Beating Heart Valve Surgery

Tomas A. Salerno MD
No conflict of interest to declare with this lecture
Objectives

1. Brief Review Myocardial Protective strategies
2. Review of Myocardial perfusion
3. Scientific Basis for Beating heart valve surgery
Myocardial Protection

- is MORE than just cardioplegia
- includes *ALL* maneuvers
- initial “resuscitation”
- anesthesia
- other support (e.g. IABP)
- pharmacology
Importance of Protection

- poor protection = poor outcome

- relationship to peri-op mortality

- role in long-term results
  - follow up: poor EF development
  - is it disease progression? or intra/peri op injury?

- no matter how good the repair, ventricular function has to be preserved over the long period (heart surgery IS myocardial protection)
Hypothermia
Effects of Hypothermia

- cell membrane fluidity
- WBC function
- cell volume regulation
- coagulation cascade
- microvascular distribution of blood flow
- heart rate
- $O_2$ consumption
Cold Blood cardioplegia (Buckberg GD)

Milestone in myocardial protective strategies


“Ideal” Protection relies on myocardial septal temperature.

Yet, How many surgeons measure myocardial septal temperature?
Buckberg’s Resuscitative Maneuvers

Warm Induction (resuscitation)
Period of “mandatory” cold ischemic arrest
Terminal Hot Shot (resuscitation)


Since we were already using continuous cold blood cardioplegia, why not perfuse with continuous warm blood cardioplegia, thereby “resuscitating” the heart during the operation?
Continuous Retrograde Warm Cardioplegia

Evolved into Beating heart retrograde warm blood perfusion, as more and more we were perfusing with warm blood rather than cardioplegia in the later stages of the operation. Although successful, this was later abandoned as laboratory evidence indicated poor protection of the RV and posterior LV wall.


**William G. Bigelow, Cold Hearts: The story of hypothermia and the pacemaker in heart surgery**

Warm Heart Surgery was born

(In the same University)
Myocardial Oxygen Utilization in the Normothermic Heart and During Hypothermic Cardiac Arrest

- 1. Normal Working Heart
- 2. Rhythmically Contracting Empty Heart
- 3. Normothermic Arrested Heart
- 4. Hypothermic Arrested Heart

CC. O₂/100 Gm. Whole Heart / Min.
Antegrade/retrograde blood cardioplegia to ensure cardioplegic distribution: operative techniques and objectives.

Antegrade cardioplegia, retrograde cardioplegia, or both?

The safety of simultaneous arterial and coronary sinus perfusion: experimental background and initial clinical results

Myocardial oxygen production at the end of simultaneous antegrade/retrograde perfusion in the beating empty state before and after 30 minutes of blood cardioplegic arrest.

Fig. 2  Myocardial water content before (Control), and after one hour of simultaneous antegrade/retrograde perfusion in left (LV) and right (RV) ventricular myocardium.
Fig. 3  Myocardial lactate production at control status, and after simultaneous antegrade and retrograde perfusion in the empty beating and arrested state.
“CONCLUSION: These experimental and clinical findings overcome perceived concerns about myocardial damage from simultaneous arterial and coronary sinus perfusion, and suggest this approach may add to the armamentarium of cardioprotective strategies.”

Does Cardioplegic arrest prevent myocardial injury in all cardiac procedures?
Increased susceptibility of the myocardium to ischemic injury

- Coronary artery disease
- Myocardial hypertrophy
- Poor left ventricular function
- Prolonged periods of cross-clamping
Intermittent Antegrade Warm Blood Cardioplegia

Warm Blood Cardioplegia basic research

Ganghong Tian, Bo Xiang, Keith W. Butler, Antonio M. Calafiore, Andrea Mezzetti, Tomás A. Salerno, and Roxanne Deslauriers

$^{31}$P-Nuclear magnetic resonance study of intermittent warm blood cardioplegia


Andrea Mezzetti, Antonio M. Calafiore, Domenico Lapenna, Roxanne Deslauriers, Ganghong Tian, Tomas A. Salerno, Anna M. Verna, Giovanni Bosco, Sante D. Pierdomenico, and Franco Caccuruollo

