International Symposium on 3D Imaging for Interventional Catheterization in CHD

3DRA Assessment of Airway Compression in Single Ventricle Heart Disease

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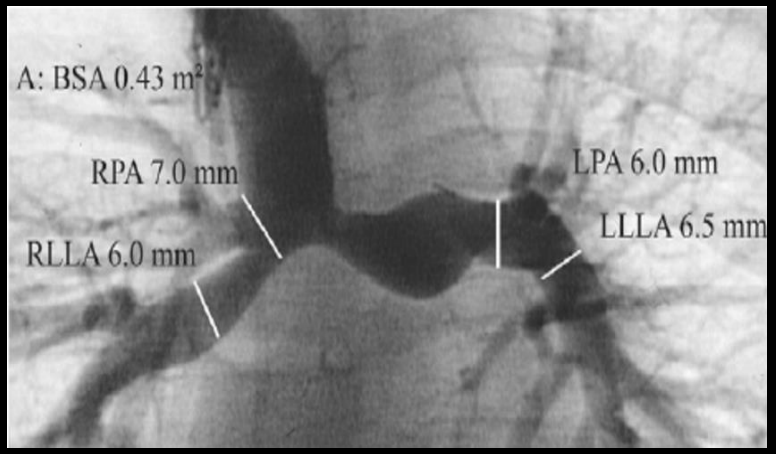
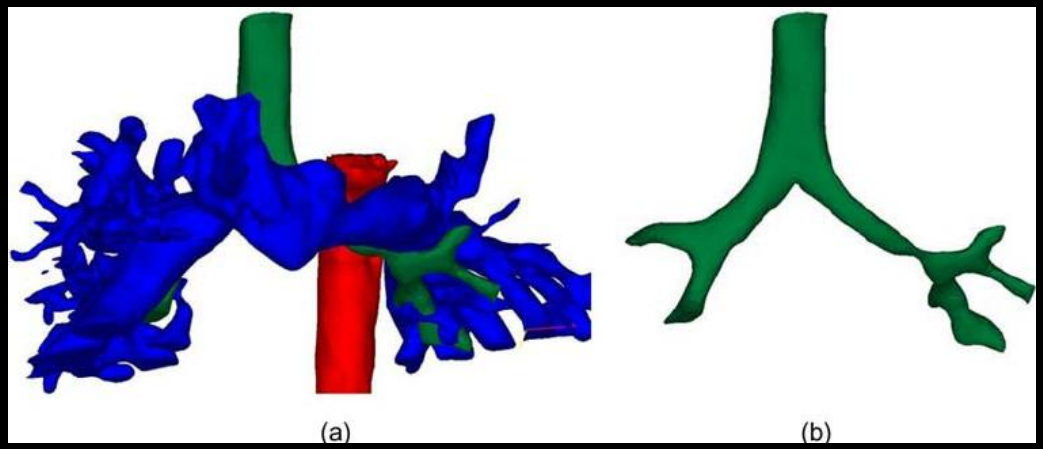
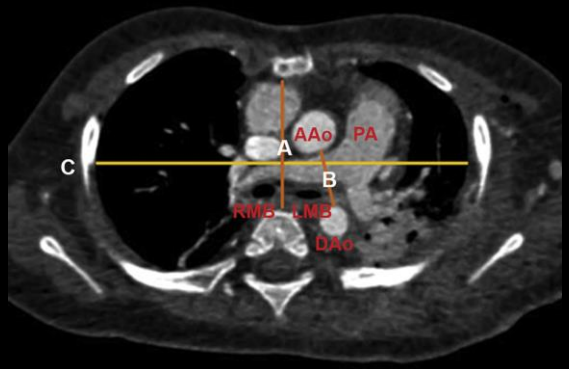
The clinical course of the child with univentricular physiology is often complicated by PA stenosis & airway narrowing, factors associated with a worsened prognosis

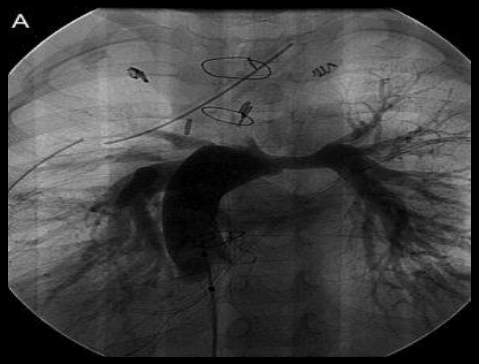
As such, their assessment an important adjunct to the hemodynamic profile prior to Fontan completion



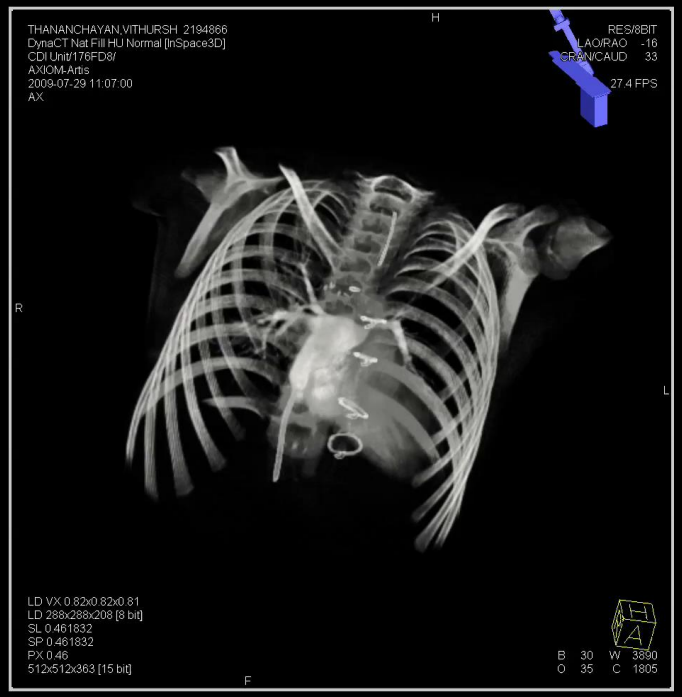


Historically, 2D-angiography has been the gold standard for imaging of the PAs, recently supplemented by cMRI & CT scanning.





Recently, 3DRA has emerged as a novel technique in the evaluation of the child with CHD & allows real-time acquisition of 3D volume rendered & tomographic images in the diagnostic & interventional catheterization lab.



