Systemic Dysfunction in Fontan Patients

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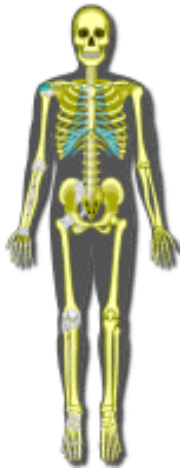
What is System in Body?



Skeletal

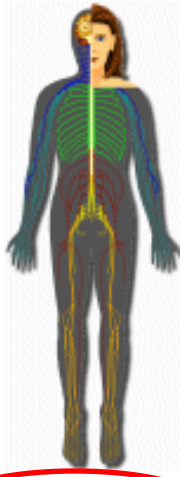
Digestive

Muscular

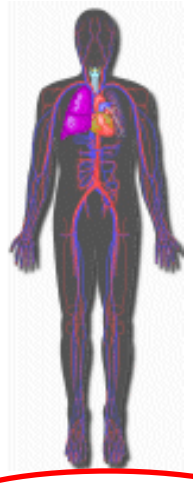
Lymphatic

Endocrine

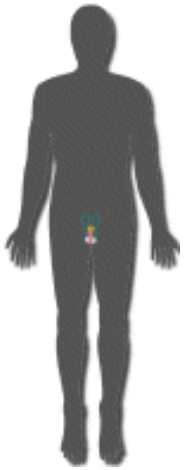
Respiratory



Nervous

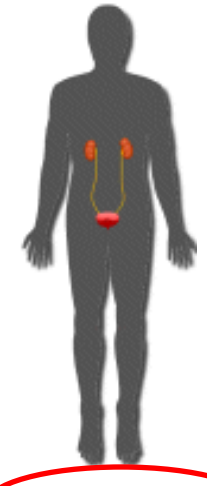


Cardiovascular



Male reproductive

Female reproductive



Urinary

Causes of systemic dysfunction in Fontan patients

- Elevated systemic venous pressure
- Persistent cyanosis
- Chronic ventricular dysfunction and low cardiac output
- Chronic inflammation
- Remained diverse anatomical problems
- Others !!

Rare problems associated with the Fontan circulation

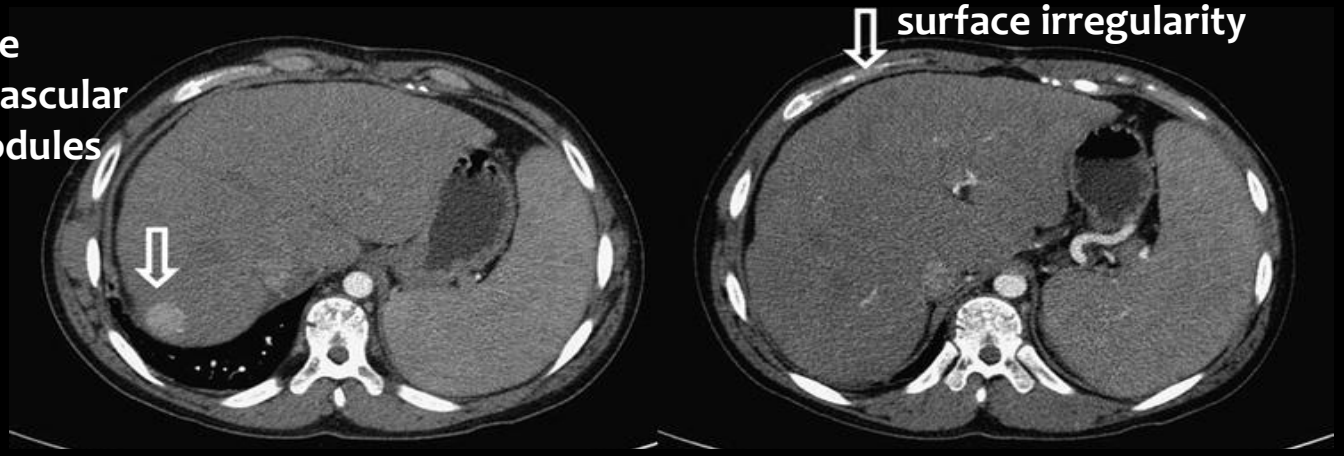
David J. Goldberg, Kathryn Dodds, Jack Rychik

