Monitoring and Interventions in ICU
Παρακολούθηση και παρεμβάσεις στην καρδιακή ανεπάρκεια στην μονάδα εντατικής θεραπείας

Pulmonologist - Intensivist
Director of Cardiothoracic Surgery Unit,
"G. Papanikolaou" GH, Thessaloniki
Left ventricular function is important predictor of hospital mortality following coronary artery bypass grafting.

Despite improvement in surgical technique, myocardial protection and postoperative care, surgical risk remains.
Preoperative ejection fraction as a predictor of survival after coronary artery bypass grafting: comparison with a matched general population

*J Cardiothorac Surg.* 2010; 5:296

Early and late mortality according to preoperative ejection fraction.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Group 1 (EF &gt; 50%) (n = 8204)</th>
<th>Group 2 (EF = 35% -50%) (n = 1717)</th>
<th>Group 3 (EF &lt; 35%) (n = 364)</th>
<th><em>P</em> Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early mortality (%)</td>
<td>129 (1.6)</td>
<td>63 (3.7)</td>
<td>38 (10.5)</td>
<td>&lt; .0001</td>
</tr>
<tr>
<td>Late mortality  (%)</td>
<td>742 (9.1)</td>
<td>296 (17.4)</td>
<td>81 (22.4)</td>
<td>&lt; .0001</td>
</tr>
</tbody>
</table>
Heart failure after Myocardial Infarction

- Death of the myocytes–Myocardial Scarring- Local Dysfunction
- Inadequate relaxation in diastole and impaired contraction in systole
- Further decrease in ventricular performance in case of aneurysm / dyssynchronous movement of the infarct area
- LV remodeling

Distortion of the ventricular structure and geometry
LV enlargement – Functional mitral regurgitation (MR)
Chronic Post-ischemic LV Dysfunction

Impaired LV contractility despite the presence of viable myocytes

The LV dysfunction is the result of months or years of chronic ischemia

Contractility can be restored after revascularization (PCI, CABG)

Goal of hemodynamic monitoring

Interventions

Maintain adequate tissue perfusion

ICU “goal-directed therapy” (GDT) protocols
No hemodynamic monitoring technique can improve outcome by itself
Monitoring requirements depend on local equipment availability and training
No optimal hemodynamic values that are applicable to all patients
We need to combine and integrate variables
Continuous measurement is preferable
S3 guidelines for intensive care in cardiac surgery patients: hemodynamic monitoring and cardiocirculatory system

- **MAP** (mean arterial pressure) >65 mmHg
- **Cardiac Index** >2.0 l/min/m²
- **CVP** 8–12 mmHg
- **LV-EDAI** 6–9 cm²/m²
- **ITBVI** 850–1000 ml/m²
- **GEDVI** 640–800 ml/m²
- **PAOP** 12–15 mmHg
- **Diuresis** >0.5 ml/kgBW/h
- **Lactate** <3 mmol/l

GMS German Medical Science 2010, Vol. 8 :1612-3174
Hemodynamic Factors

Contractility
Preload
Afterload

Heart rate
Stroke volume

CARDIAC OUTPUT

Preload
Volume of blood in ventricles at end of diastole (end diastolic pressure)
Increased in:
- Hypervolemia
- Regurgitation of cardiac valves
- Heart Failure

Afterload
Resistance left ventricle must overcome to circulate blood
Increased in:
- Hypertension
- Vasconstriction

↑ Afterload = ↑ Cardiac workload
Optimal fluid management is one of the cornerstones of hemodynamic management.
Hemodynamic monitoring and interventions step by step

- Clinical symptoms and signs
- Basic monitoring (ECG, Arterial Pressure, SPO$_2$)
- Volume status and preload responsiveness
  Absolute or relative volume deficiency very common

Effects of fluid type, timing and dose of fluid administration, and techniques for determining fluid responsiveness are actively debated topics
Volume Status

Static values

CVP
P楔
RVEDV
LVEDA

Poor prediction of fluid responsiveness with static pressures

Dynamic Indices

Pulse Pressure Variation (PPV)
Stroke Volume Variation (SVV)
Passive leg raising
Inferior Vena Cava Echo
GEDV (PiCCO)
Dynamic measures are more accurate for Volume Status estimation, before and after volume challenge

These measurements require:

- Controlled mechanical ventilation
- Tidal volume $>8$ mL/kg
- Absence of spontaneous breathing
- Normal sinus rhythm

Ultrasound measurement of inferior vena cava diameter does not appear to be useful after cardiac surgery

*Crit Care Med* 2015; 43:1477–1497
Hemodynamic monitoring and interventions step by step

Cardiac Output Estimation
Hemodynamic monitoring and interventions step by step/ Pulmonary Artery Catheter (PAC)

