Neonatal GI Ultrasound Imaging

Kassa Darge, MD, PhD
Professor of Radiology
Perelman School of Medicine
University of Pennsylvania
Chief, Division of Body Imaging
Department of Radiology
The Children’s Hospital of Philadelphia
Philadelphia
Monica Epelman, MD
Karl Muchantef, MD

THANK YOU VERY MUCH!
Introduction

- **FOCUS**
  - US of the bowel
  - Necrotizing enterocolitis

- **US of the bowel:**
  neonates and neonatal ICUs
  - Several applications
  - Underutilized
Epidemiology

→ 1-5% - NICU admissions
→ 10% - newborns <1500g
→ 10% - term newborns [CHD]
→ 1.-2. week - manifestation
  2.-4. week: very premature
→ 20-40% - mortality [-64% - VLBW]

Yee et al. (2012) Incidence and timing of presentation of NEC in preterm infants. Pediatrics 129:e298-304
Pathophysiology
- Multifactorial
- Bowel wall damage:
  - ischemia
  - necrosis
  - bowel wall thinning
  - perforation

Objectives

Bowel Ultrasound for Necrotizing Enterocolitis

① Why should we do bowel US for NEC?
② How is US for NEC performed?
③ What are the US findings?

[NEC=Necrotizing Enterocolitis]
Objectives

Bowel Ultrasound for Necrotizing Enterocolitis

1. Why should we do bowel US for NEC?
2. How is US for NEC performed?
3. What are the US findings?

[NEC=Necrotizing Enterocolitis]
Real-time direct visualization

Bowel wall
- Thickening
- Echogenicity
- Thinning
- Perfusion

Bowel peristalsis

Fluid collection
- Focal
- Free
High diagnostic value
US for Necrotizing Enterocolitis [NEC]

**US is more sensitive in detecting:**
- Intramural gas
- Portal venous gas
- Free gas
- Free fluid

**Color Doppler US:**
- More accurate than clinical exam & x-ray in prediction of necrosis
  - *x-ray:* free air in 40% - *US CD:* absence of flow in 100%

Reference: abdominal radiograph/surgery

- Faingold et al. NEC: assessment of bowel viability with color Doppler US. Radiology 235:587-594

Department of Radiology, The Children’s Hospital of Philadelphia [CHOP]
# Inter-observer reliability of radiological signs of necrotising enterocolitis in a population of high-risk newborns

Anteo Di Napoli, Domenico Di Lallo, Carlo A. Perucci, Patrizia Schifano, Marcello Orzalesi, Francesco Franco and Maria Pia De Carolis

*Paediatric and Perinatal Epidemiology 2004, 18, 80–87*

---

<table>
<thead>
<tr>
<th>Radiological signs</th>
<th>All radiographs $(n = 297)$</th>
<th>Radiographs of sufficient/good quality $(n = 247)$</th>
<th>Radiographs from infants with the clinical diagnosis of NEC $(n = 62)$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kappa $P$</td>
<td>kappa $P$</td>
<td>kappa $P$</td>
</tr>
<tr>
<td>Diffuse gaseous intestinal distention</td>
<td>0.55 $&lt;0.01$</td>
<td>0.54 $&lt;0.01$</td>
<td>0.63 $&lt;0.01$</td>
</tr>
<tr>
<td>Bowel wall thickening</td>
<td>0.22 $&lt;0.01$</td>
<td>0.25 $&lt;0.01$</td>
<td>0.33 $&lt;0.01$</td>
</tr>
<tr>
<td>Pneumatosis intestinalis (bubbly/cystic)</td>
<td>0.13 $&lt;0.01$</td>
<td>0.15 $&lt;0.01$</td>
<td>0.04 $0.71$</td>
</tr>
<tr>
<td>Pneumatosis intestinalis (linear/curvilinear)</td>
<td>0.29 $&lt;0.01$</td>
<td>0.25 $&lt;0.01$</td>
<td>0.47 $&lt;0.01$</td>
</tr>
<tr>
<td>Presence of portal venous gas</td>
<td>0.10 $&lt;0.01$</td>
<td>0.10 $&lt;0.01$</td>
<td>0.23 $&lt;0.01$</td>
</tr>
<tr>
<td>Diagnosis of NEC</td>
<td>0.31 $&lt;0.01$</td>
<td>0.32 $&lt;0.01$</td>
<td>0.39 $&lt;0.01$</td>
</tr>
</tbody>
</table>

