RPA Stent	p value
RV:SysRatio	0.80 ± 0.26	0.67 ± 0.24	p<0.01
RPA Gradient (mmHg)	31 ± 14	11 ± 10	p<0.01

B.

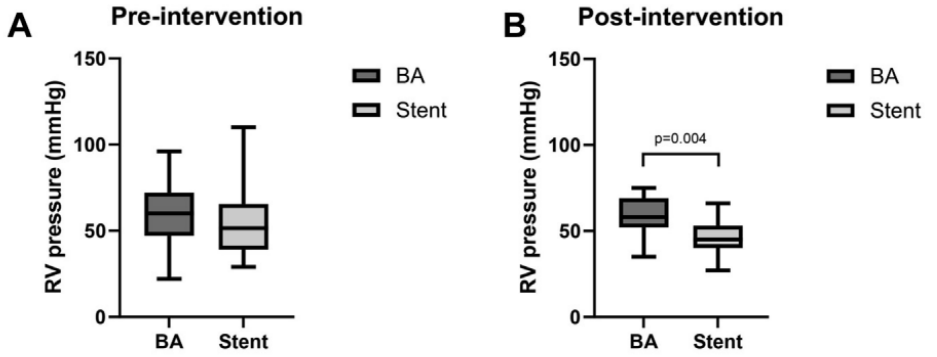


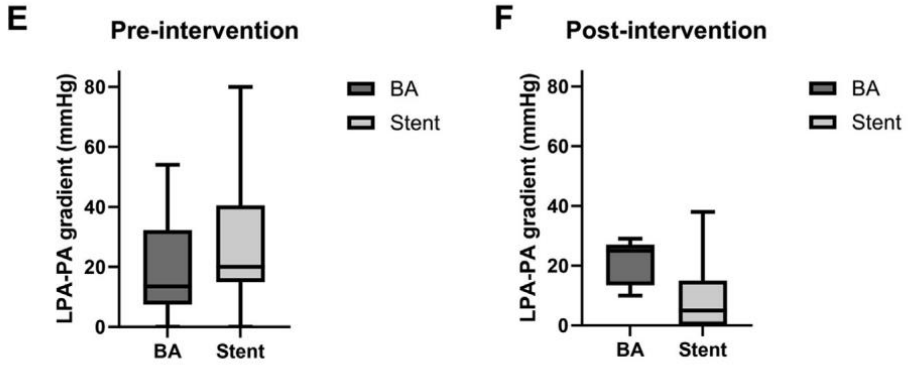
LPA Balloon N=42	Pre-balloon	Post-LPA Balloon	p value
RV:SysRatio	0.66 ± 0.17	0.54 ± 0.17	p<0.001
LPA Gradient (mmHg)	23 ± 15	13 ± 9	p<0.001

D.



LPA Stent N=16	Pre-intervention	Post-LPA Stent	p value
RV:SysRatio	0.73 ± 0.26	0.57 ± 0.15	p<0.001
LPA Gradient (mmHg)	22 ± 9	7 ± 5	p<0.01





Stent implantation seems more successful in reducing pressure gradient compared to BA only

(1) Gritti MN, Farid P, Hassan A, Marshall AC. ***Cardiac Catheterization Interventions in the Right Ventricular Outflow Tract and Branch Pulmonary Arteries Following the Arterial Switch Operation. Pediatr Cardiol. 2024*** *Feb 10. doi: 10.1007/s00246-024-03408-w. Epub ahead of print. PMID: 38341390.*

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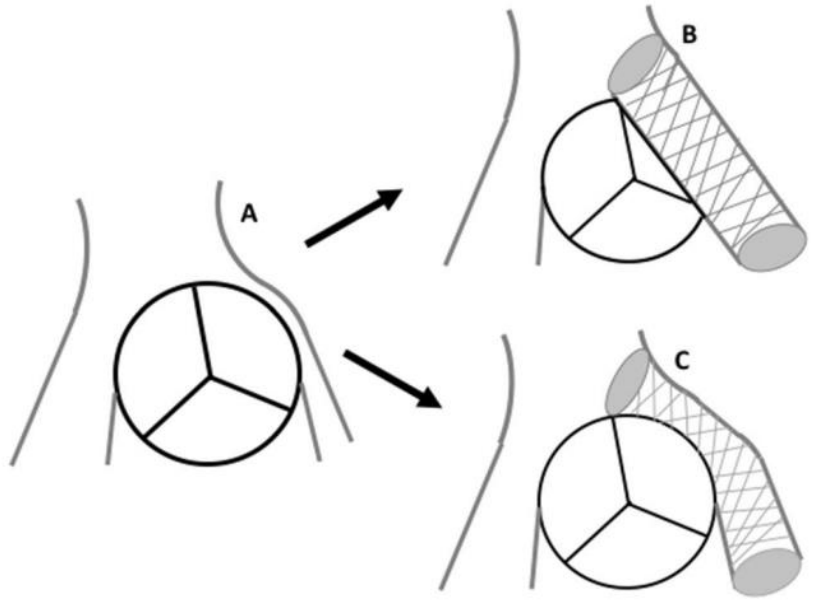
-Mechanism of stenosis: distortion and stretching rather than focal stenosis or scars, less responsive to high-pressure balloons [3,6,7]

-Balloon-expandable vs self-expandable stents: theoretical advantage of self-expandable, however longer FU is needed [6]

-Bare stents were more frequently used [3]

-Age-related: avoid stenting in small children, patients treated with BA only were significantly younger [3]



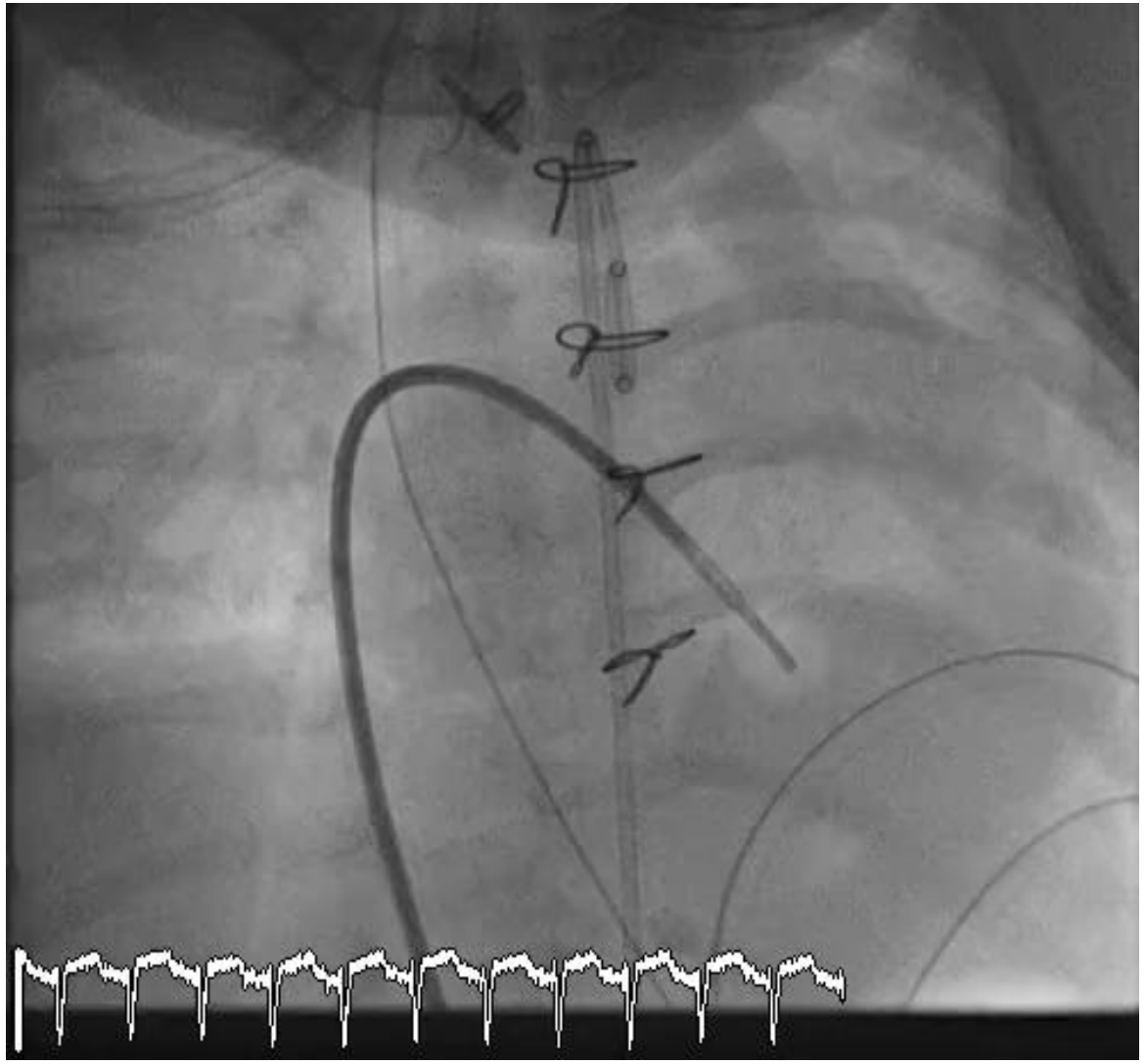
(6) Morgan GJ, Pushparajah K, Narayan S, Rosenthal E. **Large Calibre Self-Expanding Stents for Pulmonary Stenosis After the Arterial Switch, a Low-Risk Solution to a Low-Flow Situation. Pediatr Cardiol. 2018** Apr;39(4):824-828. doi: 10.1007/s00246-018-1833-8. Epub 2018 Feb 22. PMID: 29468351.
(7) Formigari R, Santoro G, Guccione P, Giamberti A, Pasquini L, Grigioni M, Ballerini L. **Treatment of pulmonary artery stenosis after arterial switch operation: stent implantation vs. balloon angioplasty. Catheter Cardiovasc Interv. 2000** Jun;50(2):207-11. doi: 10.1002/(sici)1522-726x(200006)50:2<207::aid-ccd14>3.0.co;2-u. PMID: 10842392.