Intermittent antegrade warm cardioplegia reduces oxidative stress and improves metabolism of the ischemic-reperfused human myocardium

Lotto AA et al:
Ann Thorac Surg 2003; 76; 1227-33

Retrograde and antegrade intermittent cold blood cardioplegia are associated with suboptimal protection in AVR
Time-dependent release of Troponin in both groups

Lotto, 2003
Ascione R et al:
European J Cardiothoracic Surgery 2002; 21: 440-446

Cold cardioplegia better than warm cardioplegia in AVR. Both provide suboptimal myocardial protection.
Concentration of ATP+ADP in myocardial biopsies 20 min. after reperfusion

Ascione 2002
Time-dependent release of Troponin at different time points postoperatively

Ascione 2002
Concentration of Alanine/Glutamate in myocardial biopsies 30 min. after cross-clamping

- Cold blood: P=ns
- Warm blood: P=0.005

Ascione 2002
ARE WE PERFUSING DIFFERENT VASCULAR BEDS WITH ANTEGRADE AND RETROGRADE CARDIOPLEGIA?
Cardioplegia perfusion

PCr  ATP

Subendocardium

Midwall

Subepicardium

 Interruption of cardioplegia

Pi  PCr  ATP

Subendocardium

Midwall

Midwall

Subepicardium

Figure 1. Transmural localized $^{31}$P MR spectra obtained from the anterior wall of the left ventricle of a pig heart during cardioplegic perfusion (left panel) and interruption of cardioplegia (right panel). It is clear that Pi/PCr ratio was significantly higher in the subepicardium than in the subendocardium during interruption of cardioplegic perfusion, suggesting severe ischemic change in the former than in the latter region. We believe that the observation is due to the fact that in an arrested heart more blood flow is directed to the subendocardium than to the subepicardium. The $^{31}$P spectra were acquired with image-selected in vivo spectroscopy (ISIS) in conjunction with Fourier-series-window longitudinally modulated and adiabatic excitation (FLAX). The technique will be combined with ECG gating to acquire transmural localized $^{31}$P spectra in this project.
Figure 2. Panel A shows a contrast-enhanced MR image obtained from a pig heart during antegrade cardioplegia (AC) Panel B shows a contrast-enhanced MR image acquired during retrograde cardioplegia (RC). Signal-time courses of ATP acquired from the anterior and posterior wall of the LV during RC are shown on the panel C. It is clear that RC does not deliver blood to the right ventricular wall and the part of the posterior wall of the LV. As a result, the level of ATP gradually decreased during RC in the posterior wall of the LV. We believe that retrograde perfusion of the empty-beating heart would also be heterogeneous. Ischemic changes is expected to be more severe during empty beating than during cardioplegia. As a result, we believe that retrograde perfusion should not be used alone in an empty-beating heart for a prolonged period.

JTCS, 2000; 120: 544-551
Figure 3. Representative contrast-enhanced T₁ MR images obtained during antegrade cardioplegia (AC) and simultaneous antegrade/retrograde cardioplegia (SARC) from a pig heart with the anterior descending coronary artery (LAD) occluded at its origin. SARC was carried out through the aorta and coronary sinus. Images A were obtained during AC with a MR contrast agent (Gd-DTPA) injected into the aorta. Obviously, the myocardium supported by the LAD was not perfused. Images B and C were acquired during SARC with the contrast agent injected into the aorta and coronary sinus, respectively. It is evident that both perfusion routes of simultaneous cardioplegia helped deliver blood to the LAD myocardium. Based on the results, we believe that simultaneous perfusion during empty beating will improve myocardial perfusion in jeopardized regions.
At d d i l i
Simultaneous Antegrade/Retrograde Cardioplegia
(a single coronary artery + coronary sinus)

Figure 5. Representative contrast-enhanced T₁ MR images obtained during antegrade cardioplegia (AC) and simultaneous antegrade/retrograde cardioplegia (SARC). SARC was performed through a single coronary artery and coronary sinus. During AC, a MR contrast agent (CA, Gd-DTPA) was injected into a single coronary artery at a time to determine its perfusion area. As expected, each coronary artery has its own distinct supported area of the myocardium. SARC significantly enlarged the artery-supported area, suggesting that during SARC an intact coronary artery supports not only its own designated myocardium, but also adjacent myocardium that is normally served by other arteries. The venous perfusion route mainly supported jeopardized myocardium during SARC. The results suggest that simultaneous antegrade/retrograde perfusion through a single coronary artery and coronary sinus will provide homogeneous perfusion across myocardium in an empty-beating heart. However, whether its flow is sufficient to prevent ischemic injury remains to be determined. LAD, the left anterior descending artery; LCX, the left circumflex artery; RCA, right coronary artery.

