Impact of TOE on delivery of antegrade cardioplegia

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Disclosures

• Employed University of Melbourne
  • POC workshops, courses in clinical ultrasound Certificate, Diploma and Masters

• Equipment support
  – Ultrasound – Sonosite

• Infected with the ‘echo-virus’

• $ I don’t bill for medical perfusion
1. Myocardial protection with cardioplegia

2. Research study:
   - Impact of TOE on delivery of antegrade cardioplegia
1. Myocardial protection with cardioplegia
Myocardial protection

• Undoubtedly most important development since CPB

• Allows
  – surgery on motionless, flaccid, bloodless heart
  – more types of cardiac surgery
Myocardial protection

• Long-term survival improved
• Although progress has been made, ideal method has not been found
  – myocardial stunning and infarction still common
  – research lacking
  • Single centres, mostly retrospective
‘Myocardial management’

- None – empty beating heart
- No aortic occlusion / systemic hypothermia (VF)
- Aortic occlusion – no cardioplegia (VF)
- Aortic occlusion – cardioplegia

**Solution**
- Crystalloid / blood
- Hypothermic / tepid

**Composition**
- Extracellular – high K$^+$ (standard/St Thomas)
- Intracellular – low Na$^+$ (custodiol/Bretschneider, Custodiol – long acting)

**Delivery**
- Antegrade / retrograde
- Coronary ostia
- Coronary graft

Hypothermia
- Topical
- Systemic

Aortic partial occlusion clamp
Cardioplegia

• Composition
  Extracellular – high K⁺
  (standard/St Thomas)
  Intracellular – low Na⁺
  (Custodiol/Bretschneider)
  depolarisation in diastole
  hyperpolarisation in diastole

• Solution
  Crystalloid / blood
  Hypothermic / tepid

• Delivery
  Antegrade / retrograde
  Coronary ostia
  Coronary grafts

• Hypothermia
  Topical
  Systemic

• Aortic partial occlusion clamp
<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bigelow</td>
<td>1950</td>
<td>Whole body hypothermia - canines</td>
</tr>
<tr>
<td>Swan</td>
<td>1953</td>
<td>Whole body hypothermic arrest bloodless field - humans</td>
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<tr>
<td>Melrose</td>
<td>1955</td>
<td>Chemical cardiac arrest - canines</td>
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<tr>
<td>Lillehie</td>
<td>1956</td>
<td>Hypothermic crystalloid cardioplegia administered into coronary arteries</td>
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<tr>
<td>Gerbode</td>
<td>1958</td>
<td>Potassium citrate cardiac arrest in humans</td>
</tr>
<tr>
<td>McFarland</td>
<td>1960</td>
<td>Challenged safety of Melrose cardioplegia technique</td>
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<tr>
<td></td>
<td></td>
<td>Advocated intermittent aortic occlusion or coronary artery perfusion</td>
</tr>
<tr>
<td>Bretschneider</td>
<td>1964</td>
<td>Cardioplegia with low sodium, no calcium and procaine</td>
</tr>
<tr>
<td>Gay</td>
<td>1973</td>
<td>Revival of potassium-induced cardioplegia - canine</td>
</tr>
<tr>
<td>Tyers</td>
<td>1973</td>
<td>Cold blood infused to keep heart below 4 degrees - animals</td>
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<tr>
<td>Hearse/Braimbridge</td>
<td>1975</td>
<td>Crystalloid cardioplegia – Mg, potassium - St Thomas solution 1</td>
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<tr>
<td>Effler</td>
<td>1976</td>
<td>Simple aortic clamping at room temperature</td>
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<tr>
<td>Buckberg</td>
<td>1979</td>
<td>Blood potassium cardioplegia</td>
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<tr>
<td>Akins</td>
<td>1986</td>
<td>Ischaemic pre-conditioning</td>
</tr>
<tr>
<td>Lichtenstein, Salerno</td>
<td>1991</td>
<td>Continuous warm blood cardioplegia</td>
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</table>
Current techniques

• Myocardial management complex
• Procedure and surgeon dependent
• K+ cardioplegia commonest in use
• Via an antegrade line in aortic root, directed through cor. arteries by aortic cross clamp
  – Relies on competent aortic valve
Cardioplegia A solution
20mmol of sodium bicarbonate and 28mmol of sodium aspartate are added to both these bags before use.