Division of Cardiology, The Children's Hospital of Philadelphia, Philadelphia, Pennsylvania, United States of America

Abstract The Fontan operation, originally described for the surgical management of tricuspid atresia, is now the final surgery in the strategy of staged palliation for a number of different forms of congenital cardiac disease with a functionally univentricular heart. Despite the improved technical outcomes of the Fontan operation, staged palliation does not recreate a normal physiology. Without a pumping chamber delivering blood to the lungs, the cardiovascular system is less efficient cardiac output is generally diminished, and the systemic venous pressure is increased. As a result, patients with "Fontan physiology" may face a number of rare but potentially life-threatening complications including hepatic dysfunction, abnormalities of coagulation, protein-losing enteropathy, and plastic bronchitis. Despite the staged palliation resulting in remarkable survival, the possible complications for this group of patients are complex, involve multiple organ systems, and can be life threatening. Identifying the mechanisms associated with each of the rare complications, and developing strategies to treat them, requires the work of many people at many institutions. Continued collaboration between sub-specialists and between institutions will be required to optimise the care for this group of survivors with functionally univentricular hearts.

(Cardiology in the Young 2010: 113-119)

Hepatic dysfunction after Fontan Op.



- 139 Fontan patients with cardiac CT who undergone Fontan op. between 1986 and 2003
- mean age : 19.0 ± 6.3 years (range: 5 ~ 41.5)
- mean elapsed time since Fontan operation : 11.5 ± 4.7 years
- 57 patients (41%) had hepatic complications : liver cirrhosis from CT (25.9%), thrombocytopenia (7.2%), hyperbilirubinaemia (20.9%), hepatic masses (2.9%)
- In multivariate analysis, elapsed time since Fontan op. was the only parameter correlated with hepatic complications

(Baek JS 2010 Heart)

Hepatic pathology may develop before the Fontan operation in children with functional single ventricle: An autopsy study

From CHOP

Objective: Liver fibrosis has emerged as an important long-term complication of the Fontan operation. We aimed to describe liver histology at autopsy in patients who had undergone the Fontan operation and to determine whether patient variables are associated with the degree of fibrosis.

Methods: A review was performed of all patients with a history of the Fontan operation who died and underwent autopsy at our institution from 1980 to 2009. Autopsy liver slides were evaluated independently by 2 pathologists.

Results: Twenty-two patients were studied. The median interval between Fontan and death was 20 days (range, 1 day–17.5 years). Portal fibrosis was observed in 20 (91%) patients and sinusoidal fibrosis was observed in 17 (77%) patients. Using simple linear regression, time from the Fontan operation was significantly associated with the degree of portal fibrosis on Ishak ($P = .03$) and modified Scheuer fibrosis ($P = .02$) scales. Significant portal fibrosis was observed in 8 (57%) of the 14 patients who died 30 days or less after the Fontan operation. In these 14 patients, severity of portal fibrosis was associated with length of hospitalization after pre-Fontan cardiac operations ($P = .03$) and pre-Fontan mean right atrial pressure ($P = .04$).

Conclusions: At autopsy, hepatic fibrosis was commonly observed in patients who had undergone the Fontan operation. Portal fibrosis has been previously unrecognized in this population. Significant portal fibrosis occurred in most who died soon after the Fontan procedure and was associated with pre-Fontan morbidity. Hepatic disease in the single-ventricle population is multifactorial and may begin before the Fontan operation. (J Thorac Cardiovasc Surg 2011;■:1-6)