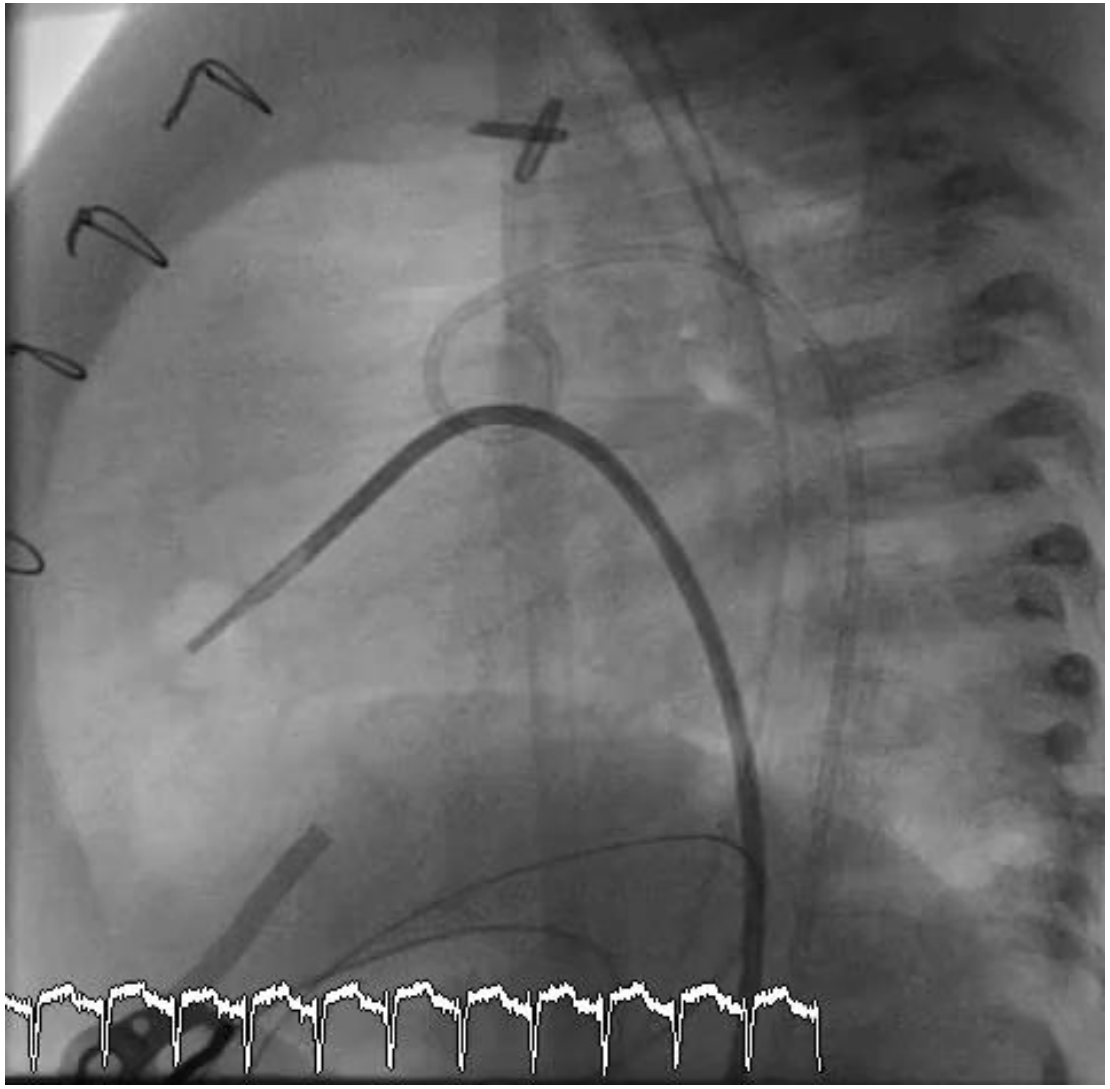
GORE® VIABAHN® VBX Balloon Expandable Endoprosthesis (VBX Stent Graft) Case Studies

