Anaesthesia for coronary artery bypass surgery without the help of cardiopulmonary bypass pump (OPCAB)

Jan Van Hemelrijck, MD, PhD
On-pump
- CPR
- Cardiogenic shock + pulmonary oedema
- Cardiogenic shock + saturation <90 %
- Cardiogenic shock: CI < 1 l/M²

Off-pump
- All other patients
- All other infarct patients
- redo, intramural, intraseptal
- small and calcified vessels
- left main
- cardiomegaly
### Drivers for OPCAB

<table>
<thead>
<tr>
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<th>SYNTAX at two years</th>
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<tbody>
<tr>
<td></td>
<td>CABG</td>
<td>PCI</td>
<td></td>
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<tr>
<td>Death/stroke/MI</td>
<td>9.6 %</td>
<td>10.8 %</td>
<td>P=0.44</td>
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<tr>
<td>Stroke</td>
<td>2.8 %</td>
<td>1.4 %</td>
<td>P=0.03</td>
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<tr>
<td>Repeat revascularisation</td>
<td>8.6 %</td>
<td><strong>17.4 %</strong></td>
<td><strong>P&lt;0.001</strong></td>
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<thead>
<tr>
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<th>SYNTAX at three years</th>
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<tbody>
<tr>
<td></td>
<td>CABG</td>
<td>PCI</td>
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<tr>
<td>Death</td>
<td>6.7 %</td>
<td>8.6 %</td>
<td>P=0.13</td>
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<tr>
<td>Stroke</td>
<td>3.4 %</td>
<td>2.0 %</td>
<td>P=0.02</td>
<td></td>
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<tr>
<td>Repeat revascularisation</td>
<td>10.7 %</td>
<td><strong>19.7 %</strong></td>
<td><strong>P&lt;0.001</strong></td>
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<tr>
<td>MACCE</td>
<td>20.2 %</td>
<td>28.0 %</td>
<td><strong>P&lt;0.001</strong></td>
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</table>
Is OPCAB better than conventional CABG?

Question still unresolved!

A simple power calculation for a randomized trial in the presence of a 3% risk and a 10% reduction of the risk with the usual $\alpha (0.05)$ and $\beta (0.1)$ errors identifies the need for 65 000 patients in each treatment arm.
On-Pump versus Off-Pump Coronary-Artery Bypass Surgery

A. Laurie Shroyer, Ph.D., Frederick L. Grover, M.D., Brack Hattler, M.D., Joseph F. Collins, Sc.D., Gerald O. McDonald, M.D., Elizabeth Kozora, Ph.D., John C. Lucke, M.D., Janet H. Baltz, R.N., and Dimitri Novitzky, M.D., Ph.D., for the Veterans Affairs Randomized On/Off Bypass (ROOBY) Study Group
## Rooby early outcome

