New Fields of Activities for Perfusionists
Now and the next decade

Frank Merkle
Academy for Perfusion and Steinbeis Transfer-Institute Perfusion
Deutsches Herzzentrum Berlin
Scope of Practice Perfusion (AmSECT)

- Extracorporeal circulation and cardiopulmonary support
- Counterpulsation
- Circulatory support and ventricular assistance
- Extracorporeal membrane oxygenation
- Blood conservation techniques and autotransfusion
- Myocardial preservation
- Anticoagulation and hematologic monitoring
- Blood gas and blood chemistry monitoring
- Induction of hypothermia and hyperthermia with reversal
- Hemodilution
- Hemofiltration
- Administration of medications, blood components
- Documentation
Challenges in Perfusionists’ Daily Work

• Specialisation of hospitals and departments

• Diversification of perfusionist related tasks

• Increasing demand for interdisciplinary work

• Intraclinical entrepreneurship

• Changing clinical demands (patient related)

• Building up professional recognition and ethos
Kondratieff Cycles in Perfusion

- Concept of Perfusion
- Physiological Experiments
- Improvements of CPB
- Perfusion Safety
- Mass Application of CPB
- ECMO
- Clinical Application of CPB
- Cardiac Assist Devices
- Total Artificial Heart
- Mini Circuits
  - Adult/Congenital
What is Biocompatibility?

“Biocompatibility is not an inherent property of a particular composition of matter, but depends upon the shape, finish, fabrication techniques, and choice of application of a particular material.”

Galletti 1998
Strategies to improve Biocompatibility

► OPCAB
► Optimizing CPB design
  ► Closed CPB system
  ► Arterial pump characteristics
  ► Coating
  ► Elimination of cardiotomy suction and vent
  ► Miniaturization (MECC)
► Heparin management
► Antifibrinolytic therapy
INFLAMMATORY REACTION TO CARDIOPULMONARY BYPASS

STIMULI
Surgical trauma
Blood contact with CPB surfaces
Endotoxemia
Ischemia

ADHESION MOLECULES
Selectins: E selectin, P selectin, L selectin
Integrins: CD11/CD18 (MAC-1)
Immunoglobulin superfamily: ICAM, VCAM, PECAM

MEDIATORS
Complement system: C3a, C5a
Cytokines: IL-1, IL-2, IL-6, IL-8, TNF-α, IL-10
iNOS
Oxygen free radicals

TRANSCRIPTION FACTOR
NF-κB

EFFECTS
Leukocyte extravasation
Lipid peroxidation
Edema
Cell death

Paparella 2002
Sucker Blood Retransfusion

► Endotoxinemia

Spanier, Perfusion 2000

► Tissue Factor – Activation of coagulation system and hemolysis

De Somer, JTCVS 2002

► Fat particles impair capillary blood flow

Appelblad, JTCVS 2002

► Activation of thrombin, neutrophils, thrombocytes, release of neuron-specific enolase

Aldea, JTCVS 2002

► Major cause of hemolysis, contributes to SIRS

Khosravi, Scand Cardiovasc J 2006
„Direct reinfusion to the CPB circuit of unprocessed blood exposed to pericardial and mediastinal surfaces should be avoided (Class I, Level B)“

„Blood cell processing and secondary filtration can be considered to decrease the deleterious effects of reinfused shed blood (Class IIb, Level B)“

Sucker Blood Retransfusion

Shann, JTCVS 2006
Biomarker Profile in Off-Pump and On-Pump Coronary Artery Bypass Grafting Surgery in Low-Risk Patients

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Background. The purpose of this study was to investigate the cytokine and chemokine profile in low-risk patients undergoing off-pump and on-pump coronary artery bypass grafting (CABG) surgery by use of a broad panel of cytokines and chemokines.

Methods. Eight consecutive blood samples were obtained from patients enrolled into a prospective, randomized study comparing off-pump and on-pump CABG in a low-risk population. Eleven patients from each group were randomly selected for analysis of 25 different cytokines and chemokines using multiplex technology. Data were compared using two-way repeated measures analysis of variance.