Current Use of the Pulmonary Artery Catheter in Cardiac Surgery: A Survey Study
Journal of Cardiothoracic and Vascular Anesthesia, Vol 29, No 1 (February), 2015: 69–75

Society of Cardiovascular Anesthesiologists (SCA) members in North America, Europe, Asia, Australia, New Zealand, and South America.
A total of 854 questionnaires were completed
For cases using cardiopulmonary bypass, 583 (68.2%) of the respondents used a PAC more than 75% of the time, while 30 (3.5%) did not use the PAC at all
Hemodynamic monitoring and interventions step by step/ Pulmonary Artery Catheter (PAC)
# Transesophageal ECHO vs PAC

TEE and PAC
NOT competitors

## TEE ECHO

<table>
<thead>
<tr>
<th>LV dimensions</th>
<th>Ejection Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid resposiveness</td>
<td>Valve Evaluation</td>
</tr>
<tr>
<td>Regional contractile dysfunction</td>
<td>Diastolic dysfunction</td>
</tr>
</tbody>
</table>

## Pulmonary Artery Catheter

<table>
<thead>
<tr>
<th>Estimation of Pressures</th>
</tr>
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<tbody>
<tr>
<td>PVRI/SVRI</td>
</tr>
<tr>
<td>CO-DO2-VO2</td>
</tr>
<tr>
<td>SVO2</td>
</tr>
</tbody>
</table>
**SvO<sub>2**

Reflects balance between oxygen delivery (DO<sub>2</sub>) (VO<sub>2</sub>)

Adequate tissue perfusion

**Lactate**

Anaerobic Metabolism
Lactate is a useful marker of an energy crisis at the cellular levels. In low-flow shock states, a lactate elevation is caused by tissue hypoxia. High lactate levels (> 3–4 mmol/L) and slow lactate clearance accurately predict major complications after cardiac surgery. The liver accounts 50% of lactate clearance. Elevated lactate levels per se are not an indication for the administration of fluids or inotropes.
Pharmacological treatment of left ventricular dysfunction after cardiac surgery

Clinical review: Practical recommendations on the management of perioperative heart failure in cardiac surgery
Critical Care 2010;14:201

Catecholamines  Dobutamine and Epinephrine low-to-moderate doses

Milrinone

Levosimendan (calcium sensitizer)

Norepinephrine

Basic principles - Inotropes

\[
\text{MAP} = \text{CO} \times \text{SVR}
\]

\[
\text{CO} = \text{HR} \times \text{SV}
\]

Preload  Contractility  Afterload
Low Cardiac Output Syndrome (LCOS) Definition

LCOS based on the STS (Society of Thoracic Surgeons) definition, consisting of the following criteria:

Need for postoperative intraaortic balloon pump or inotropic support for more than 30 minutes in the ICU in order to obtain cardiac index value greater than 2.2 L/min/m² and systolic blood pressure greater than 90 mm Hg.
Levosimendan and Cardiac Surgery

Preoperative and perioperative use of levosimendan in cardiac surgery: European expert opinion
International Journal of Cardiology 184 (2015) 323–33

27 experts from 18 countries convened to review the literature and to agree upon a series of recommendations

Levosimendan effectively improves general and pulmonary haemodynamics in patients undergoing cardiac surgery, thereby reducing the need for inotropic agents and mechanical circulatory support, and additionally optimising renal and hepatic function.

The unique inotropic and cardioprotective properties of levosimendan can provide sustained effects for several days and can thus help to reduce complications.
Levosimendan for Hemodynamic Support after Cardiac Surgery
N Engl J Med 2017; 376 :2021-31

Multicenter, randomized, double-blind, placebo-controlled trial involving patients who required hemodynamic support after cardiac surgery, the administration of levosimendan was not associated with lower 30-day mortality than placebo
The most common type of circulatory support

- Reduction of afterload and increased diastolic coronary perfusion
- Optimize the balance of myocardial oxygen demand/supply
- Avoid the excessive need of inotropic support
<table>
<thead>
<tr>
<th>Mechanical Hemodynamic Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paracorporeal</td>
</tr>
<tr>
<td>Pneumatic</td>
</tr>
<tr>
<td>Pulsatile</td>
</tr>
<tr>
<td>Uni-or</td>
</tr>
<tr>
<td>biventricular</td>
</tr>
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</tbody>
</table>

**Mechanical Hemodynamic Support**

- Paracorporeal
- Pneumatic
- Pulsatile
- Uni-or biventricular

**Implantable**

- Electric
- Continuous flow
- Atiliski design
- Smaller
- Single moving part
- Bearingless
- Partial support
Low Ejection Fraction Statistics