Beating Heart Surgery

- Beating-empty
- Normothermic
- Continuously perfused
- Antegrade and retrograde flow
Beating Heart Surgery

- Animal model of LV hypertrophy
- Empty beating vs Cardioplegic arrest
Can Hypertrophied Hearts be Better Preserved by Allowing the Heart to Beat Empty?

Background

- Hypertrophied hearts have reduced tolerance to cardioplegia

- Empty beating heart technique maintains normal electromechanical activity, and improves myocardial fluid homeostasis.
Interstitial Hydrostatic Pressure

Intra- and Extra-Cellular Compartments

J Thorac Cardiovasc Surg 2006; 132: 1314-1320
Energy Metabolism

LAD Flow

100%

50%

10%

PPM

NNSP

NHSP

J. Cardiac Surg 2008; 23: 437-443
Energy Metabolism

J Thorac Cardiovasc Surg 2006; 132: 1314-1320
J Cardiac Surg 2008; 23: 437-443
Energy Metabolism during SP and AP

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<tr>
<th>LAD flow</th>
<th>NNAP</th>
<th>NNSP</th>
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<td>100%</td>
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<td>ATP</td>
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<tr>
<td>50%</td>
<td>Pi</td>
<td>Pi</td>
</tr>
<tr>
<td>20%</td>
<td>PCr</td>
<td>ATP</td>
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Myocardial Energy Metabolism

Time Course of ATP, PCr and Pi during 90-min Alternating

Time Course of ATP and PCr during 90-min Alternating and AP

Myocardial Oxygenation Imaging during Alternating

Heart Function during Reperfusion

Conclusions

- EBHP improves tissue fluid homeostasis
- Alleviates postoperative myocardial edema relative to conventional cardioplegia
- Maintains normal energy metabolism despite coexistence of myocardial hypertrophy and moderate coronary artery stenosis.
Beating-Heart Valve Surgery in Patients with Renal Failure Requiring Hemodialysis
Saqib Masroor, Pierluca Lombardi, Hasan Tehrani, Said F. Yassin, Kushagra Katariya, Tomas A. Salerno

Division of Cardiothoracic Surgery, University of Miami-Jackson Memorial Hospital, Miami, Florida, USA
### Table I. Preoperative and intraoperative variables.

<table>
<thead>
<tr>
<th>Patient no./gender</th>
<th>Risks factor</th>
<th>Duration of hemodialysis (months)</th>
<th>Pathology</th>
<th>Cause</th>
<th>Serum creatinine (mg/dl)</th>
<th>CPB time (min)</th>
<th>Procedure</th>
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<td>MR</td>
<td>Degen.</td>
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<td>MVR</td>
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<td>AI</td>
<td>Degen.</td>
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<td>25M</td>
<td>T,S</td>
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<td>H,D,Tx</td>
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<td>MR/ASD</td>
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<td>MVR/ASD</td>
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<td>26</td>
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<td>Infection</td>
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Table II. Postoperative course of patients with beating-heart valve surgery.

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<tr>
<th>Patient no./ gender</th>
<th>Follow up (months)</th>
<th>Chest drain (ml)</th>
<th>Inotrope use</th>
<th>Complications</th>
<th>LOS in ICU (days)</th>
<th>Postoperative LOS (days)</th>
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<td>Sepsis/death</td>
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<td>-</td>
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<td>376.52</td>
<td>-</td>
<td>-</td>
<td>26.97</td>
<td>24.11</td>
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Histological evaluation through hematoxilin-eosin

Principles of Pulmonary Protection in Heart Surgery
Acknowledgment

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