Results. Of the 25 biomarkers analyzed, 11 were not detected while 14 increased significantly in both groups. Only three mediators, eosinophil, macrophage inflammatory protein (MIP)-1β, and interleukin (IL)-12 were significantly different between the two groups, increasing more in the on-pump than in the off-pump group (p < 0.001, p < 0.01, and p < 0.05, respectively). There was a marked, comparable increase in the concentrations of the cytokines IL-6, IL-10, IL-15, and IL-1Ra as well as the chemokines inducible protein (IP)-10, monokine induced by interferon gamma (MIG), monocyte chemoattractant protein 1 (MCP-1), and regulated on activation, normal T cell expressed and secreted (RANTES) in both groups (p < 0.001 for all). There was only a modest, but still statistically significant, increase in IL-8, tumor necrosis factors α, and IL-2R, without any intergroup differences. When corrected for hemodilution the production of the anti-inflammatory biomarkers IL-1Ra and IL-10 were significantly higher in the on-pump group (p < 0.001 for both).

Conclusions. The cytokine and chemokine production profile of the inflammatory response associated with CABG is largely similar using the off-pump and on-pump techniques in low-risk patients, but slightly higher concentrations of eosinophil, MIP-1β, and IL-12 were found in the on-pump group.

How to make CPB more biocompatible?

Suggested combination of various strategies:

- Reduction of sucker blood retransfusion
- Reduction of blood-air interface
- Reduction of hemodilution
- Coating of CPB circuits
- Re-design of CPB circuits
- Pharmacological interventions
Transfusion-Free Arterial Switch Operation in a 1.7-kg Premature Neonate Using a New Miniature Cardiopulmonary Bypass System

Michael Huebler, M.D.,* Matthias Redlin, M.D.,† Wolfgang Boettcher, E.C.C.P.,‡ Andreas Koster, M.D.,† Felix Berger, M.D.,§ Björn Peters, M.D.,§ and Roland Hetzer, M.D.*

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ABSTRACT In cardiac surgery, the potentially detrimental effects of transfusions on patient outcome are increasingly appreciated. Therefore, at our institution there are continuing efforts to modify our surgical, perfusion, and blood management strategies with the aim of transfusion-free cardiac surgery even in neonates and small children. Stringent improvement of these strategies, particularly the downsizing of the cardiopulmonary bypass system, have now enabled a transfusion-free arterial switch operation in a 1700-gram prematurely born neonate. doi: 10.1111/j.1540-8191.2007.00555.x (J Card Surg 2008;23:358-360)
Transfusion-Free Arterial Switch Operation in a 1.7-kg Premature Neonate Using a New Miniature Cardiopulmonary Bypass System

Michael Huebler, Andreas Kost, and Roland Hetzer

A new miniaturized cardiopulmonary bypass system reduces transfusion requirements during neonatal cardiac surgery: Initial experience in 13 consecutive patients

Andreas Koster, MD, a Michael Huebler, MD, b Wolfgang Boettcher, ECCP, c Mathias Redlin, MD, a Felix Berger, MD, d and Roland Hetzer, MD, b Berlin, Germany

ABSTRACT In car increasingly apical, perfusion, a neonates and sn cardiopulmonary gram premature

The potential detrimental effects of the transfusion of autologous blood products on patients’ outcome is increasingly appreciated.1,2 This has promoted strategies to reduce the consumption of donor blood products, as well as investigations assessing lower “critical” hemoglobin values as a trigger for transfusions.3 However, particularly in small infants

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Departments §Congenital H

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Roland Hetzer, MD, §B

ABSTRACT In cardiac perfusion, a neonates and small premature

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FIGURE 2. Course of hemoglobin values in patients without transfusions. CPB, Cardiopulmonary bypass; X-clamp, crossclamp; ICU, intensive care unit.
Effects of a comprehensive blood-sparing approach using body weight–adjusted miniaturized cardiopulmonary bypass circuits on transfusion requirements in pediatric cardiac surgery

Matthias Redlin, MD, a Helmut Habazettl, MD, PhD, a,d Wolfgang Boettcher, ECCP,b Marian Kukucka, MD, a Helge Schoenfeld, MD, c Roland Hetzer, MD, PhD, b and Michael Huebler, MD b

Objectives: Transfusion-free pediatric cardiac surgery remains a challenge, mainly owing to the mismatch between the cardiopulmonary bypass (CPB) priming volume and the infants’ blood volume. Within a comprehensive blood-sparing approach, we developed body weight–adjusted miniaturized CPB circuits with priming volumes of 95, 110, and 200 mL for, respectively, infants weighing less than 3 kg, 3 to 5 kg and 5 to 16 kg. We analyzed the effects of this approach on transfusion requirements and risk factors predisposing for blood transfusion.

