History

- 1951: Pulmonary artery banding (Muller & Dammann)
- 1954: Series of transatrial repair of VSD (Stirling)
- 1957: First VSD closure using cross-circulation (Lillehei)
- 1961: First VSD repair in infants (Kirklin)
- 1969: Deep hypothermic circulatory arrest for VSD (Okamoto)
- 1976: DHCA popularised (Barratt-Boyes)

Today
Indications

1. **Symptomatic infants**
   - Failure to thrive
   - Recurrent chest infection
   - Congestive heart failure

   **Operate as soon as medical treatment fails**

2. **Asymptomatic children**
   - PA pressure $\uparrow$ (<50% systemic pressure)
   - Qp:Qs $> 2.0$
   - PVR $\uparrow$

   **Operate soon electively**

3. **Development of aortic valve prolapse and / or aortic insufficiency**

   **Operate electively**
Contraindication

Eisenmenger Syndrome

- Predominant right-to-left shunt
- PVR:SVR > 0.5
- PVR > 8 Wood units/m² (640 dyn·s/cm⁵)

If PVR study shows a good response to pulmonary vasodilators, some may be apt for surgery after a period of medical therapy.
Surgical Treatment - Overview

- Palliative - Pulmonary artery banding
- Corrective -
  - Open heart surgery
  - Transcatheter device closure
Surgical Treatment
- Palliation

Pulmonary artery banding

- Previously employed as a two-stage strategy
- It is now usually reserved for

1. Multiple VSDs
2. Poor general condition for early corrective repair
Surgical Treatment
- Pulmonary Artery Banding

1. Possible compression on the aorta
2. Left atrial appendage
3. Ensure RPA is above the band
4. Keep enough distance from bifurcation
5. Keep enough distance from pulmonary valve and fix the band securely
Surgical Treatment
- Degree of PA banding

• Minimal handling to PA
• Keep FiO₂: 21~25%, pCO₂: 30~40mmHg

• Trusler’s number: 20mm + body weight (kg) for VSD
• Tighten the band till saturation drops to low 90s.

• Check ABG and distal pressure
• Check position and pressure gradient by echocardiogram

Aim is
1. PA pressure $< \frac{1}{2}$ systemic pressure or $<40$mmHg
2. Band should not disturb pulmonary valve or bifurcation
3. Slightly “underband”

Key is “Patience”
Surgical Treatment
- Types of PA band

1. Standard PA band - Silicon coated Teflon tape, cotton tape, silk ligature

2. Dilatatable PA band - Ligaclip to secure,
   so that balloon catheter will snap the PA band

3. Adjustable PA band - FloWatch-PAB®
Surgical Treatment
- Complication of PA banding

• There are reports of the band cutting through MPA

• Migration of PA band
  - to distal: Branch PA stenosis, thrombosis
  - to proximal: Destruction of pulmonary valve

• Worsening of TR and MR

• Band infection → aneurysm, airway compression

• Closure of VSD by septal hypertrophy

• Cardiac arrest due to tight PA band + PH crisis
Surgical Treatment
- Debanding

a. Shelf resection and horizontal suture – only for large PA
b. Anterior patch augmentation – applicable in most cases
c. End-to-end anastomosis – usually suture line is close to PV or bifurcation

Surgical Treatment – Corrective Repair

• Majority of VSD patients undergo corrective repair in the current era

• Corrective repair -
  - Surgical VSD closure
  - Transcatheter device closure
Surgical Treatment
- VSD Closure

Avoid:

- Conduction
- Damaging or disturbing tricuspid / pulmonary valve
- Damaging aortic valve behind
- Taking chordae
- Leak
Surgical Treatment
- VSD closure: Perimembranous VSD

1. Aortic valve
2. Possible leak – disguising fibrous tissue
3. Possible leak – restricted view
4. Conduction
5. Chordae

Surgical Treatment
- VSD closure: Doubly-committed juxta-arterial VSD

1. Pulmonary valve
2. Aortic valve – belly is below the commissure
3. Possible leak - restricted view
4. Chordae

Surgical Treatment
- VSD closure: Trabecular Muscular VSD

1. Watch out LAD
2. Confirm no more VSD at anterior wall

Surgical Treatment
- VSD closure: Trabecular Apical VSD

1. Stay on the left side of LAD
2. Should be able to see VSD rim

Special Consideration

- Anteriorly malaligned VSD
  - Commonly seen in TOF
  - Possible RVOTO

- Posteriorly malaligned VSD
  - Associated with aortic arch malformation
  - Possible LVOTO

Short-Term Mortality

- In current era, almost 0%
- Hence, the focus is to reduce the morbidities
- Swiss-cheese type still carries high mortality
Long-Term Mortality

**Menting ME, et al. The unnatural history of the ventricular septal defect: outcome up to 40 years after surgical closure. JACC 2015;665(18):1941-1951**
Short-Term Morbidities

- Residual shunt < 1%, thanks to TEE
- Pulmonary hypertensive crisis in infants
- Tricuspid valve regurgitation
- Pulmonary regurgitation
- Aortic regurgitation
- Arrhythmias, especially in infants
- Complete heart block < 1%
Indication and Timing for Residual VSD

- Qp/Qs > 1.5
- VSD ≥ 3mm for infants (drop out, not colour Doppler)
- VSD ≥ 1/3 Aorta
- Volume loading to LA & LV

When?
- immediately
- more than 1 month later: well-demarcated
Long-Term Morbidities

Menting ME, et al. The unnatural history of the ventricular septal defect: outcome up to 40 years after surgical closure. JACC 2015;665(18):1941-1951

A cohort of 174 consecutive patients who underwent surgical closure of a ventricular septal defect (VSD) between 1968 and 1980 were examined. The surgical characteristics and the findings on clinical outcome up to 40 years are depicted in this figure. NT-proBNP = N-terminal pro-B-type natriuretic peptide.
Transcatheter approach

- Applicable for muscular VSD
- Still controversial for perimembranous VSD
- Hybrid approach
Conclusion

• The risk of mortality including those with pulmonary hypertension is <1%.

• Over 96% of patients have excellent outcomes without major complications
Further Reading

1. Chen JM, Mosca RS. Surgical management of ventricular septal defects. Progress in Pediatric Cardiology 2001;14:187-197


Thank you!