Clinical Applications of Perfusion Ultrasound in Infants

Ricardo Faingold, MD

MONTREAL CHILDREN'S HOSPITAL
MCGILL UNIVERSITY HEALTH CENTER

Orlando, Florida
SPR US course 2016
Disclosure

• Nothing to disclose
Outline

- Doppler techniques and CEUS
- *Color Doppler Dynamic tissue perfusion measurements*
- Clinical Applications of Doppler US and DTPM in Infants
Introduction

• Knowledge of blood flow can influence clinical decisions and patient management
• Many diseases are associated with perfusion changes:
  – inflammatory processes, neoplasia, ischemia, transplants, etc.
Ultrasound and Doppler Techniques

• Color and power Doppler
• Spectral Doppler
• Contrast-enhanced US
• Dynamic Tissue perfusion Measurements
Color Doppler

- red and blue shades to depict blood flow toward or away from the transducer
- differing shades representing differing velocities of motion.
- The color hue assigned to a pixel results from the angle-dependent Doppler frequency shift
Power Doppler

• depicts the strength of the Doppler-shifted signal rather than the frequency shift of that signal.

• color hue depicted relates mainly to the volume of moving blood, rather than the velocity and direction of the flow.

• Gain in sensitivity.
Spectral Doppler

- time velocity tracing depicts variations in blood flow velocity at a point within a vessel during the cardiac cycle
- Using the spectral tracing, Resistive index may be calculated from the equation:
  - $RI = (PSV - EDV)/PSV$
  - $RI$ is usually interpreted as a parameter of blood flow
Contrast-Enhanced Ultrasound

- Intravenously injected microbubbles enhance US backscatter by producing harmonic frequencies that are multiples of the transmitted frequency
- therefore increase the US signal from flowing blood, particularly in the arterial system and microvasculature.
- Dedicated software.
Dynamic Tissue perfusion Measurement

- Software that quantifies tissue perfusion using Color Doppler videos
- refers to all relevant parameters that influence the total amount of blood passing through a tissue section during a complete heart cycle (Perfusion Intensity: cm/s)
- These are the mean perfusion velocity of all vessels and the mean perfused area of the tissue section under investigation.
DTPM

Automatic recognition of the color scale and velocity values

Automatic recognition of the distances

Predefined ROI and Sub-ROI – here distal 50% of the renal cortex

Distribution curve of all perfusion intensities within the ROI – reflects distribution of smaller and larger vessels within the tissue

Analysis form

Numerical results

General measurement results:
- area of ROI (µm²): 0.259
- average intensity: 1.216
- whole intensity: 2.116 (cm²/s)

Measurement details:
- no angle correction
- angle: 
- frontal angle:
- radial angle:

veloctrity

Intensity

Area
Blood Flow

Resitive Index

- Measures one point in one vessel
- Velocity information usually available
- Cardiac cycle dynamics preserved
- Noninvasive
- Unlimited observation time
- Inexpensive
- Fast acquisition

Contrast-Enhanced US

- Measures enhancement in an ROI
- Velocity information not available
- Cardiac cycle dynamics not preserved
- Invasive
- Limited observation time
- Expensive
- Slow acquisition, requires postprocessing

Tissue Perfusion Measurement

- Measures perfusion of all vessels in an ROI
- Velocity information available
- Cardiac cycle dynamics preserved
- Noninvasive
- Unlimited observation time
- Inexpensive
- Fast acquisition, requires postprocessing
Clinical Applications of Doppler US and DTPM

- Assessment of blood flow and organ perfusion in infants has been traditionally done by spectral Doppler and by CDS.
- Recent use of CDS with tissue perfusion quantification has shown that this technique is promising and with great potential.
- Noninvasive tool in the research setting and clinical practice.
Clinical Applications in infants

- Brain
- Gastrointestinal tract
- Kidneys
Brain

- Normal cerebral blood flow changes over time in neonates. Cerebral perfusion 25% of cardiac output in infants.
- CBF is affected by cardiac output and also with variations of pO2 and pCO2. There is a physiologic increase in CBF during the first days of life, with corresponding increase in perfusion.
- The normal RI of intracranial arteries in term infants in the first day of life has been described to be around 0.6-0.7.
- In premature neonates, resistive indices are known to be higher.
The causes of hypoxic–ischemic encephalopathy (HIE) are complex and related to multiple factors.

Combination of systemic hypotension, abnormal cerebral autoregulation leading to cerebral hypoperfusion, and subsequent HII.