Methods: A total of 288 children with body weights between 1.7 and 15.9 kg were included and divided into 3 groups: No transfusion, postoperative transfusion only, and intraoperative and postoperative transfusion. Groups were compared by analysis of variance or analysis of variance on ranks. Risk factors predisposing for transfusion were identified by multivariate logistic regression.

Results: Of the infants, 24.7% required no transfusion, 23.6% received postoperative transfusion only and 51.7% received intraoperative and postoperative transfusion. Groups differed by age, body weight, and size and by duration of surgery, CPB, and aortic crossclamp (P < .00001). Body weight (P < .00001), CPB duration (P < .00001), and persisting cyanosis (P = .03) were predictors of intraoperative and postoperative transfusion, whereas body weight (P = .00095), reoperations (P = .0051), and cyanotic heart defects (P = .035) were associated with postoperative transfusion only.

Conclusions: Our blood-sparing approach allows for transfusion-free surgery in a substantial number of infants. The strongest predictors of transfusion requirement, body weight and complexity of surgery as reflected by CPB duration, are not amenable to further improvements. Better preservation of the coagulatory system might allow for reduction of postoperative transfusion requirements. (J Thorac Cardiovasc Surg 2012; ■:1-7)
Minimal Safe Pump Flow During CPB

- Body Surface Area
- Degree of hypothermia
- Acid-base balance
- Whole-body oxygen consumption
- Degree of neuromuscular blockade
- Oxygen content
- Depth of anesthesia
- Specific organ ischemic tolerance

Murphy 2009
CPB Standard Monitoring

Anesthesia

ECG

Pressures (MAP, CVP, PAP, LAP)

Temperatures

SaO$_2$ (pulse oximetry)

CPB

Flow

Pressures (arterial line, oxygenator, cardioplegia…)

Temperatures

Online SvO$_2$, Blood Gases online or intermittently

Blood lactate, Electrolytes etc.
O₂ delivery and CO₂ production during cardiopulmonary bypass as determinants of acute kidney injury: time for a goal-directed perfusion management?

Filip de Somer¹, John W Mulholland², Megan R Bryan², Tommaso Aloisi³, Guido J Van Nooten¹ and Marco Ranucci³*

Abstract

**Introduction:** Acute kidney injury (AKI) is common after cardiac operations. There are different risk factors or determinants of AKI, and some are related to cardiopulmonary bypass (CPB). In this study, we explored the association between metabolic parameters (oxygen delivery (DO₂) and carbon dioxide production (VCO₂)) during CPB with postoperative AKI.

**Methods:** We conducted a retrospective analysis of prospectively collected data at two different institutions. The study population included 359 adult patients. The DO₂ and VCO₂ levels of each patient were monitored during CPB. Outcome variables were related to kidney function (peak postoperative serum creatinine increase and AKI stage 1 or 2). The experimental hypothesis was that nadir DO₂ values and nadir DO₂/VCO₂ ratios during CPB would be independent predictors of AKI. Multivariable logistic regression models were built to detect the independent predictors of AKI and any kind of kidney function damage.

**Results:** A nadir DO₂ level < 262 ml/minute/m² and a nadir DO₂/VCO₂ ratio < 5.3 were independently associated with AKI within a model including EuroSCORE and CPB duration. Patients with nadir DO₂ levels and nadir DO₂/VCO₂ ratios below the identified cutoff values during CPB had a significantly higher rate of AKI stage 2 (odds ratios 3.1 and 2.9, respectively). The negative predictive power of both variables exceeded 90%. The most accurate predictor of AKI stage 2 postoperative status was the nadir DO₂ level.