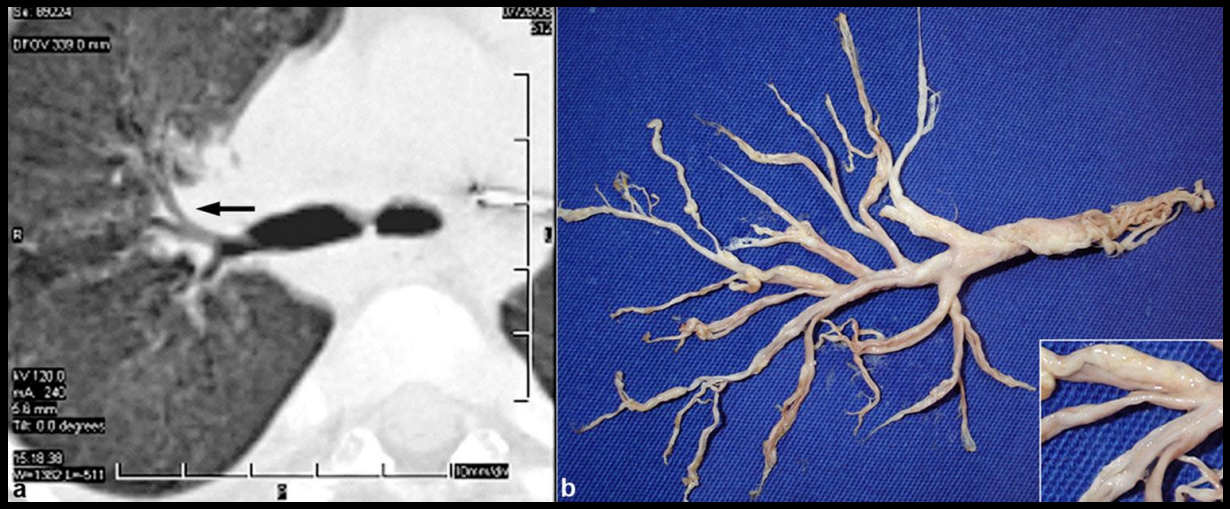
Hepatic dysfunction after Fontan Op.

- Cause
  - increased hepatic venous pressure : **3 ~ 4 times** higher than normal
- Manifestation
  - hepatic congestion, dilated bile ducts, hepatic fibrosis, hepatic cirrhosis, higher risk of hepatic neoplasm
- F/U
  - Ultrasonography, MRI
  - alpha- FP check every 6 month if surface irregularity in USG
- No definite Tx
  - Goal : **decrease of hepatic vein pr.** (decrease Pul. artery pr.)
    1. Enlargement or creation of Fontan fenestration
    2. Selective pulmonary vasodilator

Dysfunction in Respiratory System

- Plastic bronchitis
- Pulmonary AV fistula
- Aortopulmonary collaterals
- Restrictive pattern of lung function
- Others !!

Plastic Bronchitis



(Guimarães et al. 2010 Arq Bras Cardiol)

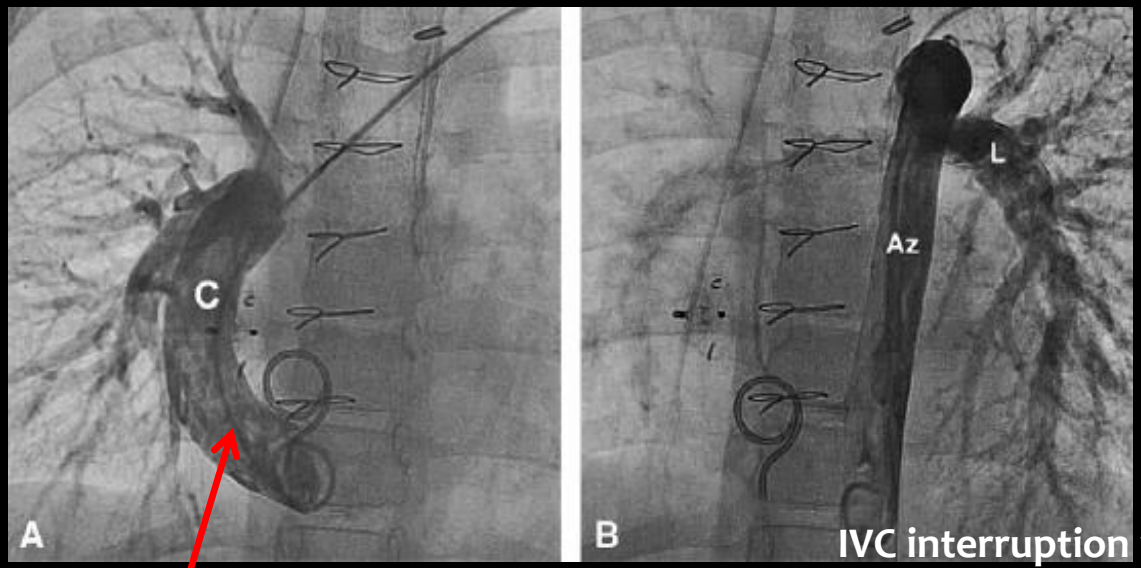
(GOO HW, 2008 Pediatr Radiol)