These stents can be uspsized

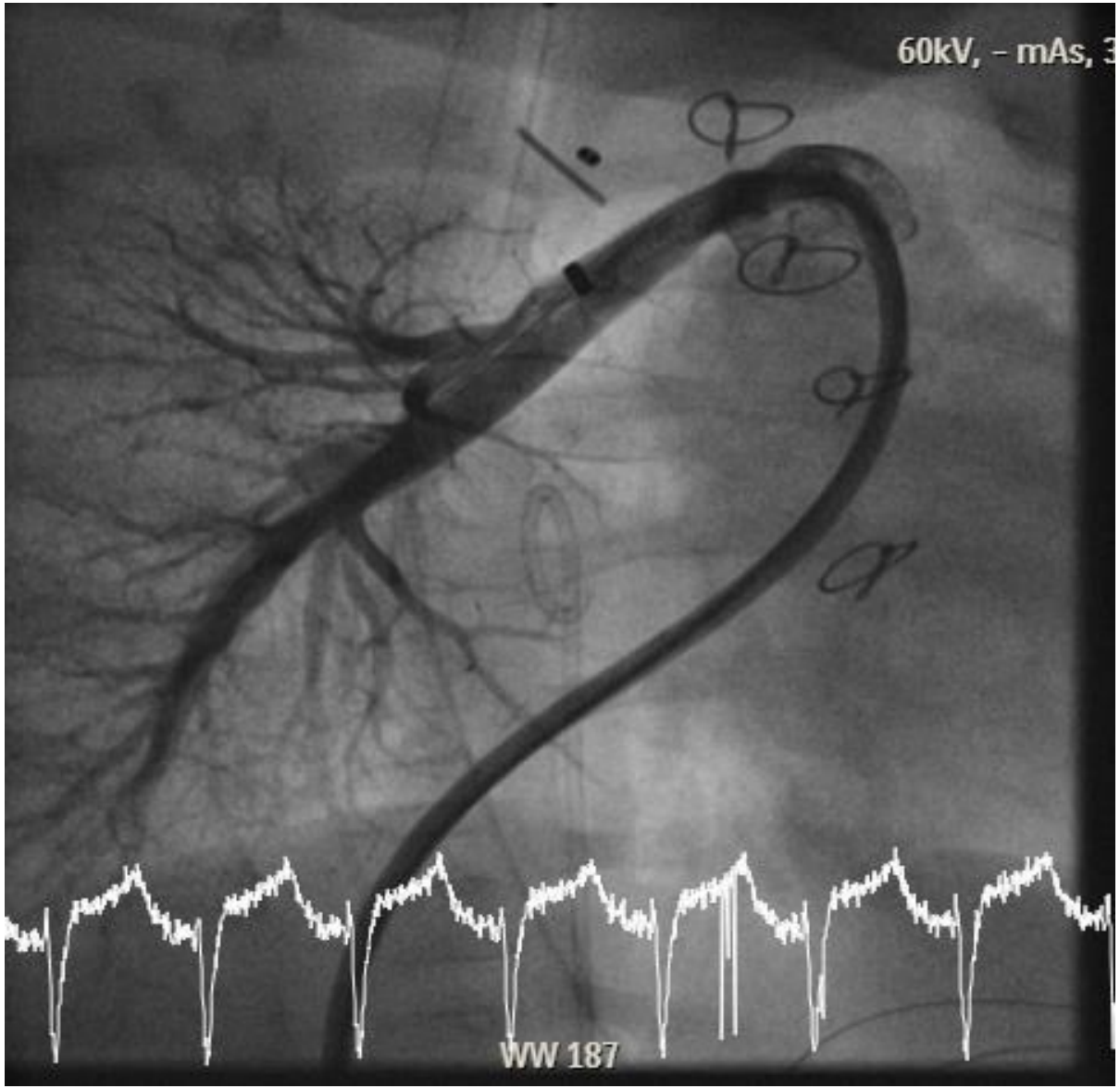
They can go through a 6-7 Fr

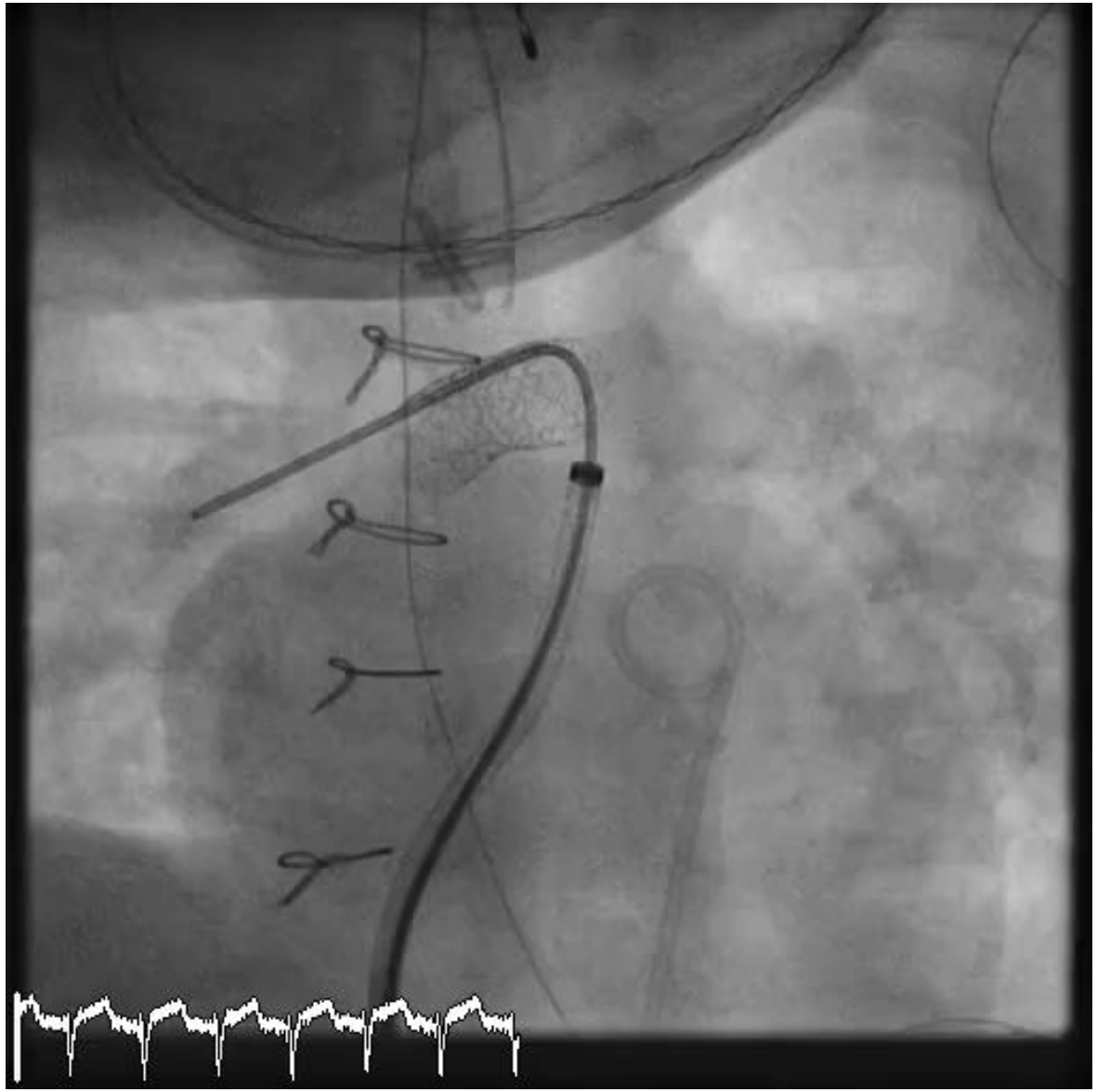
In particular the 11 mm can be dilated up to 16 mm





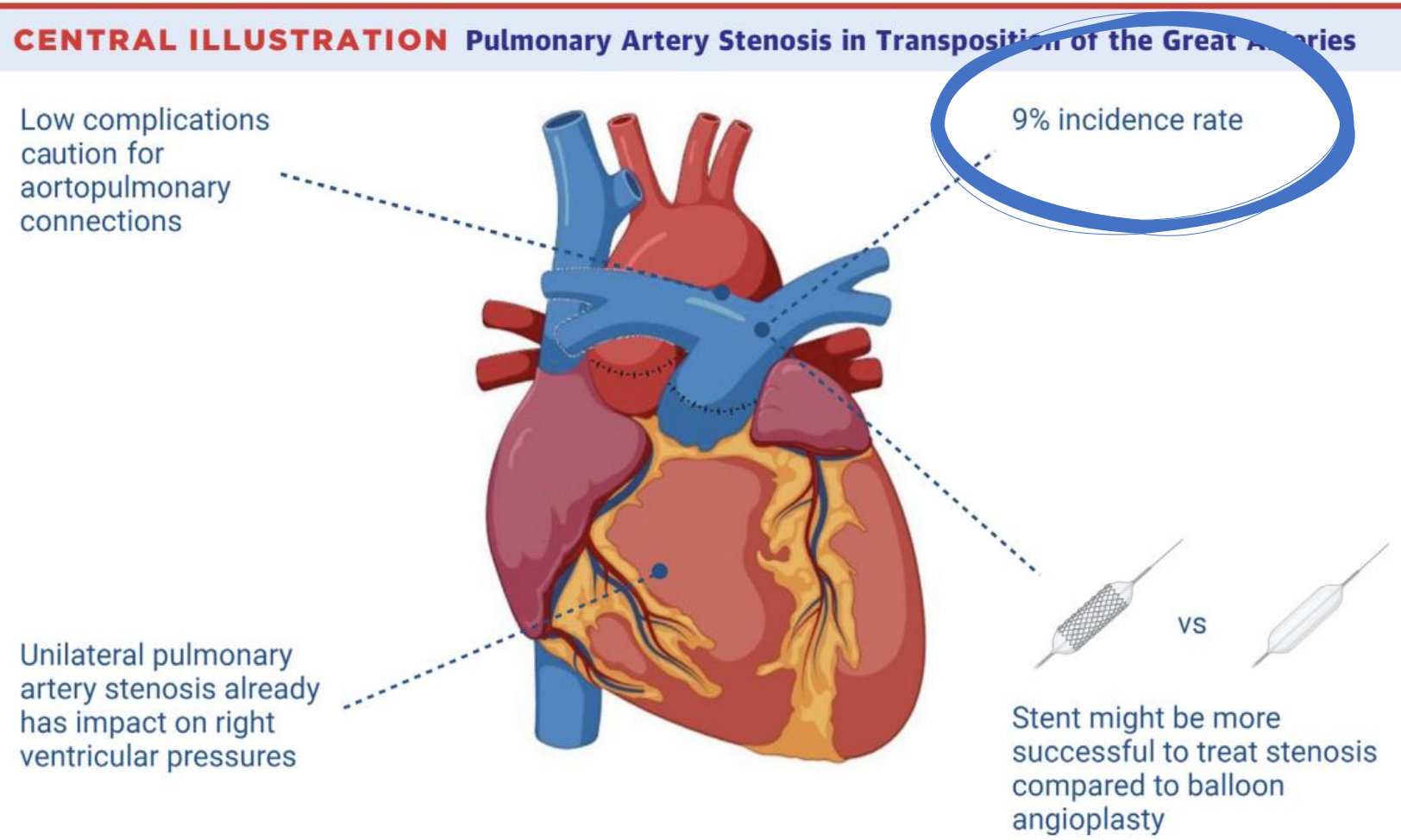
2 mo, 4.2 kg. TGA –VSD aortic coarctation. S/P ASO-LeCompte and coartectomy. **Severe RPA stenosis**





RPA BA -> Mustang 6x20mm and 8x30. Stenting -> Formula 8x20mm

CENTRAL ILLUSTRATION Pulmonary Artery Stenosis in Transposition of the Great Arteries



Joosen RS, et al. JACC Adv. 2024;3(11):101327.

Created in BioRender. Joosen, R. (2023) BioRender.com/j13u676. Abbreviations as in **Figure 1**.

Complications

- Same as MPA- PA interventions in general

- Specific risks: PA communications and coronary compression

TABLE 5 Complications All Percutaneous PA Procedures (N = 131)

Complications	17 (13)
Complications during	15 (88)
Major complications	4 (27)
Stent dislocation necessitating surgical removal	1 (25)
Pulmonary artery vessel tear treated with a covered stent	1 (25)
Iatrogenic aortopulmonary communication resulting in mortality	1 (25)
Acute cardiac failure after pulmonary artery embolism of a calcified in-stent vegetation by catheter intervention resulting in mortality	1 (25)
Minor complications	11 (73)
Recurrent hemorrhage	1 (9)
Rhythm problems without resuscitation	2 (18)
Other unplanned events with no or mild treatment	8 (73)
Complications after	2 (12)
Minor complications	2 (100)
Recurrent hemorrhage	2 (100)

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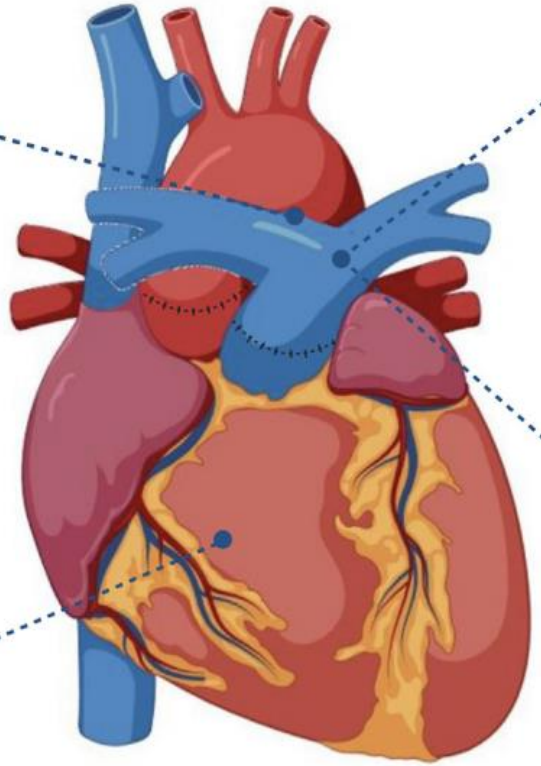
CENTRAL ILLUSTRATION **Pulmonary Artery Stenosis in Transposition of the Great Arteries**

