Stenting of pulmonary arteries

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Pulmonary artery stenosis

- Congenital:
  - hypoplasia of pulmonary arteries
  - small branches underdeveloped
  - supravalvar pulmonary stenosis
  - multiple stenosis
  - circumscribed stenosis
- Association with other CHD
  - (tetralogy of Fallot - >10% duct related LPA stenosis)
  - Pulmonary atresia/VSD: high incidence of almost 70% PA stenoses
  - Single ventricle anatomy
- Syndromes - (Williams, Noonan, Allagille, Ehlers Danlos syndrome): natural PA stenoses (multiple & peripheral)
Pulmonary artery stenosis

- Acquired in patients after surgery:
  - Blalock-Taussig shunts
  - PA band
  - Small PA branches
  - Tetralogy of Fallot repair
  - Pulmonary atresia/VSD repair
  - Common arterial trunk repair
  - Glenn shunt
  - Arterial switch
  - RV to PA conduit insertion

Indications for intervention

- Symptoms are not a good indicator as patients may be asymptomatic
- RV systolic pressure $\geq$ 50% systemic in bilateral stenoses or
- Lung perfusion to ipsilateral lung <20% in unilateral stenosis
- If pulmonary regurgitation present, or Alagille’s syndrome, criteria less rigid
Treatment of branch PA stenosis
- Technical options

- Balloon dilation
  - High pressure
  - Cutting balloon
- Stent placement

Balloon Pulmonary Angioplasty

Success: Variable results 38 - 72% with low and high pressure balloons

Complications in:
- Mortality: 0.8 – 2.8 %
- Severe PA trauma: 0 - 2%
- Aneurysm: up to 4 %
- Transient pulmonary oedema: 3-14%
- Restenosis: 0-35 %
Cutting balloon for resistant PA stenosis

Reasons for PA stenting

- Early postoperative PA stenosis
- Kinking and tenting of branch PA usually after previous surgery
- External compression
- Elastic recoil after balloon dilation
- Intimal tear after balloon dilation
- Recanalization of a totally occluded vessel
- Surgical scar related (after Blalock-Taussig shunt)
- Conduit-related stenosis: stenting may delay the timing of conduit replacement
Kinked and tortuous branch PAs

BT shunt related branch PA stenosis

Pulmonary artery stents

- In infancy, as a bridge to later conduit replacement eg common arterial trunk
- In older patients to treat native and post-surgical lesions
  - PG1910 stents can be implanted in proximal branch PAs of SMALL infants
  - Can be dilated to 15-18 mm
  - Can be implanted in infants of >5Kg
Angiographic views

- Conduit stenosis: Lateral
- RPA stenosis: AP or RAO 20-30 deg
- LPA origin stenosis: Steep LAO
- Bifurcation stenosis: AP cranial or steep LAO caudal

Technique: stent implantation

- Haemodynamic + angiographic assessment
  - Diameter + length of stenosis
  - Diameter normal adjacent vessel
- Terumo wire for initial crossing of lesion
- Long, stiff wire, as distal as possible
- Long sheath recommended:
  - Stable position
  - Facilitate balloon + stent delivery
  - Easy exchange of catheters/balloons
  - Angiographic + haemodynamic evaluation post implant
Equipment needed

• Guidewires:
  – Terumo (0.035" or 0.018") 260 cm guidewire to cross the branch PA
  – Exchanged with a Amplatz super-stiff 0.035" 260 cm guidewire

• Sheaths:
  – Mullins sheath of different profiles (must be shorter than balloon shaft length)
  – Braided sheaths to avoid kinking: Cook Flexor or Arrowflex, Cook Shuttle sheath

• Stents:
  – Stents that can be expanded later to adult size
  – Usually, Cordis Genesis10 series for PAs e.g 1910, 2910, 3910
  – Handcrimped over the balloon
  – Premounted stents (Cordis Genesis or ev3 Visipro) rarely used in small infants
  – Other stents such as Cheatham-Platinum, Andrastent, Intrastent LD Mega or Max can be used also

• Balloons:
  – Cordis OptaPro or Maxi LD (14-25mm), Cristal balloons
  – BIB balloons preferred in older children
  – Non-compliant balloons: Bard Conquest or Powerflex (7-12mm) or high pressure Atlas or Mullins(10-25mm)
Stents

- Palmaz
- Premounted Genesis
- Covered CP stent
- Intrastent

Tips

- If stent does not crimp well, use BIB balloon or partially inflate and then deflate the balloon
- Balloon/stent assembly should not be passed without a sheath
- For bilateral origin stenoses, bilateral simultaneous stenting is important
  - RFV for RPA and LFV for LPA
- If the stenoses are distal, sequential stenting
Pulmonary artery stents

Technique

- Angiography to define the lesion and the best projection
- Good distal stiff guidewire position (lower lobe preferred)
- Take time to obtain a good wire position and avoid losing this
- Place long sheath in IVC/RA junction or distal to stenosis
- Advance stent/balloon assembly up to sheath radio-opaque marker
- Advance sheath/balloon/stent as one unit over guidewire until correct position
- Check angiography through side-arm of sheath
- Use inflation device to inflate balloon

Stent implantation for pulmonary artery stenosis

Technique

*Stent/balloon/sheath assembly advanced through right heart*
Stent implantation for pulmonary artery stenosis

Multiple angiograms for positioning

Stent implantation for pulmonary artery stenosis

Check angiography after inner BIB inflation
Stent implantation for pulmonary artery stenosis

Atlas balloon – for high pressure

Origin of RULPA covered by stent

Inflation through open cells

Intrastent LD Max
Stent implantation for pulmonary artery stenosis

For bilateral origin stenosis, simultaneous bilateral PA stent implantation

Inflate both balloons simultaneously
Branch PA stenosis post arterial switch

Premounted Genesis stent used
Long term size is an issue

Branch PA stenosis post arterial switch

Premounted Genesis stent used
Infant with hypoplastic left heart syndrome

*B-T shunt and LPA stenosis*
*Premounted Genesis stents implanted in LPA*

Complications of stents in pulmonary arteries

- Death
- Rupture of vessel
- Stent thrombosis
- Stent dislocation
- Balloon rupture
- Dissection of vessel
- Aneurysm formation
- Stent fracture
- Intimal proliferation
Stent slipping off balloon

Stent migration

*Never lose guidewire position!*
Balloon rupture & stent migration

Stent migration
Never lose wire position
Place stent in alternative position
NB: use of tip deflector
**Intimal proliferation in a stent**

- Post switch LPA stent – 7 years before
- Now intimal proliferation treated with a covered atrium stent

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**Unusual complication**

- Arterial switch → LPA stenosis >>> balloon dilation of LPA → developed aorto-pulmonary fistula

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*Courtesy: Aphrodite Tzifa, Athens*
Unusual complication

- Arterial switch → LPA stenosis >>> balloon dilation of LPA → developed aorto-pulmonary fistula
- Treated with covered CP stent

*Courtesy: Aphrodite Tzifa, Athens*
Complications: how to avoid

• Vessel rupture
  – Avoid using too large a balloon for distal vessel
  – Supply of covered stents
  – Surgical help

• Occlusion of side branch possible:
  – Use open cell stent
  – Then dilate the cells covering the origin of the vessel

Stenting of pulmonary arteries

• When implanting stents in infants, premounted stents have advantages:
  – Lower profile
  – Can be manoeuvred more easily around bends
  – Less likely to slip off the balloon

• Disadvantages:
  – Stent has limitations of expansion

• Should only use stents in infants when they are likely to be removed by surgeons at a later date

• In older children, stents are treatment of choice for PA branch stenosis. They can be redilated