Degree of agreement: $k<0.4$: poor, $0.4<k<0.75$: fair to good, $k>0.75$: excellent
Appropriate staging
## Bell’s Staging

### Modified Bell’s Staging Criteria for Necrotizing Enterocolitis

<table>
<thead>
<tr>
<th>STAGE</th>
<th>SYSTEMIC SIGNS</th>
<th>INTESTINAL SIGNS</th>
<th>RADIOLOGIC SIGNS</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Suspected</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>Temperature instability, apnoea, bradycardia</td>
<td>Elevated pre-gavage residuals, mild abdominal distension, occult blood in stool</td>
<td>Normal or mild ileus</td>
<td>NPO, antibiotics x 3 days</td>
</tr>
<tr>
<td>B</td>
<td>Same as IA</td>
<td>Same as IA, plus gross blood in stool</td>
<td>Same as IA</td>
<td>Same as IA</td>
</tr>
<tr>
<td>II. Definite</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A: Mildly ill</td>
<td>Same as IA</td>
<td>Same as I, plus absent bowel sounds, abdominal tenderness</td>
<td>Ileus, pneumomatosis intestinallis</td>
<td>NPO, antibiotics x 7 to 10 days</td>
</tr>
<tr>
<td>B: Moderately ill</td>
<td>Same as I, plus mild metabolic acidosis, mild thrombocytopenia</td>
<td>Same as I, plus absent bowel sounds, definite abdominal tenderness, abdominal cellulitis, right lower quadrant mass</td>
<td>Same as IIA, plus portal vein gas, with or without ascites</td>
<td>NPO, antibiotics x 14 days</td>
</tr>
<tr>
<td>III. Advanced</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A: Severe ill, bowel intact</td>
<td>Same as IIB, plus hypotension, bradycardia, respiratory acidosis, metabolic acidosis, disseminated intravascular coagulation, neutropenia</td>
<td>Same as I and II, plus signs of generalised peritonitis, marked tenderness and distension of abdomen.</td>
<td>Same as IIB, plus definitive fluid resuscitation, inotropic support, ventilator therapy, paracentesis</td>
<td>NPO, antibiotics x 14 days, surgery</td>
</tr>
<tr>
<td>B: Severely ill, bowel perforated</td>
<td>Same as IIIA</td>
<td>Same as IIIA</td>
<td>Same as IIIIA, plus pneumoperitoneum</td>
<td>Same as IIA, plus surgery</td>
</tr>
</tbody>
</table>

US findings verified in animal studies
Bowel sonography in sepsis with pathological correlation: an experimental study

Hwa-Young Kim, In-One Kim, Woo Sun Kim, Gyeong Hoon Kang

- animal studies
- E.coli sepsis
- US + Doppler
- Pathological correlation

Doppler Sonographic Findings in an Experimental Rabbit Model of Necrotizing Enterocolitis


Young-Hun Choi, MD, In-One Kim, MD, Jung-Eun Cheon, MD, Je-Eun Kim, MD, Ee-Kyung Kim, MD, Woo Sun Kim, MD, Kyung Mo Yeon, MD
No radiation
- ABOMEN X-RAYS
  - Multiple repeat x-rays
  - Multiple repeat additional views

+ OTHER X-RAYS
  - Pre-term/term ICU
  - Multiples
Bedside ultrasound

- Intensive care patients

The NEW ENGLAND JOURNAL of MEDICINE

REVIEW ARTICLE

CURRENT CONCEPTS

Point-of-Care Ultrasonography

Christopher L. Moore, M.D., and Joshua A. Copel, M.D.

- Pediatric radiologist
- Pediatric intensive care specialist
- Neonatologist
General US features
**US**

- widely available
- cost ↓
- non-invasive
- no preparation
- duration ↓
- ↓ ↓ ↓ patient size
Objectives

Bowel Ultrasound for Necrotizing Enterocolitis

1. **Why** should we do bowel US for NEC?
2. **How** is US for NEC performed?
3. **What** are the US findings?