Low complications caution for aortopulmonary connections

9% incidence rate



vs

Unilateral pulmonary artery stenosis already has impact on right ventricular pressures

Stent might be more successful to treat stenosis compared to balloon angioplasty

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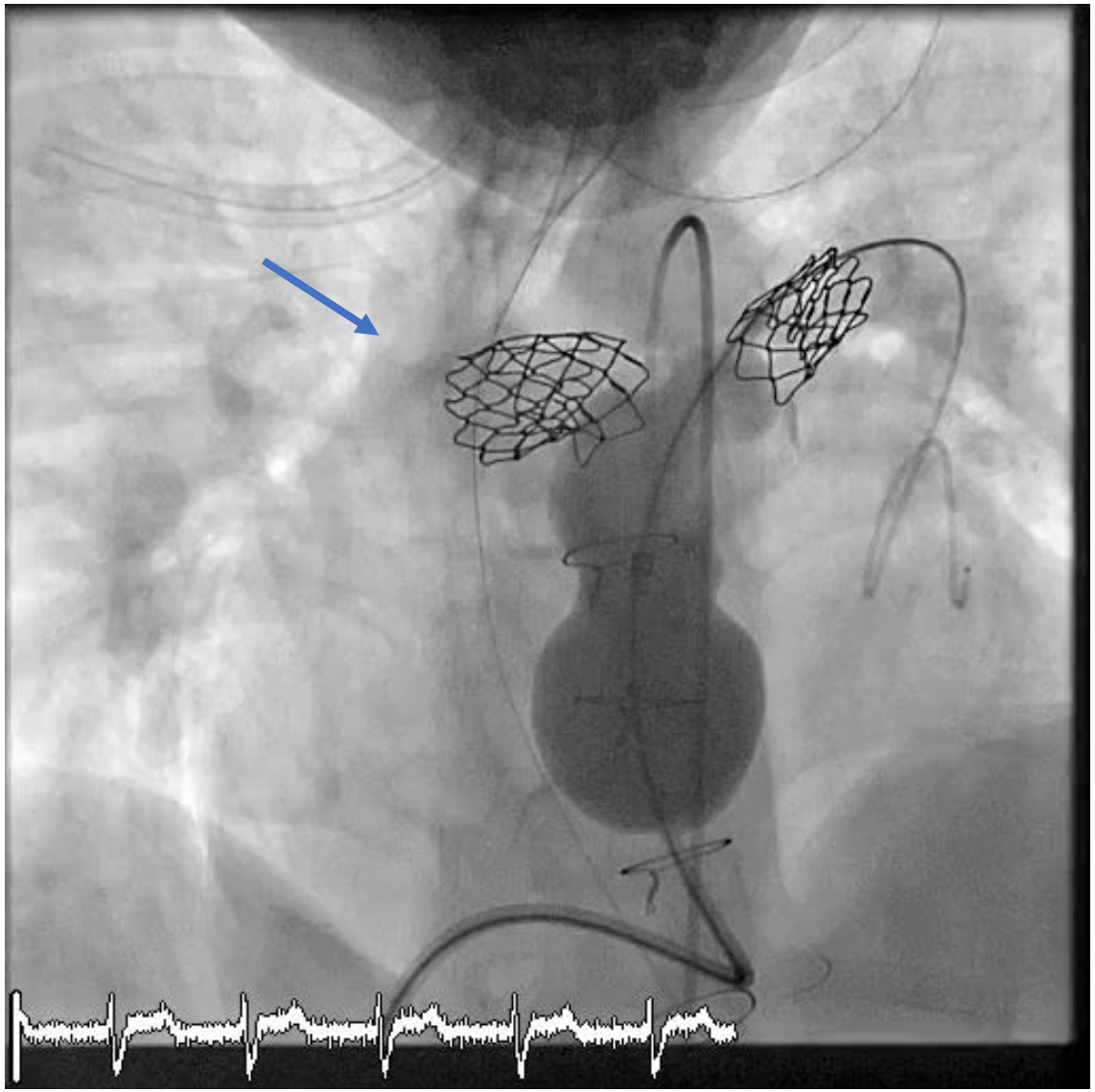
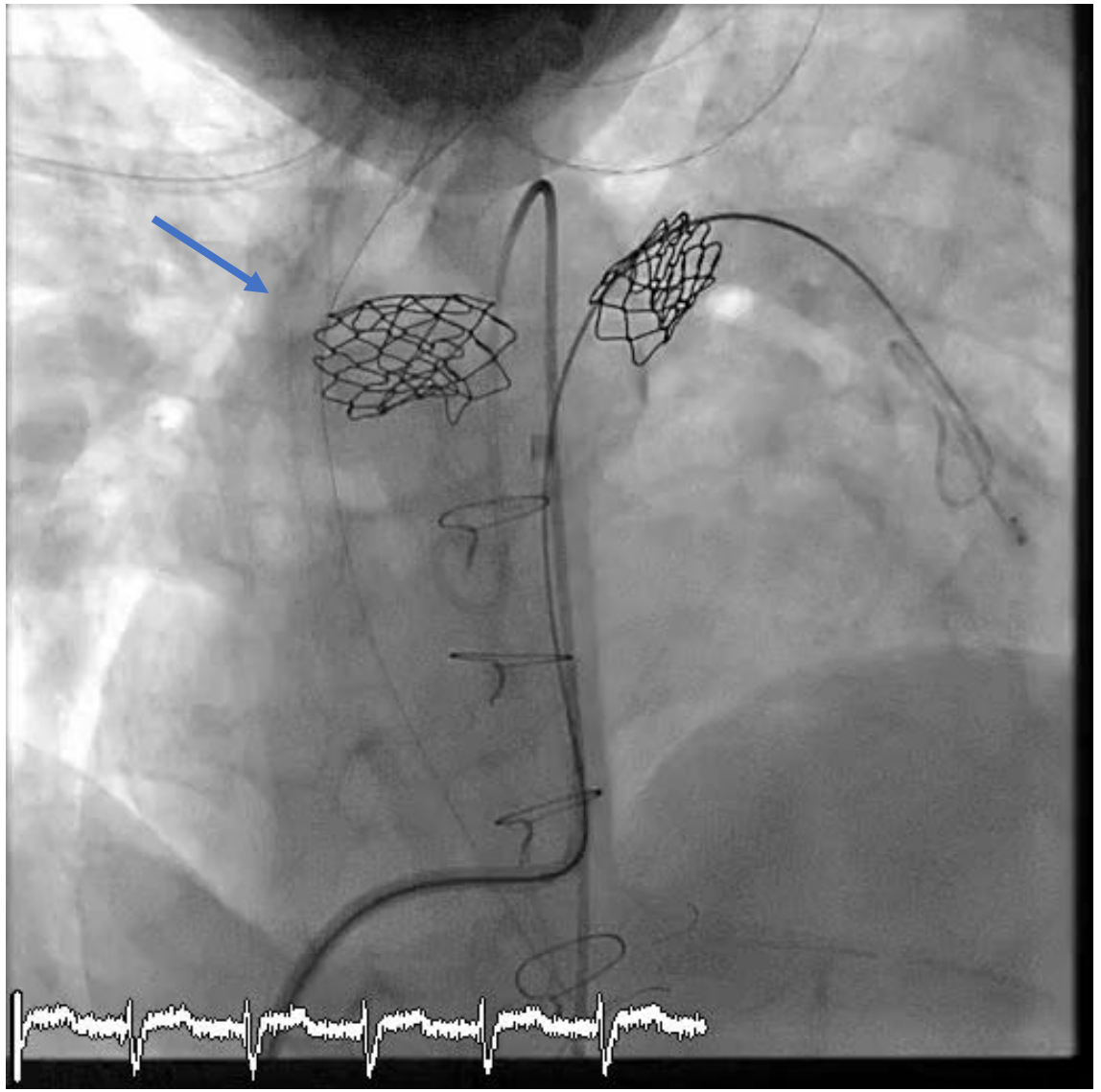




13yo. TGA-VSD. S/P ASO-LeCompte, VSD patch closure. RV-PA homograft (25mm). S/P Stenting RPA/LPA.

