The Fontan patient: 

Anesthetic aspects of the Fontan patient

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Overview

1. Brief overview of congenital heart diseases
2. History of Fontan procedure
3. Today’s Fontan procedure
4. Physiology after Fontan repair
5. Preoperative assessment
6. Peri-operative management after Fontan repair
7. Outcomes and complications
8. Conclusion
Brief overview of congenital heart diseases

- incidence of congenital heart disease: 4 to 50 in 1,000 live births

- in addition, another 20 in 1,000 live births have:
  - bicuspid aortic valves
  - isolated anomalous lobar pulmonary veins
  - a silent patent ductus arteriosus

Many complex cardiac malformations are characterized by the existence of only one functional ventricle = **Univentricular hearts**

- 7.7% of congenital heart disease diagnosed in childhood
- birth incidence of approximately 4–8 per 10,000
- increasing fraction are being recognized by prenatal ultrasound

O’Leary, P.; Prevalence, clinical presentation and natural history of patients with single ventricle, Rochester, MN, USA, El Sevier, 2002
History of Fontan procedure

• "Fontan procedure" or "Fontan - Kreutzer procedure" is a **palliative** surgical procedure performed in children with **univentricular hearts**.

• **2 major disadvantages of a single ventricle:**
  - Arterial desaturation
  - Chronic volume overload ➔ CHF ➔ death
- described as a surgical treatment for tricuspid atresia separately by:

Dr. François Fontan, Bordeaux, France (1971)  
Dr. Guillermo Kreutzer, Buenos Aires, Argentina (1973)

1958: Glenn procedure (= hemi-Fontan)  
1943: Blalock-Thomas-Taussig shunt
Surgical repair of tricuspid atresia

F. Fontan and E. Baudet
Centre de Cardiologie, Université de Bordeaux II, Hôpital du Tondu, Bordeaux, France

Surgical repair of tricuspid atresia has been carried out in three patients; two of these operations have been successful. A new surgical procedure has been used which transmits the whole vena caval blood to the lungs, while only oxygenated blood returns to the left heart. The right atrium is, in this way, 'ventriculized', to direct the inferior vena caval blood to the left lung, the right pulmonary artery receiving the superior vena caval blood through a cavo-pulmonary anastomosis. This technique depends on the size of the pulmonary arteries, which must be large enough and at sufficiently low pressure to allow a cavo-pulmonary anastomosis. The indications for this procedure apply only to children sufficiently well developed. Younger children or those whose pulmonary arteries are too small should be treated by palliative surgical procedures.

Only palliative operations (systemic vein to pulmonary artery anastomosis; systemic artery to pulmonary artery anastomosis) have been performed in tricuspid atresia. Although these procedures are valuable, they result in only a partial clinical improvement, because they do not suppress the mixture of venous and oxygenated blood.

We have initiated a corrective procedure for tricuspid atresia, which completely suppresses blood mixing. The entire vena caval return undergoes arterIALIZATION in the lungs and only oxygenated blood comes back to the left heart. This procedure is not an anatomical correction, which would require the creation of a right ventricle, but a procedure of physiological pulmonary blood flow restoration, with suppression of right and left heart failure.

FIG. 1. Case 2. Tricuspid atresia type II B. Drawing illustrates steps in surgical repair: (1) end-to-side anastomosis of distal end of right pulmonary artery to superior vena cava; (2) end-to-end anastomosis of right aortic conduit to proximal end of right pulmonary artery by means of an aortic valve homograft; (3) closure of atrial septal defect; (4) insertion of a pulmonary valve homograft into inferior vena cava; and (5) ligation of main pulmonary artery.
1973: Kreutzer's alternative to the Fontan procedure
Today’s Fontan procedure

- Indications
- Contra-indications
- Recommendations for a successful Fontan circulation
- Approach
Indications for Fontan repair

Cardiac malformations with a single functional ventricle

• absence of an AV heart valve
  (e.g. tricuspid or mitral atresia)

• absence of pumping ability of the heart
  (e.g. hypoplastic right/left heart syndrome)

• a complex congenital heart disease where a bi-ventricular repair is impossible or inadvisable
Indications for Fontan repair

- Tricuspid atresia
- Double inlet left ventricle
- Hypoplastic left heart syndrome
- Unbalanced atrioventricular septum defect
Univentricular heart

- The single ventricle is doing nearly twice the expected amount of work because it has to pump blood for the body and the lungs.