**Conclusions:** The nadir DO₂ level during CPB is independently associated with postoperative AKI. The measurement of VCO₂-related variables does not add accuracy to the AKI prediction. Since DO₂ during CPB is a modifiable factor (through pump flow adjustments), this study generates the hypothesis that goal-directed perfusion management aimed at maintaining the DO₂ level above the identified critical value might limit the incidence of postoperative AKI.
Age Distribution of Cardiac Patients in Germany
DHZB Patients’ Age Distribution 2000-2008
n=26,202
# Cardiac Procedures in Germany

<table>
<thead>
<tr>
<th>Category</th>
<th>With CPB</th>
<th>Without CPB</th>
<th>Total</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valve procedures</td>
<td>21404</td>
<td>2152</td>
<td>23556</td>
<td>5.9%</td>
</tr>
<tr>
<td>Coronary surgery</td>
<td>52386</td>
<td>6109</td>
<td>58495</td>
<td>-4.2%</td>
</tr>
<tr>
<td>Congenital lesion</td>
<td>4364</td>
<td>952</td>
<td>5316</td>
<td>0.8%</td>
</tr>
<tr>
<td>Surgery of thoracic aorta</td>
<td>5888</td>
<td>409</td>
<td>6297</td>
<td>5.7%</td>
</tr>
<tr>
<td>Other cardiac surgery</td>
<td>1766</td>
<td>1108</td>
<td>2874</td>
<td>4.0%</td>
</tr>
<tr>
<td>Assist devices</td>
<td>549</td>
<td>917</td>
<td>1466</td>
<td>18.4%</td>
</tr>
<tr>
<td>Pacemaker and ICD</td>
<td>91</td>
<td>23638</td>
<td>23729</td>
<td>1.0%</td>
</tr>
<tr>
<td>Extracardiac surgery</td>
<td>468</td>
<td>40216</td>
<td>40684</td>
<td>9.4%</td>
</tr>
<tr>
<td>Total</td>
<td>86916</td>
<td>75501</td>
<td>162417</td>
<td>2.0%</td>
</tr>
</tbody>
</table>
Neuromonitoring

- **Function**
  - (clinical)
  - EEG
  - EP

- **Perfusion**
  - CPP, ICP
  - TCD
  - CSP

- **Oxygenation**
  - NIRS
  - SvjO₂
  - Tissue O2
  - (Microdialysis)
Neuromonitoring

EEG Bispectral Index

Near Infrared Spectroscopy

Transcranial Doppler
Neuromonitoring

Possible Interventions

Surgical manipulation (cannulae, luxation)
Venous drainage
Depth of anesthesia, temperature
O_2 consumption vs O_2 delivery
Arterial / cranial perfusion pressure vs O_2 delivery
„Hybrid“-Surgery of Congenital Defects
Transapical Aortic Valve Replacement

- Conventional open CPB circuit
- Venous drainage augmented by vacuum controller
- Peripheral vascular access for both arterial and venous line with small diameter cannulae for partial flow
Clinical Assignments

- Blood Management
  - Autotransfusion
  - Platelet-Rich Plasma
  - Platelet Gel
- Limb Perfusion
- Liver Perfusion
- Vein Harvesting
Clinical Assignments
Clinical Assignments contd.

► Cardiology
  ► Echocardiography
  ► PM, AICD, CRT
  ► Electrophysiology

► Other Departments
  ► In-house ECLS rescue team
  ► Patient transport
  ► Regional perfusion (oncologic treatment)
Interviews with Perfusionists

Competencies for anticipated (future) tasks

• Professional competences: enlargement of scope of practice (cardiology, tasks within and outside of cardiac surgery), more knowledge in scientific and medical disciplines

• Methodological competences: research, international communication, economic thinking, quality management, medical documentation

• Social competences: team work, interdisciplinarity, care for VAD patients (empathy)

• Self competences: flexibility, openness, improvisation

Merkle 2007
Interviews III

Contents and structure of future perfusion education

• Content: broad general education
  broad medical and scientific education
  medically related practical education
  ongoing education for practising perfusionists

• Organization: combination of practical and theoretical modules
  interdisciplinary orientation
  visitation of different departments
  emphasis on practical training

Merkle 2007
Interviews Summary

New professional skills for perfusionists

• Knowledge in management and economics

• Knowledge in team building and leading

• Social competence

• Self-management skills

• Diversification of activities with high emphasis on medical and surgical competencies

Merkle 2007
Conclusion

• The future of the profession looks bright

• More flexibility and more clinical competencies for perfusionists are needed

• Diversification of perfusionist related tasks is currently taking place

• Higher level of education for perfusionists necessary to include B.Sc. and M.Sc. degrees