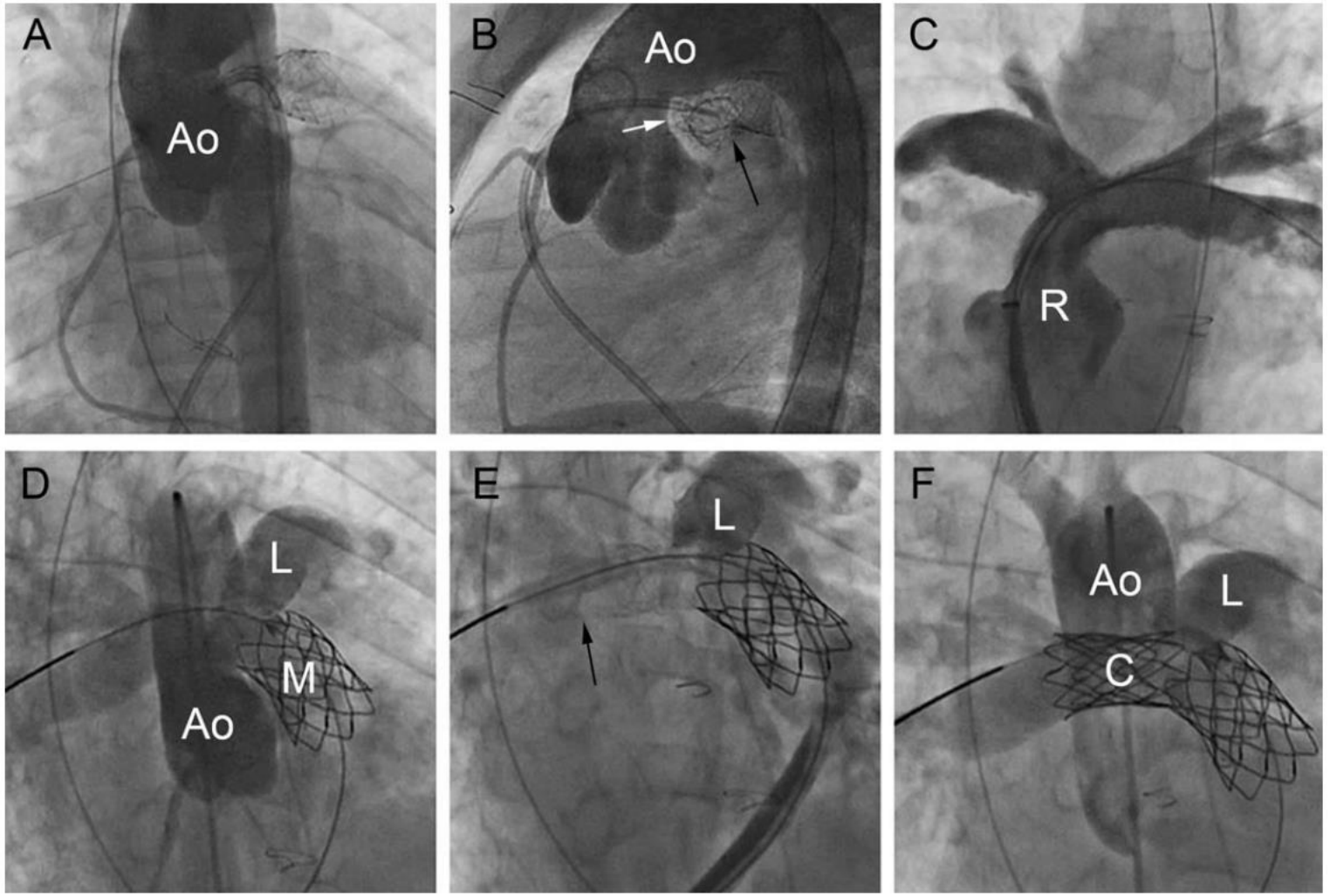
AP communications

-PA trauma and/or distortion of the neo-aortic anastomosis with subsequent erosion/dissection [8]

- Stent fracture, stent overexpansion, placement of bare stents at sites of artery distortion/close contact with the aorta, bilateral PA stenting [9]

-Diagnosis can be delayed: importance of awareness, potentially life-threatening

-Treatment: percutaneous (covered stents, devices) or surgical



(8)Torres A, Sanders SP, Vincent JA, El-Said HG, Leahy RA, Padera RF, McElhinney DB. **Iatrogenic aortopulmonary communications after transcatheter interventions on the right ventricular outflow tract or pulmonary artery: Pathophysiologic, diagnostic, and management considerations. Catheter Cardiovasc Interv. 2015** Sep;86(3):438-52. doi: 10.1002/ccd.25897. Epub 2015 Mar 16. PMID: 25676815.

(9) Lee J, Abdullah Shahbah D, El-Said H, Rios R, Ratnayaka K, Moore J**. Pulmonary artery interventions after the arterial switch operation: Unique and significant risks. Congenit Heart Dis. 2019 Mar;14(2):288-296. doi: 10.1111/chd.12726. Epub 2019** Jan 8. PMID: 30620141.

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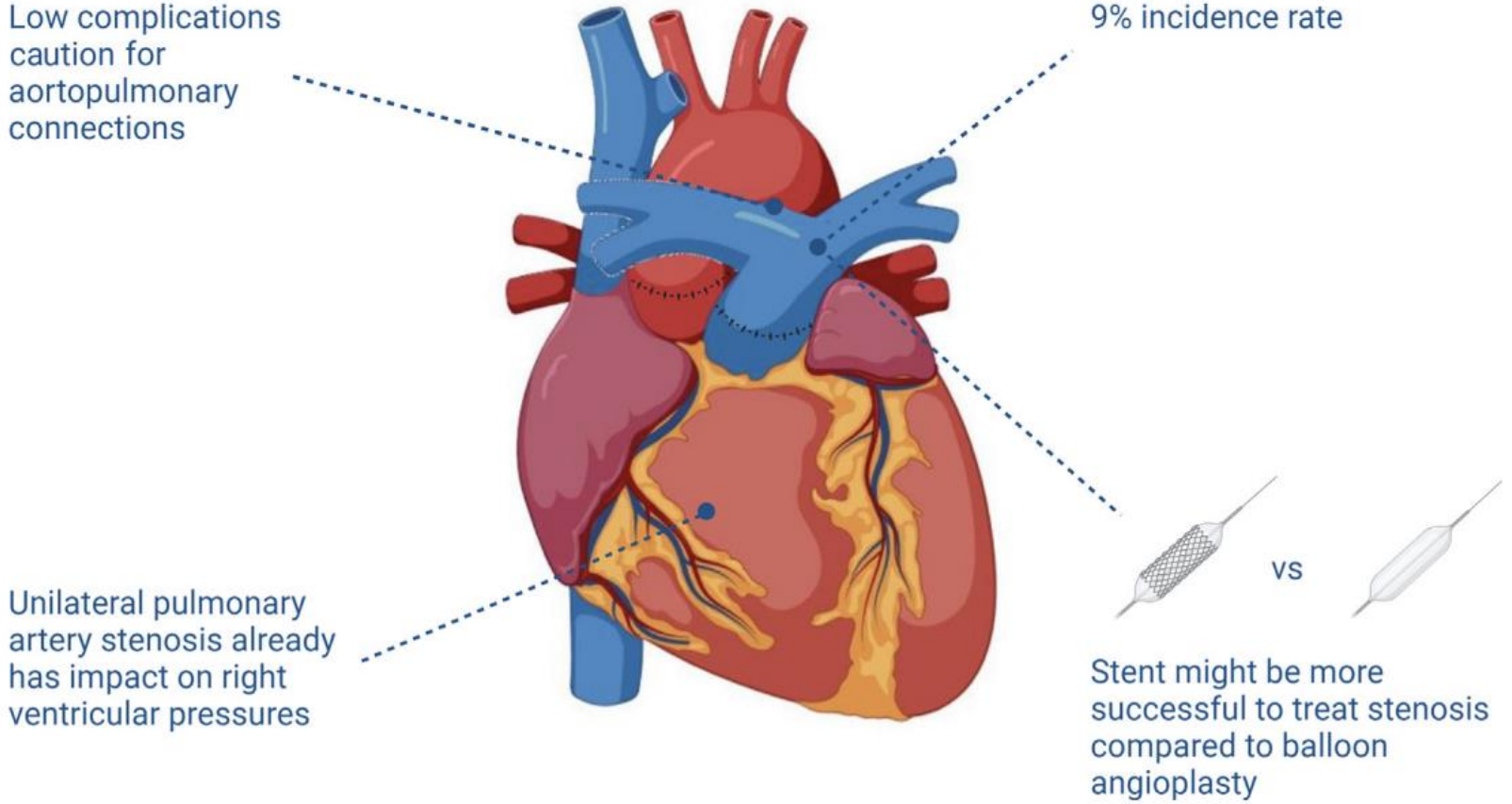

