Emergency interventions in Paediatric Cardiac ICU patients

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Nature of congenital heart disease

Anatomical/structural abnormalities → physiologic derangement → signs & symptoms

- Valvar/vessel obstructions (AS, PS, coarctation) → Pressure overload upstream ventricular hypertrophy, pump failure
- Septal defects (VSD, ASD, PDA) → L → R shunts, volume overload “heart failure” ↑ Pulmonary blood flow, pulmonary hypertension
- Transposition of great vessels → Parallel circulation (systemic venous return pumped back to systemic circulation, pulmonary venous return pumped back to lungs) No gas exchange → cyanosis
- Combined lesions Tetralogy of Fallot, more complex lesion e.g. TGA-VSD-PA, single ventricle → Pressure overload + R → L shunt Cyanosis/cyanosis + heart failure

Surgery is mainstay of treatment → all patients go back to ICU
Simple transposition

- May present with severe hypoxia and acidosis if PFO becomes very small
- Emergency balloon atrial septostomy (BAS) is a life-saving procedure (usually done at beside ICU)
Transposition of great arteries

- 2 parallel circulations
- Survival depends on mixing of blood between the pulmonary circulation of oxygenated blood and systemic deoxygenated blood through the PDA or foramen ovale
- Severe cyanosis develops with closure of PDA and PFO
1. Balloon-tipped catheter introduced into left atrium through patent foramen ovale
2. Balloon inflated
3. Balloon withdrawn producing large septal defect
4. Large septal defect allows mixing of oxygenated and deoxygenated blood
Increasingly complex operation (more complex lesions)
Done at younger age - neonates, infancy, corrective vs palliative

Post-operative problems
- Cardiopulmonary effects of CPB
- Complications of surgery
- Residual problems/suboptimal results
- Unmasking of other lesions
- Arrhythmias
Management of post op problems

- Pharmacological agents- inotropes, vasodilators, pulmonary vasodilators
- Ventilatory manipulations
- Re-operations
- Catheter interventions
- LVAD, ECMO
Catheter interventions in post-op/unoperated PICU patients

- Reduced pulmonary blood flow
  Inadequate /blocked BT shunt by thrombus, kinking
  (Opening of blockage, residual stenosis by balloon dilation)

- Critical valvar obstructions (aortic & pulmonary)
  (Balloon dilation)

- PDA in duct dependent pulmonary circulation
  (PDA stent implantation)

- Left → Right shunt – residual VSDs
  Underestimated/ undiagnosed muscular VSDs Aorto – pulmonary collaterals vessels
  (Closure of residual shunt, collateral vessels)

- High CVP/ Pulmonary resistance, need for ‘pop-off’ valve
  Post - Fontan → low CO
  (Creation/enlargement of “inter-atrial” communication)

- Right → Left shunt thru ‘pop-off’ valve, severe hypoxia
  (Device closure of ASD/PFO)

- Large vessel obstructions – pulmonary artery stenosis, coarctation, Fontan conduit (distortion)
  (Balloon dilation ± stent)
Emergency intervention on PICU patients

- Patients may be critically ill (post op e.g. residual shunts VSD or unoperated e.g. neonatal critical aortic stenosis)
  - Transportation with inotropes, chest drains, nitric oxide, monitors ...

- Vascular access may be limited – occluded or large cannulas in place for drugs and blood products may need special access e.g. carotid artery, axillary artery, internal jugular vein

- Images may be compromised by drains, open chest, drapes & clips

- Temperature control in cold laboratory environment

- Occasionally – need to be done as hybrid procedure (Hybrid lab – surgery + angiography facility)
  - Direct cannulation of cardiac chambers or pulmonary artery (open chest) for better and safer access
**Devices and interventional procedures – all done in catheter lab (fluoroscopy & angiography, haemodynamic monitoring & recording)**

- Plugs and coils, septal occluders – to close septal defects (ASD, VSD), vessels (PDA, aorto-pulmonary collaterals)

- Balloons – stenotic valves (aortic & pulmonary), cutting balloons for very tough and fibrotic lesions, vessels – pulmonary arteries, coarctation of aorta

- Balloons – stents

- Blade catheter to create/enlarge interatrial communication

**Needs to be done in cath lab – high resolution imaging for fluoroscopy & cine-angiography, recorded & for immediate review and for precise anatomic details, measurement haemodynamic monitoring & recording**
**Balloon dilation**

- Role of balloon dilation in PICU patients
  - Unoperated obstructive lesions – critical aortic and pulmonary valves (balloon dilation as primary treatment)

- Operated lesions – coarctation of aorta, branch pulmonary artery stenosis (often with stent implantation)

- Balloon dilation to disrupt thrombus in BT shunt (uncommon – systemic veins, pulmonary vein stenosis)

[Anderson et al, eds Paediatric Cardiology (1st edition 1987)]
RV and LV hypertrophy and poor contractility respectively
Critical pulmonary stenosis

- Very restrictive orifice
- ↓↓ antegrade flow (PDA flow usually essential)
- RVH ++, RV pressure ↑↑, ± RV dilation
- ± tricuspid regurgitation, dilated RA
- R → L shunt via PFO, hypoxia
- ± RV dysfunction

Severe pulmonary stenosis
Fused commissures domed valve

[(Anderson et al, eds Paediatric Cardiology (1st edition 1987)]

Pre balloon dilation
RV 180/16 mmHg
Ao 78/48 mmHg
Critical pulmonary stenosis

Balloon dilation
RF valvotomy (RFV) as alternative to surgical valvotomy

- Immediate haemodynamic and anatomic outcome known
  - RV pressure? adequate decompression?
  - Sub-valve obstruction?
  - Fate of RV-coronary sinusoids?