**INDUCTION**

blood:cardioplegia 4:1

**MAINTENANCE**

Less K and Mg

blood:cardioplegia 6:1 or 8:1 depending on serum K

K+ 40 mmol/L
Antegrade cardioplegia

- 300-400ml arrests the heart
- 500-1000ml typical dose, some up to 1500 mL
- Despite concern of maldistribution with blocked coronary arteries, perfusion studies have shown good distribution
- Often supplemented with retrograde cardioplegia via coronary sinus
LV distension

- Damage…if not vigilant
- Avoid:
  - Retro/direct admin
  - Avoid with vent eg. right upper pulmonary vein
- Treat
  - Squeeze/massage heart, ?affects coronary flow
    ?damages myocardium
  - Emerg treatment catheter across IV septum (historical)
1. Myocardial protection with cardioplegia

2. Research study:
   – Impact of TOE on delivery of antegrade cardioplegia

Accepted for publication:
Background

• Antegrade cardioplegia is the cornerstone of myocardial protection during cross-clamp
• However volume used is empiric and often excessive
  • Too much cardioplegia\textsuperscript{1,2}:
    – Hyperkalaemia, hypermagnasemia, haemodilution
    – Dysrhythmia, severe hypotension, metabolic acidosis
    – Myocardial oedema
    – LV distension and damage – relies on competent AV
  • Too little cardioplegia:
    – inadequate myocardial protection and ischaemia

Hypothesis

1. Amount of cardioplegia required correlates with LV mass
2. LV distension may occur without aortic regurgitation
Aims

• Using TOE
  • 1. Can LV mass predict the volume of cardioplegia required for asystole
    – may then be used to avoid overdose
  • 2. Can aortic regurgitation predict unacceptable LV distension,
    – may then use routes of cardioplegia to avoid LV damage
    – detection of LV distension unreliable by visualisation and palpation
Methods

- Ethics approval as audit
- Royal Melbourne and Monash Medical Centre (VIC)
- Sample size 60 patients based on prior feasibility study
- Inclusion criteria:
  - Age > 18 years
  - Open cardiac procedure
  - Aortic cross-clamp and antegrade cardioplegia
- Exclusion criteria:
  - Unable to perform TOE
  - Antegrade cardioplegia not planned
Methods

Measurements

Before cardioplegia
1. LV mass
2. Aortic regurgitation

During cardioplegia
3. Volume of antegrade cardioplegia required for asystole
4. Degree of LV distension
1. LV mass

Prolate ellipse of revolution formula

\[ \text{LV mass} = 0.7 \times (1.04[(\text{LVIDd} + \text{PWTd} + \text{SWTd})^3 - (\text{LVIDd})^3]) + 0.6 \text{ g} \]

TOE transgastric long-axis view and transgastric 2-chamber view

M-mode placed at chordae level

American Society of Echocardiography recommendations:
1. Lang et al. Recommendations for chamber quantification. Eur j Echocardiogr. 2006; 7
2. Aortic regurgitation

Vena contracta (VC) = narrowest band between flow convergence and jet width

Recorded and also graded:
- Nil VC 0.0
- Mild VC < 0.3 cm
- More than mild VC > 0.3 cm

American Society of Echocardiography recommendations:
Zhogbi et al. Recommendations for evaluation of valvular regurgitation. JASE 2003; 16
Cardioplegia

• Cardioplegia A solution
  – pH 7.4 – 7.8
  – Blood:cardioplegia 4:1
  – Room temperature

