Cardiac assessment of ventilated babies

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Conflict of interest
Objectives

• Use some cases to look at aspects of cardiac assessment

• Agree about the assessment possibilities
  – Not necessarily about the cases!

• Raise awareness of the advantages of considering cardio-respiratory assessment and some of the pitfalls
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Ideal Cardiac Assessment

- Tissue Perfusion
- Cardiac Output
- Cardiac Function
- Systemic Resistance
- Pulmonary Resistance

- Allow us to act in order to improve outcomes
Case 1

26 week gestation baby

- Emergency LSCS – profound bradycardia
- No respirations at birth
- Heart rate 20 – so 5 initial ventilations given
- Heart rate increased to >100 immediately
  - No cardiac compressions
- Ventilated + Surfactant at 7 minutes of age
- Cord pH 6.79
Case 1
26 week gestation baby

- Now 6 hours of age
- Gases reasonable.
  - pH 7.34
  - Base deficit -3.4
- 29% oxygen, 91% TC saturation
- CRT 3-4 seconds centrally
- Systolic BP 28 mmHg MAP 20 mmHg
- Nurse not happy with “how he looks”
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What would you do?

A. Treat

B. Wait and see

C. Get more information
What would you recommend?

A. 10-20 ml/kg of volume expansion

B. Inotropic support with dobutamine or dopamine or both.

C. Inotropic support with Milrinone and low dose adrenaline

D. Steroids

E. A different approach or combination
What is hypotension?

- Mean BP < 30 mmHg
- Mean BP =< Gestational Age
- Mean BP =< Gestational Age plus clinical signs
- Mean BP =< Gestational Age plus echocardiographic signs
- Systolic BP less than 3rd centile
- Systolic BP less than 3rd centile plus echocardiographic signs
Cardio-respiratory interaction

Blood Pressure

401-1000g
Fanaroff et al Pediatrics 2006;117(4):1131-1135

608 infants with 24,052 measurements
Epidemiological

Systolic blood pressure at 4–24 hours (mm Hg)

Systolic blood pressure at 10 days (mm Hg)

Gestation at birth (weeks)

Gestation at birth (weeks)

97th
90th
50th
10th
3rd
Centile

Based on 398 babies <32 weeks gestation free from severe disability at 2 years of age
26 week gestation baby

- Assessed as poor perfusion clinically with low blood pressure
- 20 ml/kg 0.9% saline given
- Oxygen requirement increased to 60%
- Base deficit increased to -9.3
- CXR requested
- Echo obtained to assess cardiac function
26 week gestation baby

- Echo demonstrates:
  - Fractional shortening 9% (25-45%)
  - Left ventricular output 80 ml/kg/min (150-350ml/kg/min)
  - LVEDD:Ao ratio > 2:1, No collapse of IVC
  - Full looking, poorly contractile heart
  - PDA with low velocity bidirectional flow
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Would this information change your approach?

A. Yes
B. No
C. Possibly
26 week gestation baby

- Inotropes added
  - FS increased to 18%
  - Improved LV output to 200 ml/kg/min
- Gases improved
- Renal failure short
- Survived
What is hypotension?

- Epidemiological
- Miall-Allen 1987
  - 33 infants of less than 31 weeks gestation MAP < 30 mm Hg for over an hour significantly associated with severe haemorrhage, ischaemic cerebral lesions, or death within 48 hours. No severe lesions developed with a MAP greater than or equal to 30 mm Hg

- Joint Working Group of BAPM Arch Dis Child 1992;67:1221-1227 recommended mean arterial pressure in mmHg at or above Gestational Age in weeks based on normative data from well babies.
• Identify the blood pressures of extremely low gestational age newborns (ELGANS) that prompt intervention.
• Identify characteristics associated with receipt of therapies intended to raise blood pressure.
• Assess inter-institutional variability in the use of these therapies
ELGAN Results

• 1387 survivors

<table>
<thead>
<tr>
<th>Gestational Age</th>
<th>23-24</th>
<th>25</th>
<th>26</th>
<th>27</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Treated in the first 24 hours</td>
<td>83</td>
<td>77</td>
<td>74</td>
<td>63</td>
</tr>
</tbody>
</table>
ELGAN Conclusions

• Blood pressures increase with gestational and postnatal age
• Lower gestational age, birth weight, male gender and illness severity were associated with treatment
• There was a large inter-centre variability (29-98%)