- bronchial casts are formed within the airways
  - ➔ potential for obstruction and asphyxiation
  - ➔ dominant symptom : respiratory distress ➔ can be fatal
- casts : large, gelatinous, usually acellular, composed of mucin and fibrin
- cause : similar to protein losing enteropathy
  - ➔ edematous bronchial mucosa and dilated lymphatics

Plastic Bronchitis - Treatment

- Limited and no known optimal approach
  - **Mucolytics** : to decrease the viscosity of the mucin component
    - N-acetylcysteine, Dornase alfa
    - nebulized 7% hypertonic saline : hydrate smaller casts
  - **Bronchoscopic removal** and mechanical clearance
  - **Improvement of hemodynamics**
    - selective pul. vasodilator, Fontan pathway fenestration
  - **Dissolve bronchial casts**
    - Aerosolized tissue plasminogen activator, urokinase
  - **Heart transplantation**

Pulmonary arteriovenous fistula



Hepatic vein

IVC interruption with azygous continuation

(McElhinney DB et al. 2011 J Thorac Cardiovasc Surg)

* Hepatic factor in hepatic venous flow (ex. Endothelin)

: role in the integrity of pulmonary vasculature

∴ Cause of pul. AV fistula

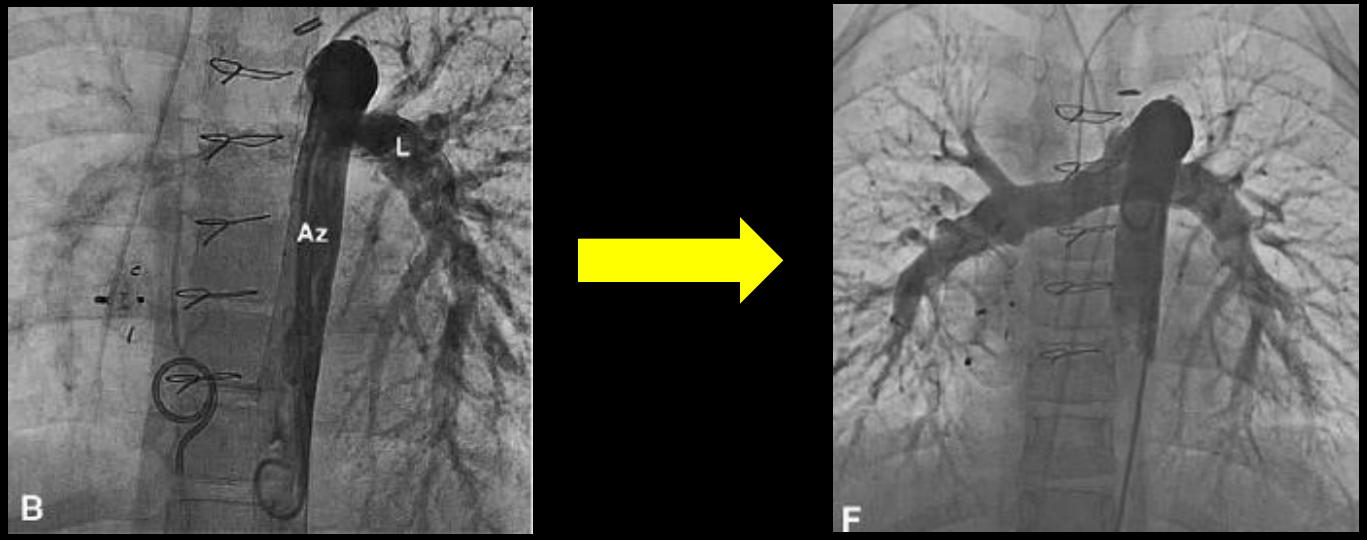
: related to the diversion of hepatic venous flow away from the pulmonary circulation

