Variance in Therapy and Registry Variables

Lecture 5: AmSECT’s Goal Directed Therapy Symposium

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Flinders Medical Centre and Flinders University
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DISCLOSURES

• Consultancy for Sorin Group in 2015
  • Speaker at “Goal Directed Perfusion Scientific Workshop”, Berlin, Oct 2015

ACKNOWLEDGEMENTS

• Richard Newland, BSc, CCP (Aus), Dip PERF
• Senior Perfusionist Flinders Medical Centre
• Project Manager Australian New Zealand Collaborative Perfusion Registry (ANZCPR)

Data courtesy of the Australian & New Zealand Collaborative Perfusion Registry (ANZCPR). Not to be reproduced without permission.
Outline

- What can influence the measurement and reporting of Goal Directed Perfusion Parameters?
- Share new evidence supporting monitoring of GDP parameters
- Where are we going and what data is already collected?

“An error does not become truth by reason of multiplied propagation, nor does the truth become error because nobody will see it.”

Mahatma Gandhi
Young India 1924-1926

Dr Rivers
- Goal directed therapy

Bob Groom
- Goal Directed Perfusion

Linda Mongero
- Electronic Data

George Justison
- Developed the GDP story
Oxygent Delivery During Cardiopulmonary Bypass and Acute Renal Failure After Coronary Operations
Marco Ramacci, MD, Federica Romitti, MD, Giuseppe Iovini, MD, Mauro Cotta, CCP, Simona Bortoli, CCP, Alessandra Bonifili, CCP, and Antonio Ditto, CCP
Department of Cardiothoracic, Anesthesia and Intensive Care and Cardiovascular Pathology, Pediatrics and Oncology, Bologna, Italy

O₂ delivery and CO₂ production during cardiopulmonary bypass as determinants of acute kidney injury: time for a goal-directed perfusion management?
Filippo de Temoa,1,2 John W. Muholland,3 Mark R. Broyam,4 Tommaso Alasia,1 Guido J. Van Norden1 and Marco Ramacci1
1de Temoa et al. Crit Care 2011, Madrid

Do you measure DO₂ during bypass?

a) Yes, as a clinical indicator of adequacy of perfusion
b) Yes, but it does not direct my clinical management
c) No

ARS  a, b, or c

Concerning Measuring DO₂/DO₂i during bypass?

a) Do you manually calculate DO₂ on pump?
b) Do you use commercial software (CONNECT) to calculate DO₂?
c) Do you use commercial software (M4) to calculate DO₂?
d) Do you use “in house” software to calculate DO₂ on pump?
e) Do not measure/calculate DO₂ during bypass.

ARS choose one answer
Do you have any shunts in your circuit eg sampling line, arterial filter purge, oxygenator purge?

- a) None open during bypass?
- b) If yes, flow through shunt <100 ml/min
- c) If yes, flow through shunt 100-300 ml/min
- d) If yes, flow through shunt 301-500 ml/min
- e) If yes, flow through shunt >501 ml/min
- f) Yes but never measured the shunt flow

ARS choose one answer

Measuring flow for DO$_2$I during bypass?

- a) Do you use roller pump to measure flow?
- b) Do you use flow probe with a roller pump to measure flow?
- c) Do you use flow probe with a centrifugal pump to measure flow?

ARS choose one answer

If you answered yes to having an open shunt during bypass?

- a) Is your flow measurement distal to any shunts you have in your circuit?
Error in DO\textsubscript{2i} (flow 4.5, Hb 9, Sat 99, PaO\textsubscript{2} 200, BSA 2) of about 4 ml/min/m\textsuperscript{2}

Oxygen delivery (DO\textsubscript{2i})

GDP formula: \( \text{DO}_{2i} = \frac{(\text{Flow} \times (\text{Hct}/2.94 \times 1.36 \times \text{SaO}_{2} + \text{PaO}_{2} \times 0.003) \times 10)}{\text{BSA}} \)
Oxygen delivery ($DO_2i$)

GDP formula: $DO_2i = \frac{\text{Flow} \times (\frac{\text{Hct}}{2.94} \times 1.36 \times \text{SaO}_2 + \text{PaO}_2 \times 0.003) \times 10}{\text{BSA}}$

Roller Flow: $DO_2i = 291$
Flow distal to shunt (300): $DO_2i = 272$
Flow distal to shunt (700): $DO_2i = 246$

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Oxygen delivery ($DO_2i$)

GDP formula: $DO_2i = \frac{\text{Flow} \times (\frac{\text{Hct}}{2.94} \times 1.36 \times \text{SaO}_2 + \text{PaO}_2 \times 0.003) \times 10}{\text{BSA}}$

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Oxygen delivery ($DO_2i$)

