Ultrasound of the Bowel in Children

Swati Mody M.D.
Department of Pediatric Imaging
Children’s Hospital of Michigan
Wayne State University School of Medicine
Why US of the bowel

- Increase in awareness of risks of radiation in neonates and children
- Reduction in CT
- Increase in use of US for pediatric bowel pathology
Indications for Bowel US

• Common indications
  – Hypertrophic pyloric stenosis (HPS)
  – Intussusception
  – Appendicitis

• Increase in use of ultrasound for bowel evaluation for other conditions
  – Necrotizing enterocolitis (NEC)
  – Henoch Schonlein Purpura (HSP)
  – Inflammatory bowel disease (IBD)
US of the Bowel

- Case based discussion
- Premies / neonates → older children
Case

2 week old twin born at 29 weeks gestation with abdominal distension
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- Portal venous gas
- Intramural gas pneumatoasis
2 week old twin born at 29 weeks gestation with abdominal distension

- Necrotizing enterocolitis (NEC)
- Distended bowel loops
- Pneumatosis
- Portal venous gas
Necrotizing Enterococolitis (NEC)

- Most common and devastating inflammatory gastro-intestinal disease of newborn
- Etiology unknown / controversial
- Mainly premature infants
- Low birth weight < 1500g
- 1 to 5 % NICU admissions
- 20-40 % mortality
NEC - Why should we do US

- X-rays mainstay imaging for NEC
  - Can not assess bowel wall on X-ray

- Why US
  - Assess Bowel wall
    - Thickening and thinning
    - Echogenicity
    - Bowel Perfusion
    - Pneumatosis
  - Peristalsis
  - Fluid - free and focal
  - Doppler – SMA and Celiac trunk
    - Increased peak systolic velocity in NEC
NEC – US Technique

• Transducers: high frequency, high resolution
  – Linear > 8 MHz, Curved > 5 MHz

• US gel
  – Warmed to body temperature!

• “Non-compression” technique
  – Large amount of gel
  – Check for vital signs on monitors
NEC – US Technique

• Gray Scale
  – Increased frequency
  – Harmonics - Decreases artifacts - Increases conspicuity
  – Video Clips – peristalsis
  – Panoramic imaging – long segment, better documentation

• Color Doppler
  » Decreased pulse repetition frequency (PRF)
  » Follow-up same PRF

• Spectral Doppler – SMA, Celiac trunk, Portal Vein
NEC – US Technique

- 4 Quadrant Technique
  - Start in RLQ >> RUQ >> LUQ >> LLQ

- Longer observation time (1 min) for peristalsis

- Gray scale and color Doppler

- Focus
  - Bowel
  - Peritoneal cavity – fluid, free air
  - Liver for portal venous gas
Transverse section through bowel
Typical “gut” signature
Hypoechoic area – prominent muscularis propria
Normal wall thickness (1.1 – 2.6 mm)

Color Doppler normal fasting (1 – 9 dots / cm²)
Normal increased flow postprandial

Faingold et al. Radiolgy 2005; 235:587-594
Edelman et al. Radiographics 2007; 27:285-305
NEC- US Findings

Sequence of events in bowel wall thickness and perfusion

- a. Normal bowel, normal flow
- b. Bowel wall thickening, increased perfusion
- c. Bowel wall thickening persists, diminished perfusion
- d. Mucosa starts sloughing, bowel wall thinning, some flow persists
- e. Sloughing continues, asymmetric bowel wall thinning, flow ceases

Edelman et al. Radiographics 2007; 27:285-305
Bowel wall thickening
Loss of “gut” signature– hypoechoic halo of muscularis

Bowel dilatation
Echogenic wall – Loss of “gut” signature

Asymmetric thinning of bowel wall

Edelman et al. Radiographics 2007; 27:285-305
NEC US – Intramural gas

Large intramural gas – pneumatosis
Hyperechoic foci posterior artifact

Intramural Vs extramural gas
- Dependent and non-dependent
- Lack of motion
- No movement with compression

Edelman et al. Radiographics 2007; 27:285-305
NEC – Color Doppler

“Y” pattern
increased flow mesenteric and subserosal vessels

“Ring” pattern
Entire circumference of bowel

Gray – scale
Thickened bowel
Markedly hyperechoic valvulae

Color Doppler
Markedly hyperemic valvulae

Zebra / herringbone pattern

Edelman et al. Radiographics 2007; 27:285-305
NEC US – Portal Venous gas

Punctate and linear hyperechoic areas in portal veins
Posterior shadowing

Spectral Doppler – portal vein
Artifacts due to portal venous gas

Abdominal decubitus
Radiograph
Portal venous gas

Edelman et al. Radiographics 2007; 27:285-305
NEC US – Peritoneal cavity

Free fluid in peritoneal cavity

Herringbone pattern of bowel

Loculated septated fluid w/ debris

Edelman et al. Radiographics 2007; 27:285-305
NEC US – Free intraperitoneal air

Large amount of free air
Long linear echogenicity below abdominal wall
With reverberation artifact
Differentiate from bowel gas