• 9 French aortic root cannula
  – roller pump
  – Aortic root pressure kept < 200 mm Hg
3. Volume of antegrade cardioplegia required for asystole

**PRIMARY ENDPOINT**

- Asystole for one full screen (5 seconds)
  - confirmed by 2nd observer (surgeon)
- Volume of cardioplegia recorded by clin. perfusionist
  - blinded to the LV mass
  - confirmed by a second perfusionist
- Recorded aortic root pressure and flow rate every 5 seconds to compare impedance to outflow
4. LV distension during cardioplegia delivery

Difference in cavity area
Transgastric short axis view mid LV after cross clamping

Baseline – after clamping  After cardioplegia - distension

Decision to abort cardioplegia delivery due to excessive distension made by surgeon
Method

• Measurements recorded by 2 observers
  – off– line
  – blinded to cardioplegia volume and LV mass

• Inter and intra observer variability compared to assess precision of the measurements
Results

60 patients recruited - 2 excluded = 58 patients analysed
(1) inadequate TOE imaging,
(2) unable to deliver antegrade cardioplegia

CABG 69%
AVR 5%
Mitral valve 2%
Tricuspid valve 2%
Valve+CABG 19%
Aorta 3%
58 patients

No AR
39 patients

LV distension acceptable
32 patients

LV distension unacceptable
7 patients
(7/39 = 18%)

Abort antegrade cardioplegia
LV decompression
Switch to retrograde cardioplegia
14/58 = 24%

AR
19 patients

LV distension unacceptable
7 patients
(7/19 = 37%)

LV distension acceptable
12 patients

LV mass correlation
Analysis
LV mass estimation

- LV mass agreement acceptable
- However unacceptable agreement with anterior and anteroseptal walls
- ?reliability of LV mass estimation with TOE
Correlation of LV mass and cardioplegia volume

Poor correlation of LV mass and cardioplegia volume required for asystole

\[ r = 0.35 \]
\[ P = 0.047 \]

No correlation with Ht, wt, BSA
Relative coronary Impedance (CABG)
No AR detected pre-CPB
However – unacceptable LV distension during cardioplegia delivery
Unacceptable LV distension ‘Failed antegrade’

<table>
<thead>
<tr>
<th>Aortic regurgitation</th>
<th>n</th>
<th>Unacceptable LV distension</th>
<th>%</th>
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</thead>
<tbody>
<tr>
<td>Nil</td>
<td>39</td>
<td>7</td>
<td>18</td>
</tr>
<tr>
<td>Mild</td>
<td>13</td>
<td>4</td>
<td>31</td>
</tr>
<tr>
<td>VC &lt; 0.3cm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More than mild</td>
<td>6</td>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td>VC &gt; 0.3cm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>58</td>
<td>14</td>
<td>24</td>
</tr>
</tbody>
</table>
Moderate correlation of AR severity and LV distension

Correlation of AR severity and LV distension

\[ r = 0.55 \]

\[ P = 0.007 \]
Aborted group had greater LV distension than non-abortion group
AR worse in aborted group
Modest prediction of unacceptable LV distension using VC of 0.3 cm

Area under curve 0.81
P 0.02
Sensitivity 71%
Specificity 81%
Conclusions

1. Intraoperative TOE estimation of LV mass using the prolate ellipse formula does not correlate with the amount of antegrade cardioplegia required to cause initial cardiac asystole.

2. Routine intraoperative monitoring for LV distension with TOE during antegrade cardioplegia delivery is recommended due to frequent and unpredictable LV distension.
Limitations

• Small pilot study
• Modest agreement between observers of LV mass estimation - ? reliability of LV mass
• End point of unacceptable LV distension not defined – surgical preference
Pinching the aorta
• Acknowledgements

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No funding support
Patient with no AR who developed unacceptable LV distension after CC during ACP (movie)