• predisposing factor: patients with IVC interruption and the polysplenia form of heterotaxy syndrome

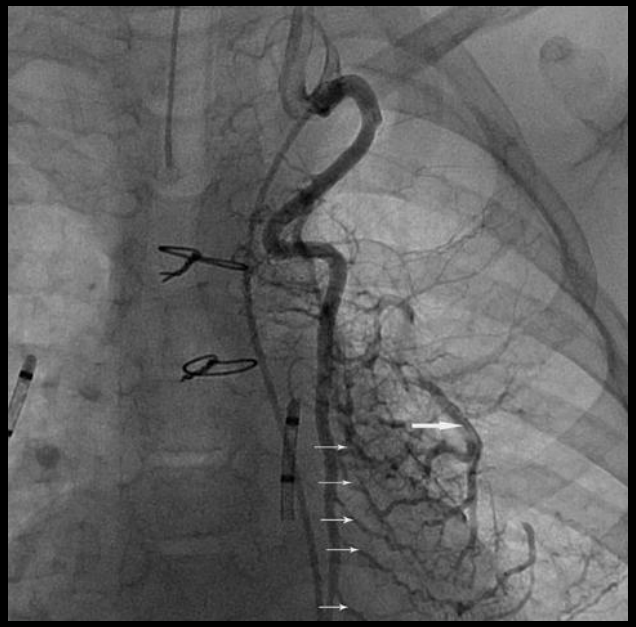
Pulmonary AV fistula - treatment

Patient no.	Original Fontan connection	SpO_2 before most recent pathway modification	Fontan pathway modifications: Central PA stent	Fontan pathway modifications: HV-azygous vein connection	Fontan pathway modifications: Other Fontan rerouting	PAVM coil occlusion	Clinical improvement	Follow-up duration (y)	SpO_2 at most recent follow-up
1	Left LT	83	X			X	Minimal	2.1	86
2	HV-RPA ECC 16 mm	80	X		Branched HV-PA conduit	X	No	0.2	Deceased
3	HV-LPA ECC 14 mm	84		X	Branched HV-PA conduit		Substantial	4.0	96
4	Right RA-PA	85			SVC-PA connection moved		Modest	13.1	90
5	HV-RPA ECC 16 mm	86		X			Substantial	1.0	97
6	HV-RPA ECC 16 mm	80		X			Substantial	1.8	91
7	Right LT	75		X			Substantial	0.2	87
8	LHV-LPA ECC 13 mm	83		X		X	No	3.5	Deceased