- Clinical manifestations (typically cyanosis and CHF) hinge on the presence or absence of pulmonary and systemic outflow obstruction.

- Natural history
  - Left ventricle dominant = 70% died before age of 16.
  - Right ventricle dominant = 50% died before age of 4.

- Fontan operation: 20-year survival rate and freedom of heart transplantation of 80%.

- Staged repair allows progressive adaption of the heart and lungs and reduces the overall perioperative morbidity and mortality.
Contra-indications for Fontan repair

• After Fontan completion, blood must flow through the lungs without being pumped by the heart

• Few absolute contraindications:
  - high pulmonary vascular resistance (> 4 Wood units.m²)
  - severe hypoplasia of the pulmonary arteries
  - severe diastolic dysfunction of the single ventricle

• After birth the pulmonary vascular resistance is high in utero and takes months to drop → Fontan procedure cannot be done immediately after birth.
Timing for Fontan repair

- Age at which Fontan is performed is steadily lowered
  - 2 years or younger if good anatomy and physiology

- Advantage:
  - ↑ oxygenation
  - ↑ somatic growth
  - ↑ neurodevelopmental outcomes
  - ↓ volume load on the single ventricle
1977: Choussat's Ten Commandments

<table>
<thead>
<tr>
<th>Condition</th>
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<tbody>
<tr>
<td>Age &gt;4 years</td>
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<tr>
<td>Sinus rhythm</td>
</tr>
<tr>
<td>Normal systemic venous return</td>
</tr>
<tr>
<td>Normal right atrial volume</td>
</tr>
<tr>
<td>Mean pulmonary artery pressure &lt; 15 mm Hg</td>
</tr>
<tr>
<td>Pulmonary arteriolar resistance &lt; 4 Wood units.m²</td>
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<tr>
<td>Pulmonary artery–aorta ratio &gt; 0.75</td>
</tr>
<tr>
<td>Left-ventricular ejection fraction &gt; 0.60</td>
</tr>
<tr>
<td>Competent mitral valve</td>
</tr>
<tr>
<td>Absence of pulmonary artery distortion</td>
</tr>
</tbody>
</table>

Recommendations for a successful Fontan circulation

**Cardiac requirements:**
- Unobstructed ventricular inflow
- Reasonable ventricular function
- Unobstructed outflow
  
  no AV valve stenosis, no regurgitation
  no subaortic stenosis, no AHT, no coarctation

**Pulmonary requirements:**
- Non restrictive connection from systemic veins to pulmonary arteries
- Good sized pulmonary arteries
- Well developed distal vascular bed
- (near) normal pulmonary vascular resistance
Approach

Operative stages for achieving a Fontan circulation:

1. **Newborn period**: aim to balance the blood flow between the lungs and the body, achieving stable oxygen levels and adequate heart function.

   - **not enough blood flow** into the lungs → **hypoxemia**

   PDA stenting
Approach

Operative stages for achieving a Fontan circulation:

1. **Newborn period**: aim to balance the blood flow between the lungs and the body, achieving stable oxygen levels and adequate heart function.

   - **not enough blood flow into the lungs** → hypoxemia

   systemic to pulmonary artery shunt
   =
   Blalock-Taussig shunt
Approach

Advantages of BTS:
- ↑ oxygen saturation
- ↑ growth of pulmonary arteries

Disadvantages of BTS:
- ventricular volume overload
- ↑ pulmonary arterial pressure
- distortion of pulmonary arteries
Approach

Operative stages for achieving a Fontan circulation:

1. **Newborn period**: aim to balance the blood flow between the lungs and the body, achieving stable oxygen levels and adequate heart function.

   - too much blood flow into the lungs → extra burden on ventricle
     pulmonary hypertension

   Pulmonary banding
Approach

Operative stages for achieving a Fontan circulation:

1. **Newborn period**: aim to balance the blood flow between the lungs and the body, achieving stable oxygen levels and adequate heart function.

