Anesthesia for Cardiovascular Surgery

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ANESTHETIC MANAGEMENT OF CARDIAC SURGERY

Basic monitoring:

• ECG
  • ≥2 leads (II and V₅)
  • Baseline print of all leads
  • ST-segment analysis
• Pulse oxymetry
• Backup manual or automatic blood pressure cuff
ANESTHETIC MANAGEMENT OF CARDIAC SURGERY

Venous Access:
• Two large-bore (16-gauge or larger) peripheral IV catheters
• One central venous line, usually IJV
• Measurement of central venous pressure (?)
• PA-catheters: on indication
  • Low EF, pulm. Hypertension, complex procedures

Arterial cannulation
• Insert before induction of anesthesia
• Non-dominant hand (caveat: radial art. harvesting)
• Direct and continuous measurement of arterial blood pressure
ANESTHETIC MANAGEMENT OF CARDIAC SURGERY

Other:

• Indwelling urinary catheter
  • Urine output, bladder temperature

• Temperature probes
  • Esophageal, nasopharyngeal, skin, bladder, tympanic, blood

• Cross-matched blood available
  • Especially if patient has already had a midline sternotomy

• Consider thoracic epidural anesthesia (only Europe)
  • Problem: epidural hematoma formation following heparinization
ANESTHETIC MANAGEMENT OF CARDIAC SURGERY

Induction of Anesthesia:

• Goal: hemodynamic stability
• Selection of induction agents:
  • High-dose opiates
  • ± Benzodiazepine
  • Modest dose propofol
  • Muscle relaxant, endotracheal intubation
  • Vasopressor if blood pressure falls >20%
ANESTHETIC MANAGEMENT OF CARDIAC SURGERY

Maintenance of anesthesia:

• Selection of anesthetic technique/agents:
  • TIVA with short acting agents, covers whole procedure
  • Volatile anesthetic agents
    • Cardioprotection
    • Difficult to use during CPB
  • Avoid N₂O! (expansion of intravascular air bubbles, pneumothorax)
  • High-dose opiates
  • Muscle relaxants
  • Vasopressor if blood pressure falls >20%
  • Goal: early extubation (1–6 h postop.), fast track?
CARDIOPULMONARY BYPASS

1. Oxygen-poor blood leaves the heart to enter the heart-lung machine.
2. Heart-lung machine pumps and adds oxygen to the blood before it returns to the body.
3. Oxygen-rich blood returns to the body, skipping the heart and lungs.

Blood bypasses heart chambers and lungs.

Tubes

Aorta

Location of heart
The CPB machine has five basic components:
1. venous reservoir,
2. oxygenator,
3. heat exchanger,
4. main pump (roller pumps of centrifugal pumps), and
5. arterial filter (air, thrombi, fat globules, calcium, tissue debris)
CPB diverts venous blood away from the heart, adds oxygen, removes CO$_2$, and returns the blood to a large artery. As a result, most blood flow through the heart and most of the flow through the lungs cease.
CARDIOPULMONARY BYPASS

Flow = non-pulsatile
Organ protection:
• Hypothermia
• Cardioplegia
  • (cold, K⁺-rich, blood or crystalloids, ante- and retrograde, repeat every 30 min)
PHYSIOLOGICAL EFFECTS OF CARDIOPULMONARY BYPASS

Initiation of CPB is associated with:

- a marked increase in stress hormones
- a variable systemic inflammatory response (sepsis-like)
  - Generation of oxygen-derived free radicals
- Activation of multiple humoral systems, including complement, coagulation, fibrinolysis, and the kallikrein system
- Mechanical trauma alters platelets and activates leukocytes
  - Depletion of glycoprotein receptors on the surface of platelets
  - Increased perioperative bleeding
PHYSIOLOGICAL EFFECTS OF CARDIOPULMONARY BYPASS

Potential methods to prevent complications (experimental):
• Glucocorticoids?
• Cyclokapron acid?
• Leukocyte depletion?
• Intraoperative hemofiltration?
• Antioxidants (Vit. C, E, Mannitol)?
• cyclooxygenase-2 inhibitors?
• Pentoxifylline?
ANESTHETIC MANAGEMENT OF CARDIAC SURGERY

Going on-pump

• Confirm adequate anticoagulation (ACT) before cannulation
• Venous cannulation
• Aortic cannulation
  • Reduce systemic arterial pressure (to 90–100 mm Hg systolic)
  • Complications: Aortic dissection, Cerebral embolism (plaque, air)
• Start CPB, pump flow gradually increased to 2–2.5 L/min/m²
• Cold blood cardioplegia
• Continue ventilation until heart stops ejecting blood
• Maintain MAP 50 - 80 mmHg (organ perfusion)
• Hemodilution due to CPB priming
  • Keep hematocrit between 20% and 25%
ANESTHETIC MANAGEMENT OF CARDIAC SURGERY