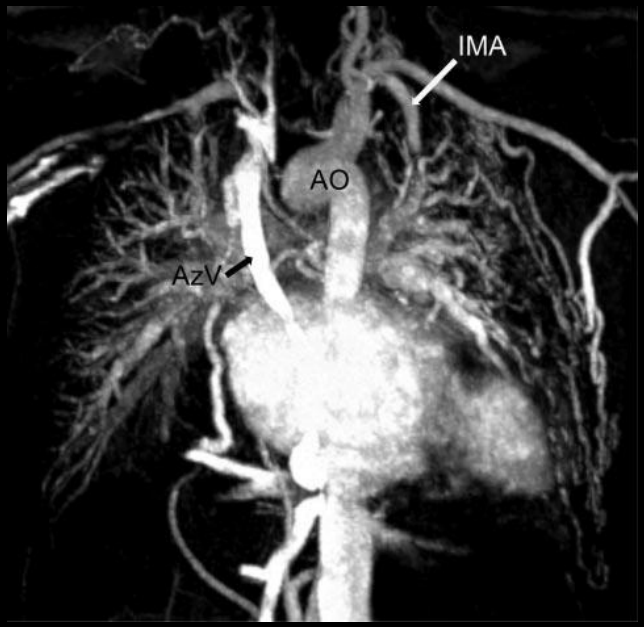
(McElhinney DB et al. 2011 J Thorac Cardiovasc Surg)



Aortopulmonary collaterals



(Stern HJ 2010 Pediatr Cardiol)



(Lars Grosse-Wortmann et al. 2009 Circ Cardiovasc Imaging)

- up to **80%** of single-ventricle patients undergoing pre-Fontan cath.
- **hypoxia** is a potent stimulus
- No consensus for impact on the mid- to long-term course of SV patients
  - **volume overloading** to the single ventricle
  - increase of PA and systemic venous pressures
  - life-threatening **hemoptysis** !!

Aortopulmonary Collaterals After Bidirectional Cavopulmonary Connection or Fontan Completion

Quantification With MRI

Lars Grosse-Wortmann, MD; Abdulmajeed Al-Otay, MD; Shi-Joon Yoo, MD

Background—Aortopulmonary collaterals (APCs) have been associated with increased morbidity after the Fontan operation. We aimed to quantify APC flow after bidirectional cavopulmonary connections and Fontan completions, using phase-contrast MRI, and to identify risk factors for the development of APCs.

Methods and Results—APC blood flow was quantifiable in 24 of 36 retrospectively analyzed MRI studies. Sixteen studies were performed after the bidirectional cavopulmonary connections (group A) and 8 after the Fontan operation (group B). APC blood flow was calculated by subtracting the blood flow volume through the pulmonary arteries from that through the pulmonary veins. The ratio of pulmonary to systemic blood flow (Qp/Qs) was 0.93±0.26 in group A and 1.27±0.16 in group B. APC flow was 1.42 (0.58 to 3.83) L/min/m^2 and 0.82 (0.50 to 1.81) L/min/m^2 in groups A and B, respectively. The mean inaccuracies corresponded to 7.9±14.5% and 7.1±13.6% of ascending aortic flow in groups A and B, respectively. Qp/Qs was negatively correlated with a younger age at the time of the bidirectional cavopulmonary connections operation (r=0.62, P=0.01) and positively correlated with the age at the time of the Fontan completion (r=0.81, P=0.01). Patients with a previous right-sided modified Blalock-Taussig shunt had more collateral flow to the right lung than those without.