<table>
<thead>
<tr>
<th>Primary End Point</th>
<th>Off-Pump Group (N = 1104)</th>
<th>On-Pump Group (N = 1099)</th>
<th>Absolute Percentage-Point Difference (95% CI)</th>
<th>Relative Risk (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Short-term</strong></td>
<td></td>
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<tr>
<td>30-Day composite&lt;sup&gt;Ⅲ&lt;/sup&gt;</td>
<td>77 (7.0)</td>
<td>61 (5.6)</td>
<td>1.4 (-0.6 to 3.5)</td>
<td>1.26 (0.91 to 1.74)</td>
<td>0.19</td>
</tr>
<tr>
<td>Death within 30 days after surgery or before discharge</td>
<td>18 (1.6)</td>
<td>13 (1.2)</td>
<td>0.4 (-0.5 to 1.4)</td>
<td>1.38 (0.68 to 2.80)</td>
<td>0.47</td>
</tr>
<tr>
<td><strong>Complications within 30 days after surgery or before discharge</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Cardiac arrest</td>
<td>20 (1.8)</td>
<td>12 (1.1)</td>
<td>0.7 (-0.3 to 1.7)</td>
<td>1.66 (0.82 to 3.38)</td>
<td>0.21</td>
</tr>
<tr>
<td>Renal failure requiring dialysis</td>
<td>9 (0.8)</td>
<td>10 (0.9)</td>
<td>-0.1 (-0.9 to 0.7)</td>
<td>0.90 (0.37 to 2.20)</td>
<td>0.82</td>
</tr>
<tr>
<td>Stroke</td>
<td>14 (1.3)</td>
<td>8 (0.7)</td>
<td>0.5 (-0.3 to 1.4)</td>
<td>1.75 (0.74 to 4.14)</td>
<td>0.28</td>
</tr>
<tr>
<td>Coma</td>
<td>4 (0.4)</td>
<td>3 (0.3)</td>
<td>0.1 (-0.4 to 0.6)</td>
<td>1.33 (0.30 to 5.93)</td>
<td>1.00</td>
</tr>
<tr>
<td>Repeat cardiac surgery</td>
<td>8 (0.7)</td>
<td>8 (0.7)</td>
<td>-0.0 (-0.7 to 0.7)</td>
<td>1.00 (0.38 to 2.65)</td>
<td>1.00</td>
</tr>
<tr>
<td>Reoperation for bleeding</td>
<td>30 (2.7)</td>
<td>23 (2.1)</td>
<td>0.6 (-0.7 to 1.9)</td>
<td>1.30 (0.76 to 2.22)</td>
<td>0.40</td>
</tr>
<tr>
<td>New mechanical support</td>
<td>17 (1.5)</td>
<td>9 (0.8)</td>
<td>0.7 (-0.2 to 1.6)</td>
<td>1.88 (0.84 to 4.21)</td>
<td>0.17</td>
</tr>
<tr>
<td>Mediastinitis</td>
<td>11 (1.0)</td>
<td>14 (1.3)</td>
<td>-0.3 (-1.1 to 0.6)</td>
<td>0.78 (0.36 to 1.72)</td>
<td>0.55</td>
</tr>
<tr>
<td>Tracheostomy</td>
<td>5 (0.5)</td>
<td>7 (0.6)</td>
<td>-0.2 (-0.8 to 0.4)</td>
<td>0.71 (0.23 to 2.24)</td>
<td>0.58</td>
</tr>
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</table>
# Rooby one-year outcome

<table>
<thead>
<tr>
<th></th>
<th>OPCAB</th>
<th>CCAB</th>
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<tbody>
<tr>
<td><strong>Long-term</strong></td>
<td></td>
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<tr>
<td>1-Yr composite $^f$</td>
<td>105 (9.9)</td>
<td>78 (7.4)</td>
<td>2.5 (0.1 to 4.9)</td>
<td>1.33 (1.01 to 1.76)</td>
<td>0.04</td>
</tr>
<tr>
<td>1-Yr composite with death from cardiac causes rather than from any cause</td>
<td>93 (8.8)</td>
<td>62 (5.9)</td>
<td>2.9 (0.6 to 5.1)</td>
<td>1.48 (1.09 to 2.02)</td>
<td>0.01</td>
</tr>
<tr>
<td>1-Yr composite with all end points from time of CABG</td>
<td>155 (14.6)</td>
<td>104 (9.9)</td>
<td>4.7 (1.9 to 7.5)</td>
<td>1.47 (1.17 to 1.86)</td>
<td>0.001</td>
</tr>
<tr>
<td>Nonfatal myocardial infarction between 30 days and 1 yr after surgery</td>
<td>21 (2.0)</td>
<td>23 (2.2)</td>
<td>-0.2 (-1.4 to 1.0)</td>
<td>0.90 (0.50 to 1.62)</td>
<td>0.76</td>
</tr>
<tr>
<td>Revascularization between 30 days and 1 yr after surgery</td>
<td>49 (4.6)</td>
<td>36 (3.4)</td>
<td>1.2 (-0.5 to 2.9)</td>
<td>1.35 (0.88 to 2.05)</td>
<td>0.18</td>
</tr>
<tr>
<td>Death from any cause within 1 yr</td>
<td>43 (4.1)</td>
<td>30 (2.9)</td>
<td>1.2 (-0.4 to 2.8)</td>
<td>1.41 (0.90 to 2.24)</td>
<td>0.15</td>
</tr>
<tr>
<td>Death from cardiac causes within 1 yr</td>
<td>29 (2.7)</td>
<td>14 (1.3)</td>
<td>1.4 (0.2 to 2.6)</td>
<td>2.05 (1.09 to 3.86)</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Less grafts than planned: 17.8% vs 11.1% (p<0.001)
Graft patency at follow-up angiogram (n=1371): 82.6% vs 87.7% (p<0.01)
Eligibility for ROOBY participants

vascular territories of the heart. The prestudy off-pump experience of the surgeons averaged 120 cases (median, 50). Sixteen sites had train-

competent in both surgical approaches. To provide the off-pump procedure an optimal chance of being identified an efficacious approach, it was felt that a minimum number of 20 cases performed off-pump for each study surgeon (with at least three cases where full and complete revascularization had been achieved in all anatomic regions of the heart) had to have been completed prior to study participation.
From OPCAB to ONCAB

