Mariann Tang
Department of Cardiothoracic and Vascular Surgery
Aarhus University Hospital, Skejby

This is my point of view

...all the cauldron contents (lung of pig, pancreas of cow, sperm of salmon etc.) swirling around the CPB...


Outlines presentation

- What do surgeons learn about cardiopulmonary bypass
- Technique/choice of cannulas
- Myocardial protection
- Problems related to CPB

What do surgeons learn about CPB?

- Honestly - not much...
- Personal interest for a lot of surgeons
**Education in cardiothoracic surgery in Denmark**

- 3 day course with theory and practice
- 3 days working with perfusionist during cardiac surgery
- Self-arranged course for young surgeons, 2 days, theory+practice

**Norway and Sweden**

- Norway
  - No specific course for CPB
- Sweden
  - No specific courses for CPB
  - Should be familiar with different intravascular catheterizations
  - Should be able to lead an operation with CPB

**Literature**

- Cohn: Cardiac Surgery in the Adult
  - 74 pages (total 1535 pages) (4,8%)
- Kirklin: Cardiac Surgery
  - 68 pages (total 1776) (3,8%)
- Sabiston&Spencer: Surgery of the Chest
  - 16 pages (total 2174 pages) (0,7%)

**Outline presentation**

- What do surgeons learn about cardiopulmonary bypass
  - **Technique/choice of cannulas**
  - **Myocardial protection**
  - Problems related to CPB

**Arterial cannulation**

- Haemodynamics for cannulas primarily evaluated on the pressure drop
  - Gradients >100 mmHg increase haemolysis
- Straight vs angled
  - intima lesions less with angled
  - Haemolysis the same

**Technique aortic cannulation**

- Palpation of aorta to avoid calcificed areas
- Double purse string
- Problems:
  - Adventitial haematoma
  - Cutting of pursestrings
  - Difficult to insert cannula
  - Dissection
Aorta vs femoral approach

- Femoral for minimal invasive surgery
- Femoral when aortic cannulation is not feasible or desirable
- Contraindications for aorta:
  - Ascending aorta aneurism
  - Diseased ascending aorta

Technique venous cannulation

- Right atrium cannulation
  - Two stage catheter
  - Vacuum assisted cannula

- Bicaval cannulation
  - Straight and bended tips
  - When opening right side of the heart

Aorta vs femoral

<table>
<thead>
<tr>
<th></th>
<th>Aorta (ascending/arch)</th>
<th>Femoral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accessibility</td>
<td>Easy</td>
<td>Difficult</td>
</tr>
<tr>
<td>Additional incision</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Cannula size</td>
<td>Unlimited</td>
<td>Limited</td>
</tr>
<tr>
<td>Risk of malperfusion of arch vessels</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Perfusion direction</td>
<td>Antegrade</td>
<td>Retrograd</td>
</tr>
<tr>
<td>Leg ischemia</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Dissection incidence</td>
<td>0.05%</td>
<td>0.6%</td>
</tr>
<tr>
<td>Wound/artery complication</td>
<td>0</td>
<td>4%</td>
</tr>
</tbody>
</table>

Venous drainage

- Problems:
  - Malposition of cannula
  - Positioning of the heart
  - Kinking of the lines/clamp left on
  - Air lock
  - Hypovolaemia
  - Vasodilatation

Atrial access vs bicaval

<table>
<thead>
<tr>
<th></th>
<th>Bicaval</th>
<th>Atrial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atrial incisions</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Speed</td>
<td>Slow</td>
<td>Fast</td>
</tr>
<tr>
<td>Technical difficult</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Right heart decompression</td>
<td>Fair/none</td>
<td>Good</td>
</tr>
<tr>
<td>Potential rewarming of heart by systemic venous return</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Caval drainage</td>
<td>Good</td>
<td>Good (less good from SVC)</td>
</tr>
</tbody>
</table>

Choice of cannulae

- Size
  - The smaller the better → for the surgical incision
  - Still want good drainage and good flow
- Recommendations from perfusionist is often the choice
What do surgeons learn about cardiopulmonary bypass
- Technique/choice of cannulas
- Myocardial protection
- Problems related to CPB