[*NEC=Necrotizing Enterocolitis*]
Diagnostic imaging for NEC

- Abdominal radiograph
  - Current modality of choice
  - Follow-up radiographs: every 6-24 hours or acute decline
  - Supine
    ± cross-table or lateral decubitus
  - At least in first 48 hours 2 views
    [higher perforation rate]
Abdomen US for NEC

- **Preparations**
  - Portable US machine
  - Transducers: *high frequency, high resolution*
    - **Linear:** > 8 MHz
    - **Convex:** > 5 MHz
  - **US gel:** *warmed to body temperature*
Abdomen US for NEC

- US scan
  - Modalities:
    1. Gray-scale
    2. Color Doppler
    3. Harmonic Imaging
    4. Video Clip
    5. Panorama Imaging
    6. Spectral Doppler

- ↑ frequency
- ↑ spatial & contrast resolution
Abdomen US for NEC

- **US scan**
  - Modalities:
    - 1. **Gray-scale**
    - 2. **Color Doppler**
    - 3. **Harmonic Imaging**
    - 4. **Video Clip**
    - 5. **Panorama Imaging**
    - 6. **Spectral Doppler**

- ↓ pulse repetition frequency (PRF)
- Follow-up same PRF
Abdomen US for NEC

- US scan
  - Modalities:
    1. Gray-scale
    2. Color Doppler
    3. Harmonic Imaging
    4. Video Clip
    5. Panorama Imaging
    6. Spectral Doppler

- Harmonics
- Wide-band
- ↓ artefacts
- ↑ conspicuity
Abdomen US for NEC

- US scan
  - Modalities:
    1. Gray-scale
    2. Color Doppler
    3. Harmonic Imaging
    4. Video Clip
    5. Panorama Imaging
    6. Spectral Doppler

- Peristalsis: presence, decrease or absence
Abdomen US for NEC

- **US scan**
  - **Modalities:**
    1. Gray-scale
    2. Color Doppler
    3. Harmonic Imaging
    4. Video Clip
    5. Panorama Imaging
    6. Spectral Doppler

- Long segment scan
- Improved documentation
Abdomen US for NEC

- US scan
- Modalities:
  1. Gray-scale
  2. Color Doppler
  3. Harmonic Imaging
  4. Video Clip
  5. Panorama Imaging
  6. Spectral Doppler

- Portal vein
- Superior mesenteric artery
Abdomen US for NEC

- **US scan**
  - Technique:
    - “Non-compression” technique
      - large amount of gel for padding
      - vital signs monitor check
  - **FOCUS:**
    1. Bowel
    2. Peritoneal cavity
    3. Portal vein system [liver]
Abdomen US scan for NEC

- **US scan**
  - **Technique:**
    - 4-quadrant scan
      - start RLQ
      - RUQ + LUQ
    
    *Note: left lobe higher than right lobe*
    
    - for perstalsis longer observation [1 min]
  
- **Modalities**
  - gray-scale, color Doppler etc.
Bowel US for NEC

FUTURE: potential applications

- Dynamic color Doppler US
- Contrast-enhanced US
Dynamic color Doppler US

- Tissue perfusion
  - Dynamically quantify color Doppler signals and obtain tissue measurements [Pixelflux Chameleon®]
  - Perfusion velocity in a region of interest [no contrast agent]
IV US contrast agent: microbubbles

- No studies in NEC
- Bowel ischemia evaluation in adults

Normal

Ischemia
Objectives

Bowel Ultrasound for Necrotizing Enterocolitis

1. **Why** should we do bowel US for NEC?
2. **How** is US for NEC performed?
3. **What** are the US findings?
### Pathological US Findings

#### 1. Bowel
- Dilatation
- Peristalsis*
  - decrease
  - absence
- Bowel wall
  - thickening
  - thinning
  - hyperechogenicity
  - pneumatosis
- Bowel wall perfusion
  - increase
  - absence

#### 2. Portal vein
- Portal venous gas

#### 3. Peritoneal cavity
- Fluid
  - loculated
  - free
- Pneumoperitoneum

[*Normal: 10 contractions/min*]
Pathological bowel US findings

Necrotizing Enterocolitis: Review of State-of-the-Art Imaging Findings with Pathologic Correlation