Pre RF valvotomy + balloon dilation
RV 180/16 mmHg
Ao 78/48 mmHg

Post RF valvotomy + balloon dilation
RV 37/13 mmHg
Ao 56/35 mmHg
3 weeks old, F
2.6 kg
Poor LV function

Post balloon dilation

5 mm coronary balloon
Neonatal coarctation of aorta – limited role of balloon dilation because of high incidence of re-coarctation (occasionally indicated in cases of poor LV function)
Neonatal modified Blalock Taussig shunt: Acute thrombosis can be a major complication

Blalock Taussig shunt
Palliation to ↑ pulmonary blood flow in complex lesions with pulmonary atresia/severe stenosis

Blocked Left BT shunt
Role of stents in obstructive lesions (balloon dilation alone usually not effective)

- Compliant obstruction with recoil characteristics – e.g. branch pulmonary artery stenosis, PDA (ineffective with balloon dilation only)

- External compression

- Kinking or tension on a vessel (after complex repairs and anastomosis e.g. Glenn shunt i.e. SVC to pulmonary artery, pulmonary arterioplasty)

- Contractile, muscular obstruction, RV outflow track in Fallot’s tetralogy
STENTS - metal scaffolding to keep dilated vessels open

1) Pre-loaded stent
2) Inflation begins
3) Sleeves release stent
4) Catheter is withdrawn
Stenting on right pulmonary artery

Post repair Tetralogy of Fallot
Right pulmonary artery stenosis at the insertion of Blalock-Taussig shunt
6 years male (Wt: 10 kg)

TOF, pulmonary atresia
Repair with conduit, severe LPA stenosis (severe heart failure, ICU)

Percutaneous stenting aborted – haemodynamic compromise

Stenting later performed in hybrid suite
6 years male (Wt: 10 kg)
TOF, pulmonary atresia
Repair with conduit, severe LPA stenosis
(severe heart failure, ICU)

Percutaneous stenting aborted – haemodynamic compromise

LPA stenting performed in hybrid suite
Role of stents – PDA stent as alternative to BT shunt

- PDA stent as additional source of pulmonary blood flow
  - PAIVS (critical PS), post balloon dilation
  - RVH ++, small RV cavity
  - ↓↓ compliance – R → L shunt at PFO → cyanosis, ↓ antegrade flow to PA

- PDA morphology – stent friendly
  - Origin from descending aorta, relatively short, straight course, usually no LPA stenosis
**RV outflow track stenting in Tetralogy of Fallot with severe cyanotic spells (severe RV outflow obstruction)**

TOF with cyanotic spell  
Severe infundibular stenosis, small pulmonary valve annulus, small pulmonary arteries

4 mm coronary stent, over 5F guiding JR catheter

6 months post stenting (pre-op angiogram)
Closure of defects/shunts in PICU patients

- Usually in post-op patients
  - Left → right
    - Residual pre-operational undiagnosed additional VSD
    - Aorto-pulmonary collateral vessels (haemodynamic effect as in PDA)
  - Right → shunt
    - Following complex rehabilitation of small RV (patients with pulmonary atresia with intact septum)
    - RV size remains borderline, RV compliance remains high, R → L shunt through ASD/PFO
Muscular VSD (rim of defect is completely muscular)
More complex lesions subjected to surgical repair

Likelihood of residual lesions (early post op) and late problems
- Residual or undiagnosed VSD (usually apical, muscular)

Some of these problems are best managed by catheter intervention e.g. muscular apical VSD

TGA, VSD, PS
Residual VSD post repair
Transcatheter device closure of residual VSD
Intraoperative perventricular closure of muscular VSD

Hybrid procedure – perventricular closure of VSD
13 mth old, 5.9 kg, mVSD, severe cardiac failure

12 mm AMVO implanted per ventricular
• Closure of interatrial communication (PFO/ASD) in patient with borderline size and hypertrophied RV following radical surgery to enlarge RV cavity (patient with pulmonary atresia with intact ventricular septum, multiple previous procedures. Cyanosis due to R → L shunt thru ASD)
Summary

Role of catheter interventions for critically ill patients in PICU

Advances in interventional techniques and devices: balloons, stents and closure device

- Unoperated patients – TGA, critical valvar stenosis, severe coarctation, duct-dependent cyanotic heart disease

- Post op patients:
  - Residual/undiagnosed additional VSDs
  - Severe obstruction of branch pulmonary artery, Fontan pathway
  - Right → left shunt (cyanosis) in patients with small/borderline RV
  - Post Fontan (for single ventricle) with high pulmonary artery pressure & inadequate “inter-atrial” communication

- Vast majority require to be done in catheterization laboratory (need for x-ray angiographic equipment and haemodynamic monitoring)

- Occasionally procedures are done in hybrid lab (combined surgery + angiogram)
Complications of intervention

- Haemodynamic compromise – ↓↓ BP and heart rate during intracardiac manipulation of catheters, guidewires, balloons and other devices
- Arrhythmias
- Blood loss
- Injury to cardiac structures – valves, vessels, chamber walls
- Migration of implanted stents, closure devices
Thank you