Three-Dimensional Rotational Angiography in the Assessment of Vascular and Airway Compression in Children After a Cavopulmonary Anastomosis

Borik et al Pediatric Cardiol 2015

- Over a 15-month period 25 children underwent a 3DRA as part of their pre-Fontan assessment

- 3DRA images were acquired on a Siemens Dyna-CT platform

Injection protocol was 1cc contrast (Isovue) diluted 1:1, with a 2 sec x-ray delay into the BCPA, with a breath hold. No pacing was used

- Radiation dose was 0.36μGy/f reduced to 0.17μGy/f without image degradation

- Airway stn was defined as ≥50% luminal reduction *vs.* proximal lumen

The reference points measured were:

1—proximal LPA, 5 mm distal to the bifurcation from the MPA
2—narrowest LPA
3—distal LPA, 5 mm proximal to the take off of the upper lobe branch
4—proximal RPA, 5 mm distal to the MPA bifurcation
5—distal RPA, 5 mm distal to the upper lobe branch
6—SVC, 10 mm proximal to the BCPA to the PA
7—narrowest left bronchus
8—narrowest right bronchus;
9—trachea, 10 mm proximal to the bifurcation

2D angiographic PA measurements were taken from AP & oblique projections at locations 1 through 6 as noted above

Of the 25 children (14 male) mean age 3.1±2.0 years & weight 13.6± 3.6 kg

PA measurements were taken from 2D angiography (n=17)

Airway & PA measurements were taken from 3DRA-derived (MPR)

tomographic slices in all patients (n = 25)

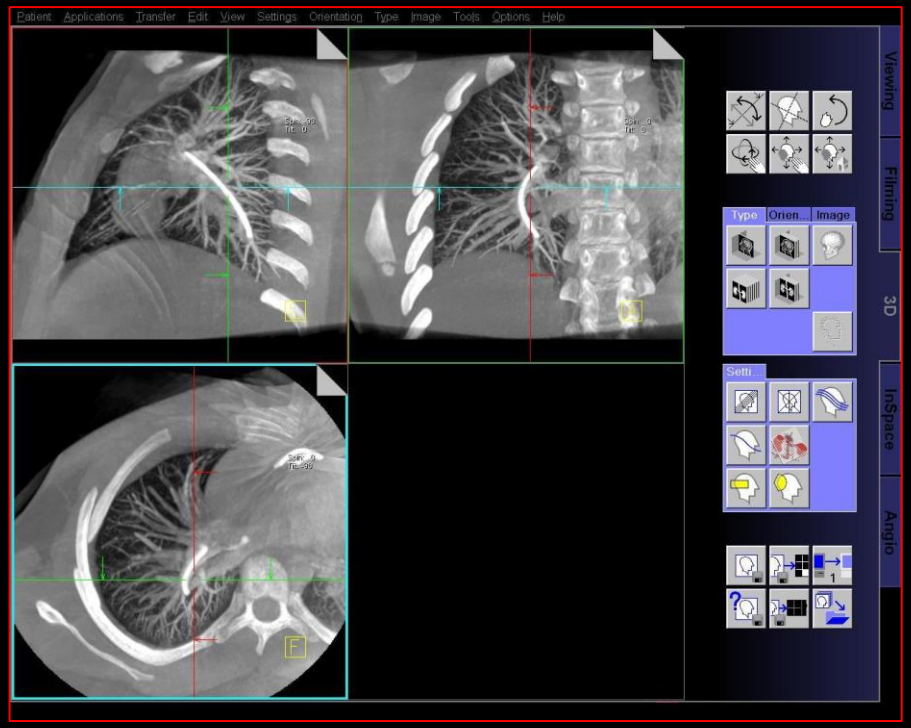


Table 1 Patient data and presence of LPA and/or bronchial stenosis on 3DRA

Patient	Age (years)	Weight (kg)	Years since BCPA	Diagnosis	Arch reconstruction	LPA stenosis	Bronchial stenosis
1.	11.4	29.1	6.7	Pulmonary atresia	No	Yes	Yes
2.	3.9	16.9	3.6	Tricuspid atresia	No	Yes	No
3.	2.2	15.1	1.8	Pulmonary atresia	No	Yes	Yes
4.	2.1	14.8	1.6	HLHS	Yes	Yes	Yes
5.	3.7	14.4	2.9	Unbalanced AVSD, hypoplastic LV, DORV	No	No	No
6.	3.9	14.3	3.4	HLHS	Yes	Yes	Yes
7.	2.6	14.3				es	Yes
8.	2.7	14.3				lo	Yes
9.	4.1	14				lo	No
10.	2.5	13.8				lo	No
11.	2.7	13.8				lo	No
12.	2.5	13.1				es	Yes
13.	3.2	12.9				lo	Yes
14.	1.7	12.7				lo	No
15.	3.4	11.1				es	Yes
16.	2.2	12.6				es	Yes
17.	2.5	12.5				lo	No
18.	2.1	12.7	1.5	Tricuspid atresia	No	No	Yes
19.	2.5	11.7	2.0	AV discordance, MV straddling, DORV	Yes	Yes	No
20.	2.8	11.7	2.5	Pulmonary atresia	No	No	No
21.	1.7	11.6	1.3	Tricuspid atresia	No	No	No
22.	2.9	10.8	2.3	Pulmonary atresia	No	No	No
23.	0.9	10.6	0.6	HLHS	Yes	Yes	Yes
24.	2.7	9.43	2.0	Tricuspid atresia	No	No	No
25.	4.4	12.7	3.9	HLHS	Yes	Yes	Yes