Intraoperative laboratory monitoring:

• Blood gas analysis (point of care):
  • Hematocrit
  • Serum potassium
  • Ionized calcium
  • Glucose

• Activated clotting time (ACT)
  • Activators: celite, kaolin, glass
  • Reference value ranges between 70-180 sec
  • During CPB the desired range is >400-500 sec
  • During OPCAB procedures usually >300-400 sec

• Thrombelastography (TEG)?
ANESTHETIC MANAGEMENT OF CARDIAC SURGERY

Anticoagulation:

• must be established prior to CPB
• must be confirmed with determination of the ACT
• Heparin: 3 mg/kg (OPCAB: 2 mg/kg)
  • Problem: resistance to heparin (AT III deficiency)
    • Solution: infuse FFP (2 units) or AT III
  • Problem: heparin-induced thrombocytopenia (HIT)
    • Solution: consider alternative anticoagulants (hirudin, bivalirudin, argatroban)
  • Problem: previous administration of glycoprotein IIb/IIIa inhibitors (abciximab [RheoPro] or tirofiban [Aggrastat]) or ADP receptor antagonist clopidogrel (Plavix)
    • Solution: aminocaproic acid (5–10 g followed by 1 g/h) or tranexamic acid (10 mg/kg followed by 1 mg/kg/h)
Anticoagulation:

A = Initial ACT
B = ACT after heparin dose
C = Measured ACT prior to reversal
Management of Respiratory Gases

- Problem: the solubility of a gas increases with hypothermia
  - As a result, the partial pressure of the gas will decrease
  - most significant for PaCO₂ (effect on cerebral blood flow)
- Example: Blood with PaCO₂ of 5 kPa and a pH of 7.40 at 37°C, when cooled to 25°C, will have a PaCO₂ of about 2.6 kPa and a pH of 7.60
Management of Respiratory Gases

- Problem: blood samples are heated to 37°C in blood gas analyzers

- Solution 1: pH-stat management
  - Temperature correcting gas tensions and maintaining a "normal" PaCO$_2$ of 40 mm Hg and a pH of 7.40 during hypothermia
  - May require adding CO$_2$ to the oxygenator
  - Increases total blood CO$_2$-content
  - Impairs cerebral blood flow autoregulation

- Solution 2: α-stat management (more common)
  - Use of uncorrected gas tensions during hypothermia
  - Preserves cerebral autoregulation of blood flow
Troubleshooting during CPB

- Problem: after start of CPB, venous reservoir empties (air enters pump circuit)
- Solution: check venous return:
  - forgotten clamps?
  - Cannula malposition?
  - Kinking?
ANESTHETIC MANAGEMENT OF CARDIAC SURGERY

Troubleshooting during CPB

• Heart does not empty
  • Solution: aortic regurgitation? Malpositioning of the venous cannula?

• MAP decreases <30 mmHg
  • Solution: search for unrecognized aortic dissection, recannulate aorta (distal)
Monitoring: Transesophageal Echocardiography (TEE)

TEE provides extremely valuable information about:
- Cardiac anatomy and
- Cardiac function during surgery (valvular function, pump function, ischemia, hypovolemia)
- Surgical result, need for re-intervention
Monitoring: Transesophageal Echocardiography (TEE)

Future: 3D echo

Figure 1: Three-dimensional echocardiographic image of the left ventricle (17-segment model, Figure 1A), with measurements of ventricular ejection fraction and volumes. Volume and ejection fraction measurements were derived from the two-dimensional echocardiography (Figure 1B) as analyzed in multiple observation planes.
CARDIOPULMONARY BYPASS

Weaning from CPB (preparation):

• A "hot shot" or warm blood cardioplegia can be administered
  • To wash out byproducts
  • Replenish metabolic substrates

• Optimise physiological conditions
  • Acidosis and hypoxia should be corrected
  • Lung ventilation must be resumed
  • Normothermia (≥36°C) should be achieved
  • Normovolemia should be achieved
  • Hb should be kept ≥5 mmol/L
CARDIOPULMONARY BYPASS

Weaning from CPB (preparation):