During the postasphyxiated period, an increase in CBF within the first few hours of life may last for hours or days.

This period is known as reperfusion phase and may be responsible for reperfusion brain injury.
Perinatal Asphyxia and Hypoxic–Ischemic Injury

- In neonates with HIE, increased CBF velocities up to three times more than controls
- Decrease in RI of the intracranial arteries to 0.5 or less, measured at 12 to 72 hours of life, have been described in severe HII.
- In neonates, at risk for stroke, CDS may also be used for assessment of luxury perfusion
Brain Perfusion
Basal ganglia perfusion using Dynamic color Doppler in HIE

- Retrospective study: QUIMS 2016

<table>
<thead>
<tr>
<th>Survivors (21)</th>
<th>Non-survivors (7)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPI</td>
<td>0.111 ± 0.082</td>
<td>0.226 ± 0.221</td>
</tr>
</tbody>
</table>

- Prospective study: IPR 2016

<table>
<thead>
<tr>
<th>Normal n=17</th>
<th>Mild n=16</th>
<th>Moderate n=17</th>
<th>Severe n=16</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.208±0.112</td>
<td>0.239±0.162</td>
<td>0.165±0.167</td>
<td>0.401±0.074</td>
</tr>
</tbody>
</table>

![Deep gray matter perfusion chart](chart.png)
Reperfusion Injury
Bowel

- US Doppler interrogation of the gastrointestinal tract is useful for assessment of superior mesenteric artery and intestinal perfusion.
- The flow pattern in the SMA is of high resistance in the fasting state and becomes of low resistance in the postprandial state.
- In normal fasting neonates, bowel wall perfusion usually ranges from one to nine color Doppler signals per centimeter square (mean = 3.78, standard error of mean = 0.20)
Necrotizing Enterocolitis

- Intestinal mural perfusion can be assessed directly, in real time at the bedside, with CDS.
- In 2005, the use of color Doppler was described to assess bowel wall perfusion and viability in necrotizing enterocolitis (NEC).
- In neonates with NEC, color Doppler US revealed three types of flow in the bowel wall:
  - normal, increased, and absent
Necrotizing Enterocolitis

• CDS flow was considered increased when certain types of hyperemic flow pattern were different from the normal neonates.
Bowel Perfusion

- “circular” flow; “Y” pattern or a “zebra” pattern
Necrotizing Enterocolitis

• CDS perfusion was considered absent when no mural CDS signals were demonstrated.

• Non-perfused bowel loops were correlated with abdominal x-rays (AXR) and with laparotomy and pathologic specimens. The sensitivity of CDS to detect gangrenous bowel was 100% compared to 40% for AXR.
Intestinal Hypoxic–Ischemic Injury

• Asphyxia may result in perinatal hypoxia and acidosis.

• It may cause redistribution of blood flow with an increase in the flow to the brain, heart, and adrenal glands and a decrease to the kidneys, bowel, and skin.

• It has been reported that pulsed Doppler interrogation in the SMA is altered with a significant decrease in the mean blood flow velocities and increase in RI, in severe HII.
Intestinal Hypoxic–Ischemic Injury

• retrospective pilot study, we evaluated 28 neonates

• a trend toward a decreased bowel wall perfusion in 7 nonsurvivors compared to 21 survivors ($0.040 \pm 0.015 \text{ cm/s} \times 0.052 \pm 0.029 \text{ cm/s}$)

• Therefore, assessment of bowel perfusion role in predicting outcomes and understanding the pathophysiology of bowel injury in HII.
Bowel Perfusion
Kidneys

• It is well known that RI of renal arteries varies in the first 12 months of life.
• In term infants, the RI ranges from 0.6 to 0.8, although in premature babies, RI may reach 0.9 in the renal arteries.
• The structural and functional immaturity of the kidneys in neonates are responsible for these changes.
Kidneys

- **Acute kidney injury (AKI)** has been associated with perinatal asphyxia, hypotension, or cardiac failure

- Decreased blood flow velocity in the renal arteries has been described in severe hypoxic–ischemic injury (HII)
Renal Perfusion
Conclusion

• Spectral Doppler, color Doppler, and power Doppler sonography are often used to assess blood flow and provide an estimate of organ perfusion.
• DTPM and other perfusion quantification methods offer a standardized, quantitative assessment of tissue perfusion and provide precise information in the clinical and research settings.
• It is fundamental to understand them to be able to use them wisely.
Thank you!