WE HAVE NO IDEA WHAT WE ARE DOING!
Current Definitions of Hypotension Do Not Predict Abnormal Cranial Ultrasound Findings in Preterm Infants


Mean MAP on each of days 1, 2, and 3 of life in 84 patients with and without each ultrasound outcome
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Case 2

26 week gestation baby

- Ventilated from birth
- Good gases
- At 36 hours of age at 0300 hrs
  - BP trending down to 25 systolic, 20 mean
  - Perfusion looks a little worse
  - Base deficit goes from -2.0 to -6.5
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Case 2

26 week gestation baby

• What would you do?
26 week gestation baby

• Given 10 ml/kg saline 0.9%
• Started on Dopamine and Dobutamine
• BP increased to 38 systolic, 27 mean
  – Dopamine 10 mcg/kg/min
  – Dobutamine 10 mcg/kg/min
• Everyone happy

• Except me in the morning
26 week gestation baby

- Low Blood pressure after first 24 hours – Why?

- Please don’t just assess – THINK!
Case 3

27 gestation week baby

- Born at St Elsewhere to primigravida mother having presented in labour
- No antenatal steroids
- Good condition at birth, ventilated, given surfactant
- 10ml/kg fluid bolus for low blood pressure
- Transferred to Level 3 unit
27 gestation week baby

- Improved to day 5 of life, increasing EBM feeds and ready for extubation

- Deteriorated with poor perfusion, distended abdomen, bile stained aspirates.
  - Abdominal XR merely air filled loops of bowel
  - Passing meconium
  - BP 48/19 MAP 30

- Pulmonary haemorrhage which caused further increase in ventilatory requirements.

- Developed a murmur
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Case 3

27 week gestation baby

• What would you do?
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27 gestation week baby

• Day 5
  – Stopped feeds
  – Started triple antibiotics
  – Platelets and CRP normal
  – AXR remained non-diagnostic

• Echo obtained:
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27 gestation week baby

- Moderate to large PDA with reverse mesenteric flow.
- PDA dimension 2.8 mm.
- LA:AO ratio 1.63 with PFO
- Left V output 580ml/kg/min
- Fractional shortening 44%
27 gestation week baby

- Planned to wait for abdomen to declare itself. Despite evidence of TIPP trial

- If further serious pulmonary haemorrhage consider closure.

- Day 7
  - Abdomen soft, baby well
  - Still needing increased ventilatory support
  - Duct unchanged on echo
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27 gestation week baby

- Medical treatment
- Extubated day 12
- Echo
  - Small PDA
  - Mature flow pattern 3mps
  - Normal mesenteric flow
  - LVO  260 ml/kg/min
  - Fractional Shortening 35%
- Baby survived and returned to referring hospital in air
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Case 4
26 week gestation baby

- Full course of steroids, PROM 14 days
- Born at 05:05, 680g, spontaneous breech delivery
- Good at birth, intubated, surfactant 11 minutes, temp >36.5
- Moved to the NICU in 25-30% oxygen
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26 week gestation baby

- Saturations fall, perfusion initially OK
- \( \text{FiO}_2 \) increased

- What now?
26 week gestation baby

- Chest moving no marked recession
- Graphics and tidal volumes OK (5ml/kg)
- Cold light negative
- CO2 suggests tracheal tube in situ.
- CXR – no pneumothorax, tracheal tube good position, RDS
- Gas shows CO₂ 4.8 kpa, in 100% O₂ Sats 88% and falling

- What now?
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26 week gestation baby

• More surfactant
  – Saturations improved and then fell again
• Oscillated MAP 14 to 17, Amp 33, 100% O₂
  – Saturations improved and then fell again

Perfusion poor, Saturations falling below 50%, Heart rate maintained at 150 bpm

What now?
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26 week gestation baby

- FS 20% but partly paradoxical motion of septum
- TR 3.18 mps (41 mmHg)
- PFO right to left, duct mainly right to left
- Reasonably filled after 10 ml/kg saline
- Aortic velocity 0.8 mps, Pulmonary 0.40 mps
- TPV:RVET ratio 0.18
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26 week gestation baby
Box and whisker plot of RVO against low, intermediate, and normal PA Vmax. The dotted line denotes 150 ml/kg/min.
Cardiac assessment of ventilated babies

26 week gestation baby

• Started inotropic support
• Started NO 20 ppm
  – Impressive response 12 – 100% saturations in 12 minutes
• Subsequent weaning of NO, ventilation when ventilating between air to 30%
• Rapid weaning of NO possible
So what are the different options for cardiac assessment?
Clinical and Biochemical signs

