Perfusion emergencies

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Contents

- **Air embolism**
- **Obstruction to venous return**
- **Malposition of arterial cannulae**
- **Carotid or innominate artery hyperperfusion**
- **Reversed Cannulation**
- **High aortic line pressures**
- **Oxygen supply failure**
- **Pump failure**
- **Runaway pump**
- **Water leak into Oxygenator**
- **Oxygenator failure**
- **Clotted oxygenator or circuit**

Air embolism/aetiology

1) Oxygenator related

- a) Break in integrity of connections
- b) Detachment of oxygenator from holder
- c) Non venting of oxygenator eg occluded gas port
- d) Bumping of oxygenator during operation

- 2) Pump related
- a) Runaway arterial pump
- b) Reversal of main pump
- c) Reversal of vent pump
- d) Cardioplegia pump flow rate exceeds arterial pump flow rate
- e) Pump boot rupture
- f) Inappropriate venting
- i) Aortic root venting with open left atrium/ventricles
- ii) Cardiac venting while aortic arch is opened (without aortic X-clamp)

Air embolism/aetiology

4)Venous reservoir related

- a) Inattention to level
- b) Failure of level sensing devices/ air sensing devices
- 4) Cardiotomy related
- a) Production of positive pressure at the input to the reservoir with air forced retrogradely up purge lines/ impair venous drainage
- i) High vent/cardiotomy flow rates
- ii) Plugging of filters due to clotting

- 5) Surgical
- a) Reversal of cannula
- b) Insertion of left ventricular vents
- c) Open heart procedures
- d) Unexpected resumption of heart beat
- (1) Eg mitral valve surgery on fibrillating heart without X-clamp

- ***Prevention***
- 1) Adherence to checklist
- 2) Attention to venous level
- 3) Attention to pump flows
- 4) Adequate heparinisation

- ***Diagnosis***
- 1) Visual presence of bubbles in circuit
- 2) Air emboli detector activation
- 3) Raised S-T segments, poor cardiac output, dysrhythmias

Management of massive systemic air embolism

a) Stop CPB

- b) Place patient in steep Trendelenburg's position [*Head down*]
- c) Clamp venous line & open recirculation line - allow bubbles in arterial line to passively retrogradely drain by gravity [several hundred mls max]
- d) Reprime pump circuitry
  - i) **Small quantity bubbles in arterial line**
  - (1) Surgeon removes A-line/cannula, flush blood
  - ii) **Large quantity bubbles in circuit**
  - (1) Surgeon joins a-line to v-line, recirculate/prime circuit
- e) Reestablish antegrade CPB
- f) Hypothermia 20°C
  - i) Increased gas bubble solubility
  - ii) Minimise organ damage due to hypoperfusion while bubbles are being resorbed by increased gas solubility
- g) Induce hypertension
  - i) Vasoconstrictors
  - ii) Hydrostatic pressure shrinks bubbles
- h) Express coronary air by massage & needle venting
- i) Drugs?
  - i) Steroids
  - ii) Mannitol
  - iii) Barbiturate coma (especially if embolism occurred while normothermic)
- j) Perfuse for 45 min
- k) Wean from CPB
- l) Continue ventilating with 100% O2 for at least 6 hours to displace N2

Management of massive systemic air embolism

- m) Options:
- i) **Retrograde cerebral perfusion**
- (a) Options
- (i) **Connect arterial line to SVC cannula with tourniquet**
- 1. Perfuse 20°C blood at 1 l/min into SVC
- 2. Measure cerebral pressure from IJ (< 25 mm Hg)
- (ii) **Coronary sinus cannula in SVC (preferable)**
- 1. Perfuse 20°C blood at 600 ml/min via coronary sinus
- 2. Measure cerebral pressure from IJ or coronary sinus (< 25 mm Hg)
- (b) 100% O2
- (c) Air + blood drains from the aortic cannula hole in aortic root
- (d) Carotid compression is performed intermittently to retrogradely purge vertebral arteries
- (e) Continue for 1-2 minutes after air is seen exiting aorta (usually < 5 min total)
- ii) **Retrograde IVC perfusion**
- (1) Rarely done
- (2) Performed after SVC perfusion
- (3) To prevent reembolisation of brain:
  - (a) Carotid arteries are clamped
- (4) Continue for 1-2 minutes after air is seen exiting aorta (approx < 5 min total)
- iii) **?Hyperbaric chamber**
  - (1) Good results
  - (2) Difficult to organise