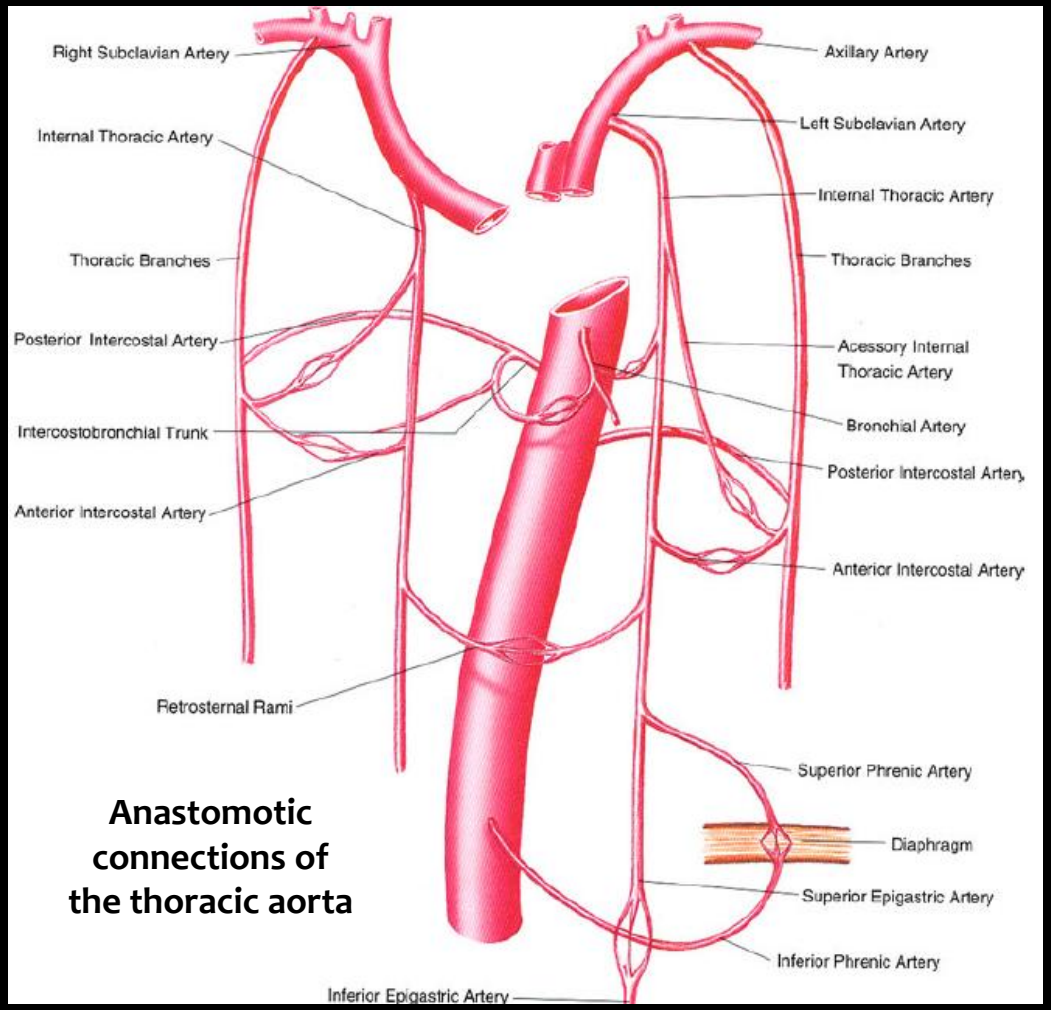
Conclusions—APC blood flow can be noninvasively measured in bidirectional cavopulmonary connections and Fontan patients, using MRI in the majority of patients and results in a significant left-to-right shunt. (***Circ Cardiovasc Imaging*. 2009;2:219-225.**)

- Risk for aortopulmonary collaterals
  - age at the time of the Fontan op.
  - previous right-sided modified BT shunt