• Heart rate
  – Affected by many factors, therefore limited but widely utilised role in assessing cardiovascular compromise

• Capillary Refill time
  – Little relationship with systemic blood flow and little validation.
  – >5 seconds more specific
    – Tibby et al. Arch Dis Child 1999

• Core-peripheral temperature difference
  – Little data to support accuracy
  – In preterm babies <30 weeks no relationship to systemic flow
    – Tibby et al. Arch Dis Child 1999

• Low urine output and hyperkalaemia
  – Strong relationship in very preterm babies between low systemic flow and subsequent low urine output or hyperkalaemia.
  – Time delay makes this less useful
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**HERO score** — heart rate characteristics monitoring
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Figure 5 Mortality reduction in HeRO monitor trial, in which 3003 very low birthweight infants were randomized to have their HeRO score displayed to clinicians (HRC monitoring) or stored but not displayed (conventional monitoring). Note: There was a 22% relative reduction in mortality ($p = 0.04$) in the HeRO display group.¹
Clinical and Biochemical signs

• Lactic Acid, pH and Base Excess
  – pH and Base excess have little relationship to low systemic flow
    – Deshpande S, Platt MW. Arch Dis Child Fetal Neonatal Ed 1997
  – Lactic acid—little evidence to support its accuracy as a measure of circulatory compromise.
  – No relationship with SVC flow. Stronger relationship with preceding events.
    – Kluckow M, Evans N. Arch Dis Child Fetal Neonatal Ed 1999
Inpatient mortality in relation to the lowest pH (7.1; $P^*=0.716$), worst base excess (-10 mmol/l; $P^*=0.734$), and peak blood lactate concentrations (5 mmol/l; $P^*=0.026$) * Fisher’s exact test.

Deshpande S A, Platt M P W Arch Dis Child Fetal Neonatal Ed 1997;76:F15-F20
Per cent reduction in blood lactate concentrations in survivors and non-survivors after becoming hyperlactataemic (blood lactate > 2.5 mmol/l) Median value for each group shown.

Deshpande S A, Platt M P W Arch Dis Child Fetal Neonatal Ed 1997;76:F15-F20

P=0.008
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Clinical Indicators

CRT > or = 3 seconds had 55% sensitivity and 81% specificity
Mean BP < 30 mm Hg had 59% sensitivity and 77% specificity
Systolic BP < 40 mm Hg had 76% sensitivity and 68% specificity
Combining mean BP < 30 mm Hg and central CRT > or = 3 seconds increases the sensitivity to 78%
Core peripheral temperature difference did not detect patients with low CO

BP and CRT are imperfect bedside tests for detecting low blood flow in the first day after birth.
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Echocardiography

• Eyeballing the heart function
• Contractility
• Volume loading
• Right and left cardiac output
• SVC flow
• PDA appearances
• Arch and gut flow velocities
• Tissue doppler
Late IVH is strongly associated with low flow states and occurs as perfusion improves.
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Hunt R, Evans N, Reiger I, Kluckow M J
Pediatrics 2004;145:588-592

Prospective observational study of 126 infants -
Low SVC flow in 1st 24 hours associated with:

a. Death or any disability at 3 years (p=0.004)
b. Abnormal DQ at 3 years (p=0.006)
c. No association for blood pressure but a trend
Mean blood pressure (BP) vs superior vena cava (SVC) flow at a mean of 5 h of age. The dotted lines represent possible lower limits of normal; for blood pressure this has been plotted at the mean gestation of the cohort (27 weeks).
Blood Pressure/Flow

- **OK**
  - Treat
  - No Treatment

- **Low**
  - Treat
  - ? No treatment

Flow

Blood Pressure
Groves AM, Kuschel CA, Knight DB, Skinner JR. Relationship between blood pressure and blood flow in newborn preterm infants. *Archives of Disease in Childhood - Fetal and Neonatal Ed* 2008;93:F29-F32

- Infants with reduced systemic perfusion have normal or high blood pressure in the first hours of life.
  - suggesting that a high systemic vascular resistance may lead to reduced blood flow.
- Low blood pressure does not correlate with poor perfusion in the first 48 h of postnatal life in sick preterm infants.

Randomized trial of dobutamine versus dopamine in preterm infants with low systemic blood flow

42 infants < 30 weeks gestation and < 12 hours after birth with low SVC flow.