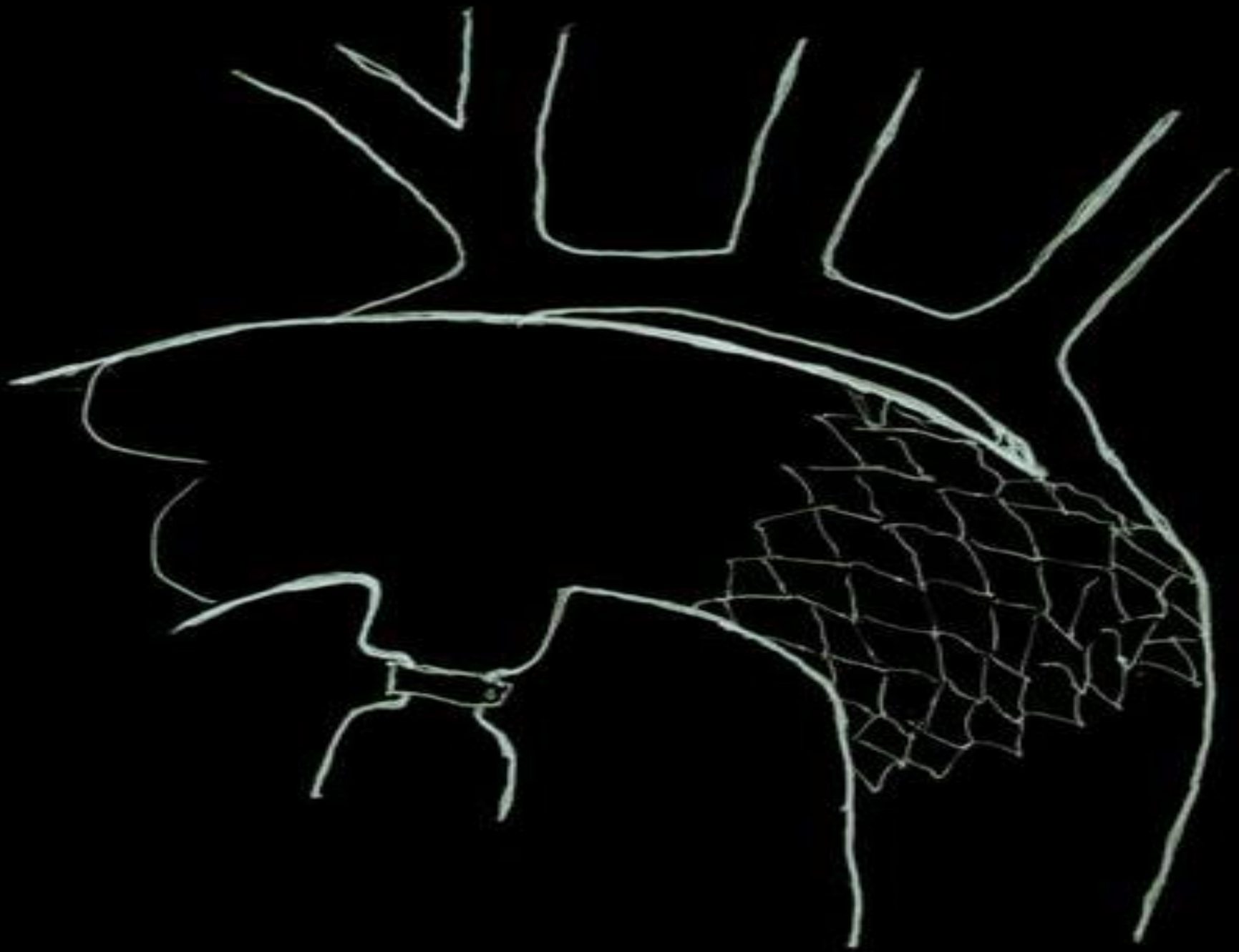
Norwood or DKS = 4

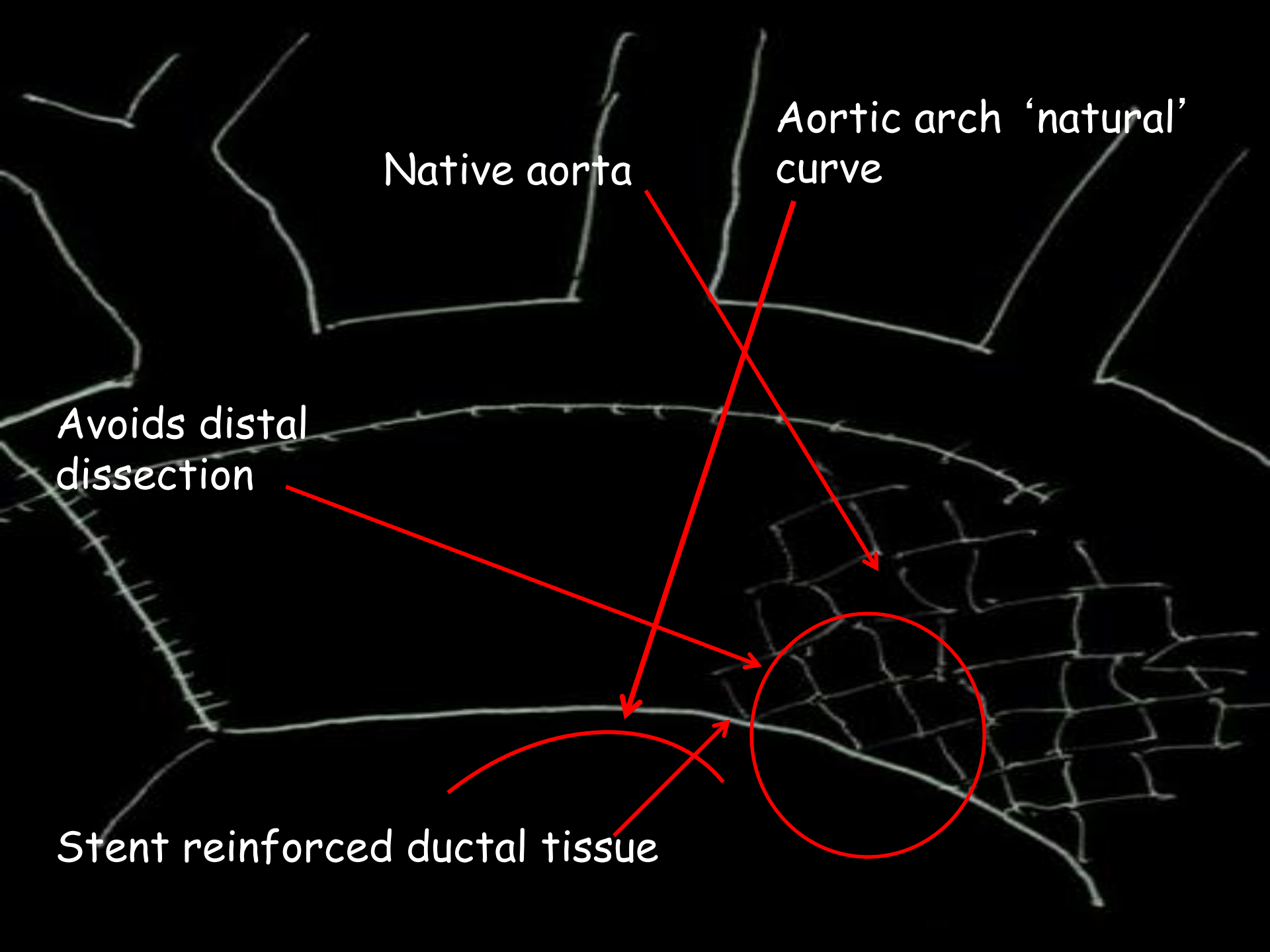
Hybrid procedure = 5

Isolated B-T shunt or no intervention = 16

Right-sided BCPA = 2; left & bilateral BCPA 1 each

Ductal stent retained in the surgical arch reconstruction in 3




Native aorta
Aortic arch 'natural' curve
Avoids distal dissection
Stent reinforced ductal tissue