Conversion to other treatment — no. (%)  
- 137 (12.4)
- 40 (3.6)
- <0.001

Conversion from OPCAB to On-pump (excluding same day acute infarct patients) versus OPCAB experience

K.U. Leuven  
N = 4500  
Conversions = 12  
Rate = 0.26%  
50 x higher conversion rates
Off-pump vs. on-pump coronary artery bypass surgery: an updated meta-analysis and meta-regression of randomized trials
Jonathan Afilalo, Mandana Rasti, Samuel M. Ohayon, Avi Shimony and Mark J. Eisenberg
Eur Heart J 2011;eurheartj.ehr307

59 randomized trials, 30 days clinical outcomes, 8961 patients.
• mortality: 1.6% vs 1.9% RR OPCAB/CCAB 0.90 (95% CI: 0.63-1.3)
• myocardial infarction: 3.4% vs 3.9% RR OPCAB/CCAB 0.89 (95% CI: 0.69-1.13)
• stroke: 1.4% vs 2.1% RR OPCAB/CCAB 0.70 (95% CI: 0.49-0.99)
Off-Pump or On-Pump Coronary-Artery Bypass Grafting at 30 Days
André Lamy, P.J. Deveraux, et al.
The CORONARY Investigators
NEJM March 26, 2012

- Randomized, controlled trial, blinded outcome assessments.
- Participating surgeons: 2 years experience, >100 OPCAB procedures.
- 4752 pts. (all with at least one risk factor)
- Cross over (off-pump to on pump): 7.9%
- Fewer grafts offpump, 3.0 vs 3.2 (p<001), and more incomplete vascularization, 11.8% vs 10.0% (p=0.05)
- Repeat revascularization: 0.7% vs 0.2%, 4.01 (1.34-12) p=0.01
Off-Pump or On-Pump Coronary-Artery Bypass Grafting at 30 Days
André Lamy, P.J. Deveraux, et al.
The CORONARY Investigators
NEJM March 26, 2012

- Primary outcome at 30 days (death, nonfatal stroke, nonfatal myocardial infarction, new dialysis): 9.8% off-pump vs. 10.3% on-pump, hazard ratio 0.95 (0.79-1.14) p=0.59.
  - Death: 2.5% vs 2.5%, hazard ratio 1.01 (0.71-1.46)
  - Myocardial Infarction: 6.7% vs 7.2%, 0.93 (0.75-1.15)
  - Stroke: 1.0% vs 1.1%, 0.89 (0.51-0.54)
  - Renal Failure: 1.2% vs 1.1%, 1.04 (0.61-1.76)
- Off-pump: shorter operation, shorter ventilatory support, less blood transfusion (50.7% vs 63.3%, relative risk 0.80 (0.75-0.85, p<0.001)
- Respiratory complications (failure or infection) less frequent with off-pump: 5.9% vs 7.5%, 0.79 (0.63-0.98), p=0.03
Off-pump versus on-pump coronary artery bypass grafting: a systematic review and meta-analysis of propensity score analyses
Oliver Kuss, Benita von Salviati, and Jochen Börgermann
J Thorac Cardiovasc Surg 2010;140:829-35

35 propensity score analyses, 123137 patients
- mortality: OPCAB/CCAB odds ratio 0.69 (95% CI: 0.60-0.75) p< 0.0001
- myocardial infarction: OPCAB/CCAB odds ratio 0.97 (95% CI: 0.73-1.3) NS
- stroke: OPCAB/CCAB odds ratio 0.42 (95% CI: 0.33-0.54) p< 0.0001
- renal failure: OPCAB/CCAB odds ratio 0.60 (95% CI: 0.51-0.70) p< 0.0001
3-month Mortality versus OPCAB experience
Hazard Functions for Early Mortality after CABG

Model: Exponential

CABG on-pump (N=1585)

CABG off-pump (N=3247)
Isolated CABG (excl acute same day infarcts), hazard function for stroke.

- Stop combined carotid-CABG
- Stop touching aorta
- Closure of LAA
- Therapeutic levels of anti-aggregation postop

- Reduction of embolic burden
- Hypoperfusion? Inflammation?

