“Failure to drain” – Inadequate Venous Drainage
Sean Clingan, MS, CCP
Cincinnati Children’s Hospital Medical Center

Pediatric Venous Cannula selection

- Important considerations
  - Anatomy of patient
  - Size of patient
  - Anticipated blood volume
  - Cannulation site
  - Vessel sizes
  - Vessel/structural abnormalities
  - Proposed procedure
  - Defect to be repaired
  - Previous surgical procedures

Potential Effects of Inadequate Venous Return

- Failure to establish cardiopulmonary bypass (CPB)
- Increased central venous pressure
  - Heart distention
- Hypotension
  - Due to inability to maintain adequate flow
- If prolonged – venous congestion
Potential Causes – Non-Anatomical

- Air-lock in venous line
- Manual lifting of the heart
- Too small of venous cannulae
- Kinked venous line
- Misplaced vena caval tourniquet

Potential Causes – Non-Anatomical

- Misplaced or entrapped cannula
- SVC cannula misplaced in azygos vein
- IVC cannula misplaced in hepatic vein(s)
- Cannula manufacturing defect

Potential Causes – Anatomical

- Undiagnosed:
  - Left SVC
  - Anomalous venous return
  - Interrupted IVC with azygous extension
  - Hepatic veins entering right/left atrium directly
  - Arterial to venous shunt
  - PDA

Potential Causes – Anatomical

- Uncontrolled systemic to pulmonary shunts
- Persistent LSVC to coronary sinus without innominate vein
- LSVC to left atrium with innominate but hypoplastic right SVC
- Left atrial isomerism with interrupted IVC and azygous continuation
- Left atrial isomerism with abdominal situs inversus
Preventative Measures\textsuperscript{3,5}

- Thorough Trans-esophageal ECHO (TEE) prior to surgery and/or cath if necessary
- Monitor CVP to detect potential build-up once cannula(e) placed
- Utilize vacuum assisted venous drainage to augment return if appropriate
- Monitor cerebral oximetry

Preventative Measures\textsuperscript{3,5}

- Train all sterile field personnel to scan for venous line obstruction
- Utilize venous line flow probe
- Construct plan ahead of time for best drainage if complex anatomy is known

Unknown Anatomical Abnormality

- Before bypass:
  - Construct a plan to cannulate based on new knowledge
  - Plan to cool further to allow for potential need for lower flows

Unknown Anatomical Abnormality

- Bypass established
  - Institute VAVD and determine any improvement
  - Reassess cannula size for vessels
  - If caval cannulation is inadequate, re-establish CPB with atrial cannulation
Unknown Anatomical Abnormality

- Bypass established
  - Add additional cannulae and connectors as situation warrants
  - If still no resolve – open atrium and establish sucker bypass
  - Last resort
  - Cool to lower temperature to allow for lower flows
    - Doesn’t fix problem necessarily

Case Report

Patient Profile

- 1 month old male born at 33 weeks with failure to wean respiratory support
- 2.73 kg
- 45.5 cm
- 0.18 m²
- NKDA
- Diagnosis:
  - Secundum ASD
  - Perimembranous VSD
  - Pulmonary venous stenosis

Prebypass Labs and Vitals

- pH: 7.488
- pCO₂: 37.9 mmHg
- PO₂: 79.2 mmHg
- Hct: 38.7 %
- Lac: 0.9
- All electrolytes and other lab values were normal

- HR: 140-160s
- MAP: 40-60s
Surgical Plan
- Aorta and Bi-caval cannulation
- Cool to 26˚C
- X-clamp – give Del-Nido cardioplegia
- Caval snare
- Right atriotomy
  - Vent through ASD
  - Pulmonary vein repair
  - VSD repair
  - ASD
- De-air through aortic root
- X-clamp off and rewarm
- Close right atrium
- Wean bypass
- MUF

Cannulation Plan
- Aorta – 8 Fr Maquet arterial cannula
- SVC – 10 Fr Edwards plastic right angle
- IVC – 12 Fr Medtronic metal right angle