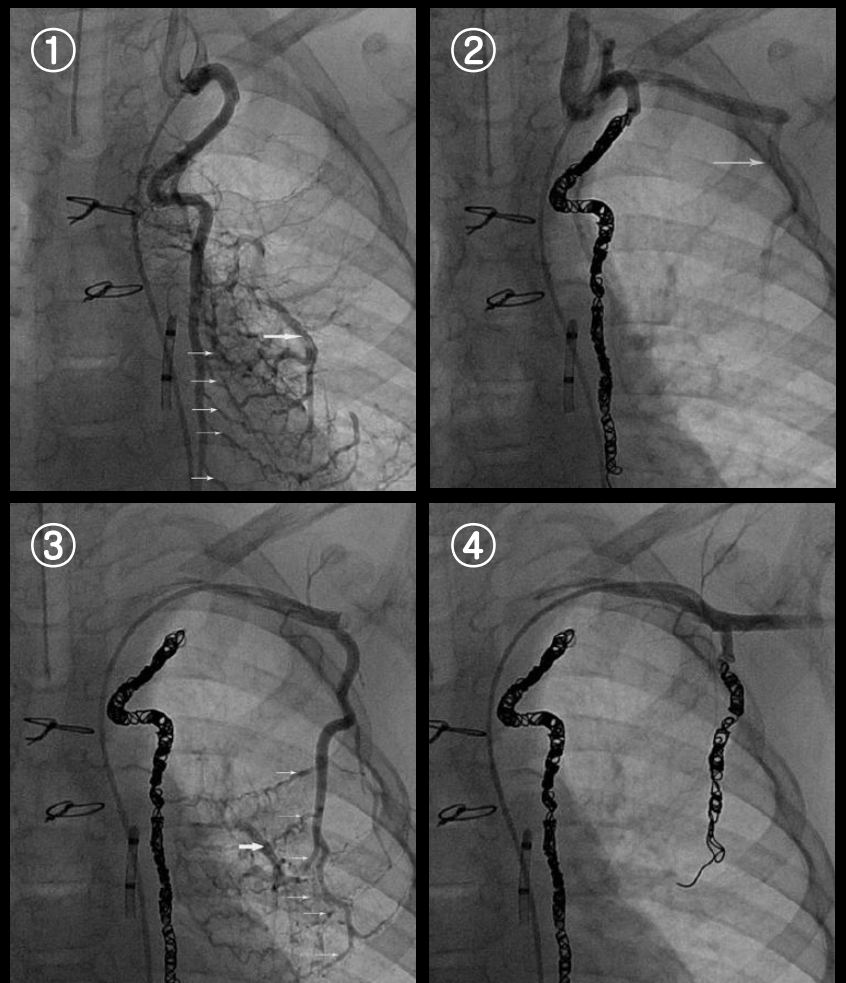
Aortopulmonary collaterals - treatment

Aggressive Coiling of Aortopulmonary Collaterals in Single-Ventricle Patients Is Warranted

(Stern HJ 2010 Pediatr Cardiol)



Anastomotic connections of the thoracic aorta



Renal dysfunction after Fontan operation

- 25 pts after Fontan op. (children's hospital of Michigan)
  - Mean age : 15.2 ± 8.8 years
  - Time after Fontan op. : 11.4 ± 6.5 years
  - All showed normal eGFR
  - 9 pts (43%) : pathologic urine microalbumin/creatinine ratio

(Anne P et al. 2009 Int J Cardiol)

- Cause of renal dysfunction
  - drop in cardiac output and renal perfusion in failing Fontan
  - Persistent cyanosis
    - secondary erythrocytosis and blood hyperviscosity
    - provoke glomerular and tubular damage

* Age at the primary Fontan : significant predictor of renal function

(Sammour F et al. 2009 Pediatr Cardiol)

Pregnancy in Fontan patients

- 38 female patients undergone Fontan palliation
- Age : 18–45 years
- Six women had 10 pregnancies
  - 5 miscarriages (50%) , one aborted ectopic pregnancy
  - four live-birth pregnancies with significant complications
- Primary amenorrhoea : 15 patients (40%)

Table 2 Overview of complications during live-birth pregnancies in women after Fontan palliation

Patient	Pregnancy number	Complications			
		Cardiac	General	Obstetric	Neonatal
V	1	NYHA ↓		PROM, PL, F, V, CS	PD, ND
	2	NYHA ↓, AFL/AF	VAG	CS	PD
W	1		PIH	PPH	SGA
LL	1			CS	SGA

AF, atrial fibrillation; AFL, atrial flutter; CS, caesarean section; F, forceps delivery; ND, neonatal death; NYHA ↓, New York Heart Association class deterioration during pregnancy; PD, premature delivery; PIH, pregnancy-induced hypertension; PL, premature labour; PPH, postpartum haemorrhage; PROM, premature rupture of membranes; SGA, small for gestational age; V, vacuum delivery; VAG, vaginal bleeding.

(Drenthen W et al. 2006 Heart)

Pregnancy in the Fontan is inadvisable ???

Thank You for Attention !