Graph showing hazard function for stroke over time after CABG surgery.

- CABG on-pump (N=1583)
- CABG off-pump (N=3247)
“Although the pathogenesis of adverse neurologic events after CABG is probably multifactorial, there is growing evidence that patient-related risk factors, such as the extent of preexisting cerebrovascular and systemic vascular disease, have a greater effect on both short- and long-term neurologic sequelae than do procedural variables, such as on-pump versus off-pump surgery.”
Birds flying in formation fly 70% further than solo birds, using the same amount of energy.

**Teamwork and communication**
Communication

The surgeon:

• informs the anesthesiologist about every position change, incision of the coronary artery, shunt insertion
• asks permission before exteriorisation of the heart

The anesthesiologist:

• informs the surgeon about the hemodynamic changes
• informs the surgeon when ischemia is detected or suspected
• may ask the surgeon to restore the position of the heart if hemodynamics are not optimal.
Low fidelity simulation: training, training, training....
The stitch is placed in the posterior pericardium, as far cranially as possible and toward the right inferior pulmonary vein.
Enucleation of the heart using the sling
Surgical technique
Preoperative medication

- preoperative cardiovascular medication continued:
  - beta-blockers
  - statins
  - Ca-channel blockers
  - sartans and ACE-inhibitors: if used for heart failure
- antithrombotic agents and platelet inhibitors:
  - liberal interpretation of the ACCF/AHA guidelines
  - often continued till the day before surgery to decrease thrombotic risk
  - increases the use of blood products and hemostatic therapy
- anxiolytics to decrease preoperative apprehension
European and ACC guidelines

- Aspirin (80-325 mg/d): continue
- Clopidogrel (Plavix), ticagrelor (Brilique): stop 5 days before elective CABG
- Prasugrel (Effient): stop 7 days before elective CABG
- Urgent CABG: clopidogrel and ticagrelor discontinued at least 24 hours
- Short acting glycoprotein IIb/IIIa inhibitors, eptifibatide (Integrilin) and tirofiban (Agrastat): stop 2 to 4 hours before surgery
- GP IIb/IIIa inhibitor abciximab (Rheopro): stop 12 hours before surgery
Choice of anaesthetic agents

The important matter is not which drugs are being used for anaesthesia but the way they are used.

The anaesthetic technique should serve the haemodynamic goals but haemodynamic instability should be treated with cardiovascular drugs, not by decreasing the dose of anaesthetics.

- smooth induction: opioid, midazolam/etomidate/propofol
- maintenance:
  - volatile agent (preconditioning?? No strong clinical evidence and certainly not active in every patient)
  - sufentanil/remifentanil (fast track or not?)
Anticoagulation and hemostasis

OPCAB surgery is associated with hypercoagulability with possible thromboembolic complications and graft thrombosis:

- continuation of antithrombotic therapy if necessary
- heparine after mammary artery harvesting: 2.5 – 3 mg/kg
- ACT = 400 sec during coronary anastomoses
- protamine 1/1 for heparine reversal after last anastomosis
- antifibrinolytics are not used routinely, only on indication (repeat surgery)
Monitoring

• ASA monitors, arterial line
• ECG monitoring with automated ST-segment analysis
• TEE examination:
  • after induction:
    • contractility, ventricular relaxation, regional wall motion
    • valve function: undiagnosed important aortic or mitral valve dysfunction may preclude safe mobilization of the heart
  • during mobilization of the heart much of the TEE image is lost
  • after repositioning of the heart: new RWMA?
Monitoring

- thermodilution pulmonary artery catheter, continuous CO and fiberoptic mixed venous saturation
  - especially useful for ischemia detection during enucleation of the heart (when ECG is flat and TEE impossible)
  - correction of circulation during conditioning of the patient
- NIRS: never desaturations in the unsafe range and changes always in parallel with mixed venous oxygen saturations
- glycemia: 70 – 180 mg/dl
Foresigth in OPCAB

N=30
Haemodynamic goals

Amelioration of myocardial oxygen supply/demand ratio

- heart rate 55 – 70 bpm
- systolic arterial pressure > 85 mmHg
- diastolic arterial pressure > 50 mmHg
- PCWP or diastolic pulmonary artery pressure < 16 mmHg
- cardiac index > 2 l/m²
- normoxia – normocarbia – normothermia
- Hemoglobin > 8.5 mg/dl
Preload