   - **Setting**: HLHS
     - Modified Norwood 1
     - Sano repair

     - First 2 weeks of life
     - Permanent systemic outflow utilising the right ventricle
     - Temporary pulmonary blood supply to allow the pulmonary vasculature to develop
     - Up to 20-25% mortality rate
Approach

Operative stages for achieving a Fontan circulation:

HLHS: Modified Norwood 1

- Main pulmonary artery is divided
- Proximal MPA is anastomosed to the ascending aorta
- Aortic arch is repaired
- Augmented pulmonary blood flow is maintained via a modified BTS
Approach

Operative stages for achieving a Fontan circulation:

HLHS: Modified Norwood 1
Approach

Operative stages for achieving a Fontan circulation:

HLHS:  **Sano repair**

- Similar to NW1
- RV-PA instead of BTS
- Theoretical advantage: no competitive flow between the lungs and coronary arteries
- Theoretical disadvantage: may be more invasive, obstruction
Approach

Operative stages for achieving a Fontan circulation:

2. Late infancy:

- Superior cavopulmonary anastomosis
  - Bi-directional Glenn
  - Hemi-Fontan

- Around 3 to 6 months of age, when PVR ↓
- If BTS present, it is removed
- If PA banding is present, it may be removed but can also be left in place
Approach

Operative stages for achieving a Fontan circulation:

2. Late infancy: Bi-directional Glenn
Approach

Operative stages for achieving a Fontan circulation:

2. Late infancy: **Hemi-Fontan**

- Returning blood from upper body is sent directly to lungs
- BT shunt is removed
- Patch placed in right atrium
Approach

Operative stages for achieving a Fontan circulation:

2. Late infancy: Bi-directional Glenn or Hemi-Fontan

- Advantages of superior cavopulmonary anastomosis:
  - ability to grow with the child => BTS
  - ↓ intracardiac volume overload
  - ↓ cyanosis (oxygen saturation levels 75-85%)

- Disadvantage of superior cavopulmonary anastomosis:
  - PAVMs occur in 20% of SCPA (exclusion of growth modulating factor liver?)

- This stage is tolerated best of all stages with a survival rate of 95% or better.
<table>
<thead>
<tr>
<th>Procedures</th>
<th>Bidirectional Glenn</th>
<th>Hemi-Fontan</th>
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</thead>
<tbody>
<tr>
<td>Cardiopulmonary Bypass</td>
<td>+/-</td>
<td>+</td>
</tr>
<tr>
<td>SVC-PA connection</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Transection of SVC</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Repair of TV &amp; PA</td>
<td>+/-</td>
<td>+</td>
</tr>
<tr>
<td>Procedures</td>
<td>Bidirectional Glenn</td>
<td>Hemi-Fontan</td>
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<tr>
<td>----------------------------------</td>
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<td>---------------------</td>
</tr>
<tr>
<td>Early Mortality rate</td>
<td>5%-10%</td>
<td>Same</td>
</tr>
<tr>
<td>Ideal type of Fontan</td>
<td>Extracardiac</td>
<td>Lateral Tunnel</td>
</tr>
<tr>
<td>Noncompetitive Fontan flow pattern</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Post-Fontan Mortality rate</td>
<td>21%</td>
<td>2%-5%</td>
</tr>
</tbody>
</table>
Approach

Operative stages for achieving a Fontan circulation:

3. Childhood:

Total cavopulmonary connection → Fontan completion

• 18 months – 4 years old
• 6-18 months post-Glenn or hemi-Fontan: if later risk for intrapulmonary arteriovenous shunts

• **3 types:**
  o Atropulmonary connection = **Original Fontan**
  o Intracardiac total cavopulmonary connection (lateral tunnel)
  o Extracardiac total cavopulmonary connection → **Modified Fontan**
A. Classical Fontan

- Right auricle used as a conduit to the RPA
- ASD closed
- Tricuspid valve closed

B. Lateral tunnel (intra-atrial baffle)

- Anastomosis of enlarged cardiac end of SVC to RP
- Placement of baffle inside right atrium, forming a channel with a decreased diameter

C. Extra-cardiac conduit

- Gore-tex conduit
- RA closed
The modern Fontan operation: Lateral Tunnel Fontan

- improved pulmonary blood flow
- only the lateral wall of the atrium is exposed to central venous hypertension
- no dilated atrium to serve as a source of thrombus
- extensive atrial suture lines = risk for arrhythmia.
The modern Fontan operation: Extracardiac Fontan