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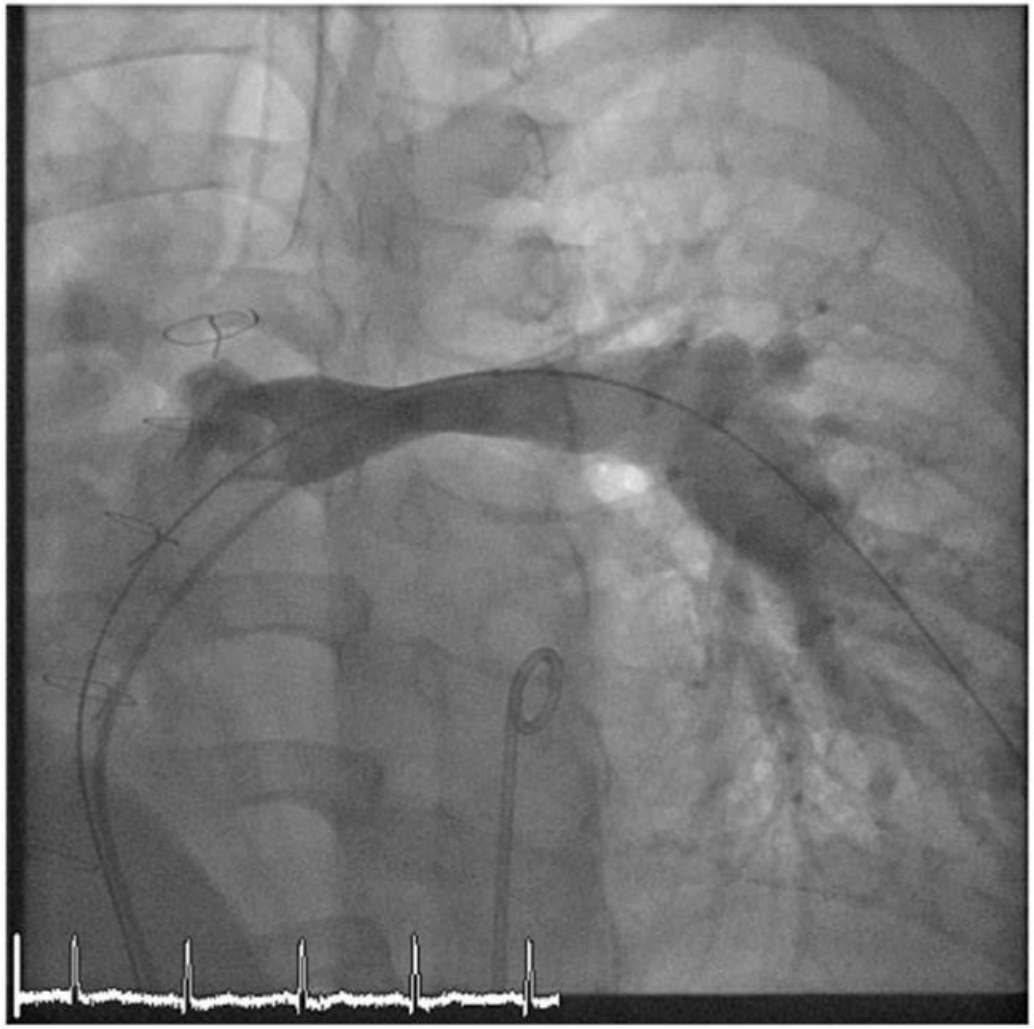
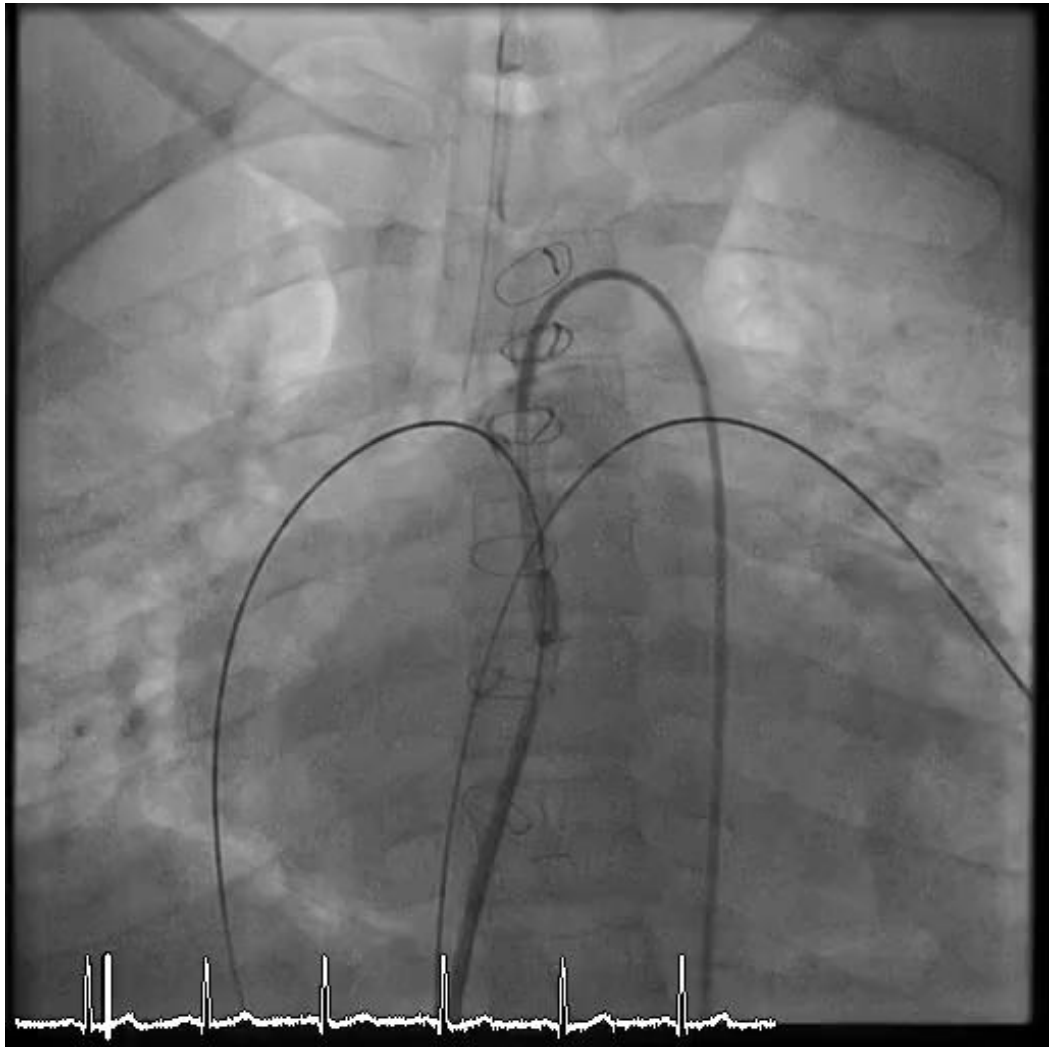
Created in BioRender. Joosen, R. (2023) BioRender.com/j13u676. Abbreviations as in **Figure 1**.

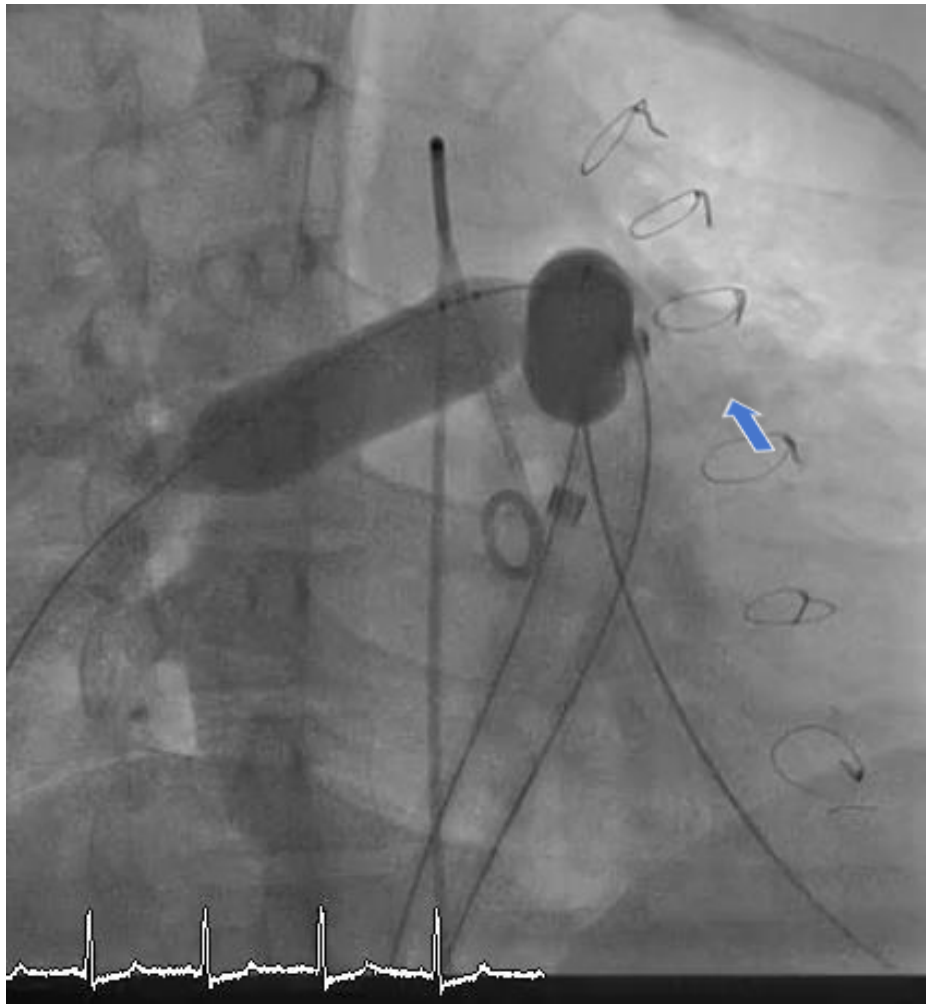
Other potential complications !!!