Decrease due to obstructed inferior or superior caval or pulmonary venous return

• elevation of the legs: temporary mobilisation of volume
• colloids to increase CVP
• Trendelenburg position: very seldom, may compromise SCV return

Obstruction of RV outflow can decrease preload of LV (serial ventricular interdependence)

• communicate to surgeon: reposition the heart
Afterload

Low diastolic blood pressure compromises coronary perfusion: often a low dose of alpha 1-agonist is used (phenylephrine, norepinephrine).
- increases coronary perfusion pressure and collateral coronary blood flow
- increases preload by decreasing venous capacitance
- counteracts the vasodilatory effect of the anaesthetics

If the left ventricle is severely depressed or in the presence of mitral valve regurgitation: administer a PDE3 inhibitor (enoximone or milrinone)
- decreases afterload
- increases contractility
- minimal effect on HR and myocardial oxygen consumption
- beneficial pulmonary vasodilatory effect
Rate-rhythm

Maintain sinus rhythm between 55 – 70 bts/min if possible. A regular rhythm makes surgery easier.

- normal potassium (> 4 meq/l)
- often MgSO$_4$ (1 – 3 g)
- lidocaine (VES)
- metoprolol or esmolol

In the event of
- bradycardia: external atrial pacemakers leads are placed
- conduction block: atrial and ventricular leads
- atrial fibrillation unresponsive to defibrillation: ventricular pacing at 70/min, if necessary after AV-conduction inhibition (beta-blockers)
**Contractility**

Myocardial fuel consumption is directly related to the inotropic state: **inotropic stimulation should be avoided** as much as possible

- **in case of low cardiac output** (CI < 2 L/min/m²) or important mitral regurgitation: PDE3 inhibitor (enoximone or milrinone) to improve circulation before mobilization of the heart
- **in case of stunning during the post-grafting period**: low dose of dobutamine may be added to PDE3 inhibitor
- **in case of increased diastolic PA pressure**: isosorbide dinitrate infusion to decrease preload and wall tension
- **in case of high CI** (>2.5 and satₐ >75%): beta-blocker or more anaesthesia
Temperature management

Patient’s temperature should remain normal (36 - 37 °C) to avoid adrenergic stress during rewarming and to preserve coagulation

• avoid excessively low room temperature
• cover the patient
• use warming mattress
• administer warm iv fluids and transfusion products
Detection (suspicion) of ischemia

Circulatory instability: obvious

**Subtle indications should lead to corrective measures:**

- ECG changes: automated ST segment analysis, extrasystoles
- TEE: NWMA, increasing mitral valve dysfunction
- Increasing “stiffness” of left ventricle and possible mitral valve dysfunction:
  - decreasing CO and mixed venous oxygen tension
  - increasing diastolic pulmonary artery pressure (> 15 mmHg) without alternative explanation, or a change in the waveform (square) as signs of increased left ventricular end-diastolic pressure
What to do when ischemia is suspected?

Warn the surgeon:

- stabilizer position ok? (no suction over coronary artery?)
- shunt functioning well?
- realignment atrium-ventricle?
- reposition the heart to improve circulation?
- how much time left to complete the anastomosis?
What to do when ischemia is suspected?

Anaesthesia:

• decrease myocardial oxygen consumption:
  • heart rate > 70 ?: increase beta-blockade ?, deepen anaesthesia?
  • decrease wall tension: nitrates till diastolic PA < 15 mmHg, beta-blockers if CO is high
• improve oxygen delivery:
  • diastolic pressure > 50 mmHg: vasopressors
  • oxygen content (hemoglobin and saturation)
  • coronary or bypass vasospasm ?: nitrates, ca-antagonists
  • ACT ?
When to convert to CPB?

In case of **continuing ischemia** leading to **hemodynamic instability**, not responding to the combination of the anti-ischemic treatment by the anaesthetist and the corrective measures by the surgeon (eventually repositioning the heart): warn the perfusionist and consider:

- Intra-aortic balloon pump?
- Partial bypass (femoral cannulation) to support circulation?
- Full bypass with cardioplegia?
Conclusion

OPCAB surgery can be performed with a technical success rate approaching 100% and a very acceptable low risk for the patient under condition that:

• all the steps of the surgical and anaesthetic management are thoroughly planned and accurately performed
• surgeons, anaesthesiologists, nurses: teamwork
QUESTIONS ?