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8.	2.7	14.3	2.3	HLHS	Yes	No	Yes
9.	4.1	14				No	No
10.	2.5	13.8				No	No
11.	2.7	13.8				No	No
12.	2.5	13.1				Yes	Yes
13.	3.2	12.9	2.4	DILV, TV straddling, VA concordance	No	No	Yes
14.	1.7	12.7				No	No
15.	3.4	11.1				Yes	Yes
16.	2.2	12.6	1.7	Tricuspid atresia	Yes	Yes	Yes
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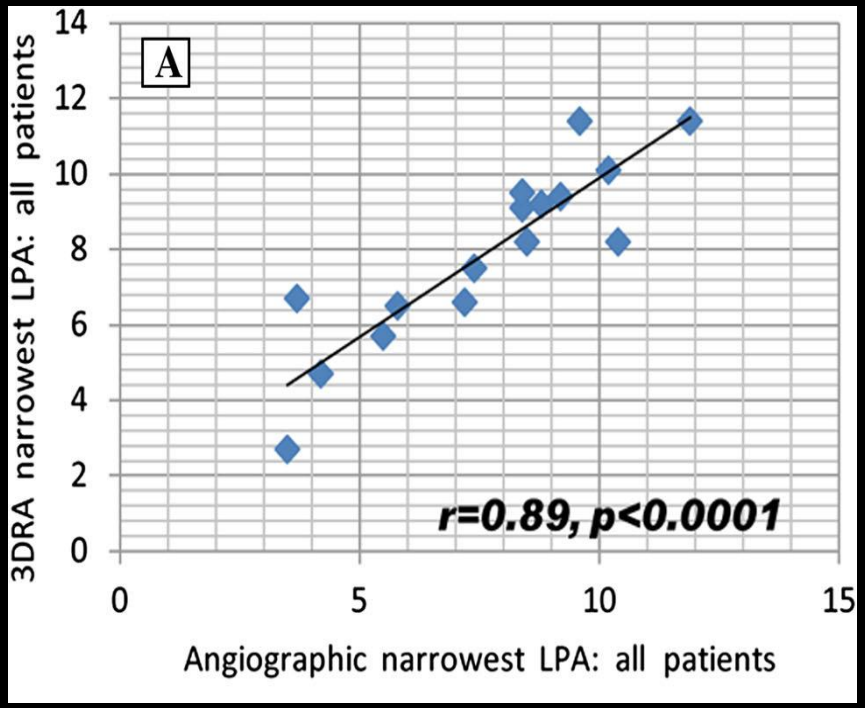
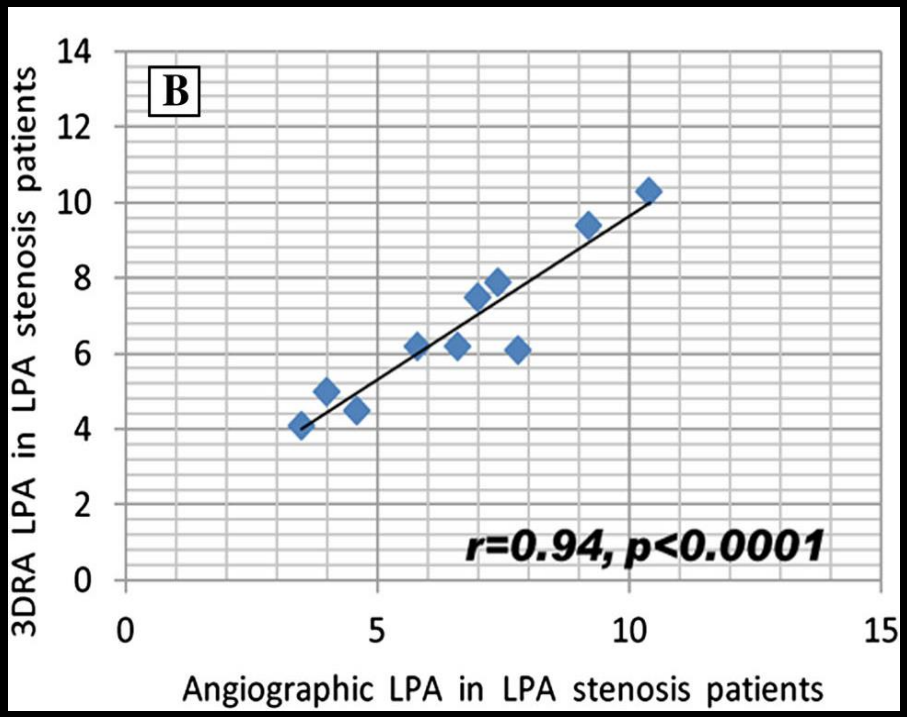
10 of 25 (40%) had both LPA & bronchial stn

2 of 25 LPA stn alone

3 of 25 bronchial stn alone

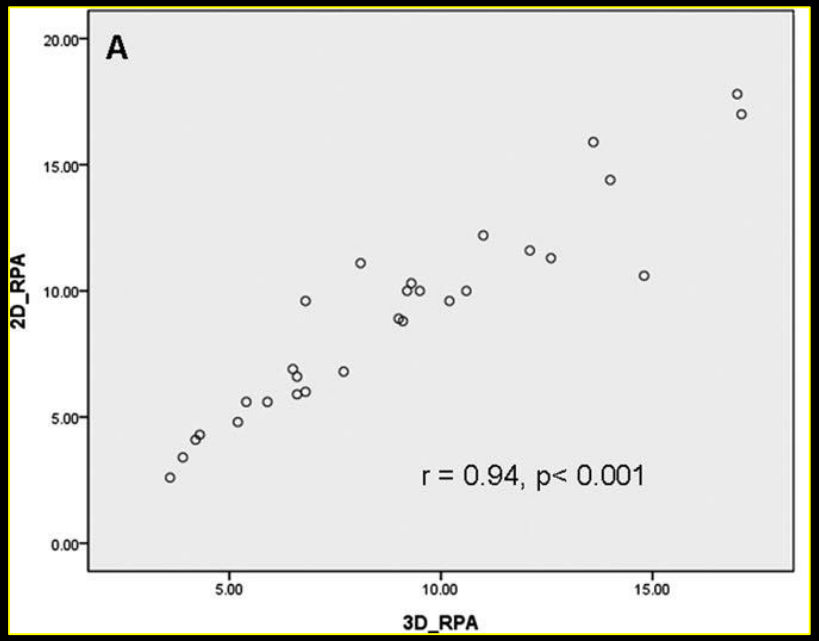
- 3DRA-derived measurements of the branch PA's correlated well with the corresponding images on 2D angiography

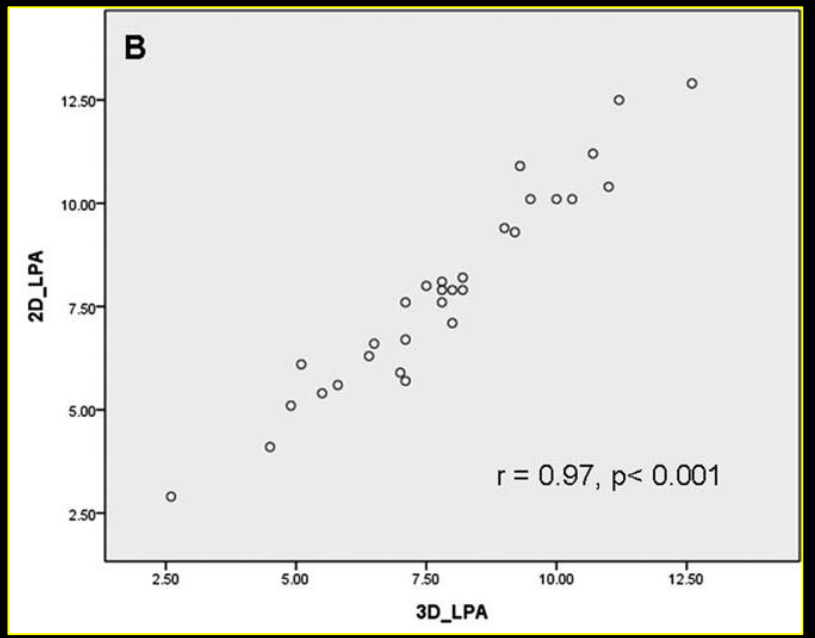




The Use of Three-Dimensional Rotational Angiography to Assess the Pulmonary Circulation Following Cavo-Pulmonary Connection in Patients with Single Ventricle

Berman et al CCI 2012





- The SVC diameters correlated only modestly, & proximal RPA measurements, with overall similar mean values, correlated poorly

Table 2 Correlation between measurements on 3DRA-derived tomographic images and 2D angiography