GDP formula: $DO_2i = \frac{\text{Flow} \times (\frac{\text{Hct}}{2.94} \times 1.36 \times \text{SaO}_2 + \text{PaO}_2 \times 0.003) \times 10}{\text{BSA}}$

M4 formula: $DO_2i = \frac{\text{Flow} \times \text{Hb} \times 1.34 \times \text{SaO}_2 \times 10}{\text{BSA}}$
Do you routinely measure exhaust CO\(_2\) during bypass?

a) Yes
b) No

ARS yes/no

If you do, how do you routinely measure exhaust CO\(_2\) during bypass?

a) Dedicated capnograph to measure ExhCO\(_2\)?
b) Use the anaesthetic machine capnograph to measure ExhCO\(_2\)?
c) Use a M4 to measure ExhCO\(_2\)?
d) Other device

ARS choose one answer
Do you routinely measure PaCO\textsubscript{2} and PvCO\textsubscript{2}?

a) Yes

b) No

ARS yes/no

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Oxygenator CO\textsubscript{2} monitoring

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CO\textsubscript{2} production (VCO\textsubscript{2i})

GDP formula: VCO\textsubscript{2i} = (Gas flow * CO\textsubscript{2}exh * 1.15) / BSA

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CO₂ production (VCO₂i)

GDP formula: \[ \text{VCO₂i} = (\text{Gas flow} \times \text{CO₂exh mmHg} \times 1.15) / \text{BSA} \]

M4 formula: \[ \text{VCO₂i} = (\text{Gas flow} \times (\text{FeCO₂} - \text{FiCO₂} \%)) \times 100 / \text{BSA} \]
In-vitro oxygenator comparison

- Calculation of \( VCO_2 \) requires measurement of \( CO_2 \) concentration in the oxygenator exhaust gas
- Accuracy may be limited by:
  - design of the oxygenator
  - measurement device used
  - alterations in the exhaust gas flow

- Aim:
  - Compare the measurement of \( CO_2 \) concentration in the oxygenator exhaust gas using 2 different capnographs and an exit \( CO_2 \) sensor in 5 (2/3) different oxygenators.

In-vitro oxygenator comparison

- RX (Terumo)
- Inspire (LivaNova)
- Fusion (Medtronic)
- FX (Terumo)
- Compactflo (Dideco)
In-vitro oxygenator comparison

- Primed with Plasmalyte solution and expired donor blood added (Hb 8 g/dl)
- CO₂ titrated to achieve an arterial pCO₂ 35-45 mmHg
- Drager scavenging device attached to the M4 gas module with wall suction applied to provide passive collection of exhaust gas
- Vamos and Datex capnographs connected via sampling tubing immediately distal to the M4 exit gas sensor
- 3/8” luer connector utilised to enable measurements to be obtained with the scavenging system vented (luer cap off) or non vented (luer cap on)

![Diagram of oxygenator setup]

In-vitro oxygenator comparison: CO₂ monitoring

![Graph showing CO₂ monitoring results]
Outline

- What can influence the measurement and reporting of Goal Directed Perfusion Parameters?
- Share novel supporting evidence for monitoring of GDP parameters
- Where are we going and what data is already collected?
Blood glucose & lactate

Peak arterial blood lactate value during cardiopulmonary bypass (CPB) according to the CPB duration. The plot shows the cubic spline values, calculated as the medians of both variables at equal time intervals.

Blood glucose & lactate

Peak arterial blood lactate value according to the peak blood glucose levels. Data are shown as rolling deciles (75% overlapping). Symbols (open boxes) represent the mean value recorded for each decile.

Data courtesy of the Australian & New Zealand Collaborative Perfusion Registry (ANZCPR). Not to be reproduced without permission.
Oxygen delivery & lactate

Peak arterial blood lactate levels according to the lowest oxygen delivery. Data are shown as rolling deciles (75% overlapping), symbols (open boxes) represent the mean value recorded for each decile.

N=470

Oxygen delivery & lactate

Peak arterial blood lactate value during cardiopulmonary bypass (CPB) according to the lowest oxygen delivery. The plot shows the cubic spline values, calculated as the medians of both variables at 2D intervals.

N=12,397

Data courtesy of the Australian & New Zealand Collaborative Perfusion Registry (ANZCPR). Not to be reproduced without permission.