Cardioplegia
- Crystalloid
  - St Thomas
  - Single dose vs. Multidose
- Blood cardioplegia
  - Increasingly preferred especially complicated cases

Myocardial protection
- Cardioplegia
- Hypothermia

Antegrade vs retrograde
- Retrograde may give inadequate perfusion of cardioplegia
- Randomized trial in aortic valve substitution (n=20)
  - Increased cardiomyocyte apoptosis in retrograde group
  - Systolic mitral annulus movement was decreased immediately after operation in retrograde group
  - 9 month postoperative MR better function in antegrade group (regression of hypertrophy)

Outline presentation
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Problems related to CPB
- Immune response/inflammatory response
- Organ failure
- Coagulopathy
  - Haemodilution
  - Hypothermia
  - Acidosis

**Immune/inflammatory response**
- Exposure to non-endothelial cell surfaces
- Inflammatory responses
  - Power thrombotic stimulus
  - Vasoactive and cytotoxic substances

**Leukocyte response to CPB**
- Decrease in number during CPB, but increase postoperatively
- Activation (contact and complement system)
- Inhibition of apoptosis and prolongs activity of neutrophils (interleukins)
- Reactive oxidants from neutrophils, monocytes and macrophages
  

**Neutrophils after CPB**

**Leukocyte depletion during CPB**
- Inflammatory response
- Leukocyte filters in a period of 2.5 months
- Control group 2.5 month before and after
- No difference in postoperative leukocyte level, transfusion requirements or mortality


**Corticosteroids**
- Cochrane review, 54 randomized trials (3615 patients):
  - Outcome: Mortality, cardiac or pulmonary complications
  - No mortality reduction
  - No effect on cardiac or pulmonary complications


**Organ dysfunction**

**Microemboli**
- Atherosclerotic debris
- Fat
- Air
- Hypoperfusion
- Cytotoxic substances
- Ischemic reperfusion injury
- Regional perfusion/temperature mismatch

Renal failure
- Increased risk
  - Age >70 years
  - Diabetes
  - Type of surgery
  - Heart failure
- All patients have post-pump proteinuria

Gastrointestinal complications
- Decrease of gastric pH
  - Less of a problem after histamin blockers
- Vascular ischemia
  - Rare but often fatal
  - Role of CPB not fully understood

Neurological deficit after CPB
- Abnormal neuropsychologic outcomes at 1 week and 1 month postoperative (n=374)

Pulmonary problems
- Ischemia/hypoperfusion – not known in lung tissue
- Increase pulmonary capillary permeability
- Increase interstitial lung water
- Atelectasis

Heparinization
- Full heparinization (300 IE pr. kg)
  - ACT >400
  - Reverted with protamine sulphate
- Heparin rebound effekt
  - Faster metabolization of protamine
  - Heparin bound to plasma proteins and therefore not neutralized
  - Inverse effekt af protamine sulphate
    - Dosage above 2.5 x normal dosage

Hematocrit
- Ideal hematocrit
- Low hematocrit
  - Reduce viscosity and hemolysis
  - Reduce oxygen carrying capacity
  - Increase risk of neurological complications
**Normothermia**
- Increase inflammatory response

**Mild hypothermia**
- Cardioprotective
- Brain protective
- Affects coagulation
- Increase vascular resistance
- Interfere with organ function/enzyme activity

**Acidosis**
- Tissue hypoperfusion
- Intravascular fluids/iatrogenic
- Worse outcome with acidosis after cardiac surgery
- Alpha stat vs pH stat

**Hypothermia**
- Reduce platelet activity and adhesion
- Reduce enzymatic activity (thrombin generation)

**Low fibrinogen levels caused by:**

Acidosis
- Acidosis increased fibrinogen breakdown by 1.8-fold

**Combination of acidosis and hypothermia**
- Acidosis
  - Increase APTT, ACT and PT
- Hypothermia
  - Increase APTT and PT (temp.<35°C)
- Thromboelastometry
  - Acidosis alone no effect
  - Hypothermia prolong clotting time
  - Combination synergistic effect

**Thrombin generation**

**Alpha stat vs pH stat**

“Acidosis increased fibrinogen breakdown by 1.8-fold”