Vessel	2D angiography (mm)	3DRA (mm)	Correlation coefficient (*r*)	*p* value
Proximal LPA	9.6 ± 2.3	9.6 ± 1.7	0.81	<0.0001
Narrowest LPA	7.7 ± 2.5	8.0 ± 2.1	0.89	<0.0001
Distal LPA	7.7 ± 2.5	7.8 ± 2.0	0.83	<0.0001
Proximal RPA	10.0 ± 1.8	10.2 ± 1.7	0.28	0.30
Distal RPA	8.7 ± 1.4	8.5 ± 1.6	0.75	0.001
SVC	11.4 ± 2.1	12.4 ± 1.9	0.50	0.06

3DRA:

Median air kerma 11 (range 6–38, mean 13±7) mGy

DAP 245 (range 65–1038, mean 258±191) µGy*m^2

2D angiography & fluoroscopy:

Median air kerma 21 (range 5–390, mean 44±75, p = 0.0005) mGy

DAP 178 (range 49–3566, mean 379±683, p=ns) µGy*m^2

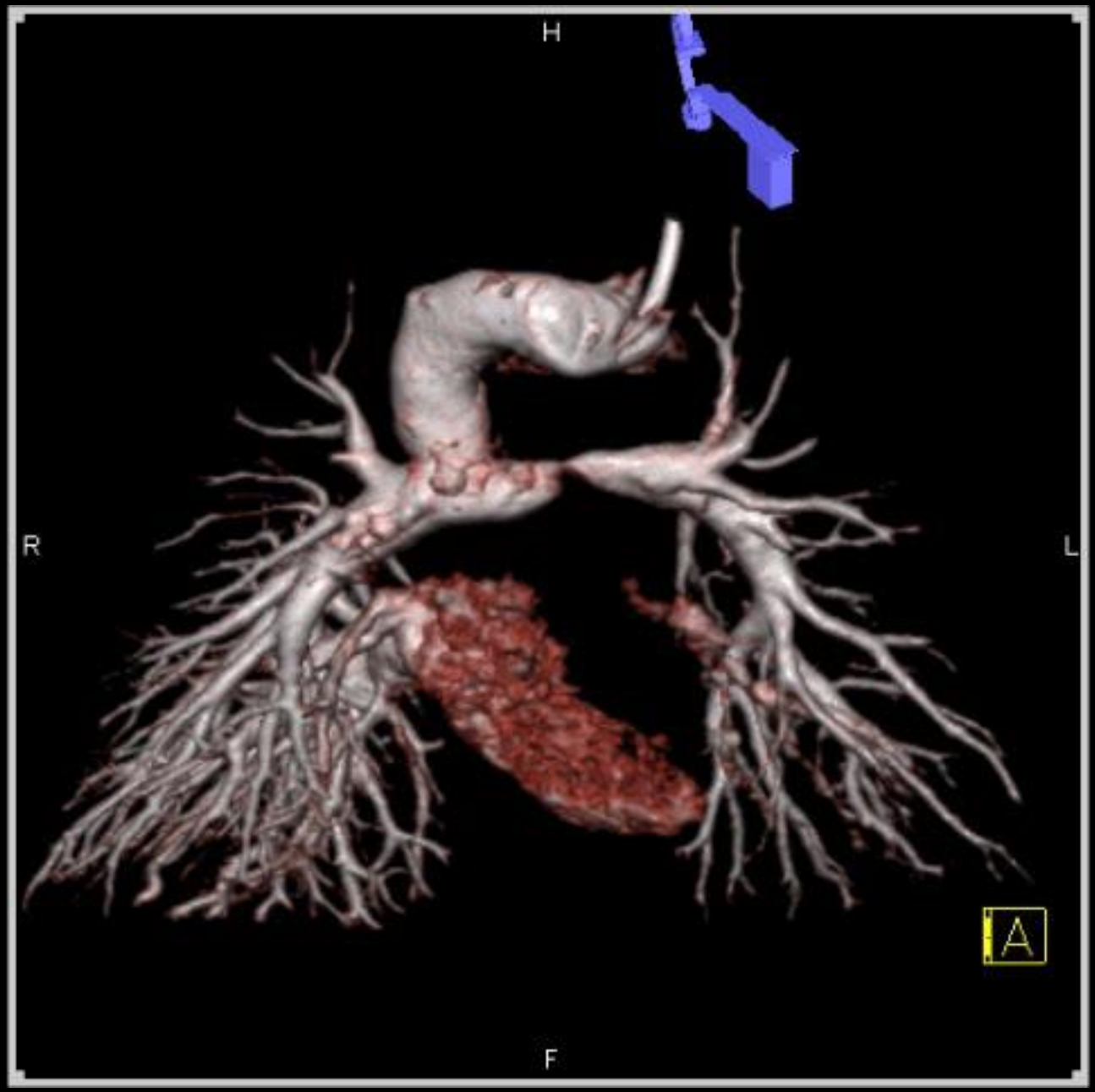
- LPA stn was identified in 12 children, requiring an intervention in 7 (28%)

- LPA stenosis & left bronchial stn, was noted in 10 of these 12 (83%), confirmed in 4 with bronchoscopy

- Symptoms included wheezing, obstructive sleep apnea, or recurrent respiratory infections

- Patients with qualitative bronchial narrowing had a mean left bronchial diameter of 4.4±1.6 mm (3DRA)