- Conduit made of polytetrafluoroethylene connects VCI to RPA.
- greatly reduces the number of atrial incisions and hopefully the long-term development of atrial arrhythmias.
Bidirectional Glenn for HLHS
Superior vena cava connected to pulmonary artery

Anastomosis of enlarged cardiac end of SVC to RPA

Placement of baffle inside right atrium, forming a channel with a decreased diameter

Lateral tunnel (intra-atrial baffle)

GORE-TEX conduit

Extra-cardiac conduit

RA closed

KU LEUVEN
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<tr>
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<th>Lateral Tunnel</th>
<th>Extracardiac</th>
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<tbody>
<tr>
<td>Age/Weight</td>
<td>( \geq 2 \text{ years old} )</td>
<td>( \geq 5 \text{ years old (13 kg)} )</td>
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<tr>
<td>CPB</td>
<td>+</td>
<td>+/-</td>
</tr>
<tr>
<td>Growth potential</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Exercise tolerance</td>
<td>Similar</td>
<td>Similar</td>
</tr>
<tr>
<td>Arrhythmia</td>
<td>Similar</td>
<td>Similar</td>
</tr>
<tr>
<td>Thrombosis</td>
<td>Low risk</td>
<td>High risk</td>
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<tr>
<td>Effusions</td>
<td>Less prolonged</td>
<td>Prolonged</td>
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<tr>
<td>Early mortality</td>
<td>2%-5%</td>
<td>Similar</td>
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<tr>
<td>20-yr. survival</td>
<td>82%</td>
<td>Similar</td>
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<td>STAGE 1: AT 1 MONTH OF AGE</td>
<td></td>
<td></td>
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<tr>
<td>----------------------------</td>
<td></td>
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<tr>
<td>○ OPTIMISE QP/QS:</td>
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<td></td>
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<tr>
<td>○ BT SHUNT/PA BAND</td>
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<table>
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<th>STAGE 2: AT 4-12 MONTHS</th>
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<tr>
<td>○ OPTIMISE VENTRICULAR VOLUME:</td>
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<tr>
<td>○ BD GLENN/HEMI FONTAN</td>
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<table>
<thead>
<tr>
<th>STAGE 3: AT 1-5 YEARS</th>
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<tr>
<td>○ REDUCE ADMIXTURE &amp; DIRECT FUNCTIONAL VENTRICLE TO SYSTEMIC CIRCUIT</td>
</tr>
<tr>
<td>○ FONTANS</td>
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</table>
Physiology after Fontan repair

The normal cardiovascular circulation
Physiology after Fontan repair

The patient with a univentricular heart
Physiology after Fontan repair

The Fontan Circulation
Preoperative assessment of the Fontan patient

• **directed history:**
  - functional status
  - presence of major complications after Fontan surgery

• **striking reductions in anaerobic threshold** (< 50% of control subjects)
  - VO2 max (< 33% of control subjects)

• patients' self-assessment grossly overestimates their objective exercise capacity.

(Cardiac Anesthesia, Kaplan J., El Sevier, Sixth edition, 2006, pp. 645)
The functional state of Fontan patients falls into two groups:

1. **Majority of patients:**
   - New York Heart Association Class I-II level of function
   - much less cardiorespiratory reserve than age-matched two-ventricle control subjects
   - will tolerate most surgical procedures with an acceptably low risk.

2. **Minority of patients:**
   - manifested one of more of the “failing Fontan” criteria.
   - surgery = greater risk
   - should only be undertaken after careful consultation
Failing Fontan = a marked limitation of functional status.

manifests as combination of

- Refractory arrhythmias
- Protein loosing enteropathy
- Liver dysfunction
- Hypoxemia
- Congestive heart failure

How to deal with Failing Fontan?

- search for correctable lesions
- obstructions within the Fontan pathway → percutaneous techniques of dilation and stenting
- loss of sinus rhythm → pacing
- severe tachyarrhythmias → Fontan conversion surgery
• Aortopulmonary collaterals → progressive volume overload single ventricle.

• Collaterals from the venous system to the systemic atrium or ventricle → hypoxemia.

• If collateral vessels:
  
  o coil occlusion in the catheterization lab.
  
  o creation of a fenestration
    ▪ ↑ cardiac output
    ▪ ↓ lower central venous pressures
    ▪ right-to-left shunt.
Technical investigations

• TTE = initial preoperative investigation
  o Mandatory except for minor surgery
  o Normal ventricular function = “low risk” only in the context of patients with Fontan circulation.