Perfusion Plan
- Alpha-stat blood gas management
- On bypass Hct of 28 %
- Off bypass post MUF Hct of >30 %
- DUF entire case
- Target Flow 420 ml/min (2.4 CI)

TEE Findings
- TEE confirmed diagnosis of:
  - Secundum ASD
  - Perimembranous VSD
  - Right upper and lower pulmonary vein stenosis
  - Flow acceleration as they enter left atrium
  - Mean gradient of 6-7 mmHg
  - No mention of hepatic veins into RA or IVC issues
Bypass Sequence Of Events

- Initiated bypass with SVC cannula in SVC and IVC cannula placed in right atrium
- Bypass initiated without issue and drainage was appropriate
- Began DUF
- Began cooling to 26°C
- PDA snared

Bypass Sequence Of Events

- Surgeon attempted to flip IVC cannula into IVC
  - Immediately lost significant venous drainage
  - Pulled back on cannula while perfusion applied VAVD (~24 mmHg)
  - No significant aid to drainage
  - Put back in RA for a moment

Bypass Sequence Of Events

- Re-checked to make sure IVC cannula was appropriate
  - Even though cannula was appropriately sized it was decided to down size to a 10 Fr
- Stopped cooling – was 33°C at this point
  - Low flow while removing IVC cannula from RA and replacing with new cannula
  - Off bypass for few seconds to disconnect old cannula and connect new IVC cannula

Bypass Sequence Of Events

- Re-initiated bypass with IVC cannula (now 10Fr Right angle) again in RA
  - Once full flow tried to manipulate IVC cannula into IVC but would not go without losing almost all venous drainage.
  - Again attempted to apply VAVD (~ -25 mmHg)
Bypass Sequence Of Events

- Surgeon could not manipulate IVC cannula to allow for adequate venous drainage without being in RA
- Surgeon requested to cool to 18°C for possible circulatory arrest
  - Began pH-stat blood gas management
  - Ice placed on patient head

Bypass Sequence Of Events

- Noted 3 very small hepatic veins draining directly into RA with no true IVC
  - None of which were large enough to cannulate.
- Surgeon requested circulatory arrest and performed entire repair
- ASD, VSD, and pulmonary vein stenosis repaired under circulatory arrest

Bypass Sequence Of Events

- After 74 min circulatory arrest, bypass resumed and X-clamp removed
- Rewarmed to 36°C
- Weaned bypass
- MUF
- TEE confirmation of good repair
Post-bypass Labs and Vitals
- pH: 7.36
- pCO\(_2\): 45.3 mmHg
- PO\(_2\): 213 mmHg
- Hct: 34.2 %
- Lac: 5.5
- Base: 0.1 mmol/L
- All electrolytes and other lab values were normal

Post-operative period
- Uneventful ICU stay
- Extubated 3 days post-operatively
- Discharged home 3 weeks after surgery
  - Feeding issues was main hurdle

Bypass times
- CPB: 86 min
- X-Clamp: 85 min
- Circ Arrest: 74 min

Readmission
- Readmitted 4 months after initial surgery due to recurrent right pulmonary vein stenosis
- Repaired on bypass but had a plan for known (now) issue
  - Went on with single atrial cannula and planned for circulatory arrest.
  - Uneventful CPB run
    - 55 min circulatory arrest period
- Extubated 3 days later
- Discharged home after 7 days
Outcome and Improvement

- Outcome resulted in patient doing well and being discharged home without issue.
- TEE and/or pre-operative cath procedure are the only ways anatomy could have presented itself.
  - Surgeon said on the outside it looked like a single vessel but inside had 3 separate hepatic vein lumens.

Outcome and Improvement

- Knowing the anatomy would not have changed the overall need for circulatory arrest or our eventual plan.
  - Would have allowed for a plan pre-operatively.
  - Maybe would have done ACP knowing the entire repair would need to be done under circ arrest.
  - Would have shortened the first CPB run.
  - Due to all the time spent on manipulating cannulas and making a plan on the fly.

Thank you

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References

5. Grist, G. CPB FMEA #32: Inadequate venous return caused by abnormal anatomy. The AmSCEnt safety committee.