Darlington et al: J Trauma, 2011 Epub
Reed et al: Circ Shock 1999;50:144-52
Triangle of death (trauma)

Coagulopathy
- Loss, consumption and dilution
- Colloid impairment
- Hyperfibrinolysis
- Anaemia
- Fibrinogen deficiency
- Platelet/factor deficiency

Hypothermia  Acidosis

Haemodilution
- CPB priming, iv fluids, cardioplegia
- Bypass associated dilutional (BAD) coagulopathy
- Haemodilution = coagulopathy

Loss of coagulation factors

Colloid induced coagulopathy

Changes plasma activity -24 h postoperative

Cardio pulmonary bypass and coagulation

HEMODILUTION
- Contact activation
- Platelet
- Fibrinogen
- Platelet/factor deficiency

ACTIVATION
- Coagulation
- Thrombin
- Platelet
- Fibrinogen

CONSUMPTION
- Hemodilution
- Coagulation
- Fibrinogen
- Platelet


Ternström L. et al. Thrombosis Research 2010; 126:128-33
Colloid induced coaguloapthy

Haemostatic intervention

MCF = 60
- Platelets
- FXIII
- Fibrinogen


Fibrin polymerisation

MCF = 50


Clot stability

Thrombin generation

Factors associated with bleeding

- Type of procedure
- Time on cardiopulmonary bypass
- Age↑
- Sex (female)
- BMI↓
- Hct↓
- Acute surgery
- Preoperative aspirin/clopidogrel
- Redo operations
- Renal insufficiency

The surgeon...

- Perhaps the most important factor...
- ...and the hardest to correct for!!
Re-operation for bleeding

- Increase mortality¹
- Increase morbidity¹
- Prolonged stay in ICU
- Prolonged admission time¹,²
- Coagulopathy worse prognostic than surgical bleeding¹
  - (87.5% survival vs. 91.3% - no blødning 98.0%) ¹²

¹: Hall et al; Ann Thorac Cardiovasc Surg 2001;7:352-7
²: Kartik et al; Ann Thorac Surg 2004;78:537-534

Autotransfusion

- Reduce transfusion requirements¹
- Reduce bleeding¹
- Should not affect coagulation further²


Transfusion of blood products

- Remember balanced transfusion¹
- Increase mortality and morbidity²
  - Infection³
  - Ischaemia (AMI, stroke)
  - Renal failure (creatin >200 mmol/L)
  - Prolonged hospital stay

¹: GUIDELINES (udgivet 2007, opdateret 2011)
Society of Thoracic Surgeon and the Cardiovascular Anesthesiologists blood conservation clinical practice guidelines
²: Murphy et al; Circulation 2007; 116; 2544-2552

Complications related to transfusion

- Delayed
  - Increased mortality !!
  - Delayed hemolytic transfusion reactions
  - Transfusion-related immunomodulation
  - Transfusion-transmitted disease
  - Post-transfusion GvH disease
  - Post-transfusion purpura

Blood transfusion kills you


Young blood is the best
But it still kills you !!


Coagulation factor concentrates

- Fibrinogen concentrate
  - Increase clot stability in haemodilution
- Prothrombin complex concentrate (factor II, VII, IX, X) (Octaplex)
  - Reversal warfarin
  - Promising results in trauma
- Recombinant factor VIIa (Novoseven)
  - Many case reports
- Desmopressin (Octostim)
  - Activate platelets

Is it worth the cost?

Cost effectiveness

- Berlin – 2006
  - 1118 patients
    - 6% excessive bleeders (>200 ml/h or >2 ml/kg/h in two hours in a row)
  - 6251 Euro more expensive per patient:
    - Prolonged stay in ICU
    - Prolonged hospital admission


Conclusions

- Surgeons get little formal education in CPB and cannulas in Scandinavia
- Recommendations from perfusionist are often followed
- Communication and respect for each others knowledge is important

- CPB still contributes to a lot of the postoperative complications
- Consider the possible drawbacks of mild hypothermia
- Reduce haemodilution to avoid further coagulopathy
- Remember potential adverse effects of transfusion and alternative haemostatic interventions