From June 2012 – December 2017

A total of 1635 isolated CABG

Low EF: 192 (11.7%)
<table>
<thead>
<tr>
<th></th>
<th>Low EF</th>
<th>Rest of cohort</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td>64.8±9.9</td>
<td>64.9±9.5</td>
<td></td>
</tr>
<tr>
<td><strong>Female</strong></td>
<td>24(12.5%)</td>
<td>210(14.6%)</td>
<td>0.48</td>
</tr>
<tr>
<td>Ιστορικό OEM</td>
<td>133(69.3%)</td>
<td>702(48.6%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>CPB time</strong></td>
<td>95.5</td>
<td>89</td>
<td></td>
</tr>
<tr>
<td><strong>(median,min)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Data –base
George Papanikolaou Hospital
Cardiothoracic Department

<table>
<thead>
<tr>
<th></th>
<th>Low EF</th>
<th>Rest of cohort</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCOS(SIMDAX)</td>
<td>68(36%)</td>
<td>24(1.7%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>IABP</td>
<td>42(22.1%)</td>
<td>62(4.3%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>AF</td>
<td>78(41.1%)</td>
<td>430(29.8%)</td>
<td>0.002</td>
</tr>
<tr>
<td>Mortality</td>
<td>14(7.4%)</td>
<td>14(1%)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
Low Ejection Fraction and Renal Function

Cardio-Renal Syndrome

Pathophysiologic disorder of the heart and kidneys whereby acute or chronic dysfunction in one organ may induce acute or chronic dysfunction in the other organ

C et al. JAmCollCardiol 2008;52:1527-1539
# Heart-Renal interactions Classification system

<table>
<thead>
<tr>
<th>Classification of Cardiorenal syndrome</th>
<th>Clinical manifestation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type I</strong>: Acute cardiorenal syndrome,</td>
<td>Acute kidney injury (AKI) in the setting of sudden worsening cardiac function</td>
</tr>
<tr>
<td><strong>Type II</strong>: Chronic cardiorenal syndrome</td>
<td>Progressive renal dysfunction in the setting of chronic cardiac dysfunction</td>
</tr>
<tr>
<td><strong>Type III</strong>: Acute renocardiac syndrome</td>
<td>AKI precipitating worsening cardiac function</td>
</tr>
<tr>
<td><strong>Type IV</strong>: Chronic renocardiac syndrome</td>
<td>Chronic renal dysfunction leading to chronic cardiac dysfunction</td>
</tr>
<tr>
<td><strong>Type V</strong>: Secondary cardiorenal syndrome</td>
<td>Worsening renal and cardiac function in the setting of underlying systemic illness</td>
</tr>
</tbody>
</table>
Bidirectional relationship

Chronic heart disease

- Anemia
- Na + H₂O retention
- Uremic solute retention
- Ca and Phos abnormalities
- Hypertension

Genetic risk factors
- Acquired risk factors
- Low cardiac output (CO)

Low cardiac output (CO)
- Subclinical inflammation
- Endothelial dysfunction
- Accelerated atherosclerosis

Chronic hypoperfusion
- Increased renal vascular resistance
- Increased venous pressure
- Embolism

Anemia, hypoxia
- RAA and sympathetic activation
- Na + H₂O retention
- Ca and Phos abnormalities
- Hypertension, LVH

Increased susceptibility to insults
- Chronic hypoperfusion
- Apoptosis

Insult and initiation of kidney damage
- Sclerosis - Fibrosis

Progression of CKD
- Anemia
- Na + H₂O retention
- Uremic solute retention
- Ca and Phos abnormalities
- Hypertension
## Risk factors associated with Acute Renal Failure After Cardiac Surgery

<table>
<thead>
<tr>
<th>Patient-Related</th>
<th>Procedure-Related</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female gender</td>
<td>Length of CPB</td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease</td>
<td>Cross-clamp time</td>
</tr>
<tr>
<td>Diabetes</td>
<td>Off-pump <em>versus</em> on-pump</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>Nonpulsatile flow</td>
</tr>
<tr>
<td><strong>Renal insufficiency</strong></td>
<td>Hemolysis</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>Hemodilution</td>
</tr>
<tr>
<td><strong>LV ejection fraction &lt;35%</strong></td>
<td></td>
</tr>
<tr>
<td>Need for emergent surgery</td>
<td></td>
</tr>
<tr>
<td>Cardiogenic shock (IABP)</td>
<td></td>
</tr>
<tr>
<td>Left main coronary disease</td>
<td></td>
</tr>
</tbody>
</table>

*CJASN January 2006 (1): (1) 19-32*
**Delay in AKI diagnosis** during early postoperative period
delayed increase of serum creatinine in response to nephron injury
positive fluid balance influencing the volume of distribution of creatinine

**No specific recommendations for**
type of fluid - vasoactive drug- hemodynamic parameters values
Loop diuretics convert oliguric AKI into non-oliguric AKI
Frusemide is not associated with any significant clinical benefits in the prevention and treatment of acute renal failure in adults. High doses may be associated with an increased risk of ototoxicity