• Further testing is guided by the results of the TTE and in consultation with an cardiologist experienced in CHD.

• CXR: lung disease

• ECG: rhythm

• MRI: pulmonary arterial anatomy and flows, collateral circulation

• Cardiac cath: pulmonary arterial anatomy, PVR
Pregnancy

- Can a Fontan patient cope with increased cardiovascular demands of pregnancy?
  - myocardial oxygen consumption ↑ 20%
  - heart rate ↑ 20%
  - stroke volume ↑ 40%

- Fontan patients are known to have decreased cardiac reserve

- Because pregnancy is a “stress test,” who will pass this test and who will fail?


Pregnancy

Literature provides conflicting data:

• 1 series of 33 pregnancies found women tolerated pregnancy, labor, and delivery well, but there was an increased risk for spontaneous abortion.

• A smaller series found live birth pregnancies complicated by:
  - high rates of NYHA class deterioration
  - atrial arrhythmia
  - thromboembolism
  - prematurity
  - intrauterine growth retardation
Pregnancy

What can be made of these reports? retrospective and self-reporting
provide reassuring information

• pregnancy only in patients with relatively good functional status
  o high infertility rate (21%)

• pregnancy can be successfully carried to term
  o ↑ miscarriage (33%)
  o ↑ premature delivery (70%)

• epidural analgesia is well tolerated and recommended for the first stage of labor
Pregnancy

- Caesarian section rate = 50%
- neuraxial anesthesia for Caesarian section preserves spontaneous ventilation
- no increased risk from general anesthesia was identified
- perioperative complications are low
- peripartum cardiac decompensation is rare
Perioperative management after Fontan repair

**Management principles for patients with Fontan physiology:**

1. **Maintenance of preload.**
   - Avoid a prolonged period without intravenous hydration.
   - ↑ Vascular capacitance in the Fontan patient

2. **Use regional and neuraxial techniques.**
   - Attention to volume status
   - Bad choice if high level of block is required
   - Slowly titrated epidural > spinal anesthetic

3. **Avoid increases in pulmonary vascular resistance**
   - Avoid hypercarbia, hypoxemia, acidosis, stress, pain, high intrathoracic pressures
4. Adequate levels of anesthesia during laryngoscopy.

- ↑ catecholamines ➞ dangerous tachycardia.

5. Spontaneous ventilation if possible.

- ↑ pulmonary blood flow and venous return
- cave: hypercarbia!

6. Treat tachyarrhythmias.

7. Check pacemakers

- Avoid interference electrocautery

8. Invasive monitoring with central lines and transesophageal echocardiography

- Fluid management guided by CVP or TEE
- Assess contractility
9. Anesthetic technique

- Similar to patients with acquired coronary artery disease
- no right drug for these patients
- It is not the drugs used, but rather how they are used

10. postoperative pain management.

- Adequate analgesia improves pulmonary mechanics and oxygenation
- Avoid the effects of hypercapnia secondary to opioids
- Epidural analgesia useful but may not be possible because of anticoagulation

11. Experienced cardiologist should be involved perioperatively
**Ventilatory Management**

- minimize pulmonary vascular resistance, avoid hypercarbia.

- functional residual capacity should be maintained by the application of small amounts of PEEP or CPAP (<6 cm H2O)

- excessive lung volumes should be avoided

- limit peak inspiratory pressure (<20 cmH2O)

- use spontaneous ventilation to
  - minimize intrathoracic pressure
  - encourage forward flow into the pulmonary circulation
Outcome

- Fontan procedure is **palliative**, not curative
- can result in normal or near-normal growth, development, exercise tolerance, and good quality of life.

but

- freedom from morbidity is unlikely in the long term.
- in 20-30% cases patients will eventually require heart transplantation
Survival curves representing the observed outcomes for patients with single ventricle after the Fontan operation.

• While early reports showed improved long-term survival rates, recent modifications have produced even better results.

• Multiple centers have reported greater than 80% survival rates at more than 5 years after Fontan.

• Stamm et al. from Boston Children’s Hospital achieved a 10-year survival of 87%.