Management of Localised myocardial air embolism

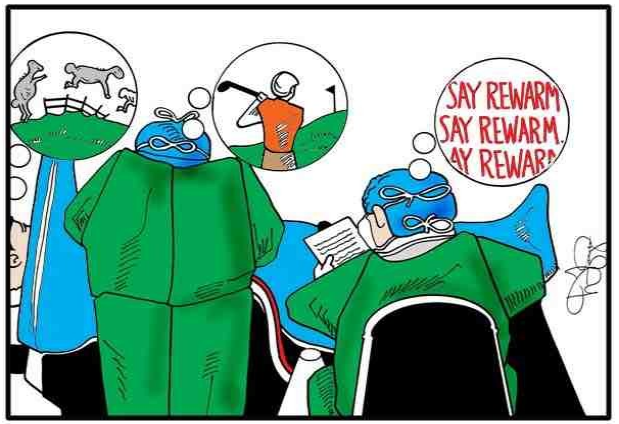
- a) **During X-clamping**
- i) Surgeon initiated cardiac deairing techniques (needle aspiration, ballotment etc)
- ii) Appropriate venting
- iii) Retrograde cardioplegia
- b) **Post removal X-clamp**
- i) Dissipate bubbles
  - (1) Raised coronary perfusion pressures
  - (2) 100% oxygen
  - (3) Hypothermia usually not applicable
- ii) Reduce ischaemia
  - (1) Raised coronary perfusion pressures
  - (2) Minimal ventricular distention
  - (3) Sinus rhythm
  - (4) Minimal inotropes (increases myocardial workload)
- iii) Anticipate inotropes, pacing, IABP to wean

OBSTRUCTION TO VENOUS RETURN

1) Air Lock -*Presence of large air bubbles in venous line producing an airlock*

- · ***Aetiology***
- 1) Air enters venous line via cannula in right atrium
  - a) Coronary sinus cannulae
  - b) Venous cannula
- 2) Excessive exsanguination (eg during circulatory arrest)
- · ***Prevention***
- 1) Maintain adequate right atrial filling during insertion right atrial cannula
- · ***Diagnosis***
- 1) Rapidly falling venous reservoir level
- · ***Management***
- 1) Source of air entry must be closed
- 2) 'Milk' air into reservoir
- 3) Temporarily reduce pump flow rate, add fluid to reservoir

OBSTRUCTION TO VENOUS RETURN



2) Mechanical

- · ***Aetiology***
- 1) Lifting heart impairs venous drainage
- 2) Kinked venous cannulae
- 3) Malpositioned venous cannula
- 4) Too small venous cannula
- 5) Presence of thrombus or tumour
- · ***Prevention***
- 1) Observe for high regional venous pressures
- 2) Adequate heparinisation
- · ***Diagnosis***
- 1) Rapidly falling venous reservoir level
- 2) Increased CVP (note if CVP monitored within RA may still remain low)
- Note: Difficult to ascertain an IVC obstruction
- · ***Management***
- 1) Reduce pump flow until cause identified

MALPOSITION OF ARTERIAL CANNULAE

- **Aortic dissection (or femoral dissection)**
- · ***Aetiology***
- 1. Cannula orifice is located within aortic wall not lumen
- · ***Prevention***
- 1. Degree of damage ie extension of false lumen can be minimised by diagnosing problem before commencing CPB
- 2. Monitor for pulsatile waveform of a mean pressure correlating with radial line (after correcting for height difference between CPB & patient)
- · ***Diagnosis***
- 1. Inappropriate high arterial line pressures
- 2. Inappropriate very low radial pressures
- 3. Loss of volume
- 4. TOE
- 5. Organ hypoperfusion (pupil dilation, anuria)
- · ***Management***
- 1. Discontinue CPB
- 2. Surgical reposition of cannulae
- 3. Surgical repair of aorta
- · ***Complications of aortic dissection***
- 1. Global hypoperfusion
- 2. Occlusion origin of arteries from aorta 3. Occlusion of aorta
- 4. Aortic rupture 5. Aortic regurgitation

Carotid or innominate artery hyperperfusion

- . ***Aetiology***
- 1. Preferential direction of perfusion into brachiocephali artery
- . ***Prevention***
- 1. Surgical vigilance
- 2. Use of short aortic cannula with flange
- . ***Diagnosis***
- 1. Ipsilateral
  - a)Blanching of face (not seen if blood in prime)
  - b)Pupil dilation
  - c) Conjunctival oedema
- 2. Low left radial BP
- 3. Low femoral BP
- 4. High right radial BP (if innominate hyperperfused)
- . ***Management***
- 1. Reposition aortic cannulae
- 2. Reduce cerebral oedema (mannitol; head up)
- . ***Complications***
- 1. Cerebral oedema
- 2. Arterial rupture