Look at lowest oxygen delivery:
leveraging electronic data
Outline

- What can influence the measurement and reporting of Goal Directed Perfusion Parameters?
- Share new evidence supporting the role of GDP
- Where are we going and what data is already collected?
Results: AUC above or below 270 ml/min/m²

<table>
<thead>
<tr>
<th></th>
<th>AUC + (n=89)</th>
<th>AUC - (n=121)</th>
<th>p</th>
</tr>
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<tbody>
<tr>
<td>Received RBC transfusion</td>
<td>8%</td>
<td>38%</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Acute kidney injury</td>
<td>7%</td>
<td>20%</td>
<td>0.007</td>
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Results: AUC above or below 270 ml/min/m²
Calculated parameters utilising data obtained from the Spectrum M4

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<td>Average DO₂i, l/min/m²</td>
<td>297 (24)</td>
<td>228 (28)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>AUC DO₂i, 270 l/min/m²</td>
<td>1960 (681-3507)</td>
<td>-3080 (-4968-1299)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Nadir DO₂i/VCO₂i</td>
<td>4.4 (9.5)</td>
<td>3.6 (2.2)</td>
<td>0.817</td>
</tr>
</tbody>
</table>

Results: AUC above or below 270 ml/min/m²
Calculated parameters utilising data obtained from the Spectrum M4

<table>
<thead>
<tr>
<th></th>
<th>AKI (n=30)</th>
<th>No AKI (n=181)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nadir* CPB hct, g/l</td>
<td>25 (4)</td>
<td>27 (4)</td>
<td>0.002</td>
</tr>
<tr>
<td>Nadir* DO₂i, l/min/m²</td>
<td>170 (126-184)</td>
<td>180 (147-210)</td>
<td>0.08</td>
</tr>
<tr>
<td>Nadir* DO₂i, l/min/m²</td>
<td>233 (40)</td>
<td>261 (42)</td>
<td>0.001</td>
</tr>
<tr>
<td>AUC DO₂i, 270 l/min/m²</td>
<td>455 (6512-455)</td>
<td>1835 (-553-3273)</td>
<td>0.001</td>
</tr>
<tr>
<td>Nadir* DO₂i/VCO₂i</td>
<td>3.2 (3)</td>
<td>4.2 (7.8)</td>
<td>0.258</td>
</tr>
</tbody>
</table>

Challenged our interpretation of VCO₂ data

Avg GDP VCO₂ = 52        Avg M4 VCO₂ = 92

GDP:
If DO₂i = 270, VCO₂ = 54  DO₂i/VCO₂ = 5

However with M4 data,
If DO₂i = 270, and VCO₂ = 94  DO₂i/VCO₂ = 2.9
Definition and calculation of GDP parameters

- Consensus needed on how we define “lowest” GDP parameters in data analysis;
  - What is the lowest Hb, pO₂, VCO₂?
  - Should we use intermittent or continuous blood gas data
  - How do we define the lowest flow during CPB using continuous data?
  - How do we time weight lowest values?
    - What is the critical time value for each GDP parameter threshold?

Electronic Data Acquisition into the EMR

- Unlimited potential
- Commercial systems
  - LivaNova CONNECT/GDP
  - Spectrum M4
  - Terumo CDI-500
- Need to know the equipment
- Raw data or transformed
- Value of point estimates
  - Manually or electronically calculated

Registry Data

- ANZCPR
  - The raw data we collect allows us to calculate a DO₂ for every case
- Depending on what you need
  - Transformed or raw data
    - DO₂, VCO₂, VO₂
  - Need common definitions, time periods
  - Flow, Hb, pO₂, pO₂, pCO₂, pCO₂, SₐO₂, S₂O₂, SCO₂, S₂CO₂, SClCO₂, FeCO₂, FeCO₂, exhaust capnography
## Defining minimum DO₂?

<table>
<thead>
<tr>
<th>Ranucci et al</th>
<th>DeSomer et al</th>
<th>ANZCPR</th>
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</thead>
<tbody>
<tr>
<td>Lowest HCT</td>
<td>Measured every 20 min</td>
<td>Measured every 10 min</td>
</tr>
<tr>
<td>Arterial oxygen tension</td>
<td>Recorded simultaneously to lowest HCT</td>
<td>Recorded simultaneously to lowest HCT</td>
</tr>
<tr>
<td>Cardiac index</td>
<td>Mean value during 30 minutes of CPB around the time when the lowest HCT was recorded</td>
<td>Recorded simultaneously to lowest HCT</td>
</tr>
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### Metabolic data during CPB

<table>
<thead>
<tr>
<th>Time (minutes)</th>
<th>V̇E (L/min)</th>
<th>V̇O₂ (mL/kg/min)</th>
<th>V̇O₂/CO₂</th>
<th>V̇O₂/CO₂ (mmHg)</th>
<th>VO₂ (mL/kg/min)</th>
<th>VO₂/CO₂ (mmHg)</th>
</tr>
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<tbody>
<tr>
<td>0</td>
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Thank you

"Measurement is the first step that leads to control and eventually to improvement. If you can't measure something, you can't understand it. If you can't understand it, you can't control it. If you can't control it, you can't improve it."

H. James Harrington
Quality/Improvement/Business