No significant difference was reported in mortality to discharge, PIVH, grade 3 or 4 PIVH or NEC.

Dobutamine produced a significantly greater increase in SVC flow at the highest dose reached (MD 13.10, 95% CI 2.87, 23.33), whereas dopamine produced a significantly greater increase in mean BP.

At three years, there was no significant difference in cerebral palsy, deafness, Developmental quotient > 2 sd below norm or combined disability (RR 0.10, 95% CI 0.01, 1.56).

Surviving infants treated with dobutamine had a significantly higher development quotient (MD 35.00, 95% CI 17.68, 52.32).
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Functional Echocardiography

- Intra-observer variability = 10%
- Inter-observer variability = 20%
CO Measurement in Preterm Neonates: Validation of USCOM by comparison with Echocardiography

Phillips RA, Paradisis M, Evans NJ, Southwell DL, Burstow DJ, West MJ

The University of Queensland, Brisbane, Australia and Prince Charles Hospital, Brisbane, Australia.
The University of Sydney, Sydney, Australia and Royal Prince Alfred Hospital, Sydney, Australia.

![Graph showing CO measurement comparison between Echo and USCOM vs weight (Kg).](image1)

![Graph showing difference in CO measurement between Echo and USCOM.](image2)

**Mean diff** = 0.00 ± 0.08 L/min
**Mean of means** = 0.36 ± 0.16 L/min
**Mean % error** = -3.7 ± 20.1
Near infrared spectroscopy

- Trends may be helpful
  - Cardiac units already using
  - Some NICU using to gauge when to close ducts
- Used experimentally to assess organ/gut perfusion but mainly used to investigate brain perfusion
- A multicentre European neonatal trial running at present
  - Phase II trial
  - Hyttel-Sorensen S et al. BMJ. 2015;5;350:g7635
    - No difference in short term neurological outcome
    - More time in normal range
Near infra-red spectroscopy

- Newborn head is optimal for NIRS
- Reproducibility of 17-24%
- Low precision
  - Limits of agreement between measurements -12 to +11%
  - -17% to +17% if optodes replaced
- Thus a 30% drop in CBF may only reduce tissue oxygen saturation from 70 to 60%
  - Within limits of error of measurement.
- Not yet been shown to improve outcome
- Experimental but adds to the whole picture
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Electrical Velocimetry

- LVO as accurate as echo
  - Noori S et al. ADC 2012

![Image of human heart and blood flow diagrams]

![Box plot showing LVO values]

![Scatter plot comparing LVO values]

Bias = -4 mL/min, Limit of agreement -238, 229 mL/min
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MRI

Groves AM et al.. Arch Dis Child Fetal Neonatal Ed. 2011
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- Advantages of cardiovascular assessment:
  - Understand more about what we are treating
    - More logical
    - Focus and individualise treatment
  - All available information
  - Beginning to challenge mythology
  - Aid in further research

- Likely to need more than one approach
  - Need to maintain a global view

- Pushing the development of equipment, techniques and understanding
Beware

- Term baby, “blue do” D1
  - Screened for infection but low saturations noted
- Level 2 SCBU put on oxygen, HiFlow
- D3 echo showed “high right pressures with small marked TR and small muscular VSD
- Diagnosis of “PPHN”, increased oxygen
- Oxygen went up to 100% so put on CPAP
- D4-5, D/W us and transported
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Cardiac assessment of ventilated babies

Beware
Cardiac assessment of ventilated babies

Where Now?

• Many different techniques
• For the present act logically

BUT BEWARE

• Don’t just assess, also THINK! Look at the whole picture

• Danger of implementation without evidence
• Randomized Controlled Trials
  – We need to agree what to test
  – We need to be able to identify which subsets to study.
  – Go for real outcomes
    • Mortality and Morbidity
    • Long term outcomes
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Thank you
Near Infrared Spectroscopy

• Assessed during cardiac surgery and recommended.

• Cerebral oximetry during surgery is partly based on the use of trends with a baseline either pre-op or at an intervention.

• Used by a number of neonatal units clinically
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MRI

- Improving an understanding of the pathophysiology of circulatory failure
- Possibly the new “Gold Standard”
  - Not widely practical
  - Can be used without changing state of infant
- Method to assess more accessible techniques
Correlations of arterial blood pH and base excess with blood lactate concentrations.

Deshpande S A, Platt M P W Arch Dis Child Fetal Neonatal Ed 1997;76:F15-F20
Cardiac assessment of ventilated babies

Beware