  The normal appearing bronchus measured 5.9±1.1 mm ($p = 0.009$)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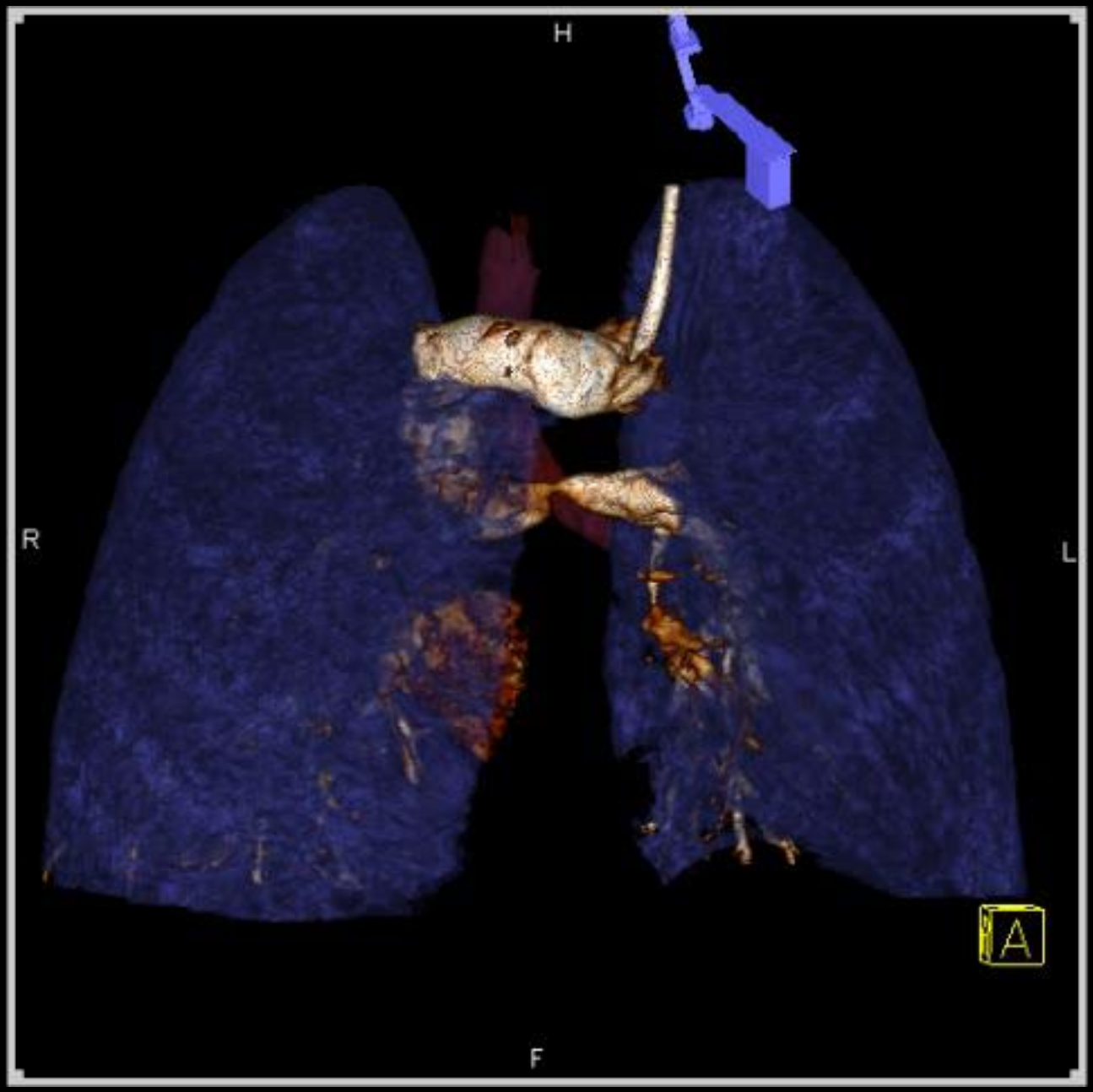
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Associations:

Table 3 Prevalence of LPA and bronchial stenosis in children with and without a previous arch reconstruction

3DRA/clinical finding	DKS group (%)	Non-DKS group (%)	Odds ratio	*p* value
LPA stenosis	78	31	7.7	0.04
LPA and bronchial sten				0.03
Bronchial stenosis				0.04
Bronchial stenosis on ir				0.01

Some Observations:

DKS group:

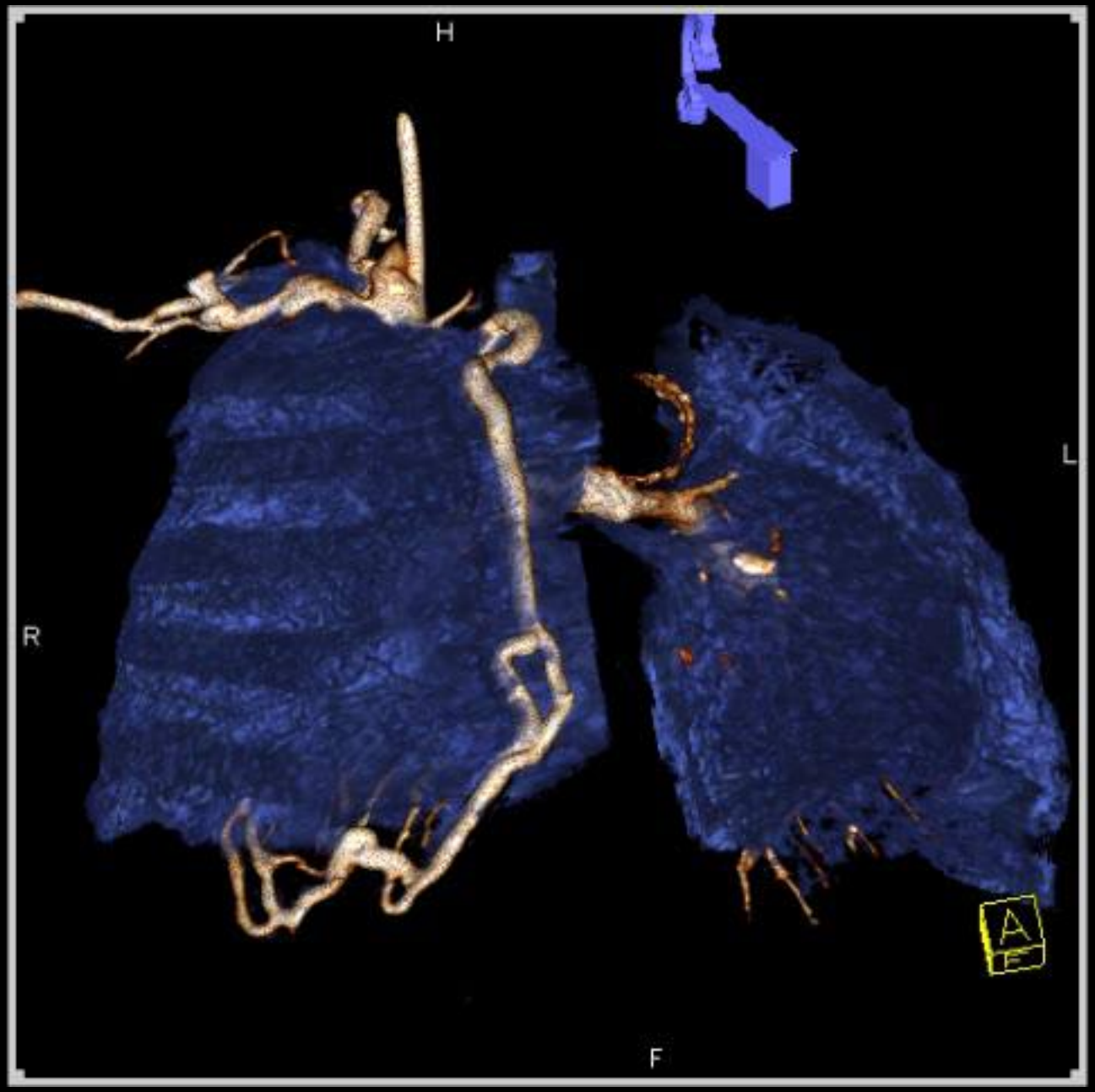
Proximal LPA was 6.1±2.0 mm *vs.* 9.0±1.2 mm (p=0.0002)

Distal LPA was 6.1±1.7 *vs.* 8.7±1.6 mm, p = 0.0008)