Department of Radiology, The Children's Hospital of Philadelphia [CHOP]
Bowel dilatation
Bowel dilatation
Bowel wall findings

BW measurements
- Normal: 1.7 [1.1-2.6] mm
- BW thickening ≥ 2.7 mm
- BW thinning ≤ 1.0 mm*

[Necrotizing Enterocolitis: Assessment of Bowel Viability with Color Doppler US\(^1\)]

[*Stretching: normal echogenicity + peristalsis]
Bowel wall findings

- Hyperechoic rim: along mucosa
- Loss of hypoechoic rim: muscularis mucosa
Bowel wall findings

- “Pathognomonic” – NEC
- Incidence: 19-98%
- Distal small and large bowel
- Dependent portion of bowel
- Intramural or intraluminal
  - lack of motion
  - lack of movement with compression
Bowel wall findings
Bowel wall findings

Perfusion: absent
Portal vein finding

- Umbilical venous line?
- 30% of those with NEC
- Focal/diffuse
- Spectral Doppler:
  - bidirectional spikes
Peritoneal cavity findings

Localized fluid
Peritoneal cavity findings

- Free fluid with and without perforation
- Low-level echoes or septations suggestive of perforation
- Perforation with FF in absence of free gas on x-ray
Peritoneal cavity findings

- Echogenic lines/foci
- Posterior ring-down or comet -tail artifacts
- Outside bowel, posterior to abdominal wall
- Perforation: ↑distal ileum/colon

Liver
### Table 1: Categorization of sonographic features correlated with outcome

<table>
<thead>
<tr>
<th>Category</th>
<th>Sonographic features</th>
<th>Group A (n=18)</th>
<th>Group B (n=22)</th>
<th>Risk ratio for poor outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Free gas</td>
<td>0</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Focal fluid collections</td>
<td>0</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Increased wall echogenicity</td>
<td>4</td>
<td>18</td>
<td>3.65</td>
</tr>
<tr>
<td></td>
<td>Absent perfusion</td>
<td>2</td>
<td>8</td>
<td>3.27</td>
</tr>
<tr>
<td></td>
<td>Portal venous gas</td>
<td>1</td>
<td>4</td>
<td>3.27</td>
</tr>
<tr>
<td></td>
<td>Bowel wall thinning</td>
<td>4</td>
<td>15</td>
<td>3.07</td>
</tr>
<tr>
<td></td>
<td>Bowel wall thickening</td>
<td>4</td>
<td>15</td>
<td>3.07</td>
</tr>
<tr>
<td></td>
<td>Free fluid with echoes</td>
<td>5</td>
<td>17</td>
<td>2.78</td>
</tr>
<tr>
<td></td>
<td>Intramural gas</td>
<td>7</td>
<td>14</td>
<td>1.64</td>
</tr>
<tr>
<td>3</td>
<td>Increased perfusion</td>
<td>12</td>
<td>14</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>Anechoic free fluid</td>
<td>5</td>
<td>1</td>
<td>0.16</td>
</tr>
</tbody>
</table>

**US findings ➔ PROGNOSIS**

*Correlation of sonographic findings and outcome in necrotizing enterocolitis*

Cicero T. Silva • Alan Dunneman • Oscar M. Navarro • Alden M. Moore • Rahul Moineddin • J. Ted Gerstle • Ashok Mittal • Mary Brindle • Monica Epselman
ABDOMEN US FOR NECROTIZING ENTEROCOLITIS

Where to start?

- Discrepancy between clinical and x-ray findings
  - Positive clinical findings + gasless abdomen
  - Positive clinical findings + absence of intramural gas on x-ray
  - Clinical deterioration but no free air on x-ray

- Differentiate from other causes of bowel distention

- Follow-up studies

- Determine time to reinitiate feeding

Department of Radiology, The Children’s Hospital of Philadelphia [CHOP]
ABDOMEN US FOR NECROTIZING ENTEROCOLITIS

Where to start?

- Discrepancy
  clinical - x-ray
- Differentiate other
- Follow-up studies
- Reinitiate feeding
ABDOMEN US for Necrotizing Enterocolitis

• useful & practical imaging modality
  ▪ adjunct to x-ray
  ▪ easy to learn
  ▪ widespread use

needs to be encouraged
THANK YOU FOR YOUR ATTENTION!