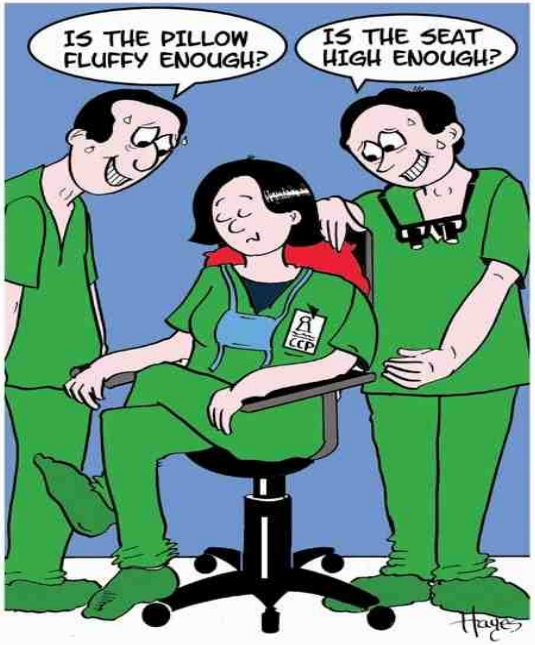
So much for the "Captain of the ship' philosophy.

Reversed Cannulation

- · ***Aetiology***
- 1. Blood is drained from aorta
- 2. Blood is pumped into vena cava
- · ***Prevention***
- 1. Monitor for pulsatile waveform of a mean pressure correlating with radial line
- · ***Diagnosis***
- 1. Severe arterial hypotension
- 2. High CVP
- 3. Facial oedema
- · ***Management***
- 1. Discontinue CPB
- 2. Place patient in steep Trendelenburg's
- 3. Disconnect cannulae & observe for air (if air is present follow gas embolism protocol)
- 4. Resume CPB
- 5. Consider mannitol, steroids, barbiturates to reduce cerebral oedema
- · ***Complications***
- 1. High venous pressures may rupture veins
- 2. Bubble formation in aorta which may be reinfused when problem is corrected

High aortic line pressures

- . ***Aetiology***
- 1. Cannulae lumen against wall of aorta
- 2. Long thin cannulae
- 3. Small lumen cannulae
- . ***Prevention***
- 1. Monitor for pulsatile waveform of a mean pressure correlating with radial line
- 2. Use as large an orifice as possible
- 3. Avoid long narrow cannulae
- . ***Diagnosis***
- 1. High aortic line pressures
- . ***Management***
- 1. Reposition cannula
- 2. Replace cannula
- . ***Complications***
- 1. Hypoperfusion
- 2. Haemolysis
- 3. ‘Sand blasting” effect of artery intima



Oxygen supply failure

- . ***Aetiology***
- 1. Inadequate gas flow
- 2. Hypoxic gas mixture
- 3. Leaks in O2 supply line
- . ***Prevention***
- 1. Use of O2 analyser on gas inflow line
- 2. Observe rise of flowmeter bobbin
- 3. Ensure tightness of fit in all fresh gas delivery components
- 4. Observe fall and then brisk rise of bobbin when momentarily clamping fresh gas supply line
- 5. Feel hot oxygenator effluent gas
- 6. Effluent gas (CO2) monitoring
- . ***Diagnosis***
- 1. Dark blood in arterial line (same colour as venous)
- 2. Dropping SvO2
- 3. Blood gases
- 4. Severe vasodilation
- . ***Management***
- 1. Connect portable O2 tank to oxygenator
- 2. Urgently contact maintenance engineers and medical gas fitters
- 3. Exhale down gas inflow line
- 4. Cool patient maximally

Pump failure

- ***Aetiology***
- 1. Electrical failure
- 2. Mechanical failure
- 3. Runaway pump
- ***Diagnosis***
- 1. Pump unresponsive to RPM control
- ***Management***
- 1. The patient should be maintained in one of the following states
  - a) Normothermic with cardiac output and ventilation
  - b) Enough volume in patient to enable internal cardiac massage and ventilation
  - c) Deep hypothermic arrest
- 2. If pump stops — isolate source of power loss:
- 3. Pump module failure:
  - a) Clamp patient off CPB
  - b) Replace module
    - a) Adjacent module (eg sucker)
    - b) Replacement module
- 4. Total mains AC failure
  - a) Hand crank main pump to maintain SvO2 > 60%; ensure correct direction of rotation
  - b) Use torch to monitor venous reservoir level
- 5. If total mains AC failure, air compressor will be off
- 6. Disconnect gas line from blender and reconnect to O2 out
- 7. Automatic take over of emergency generator should occur within 5 sec
- 8. Urgently contact maintenance engineers