LPA & bronchial stn was related to the presence of a retained ductal stent

Table 4 LPA and bro

3DRA/clinical finding			roup (*n* = 16)
LPA stenosis			
LPA and bronchial stenosis	100	25*	19*
Bronchial stenosis	100	50	38*
Bronchial stenosis on imaging	80	0*	0*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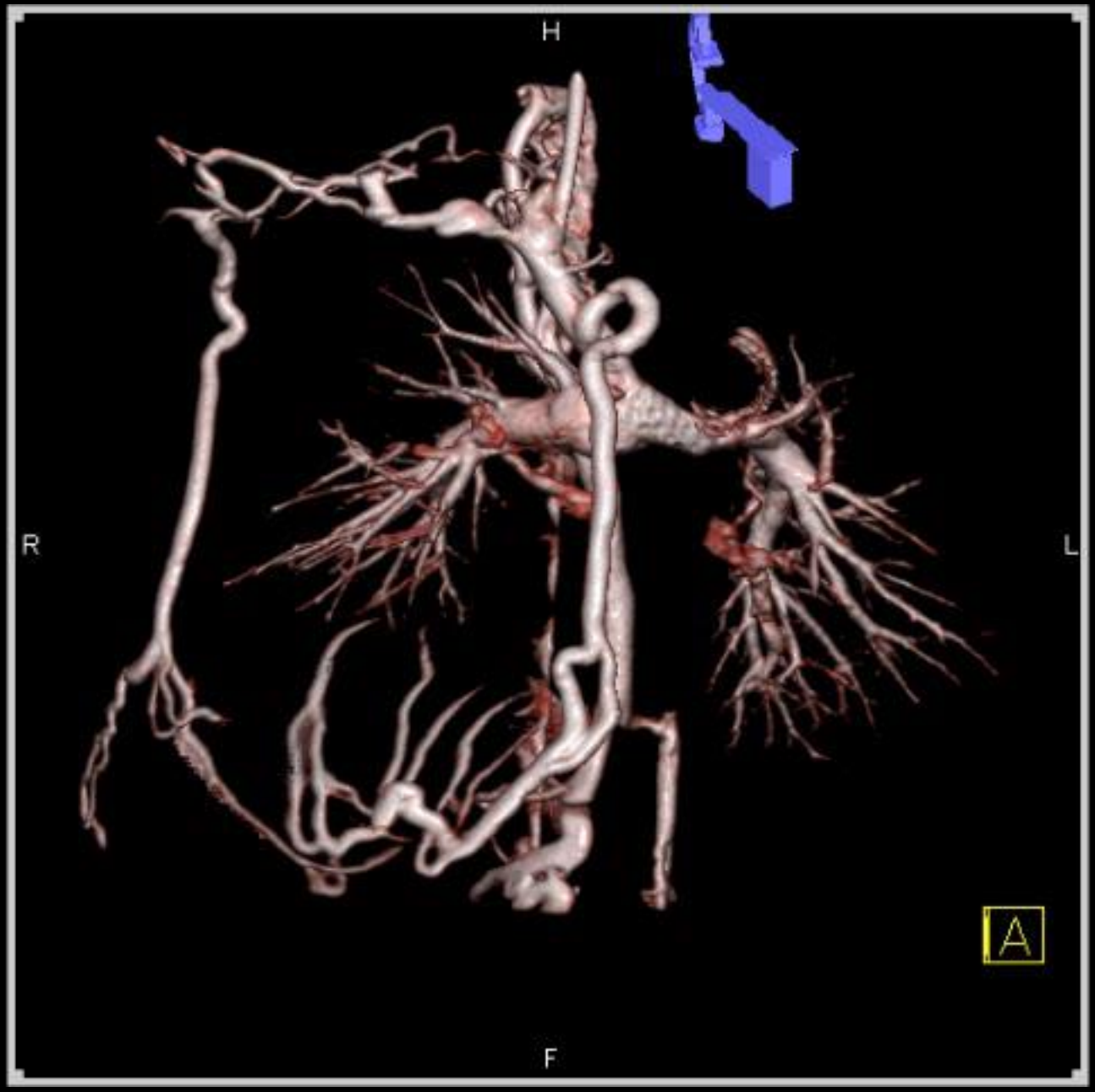
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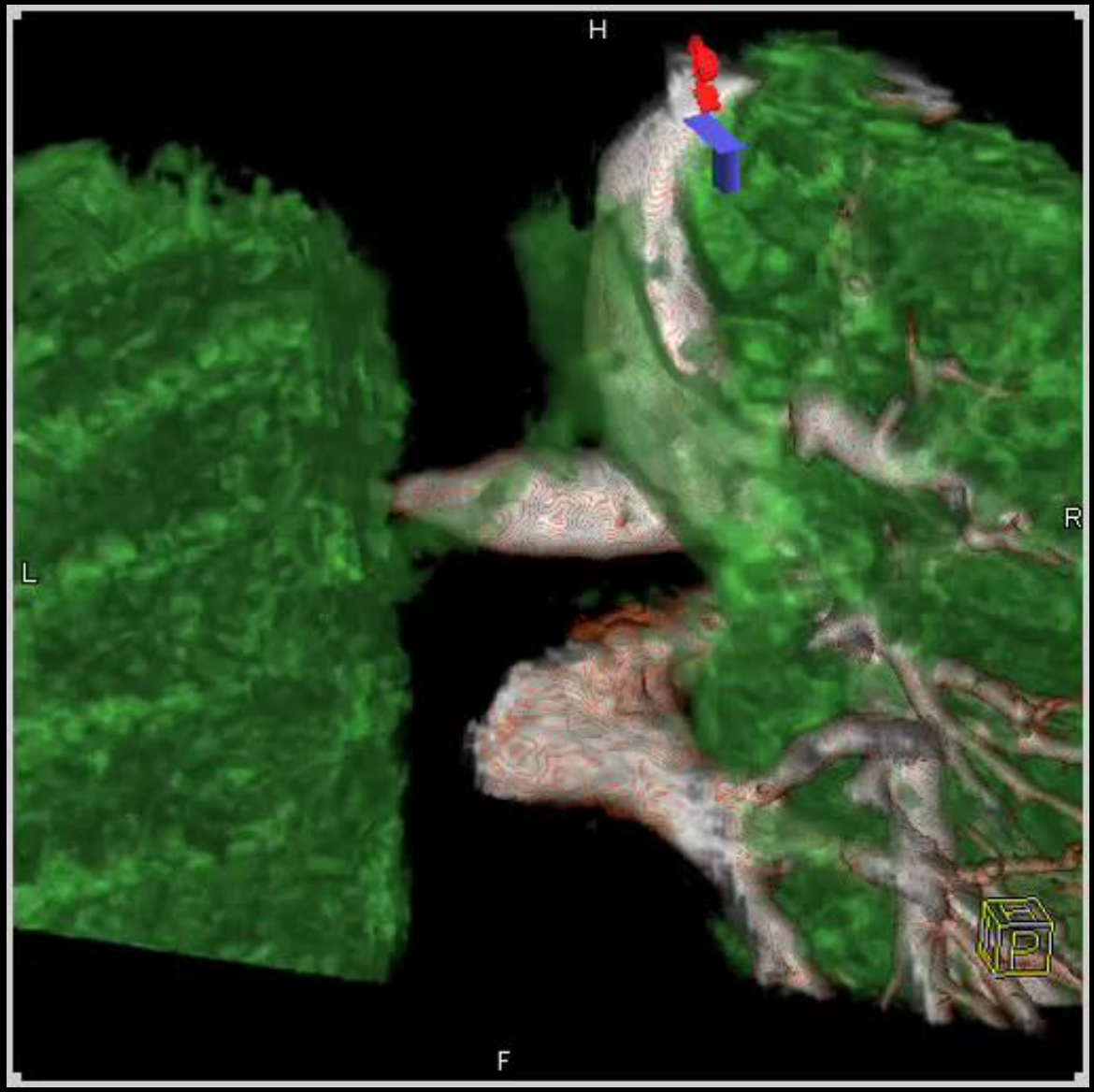
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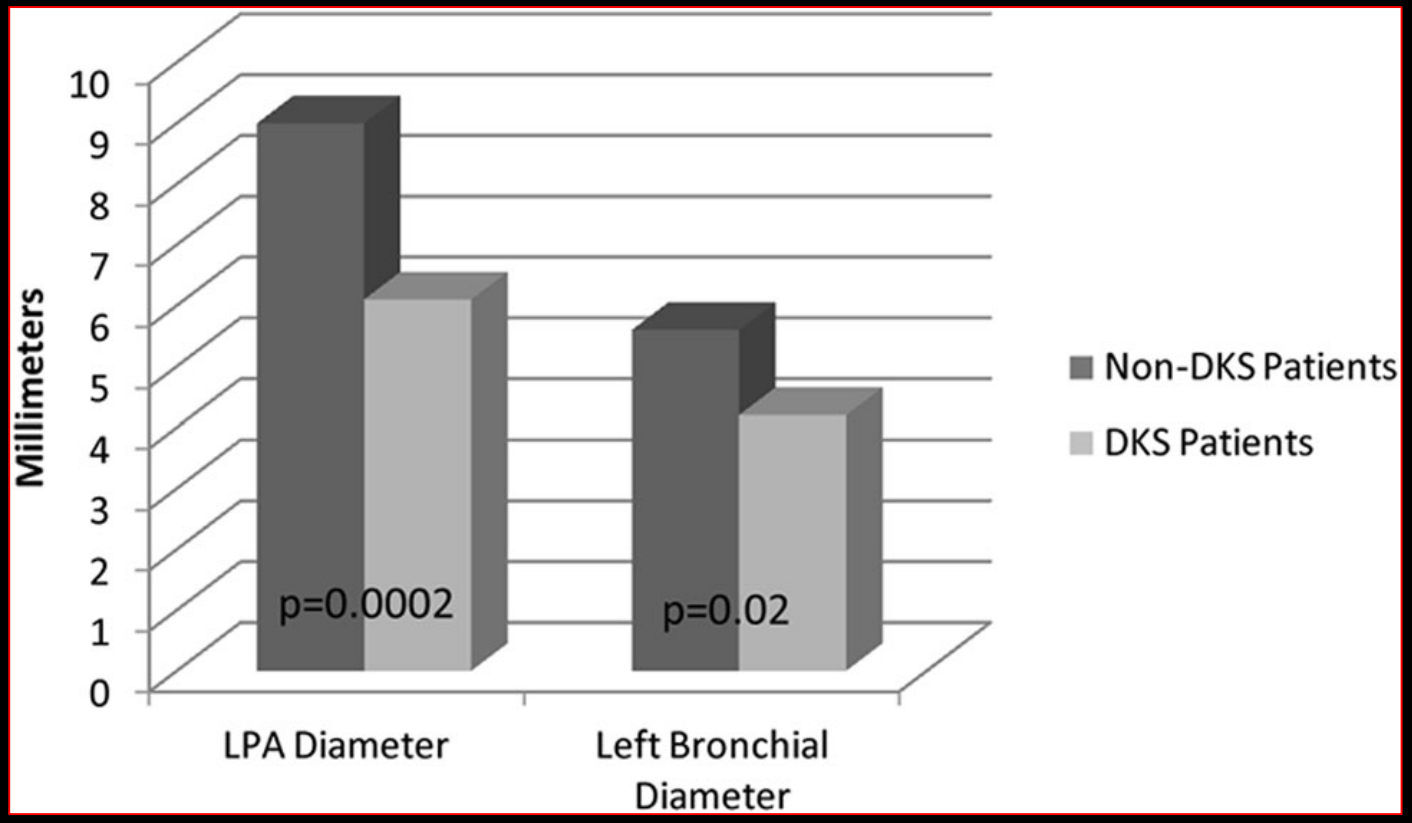