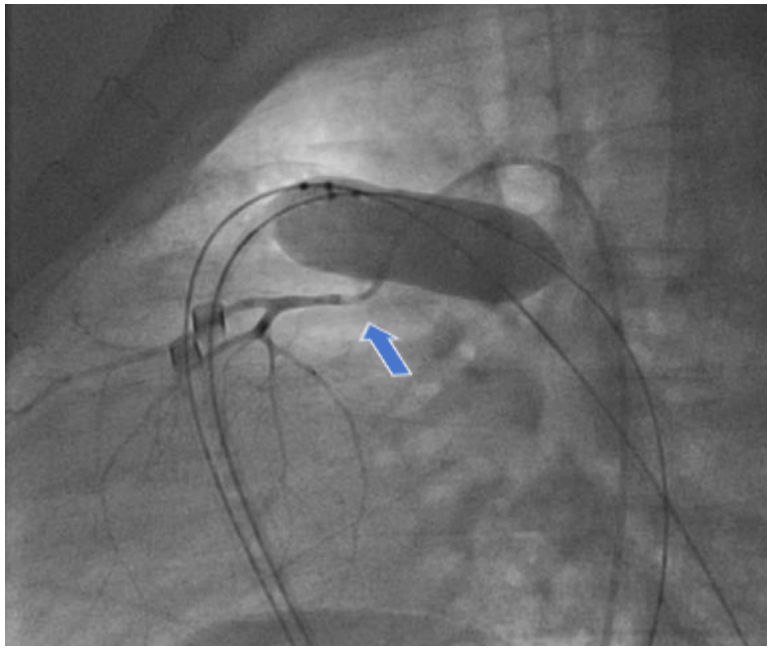


15 yo. TGA, PS. S/P ASO, RV-PA Homograft (15mm) and PA plasty. Residual LPA stenosis.

Coronary compression



-Increased risk of coronary compression during PA BA/stenting after coronary translocation [9,10]
-Routine balloon testing for coronary involvement
-3D/rotational angio can be useful, 3D CT scan



selective LCA injection with a balloon inflated in LPA showing coronary compression

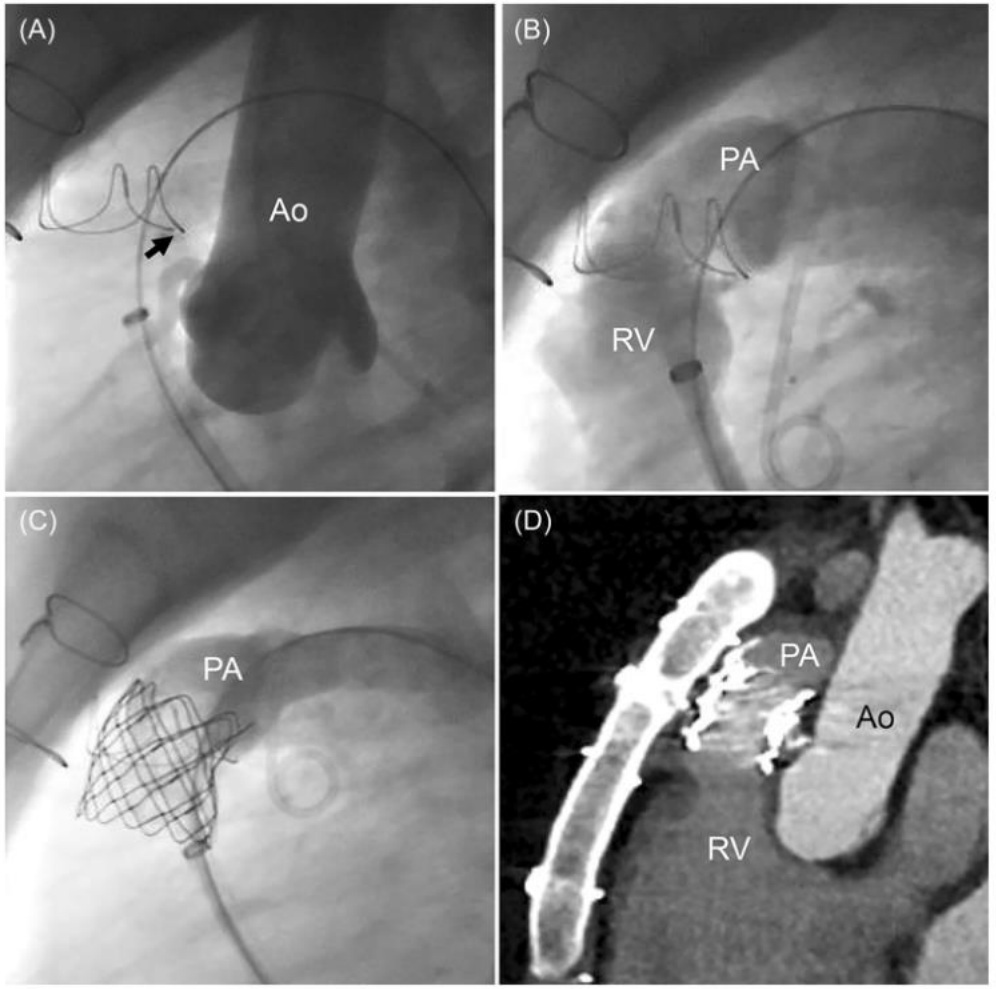
(10) Quatrini M, Pilati M, Butera G. **Coronary artery compression by pulmonary artery stenting after arterial switch operation: a novel indication for coronary compression test. Cardiol Young. 2023 Aug**;33(8):1468-1470. doi: 10.1017/S1047951122004292. Epub 2023 Feb 1. PMID: 36720716.

PPVI after ASO

- coronary compression or aortic root distortion precluded TPVR in one-third of patients (11)

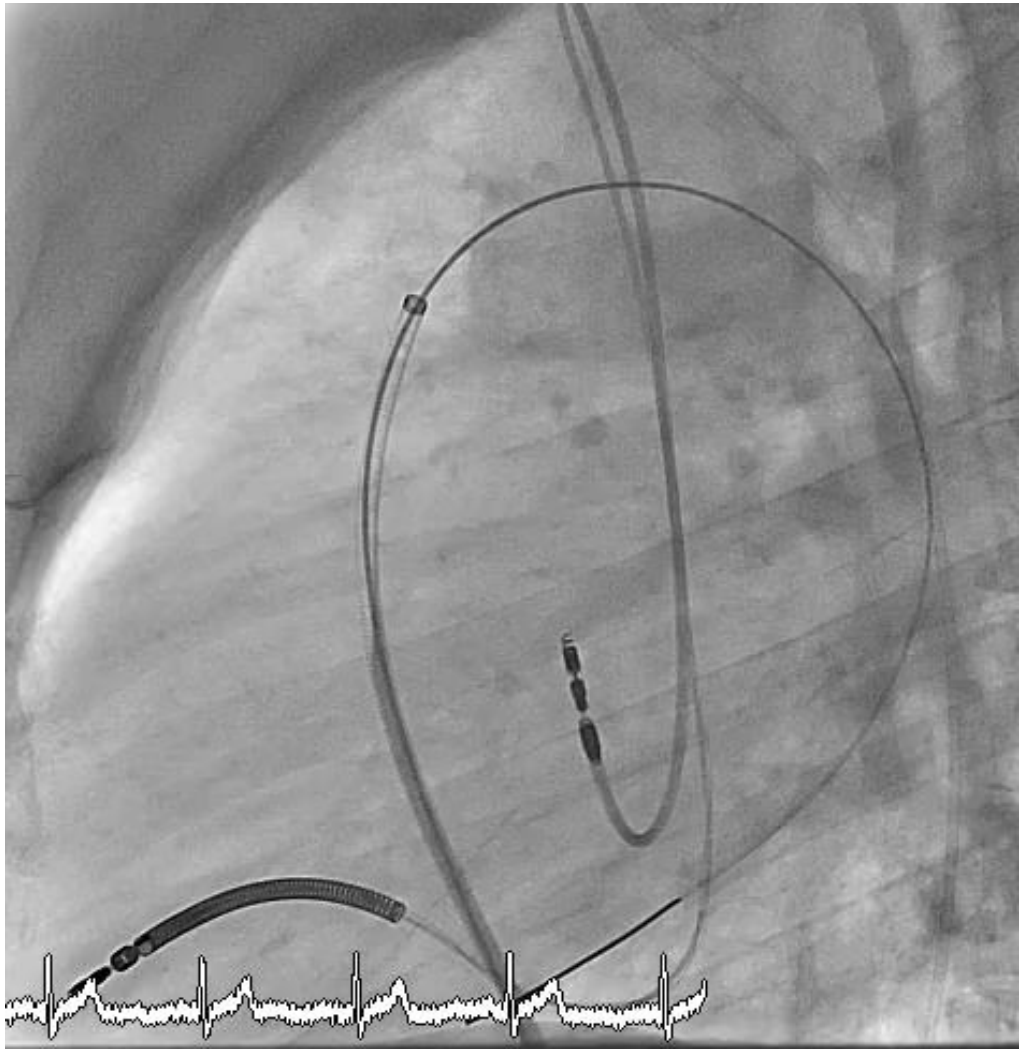
- relatively short MPA can also be an issue (jailing PA)