• Evolving surgical techniques, improved selection criteria and the ability to perform the operation at younger ages with low early risk have all contributed to improved outcomes.
Overall survival by type of Fontan

- Ap connection
- Lateral tunnel
- Extracardiac conduit
- Other

Follow-Up Time (Year)

<table>
<thead>
<tr>
<th>Type</th>
<th>Count</th>
<th>Follow-Up</th>
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</thead>
<tbody>
<tr>
<td>Ap connection</td>
<td>616</td>
<td>401</td>
</tr>
<tr>
<td>Lateral tunnel</td>
<td>262</td>
<td>167</td>
</tr>
<tr>
<td>Extracardiac conduit</td>
<td>120</td>
<td>45</td>
</tr>
<tr>
<td>Other</td>
<td>54</td>
<td>37</td>
</tr>
</tbody>
</table>

p < 0.001
Significant risk factors for early mortality

- development of postoperative renal failure
- elevated postoperative right atrial pressures: 20 mmHg
- presence of a common atrioventricular valve.

(duration of follow-up in this group was not long enough to identify factors associated with late mortality)

Complications

Short term complications after Fontan

**pleural effusions (25%)**

- fenestration from the venous circulation → atrium

When the pressure in the veins is high, some of the oxygen-poor blood can escape through the fenestration to relieve the pressure.

This results in hypoxia, so the fenestration may eventually need to be closed by an interventional cardiology.

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Long term complications after Fontan

Arrhythmia (10-40%)

- high incidence related to multiple suture lines near the sinus node
  atrial enlargement
  ↑ atrial pressure.

- Loss of atrioventricular synchronisation ➔ ↑ pulmonary venous atrial pressure ➖ ventricular preload

- Poorly tolerated: immediate cardioversion may be necessary
  full anticoagulation
Thromboembolism (30%)

- low flow state
- atrial scarring
- arrhythmias
- dehydration
- hypercoagulable state
Lymphatic abnormalities

- ↑ venous pressure
- ↓ impaired thoracic duct drainage

1. Interstitial pulmonary edema

2. Lymphedema

3. Protein loosing enteropathy (13%)
   - Excessive loss of serum proteins in intestinal lumen with mesenteric vascular inflammation
   - Poor prognosis: 60% 5 year survival, 20% 10 year survival after diagnosis
Lymphatic abnormalities

3. Protein loosing enteropathy (13%)

- **Manifestations:**
  - edema
  - immunodeficiency
  - ascites
  - fat malabsorption
  - hypercoagulopathy
  - hypocalcemia
  - Hypomagnesaemia

- **Treatment:** - diet low in salt, high in calories, protein content and MCT
  - diuretics, CS, heparin, octreotide
  - fenestration, Fontan revision, hearttransplant
Shunts

Left to right

• Aortopulmonary collaterals → volume overload
  high regional pulmonary flow → \( \uparrow \) PVR

Right to left

• Residual shunt through fenestration
• Drainage coronary sinus into systemic circulation → Desaturation
Lymphatic abnormalities

4. Plastic bronchitis (1-2%)

• Non-inflammatory mucinous casts that form in the tracheobronchial tree and obstruct the airway

• Enteric loss of alpha-1-antitrypsin

• Manifestations:
  - Dyspnea
  - Cough
  - Wheezing
  - Expectoration of casts

• Treatment:  - management is difficult: repeat bronchoscopy
  - fenestration, Fontan revision, heart transplant
Diminished exercise tolerance and ventricular dysfunction (70%)

- Volume overloaded ventricle $\rightarrow$ underloaded ventricle
- The deprived ventricle shows signs of systolic and diastolic dysfunction
- Low preload $\rightarrow$ remodeling
  - reduced compliance
  - poor ventricular filling
  - $\downarrow$ cardiac output
- This phenomenon occurs at a chronic preload of less than 70% of the “due” preload

= Progressive “disuse hypofunction”
Sources:

Kaplan Joel, Kaplan’s Cardiac Anesthesia: The Echo Era. Sixth edition.


Fontan, F., 1971, Surgical repair of tricuspid atresia

Gutfried, C., 2003, Ventrikeldimension, Masse und Funktion spät nach Fontan-Operation Quantifizierung durch Magnet Resonanz Tomographie

O’Leary, P.; Prevalence, clinical presentation and natural history of patients with single ventricle, Rochester, MN, USA, El Sevier, 2002


Thank you for your attention!