- Surgeon unclamps the aorta
  - Washes out cardioplegia (heart re-starts)
- Re-start pulmonary ventilation
- Continue CPB additional 5 – 10 mins after heart re-start
  - Keep heart in empty and beating state
  - Stabilizes heart, minimal metabolic requirements
- A stable rhythm (preferably sinus) must be present
  - Atrioventricular pacing may be necessary (80–100 bpm)
- TEE monitoring (chamber vols, contractility, valvular function)
CARDIOPULMONARY BYPASS

Weaning problems:

- Problem: residual air (TEE, ECG)?
- Solution:
  - Evacuate air from the heart and any bypass grafts
  - Increase perfusion pressure (norepinephrine)
CARDIOPULMONARY BYPASS

Weaning problems:

• Poor cardiac function
  • Consider inotropic support:
    • dobutamine (1\textsuperscript{st} choice)
    • milrinone (esp. right ventricular failure)
    • Norepinephrine
    • (epinephrine, dopamine)
    • Levosimendan (not approved in NL)
  • Consider reperfusion
  • Consider afterload reduction (nitroprusside, milrinone)
  • Consider intraaortic balloon pump (IABP)
  • Consider left or right ventricular assist device
Intraaortic balloon pump

**Systole: deflation**
- Decreased afterload
- Decreases cardiac work
- Decreases myocardial oxygen consumption
- Increases cardiac output

**Diastole: inflation**
- Augmentation of diastolic pressure
- Increases coronary perfusion
Intraaortic balloon pump
Reversal of anticoagulation:

- Protamine binds and effectively inactivates heparin
- Dose: 1 mg of protamine per mg of (initial) heparin
- Infuse slowly
  - Hemodynamic side-effects
    - Hypotension (vasodilation)
    - Myocardial depression
    - Pulmonary hypertension
    - Allergic reactions
- Check effect with ACT
- Consider supplemental protamine (50–100 mg) after administration of CPB blood
PATHOLOGICAL EFFECTS OF CARDIOPULMONARY BYPASS

• **Underlying problems**
  – Age
  – Comorbidities
  – Procedural complexity
  – Equipment issues

• **Postoperative problems**
  – Stroke, incidence 1-3%, higher in aortic surgery
  – Delirium, incidence 10-60%
  – POCD, incidence 24-53%
  – Longer hospital LOS
  – Higher costs
11,825 CABG Patients, 1.5% Incidence of Stroke

75% of strokes occurred among low or medium preoperative risk patients
  – Many of these strokes may be preventable
  – Traditional pre-op risk assessment is unreliable
  – Additional intraoperative monitoring (e.g. NIRS) may be of value
Cerebral Oxymetry

Changes in INVOS values are influenced by the critical balance between arterial oxygen delivery and cerebral consumption.

Imbalances are identified by changes in rSO$_2$. 
Cerebral Oxymetry: Results

Monitoring Brain Oxygen Saturation During Coronary Bypass Surgery: A Randomized, Prospective Study


200 CABG patients;
• 100 blinded rSO₂ monitoring
• 100 intervention protocol
PATIENTALOGICAL EFFECTS OF CARDIOPULMONARY BYPASS


Lawrence J. Dacey, MD, Donald S. Likosky, PhD, Bruce J. Leavitt, MD, Stephen J. Lahey, MD, Reed D. Quinn, MD, Felix Hernandez, Jr, MD, Hebe B. Quinton, MS, Joseph P. Desimone, MD, Cathy S. Ross, MS and Gerald T. O’Connor, DSc, PhD, for the Northern New England Cardiovascular Disease Study Group

35,733 CABG patients
Stroke incidence 1.61%

“Patients who had perioperative stroke were at a significantly increased risk for death...Survival at each time point was lowest among patients who had hypoperfusion strokes.”
Any questions?
Monitoring: Transesophageal Echocardiography (TEE)

Twodimensional, multiplane TEE: nomenclature
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Assessing Ventricular Function

- Normal
- Hypokinesis
- Akinesis
- Dyskinesis
Monitoring: Transesophageal Echocardiography (TEE)

Coronary artery supply of the left and right ventricles

Dark blue, RCA; light blue, LAD; white, CX.
Monitoring: Transesophageal Echocardiography (TEE)

Assessing Valvular Function: MV
Monitoring: Transesophageal Echocardiography (TEE)

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Assessing Valvular Function: MV
Monitoring: Transesophageal Echocardiography (TEE)

Assessing Valvular Function: AV
Monitoring: Transesophageal Echocardiography (TEE)

Assessing Valvular Function: AV
Monitoring: Transesophageal Echocardiography (TEE)

Assessing Valvular Function: AV
Monitoring: Transesophageal Echocardiography (TEE)

Views of the aortic arch and descending aorta