BMJ 2006 Aug 26;333(7565):420

The continuous infusion of dopamine was ineffective for renal protection and not superior to isotonic saline in preventing postoperative dysfunction
Lassnigg et al  


Large randomized trial in early ARF has failed to show any benefit of the dopamine in preventing renal injury, renal replacement therapy, or death
Bellomo R  

Lancet 2000; 356: 2139-2143
Renal Protection

- Glycemic control
- Less transfusions
- Optimize hemodynamics
- Optimize perfusion pressure
- Avoid NSAIDs
- Avoid administration of contrast media 24 hours before surgery
Acute Renal Failure After Cardiac Surgery

**Renal Replacement Therapy** required when

- hyperkalemia
- fluid overload
- treat uremia
- acidosis
### AKI and Low EF
G.Papanikolaou Database

<table>
<thead>
<tr>
<th></th>
<th>Low EF patients</th>
<th>Ef&gt;30%</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AKI</strong></td>
<td>40 (21.1%)</td>
<td>159 (11%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Dialysis</strong></td>
<td>13 (6.8%)</td>
<td>24 (1.7%)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

"Goal-directed therapy” may reduce AKI and length of stay *Br J Anaesth.* 2013;110(114):510–7
Low preoperative ejection fraction represents a risk factor of developing postoperative respiratory failure

Respiratory Failure After Cardiac Surgery

**Specific to cardiac surgery:**
- Cardiopulmonary bypass (CPB)
- Transfusion of blood product
- Topical heart cooling
- Dissection of the IMA artery
- Effects of general anesthesia

**Anomalies in gas exchange:**
- Increased microvascular permeability
- Increased pulmonary shunt fraction
- Intrapulmonary aggregation of leukocytes and platelets

**Alterations in lung mechanics:**
- Reductions in vital capacity
- Reduction of functional residual capacity
- Reduction of lung compliance
Chronic Heart Failure and Respiratory System

✓ Chronic volume overload-Interstitial/Alveolar edema/Pleural effusions

✓ Lung Stiffness

✓ Chronic changes to alveolocapillary membrane

✓ Restrictive pattern in spirometry

✓ Sleep disorders
The application of postoperative NIV by a trained and experienced ICU team, with careful patient selection, should optimize patient outcome

Anesthesiology 2010; 112:453–61

<table>
<thead>
<tr>
<th>G.Papanikolaou Data</th>
<th>Low EF</th>
<th>Rest of cohort</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mech ventilation (median hours)</td>
<td>8</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td><strong>Prolonged ventilation (&gt; 24 h)</strong></td>
<td>17(8.9%)</td>
<td>31(2.1%)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>NIV</td>
<td>26(13.7%)</td>
<td>105(7.3%)</td>
<td>0.02</td>
</tr>
<tr>
<td>Re-intubation</td>
<td>11(5.8%)</td>
<td>21 (1.5%)</td>
<td>&lt;0.01</td>
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</tbody>
</table>
Postoperative Stroke

The use of the stroke risk index to predict neurological complications following coronary revascularisation on cardiopulmonary bypass *Anaesthesia, 2005,60: 654–659*

- A reduced **LVEF affects brain perfusion**, contributing to neurological events
- LV hypocontractility may cause **intracavitary thrombosis** and embolism
- Severely impaired **LVEF < 30% was found to be the strongest pre-operative determinant** for neurologic complications after CABG

Stroke After Coronary Artery Bypass *Stroke. 2001;32:1508-1513*

Independent predictors of stroke included
- chronic renal insufficiency - recent myocardial infarction- carotid artery disease
- previous cerebrovascular accident- hypertension- diabetes- advanced age
- **moderate/severe left ventricular dysfunction- low cardiac output syndrome**
- and new-onset atrial fibrillation
Neuroprotective Strategies

Before Surgery
- Identification of patients at high risk
- Alternative surgical procedures (off-pump) Use of PCI therapy

During Surgery
- Use of epiaortic/TEE ultrasound to identify ascending and arch aortic disease
- Modifications to surgical procedure:
  - minimize aortic manipulation, use of single aortic cross clamp for proximal grafts, no touch aortic technique

After Surgery
- Prevention of atrial fibrillation
- Diagnosis and identification/arrhythmias
- CT Scan
- Early blood pressure interventions to minimize infarction size
- Fibrinolytic treatment is contraindicated due to elevated risk for hemorrhage
- Mechanical thrombectomy

Stroke. 2006;37:562-571
### Postoperative Stroke

#### Sources of cerebral macroemboli
- ✓ atherosclerotic emboli from the ascending aorta
- ✓ carotid disease
- ✓ intracardiac cavities

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Ευχαριστώ