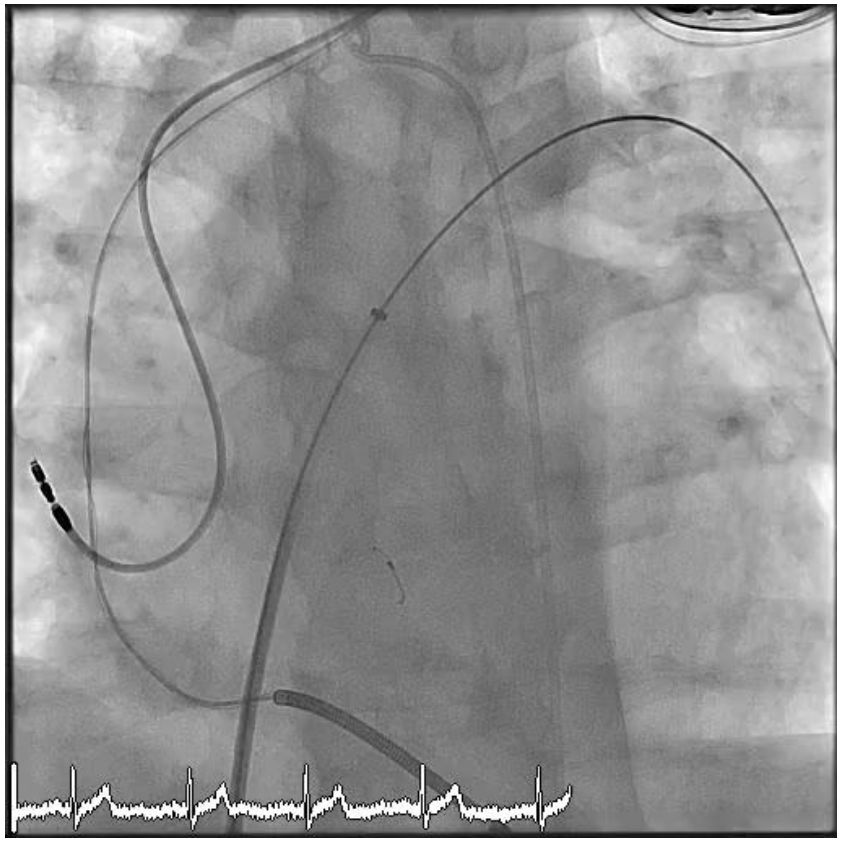
- the rate of RVOT reintervention after TPVR was higher in this cohort of ASO patients than in prior studies (11)

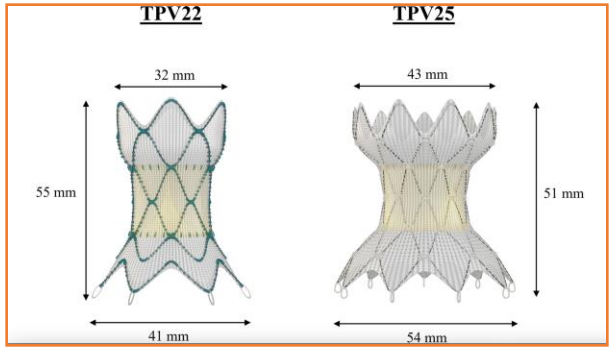


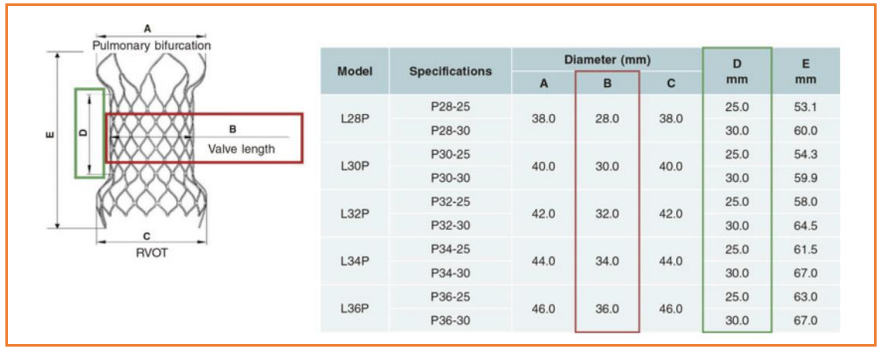
(11) Nageotte S, Salavitabar A, Zablah JE, Ligon RA, Turner ME, El-Said H, Guyon P, Boucek D, Alvarez-Fuente M, McElhinney DB, Balzer D, Shahanavaz S. **Transcatheter pulmonary valve replacement after arterial switch operation. Catheter Cardiovasc Interv. 2024** Sep;104(3):531-539. doi: 10.1002/ccd.31152. Epub 2024 Jul 20. PMID: 39033329..

PPVI after ASO









Model	Specifications	Diameter (mm) A	Diameter (mm) B	Diameter (mm) C	D mm	E mm
L28P	P28-25	38.0	28.0	38.0	25.0	53.1
	P28-30				30.0	60.0
L30P	P30-25	40.0	30.0	40.0	25.0	54.3
	P30-30				30.0	59.9
L32P	P32-25	42.0	32.0	42.0	25.0	58.0
	P32-30				30.0	64.5
L34P	P34-25	44.0	34.0	44.0	25.0	61.5
	P34-30				30.0	67.0
L36P	P36-25	46.0	36.0	46.0	25.0	63.0
	P36-30				30.0	67.0

36 yo. TGA-IVS + supravalvular PS. S/P ASO (1988) , TA patch (2002). Syncope. Scheduled for PPVI

Ground-breaking and mid-blowing thoughts among Interventionalists

As an interventional cardiologist what do you think about the "ballooning" theory proposed today by Prof Antoon Mormoon about DORV embriology?

Dear Friend,
This is an interesting approach however …….

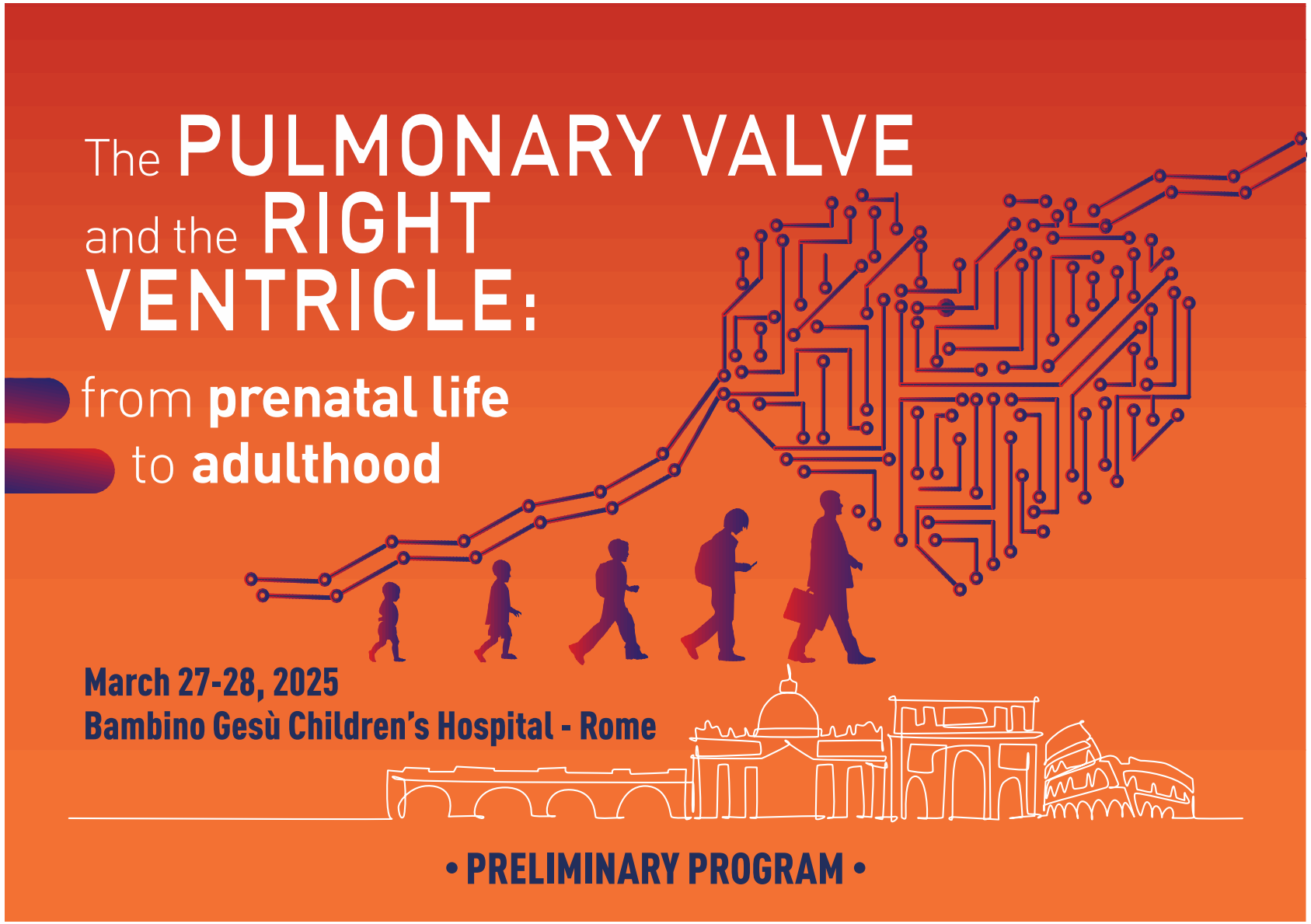
Ground-breaking and mid-blowing thoughts among Interventionalists

As you heard today
during my talk i'm
more prone
to consider
the **stenting approach**
as my preferred one

Thank you for your attention !

Gianfranco Butera

Bambino Gesù
OSPEDALE PEDIATRICO



Registration link: www.leanevent.it/valve_reg