- ***Prevention***

1. Availability of backup equipment
2. Frequent servicing of equipment
3. Battery backup

Runaway pump

- · ***Aetiology***
- 1. Pump module circuitry failure
- · ***Prevention***
- 1. Availability of backup equipment
- 2. Frequent servicing of equipment
- · ***Diagnosis***
- 1. Unable to manipulate rpm of pump
- · ***Management***
- 1. Switch off module
- 2. Hand crank main pump to maintain SvO2 > 60%
- 3. The patient should be maintained in one of the following states while replacing module:
  - a)Normothermic with cardiac output and ventilation
  - b)Enough volume in patient to enable internal cardiac massage and ventilation
  - c)Deep hypothermic arrest
- 4. Replace module



Perfusionist Occupational Hazards

Water leak into Oxygenator

- · ***Aetiology***
- 1. Heat exchange loss of integrity within oxygenator
- 2. Note: small leaks may be difficult to diagnose
- · ***Prevention***
- 1. Test heat exchanger by subjecting to very cold water prior to priming, observing for a raising fluid level within oxygenator
- · ***Diagnosis***
- 1. Rising venous reservoir level
- 2. haemoglobinuria
- · ***Management***
- 1. Exchange oxygenator [oxygenator exchange protocol]
- 2. To remove excess blood water:
  - a) Haemoconcentrator
  - b) Cell saver
- 3. Drugs:
  - a) Diuretics; mannitol
  - b) Antibiotics

Oxygenator failure

- ***Aetiology***
- 1. Manufacturing defect
- 2. Clogging due to clot
- 3. Disruption of shell (trauma, spill of Isoflurane)
- ***Prevention***
- 1. Availability of backup equipment
- ***Diagnosis***
- 1. Dark blood in arterial line (same colour as venous)
- 2. Dropping SvO2
- 3. Blood gases
- ***Management***
- 1. If failure is partial but deteriorating, cooling (or rewarming?) may be instituted to render the patient in one of the following states:
  - a) Normothermic with cardiac output and ventilation
  - b) Enough volume in patient to enable internal cardiac massage and ventilation
  - c) Deep hypothermic arrest
- 2. Remove from failing oxygenator:
  - a) Water lines
  - b) Gas outlet line
  - c) Temperature probe
- 3. Turn off pump
- 4. Clamp patient ‘off CPB’; clamp arterial and venous lines
- 5. Double clamp (leaving 1 inch between clamps) adjacent to connectors at oxygenator:
  - a) Arterial outlet
  - b) Venous inlet
  - c) Cardioplegia outlet

Oxygenator failure/management

- 6. Cut [close to clamp nearest oxygenator]
  - a)Arterial outlet
  - b)Venous inlet
  - c)Cardioplegia outlet
  - d)Gas line
- 7. Remove defective oxygenator (and keep)
- 8. Install new oxygenator into holder : ensure is tilted with recirculation port on top
- 9. Attach cut tubing to
  - a)Arterial outlet
  - b)Venous inlet
  - c)Cardioplegia outlet
  - d)Gas port
- 10. Remove all 4 clamps
- 11. Add additional prime to venous reservoir
- 12. Prime oxygenator via recirculation line
- 13. Reestablish CPB with bleed line from arterial filter open



Clotted oxygenator or circuit

- · ***Aetiology***
- 1. Inadequate heparinisation
- 2. Direct administration of FFP to reservoir during CPB
- · ***Prevention***
- 1. Appropriate and frequent assessment of ACT:
  - a) Prior to commencement of CPB
  - b) 1/2 - 1 hourly interval whilst on CPB
  - c) Whilst rewarming
  - d) More vigilance when heparin resistant
- 2. FFP should be heparinised in bag (1000 u per bag) prior to administration
- · ***Diagnosis***
- 1. Elevated arterial line pressures [indicating clotting arterial filter]
- 2. Elevated pre oxygenator pressures [indicating clotting within oxygenator]
- · ***Management***
- 1. Stop CPB
- 2. Replace oxygenator & circuit
- 3. The patient should be maintained in one of the following states while replacing circuit & oxygenator:
  - a) Normothermic with cardiac output and ventilation
  - b) Enough volume in patient to enable internal cardiac massage and ventilation
  - c) Deep hypothermic arrest
- 4. Reheparinise patient & circuit using a different batch of heparin
- 5. Recommence CPB
- 6. If only arterial filter is blocked — open arterial bypass line
- 7. If clots appear in oxygenator
  - a) Give heparin equal to initial dose from a different batch

Questions/Discussion

- Thank you



"Would you like a *shake* with those fries, sir?"