Mean left bronchial diameter was 4.2±1.8 mm (DKS) *vs.* 5.6± 1.1 mm (non-DKS) p=0.02

The hybrid group were at a higher risk than the non-DKS group of having bronchial stenosis (OR 17.8, p = 0.03) or airway narrowing on imaging (OR 99) p=0.0008

Clinical impact:

Due to obstructive airway symptoms & evidence of left bronchial stenosis on 3DRA, 1 child following a hybrid procedure underwent bronchoscopy which confirmed a diffusely hypoplastic left bronchus with 30% luminal narrowing due to pulsatile compression by neighboring vascular structures

This child's LPA, although significantly stenotic, was not stented in order to prevent worsening of the concomitant bronchial compression

Conclusions

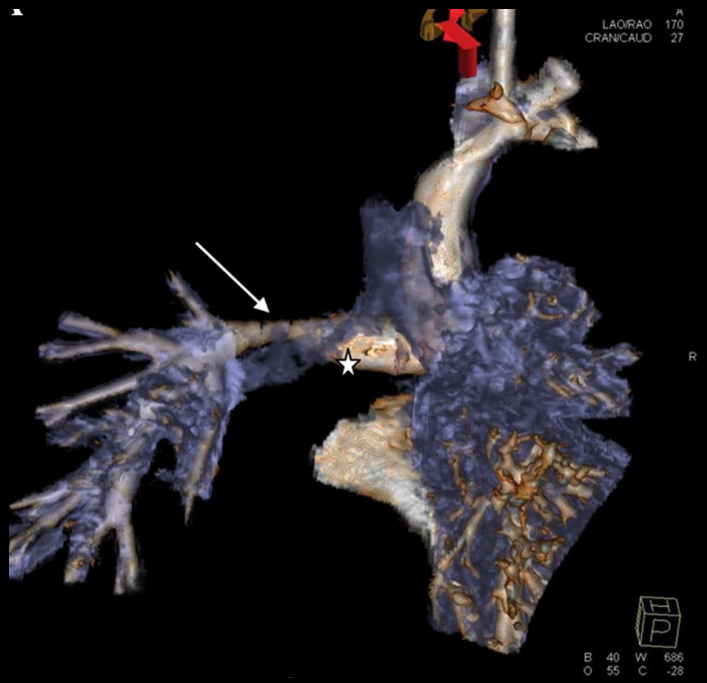
- There was a statistically significant association between the presence of an arch reconstruction and LPA stn, especially in the hybrid subgroup

- There was a qualitative relationship to the presence of a retained ductal stent, suggesting the mechanism to be related to vascular crowding and compression emphasizing the importance of 3D spatial evaluation of vascular structures in single ventricle patient

- 3DRA provides topological airway relationships from the same data set obtained for vascular imaging, hemodynamics at low airway pressures

Conclusions

- Evaluation of the airway has not historically been a component of the pre-Fontan assessment, and it should be factored into pre-op evaluation as such airway issues may have serious clinical consequences



Thank you