Small free air
Hyperechoic foci between liver and anterior abdominal wall

Occasionally real time
Bubbles of free air from bowel

Edelman et al. Radiographics 2007; 27:285-305
1 week old premie born at 28 weeks gestation with abdominal distension

US is a valuable adjunct to X-rays for NEC

Abdominal radiograph
“Gasless” abdomen

Doppler US
Thickened bowel loop
No perfusion - necrosis

Surgical findings: Dilated loops of bowel with segmental necrosis

Edelman et al. Radiographics 2007; 27:285-305
Case

1 month old male with projectile vomiting
1 month old male with projectile vomiting

US upper abdomen, midline, RUQ
1 month old male with projectile vomiting

US upper abdomen, midline, RUQ

Thickened elongated pyloric channel

Distended stomach

Hypertrophic Pyloric Stenosis (HPS)
Hypertrophic Pyloric Stenosis (HPS)

- Cause unknown, evolution not well understood
- Common 2-5 of 1,000 birth, Caucasian
- First born males, male to female ratio 4:1
- Familial predisposition
  - 5 times more common 1st degree relatives
- 3rd – 12th week of life – typically 4th week
- Non-bilious intermittent vomiting >>> projectile vomiting with complete gastric outlet obstruction
Hypertrophic Pyloric Stenosis (HPS)

- US – sensitivity and specificity ~ 100%
- US has virtually replaced physical exam - “olive”
HPS – US Technique

- Linear-array transducer (5-12 MHz)
- Transducer placed transverse oblique plane parallel to right lower costal margin
- Use liver as acoustic window
- Transducer angled slightly downward
HPS – US Technique

- Gall bladder as landmark
  - Pylorus just lateral to gall bladder
- Search for gastric antrum and normal triangle of duodenal bulb just distal to antrum
HPS – US Technique

• Posterior oblique position of infant – gastric content to distend antro-pyloric region
• If stomach empty, Pedialyte to infant

• **US for pylorus in normal patient is challenging – learning curve!**
HPS – US Technique

- Imaging and measurements in long axis
- Short axis view also obtained
- Cine clips: Observe gastric content flowing through
HPS – US Findings

- Measurement of pyloric muscle thickness - most accurate sign
- Calipers placed at superficial and deep borders of a single – anterior layer
- **Threshold for diagnosis is thickness < 3-4 mm**

Longitudinal pyloric channel
HPS – US Findings

• Length of pyloric channel less accurate

• **Abnormal > 14 mm**

• Diagnosis made with combination of
  • Muscle thickness
  • Channel length
  • Morphology
  • **Real time passage of gastric contents**
Evolution of HPS

5 weeks old male with intermittent vomiting, now projectile

Day 1
Long – muscle thickness 3.0 mm

Day 1
Flow though pyloric channel
?
equivocal

Day 3
Long – muscle thickness 4.1 mm
No flow gastric contents on real time

HPS
HPS US – False Negative Results

• Most common – overdistension of stomach with posteriorly directed antrum and pylorus

• Real challenge!
  - Scan from right flank
  - Change position – right lateral, prone
  - Place NG tube and decompress stomach
HPS US – False Negative Results

- Off line or tangential images
  - Long axis with equal thickness of anterior and posterior muscle
  - Verify with measurements in axial plane

Pyloric muscle thickness

- Longitudinal – 2.7 mm
- Longitudinal – 3.6 mm
- Axial – 3.5 mm
HPS US Mimic

- Transient Pylorospasm
  - Muscle thickness will be borderline, typically < 3 mm
  - Muscle will relax during exam
  - Gastric contents will flow though
  - Don’t be in a hurry!

- Look out for malrotation as the cause for vomiting!
Case

1 day old male with multiple congenital anomalies, vomiting
1 day old male with multiple congenital anomalies, vomiting

Transverse upper abdomen US

SMA/SMV relationship is abnormal

SMV should be always to the right of SMA

Malrotation
1 day old male with multiple congenital anomalies, vomiting

Abdomen radiographs

- Supine
- Left lateral decubitus

“Double bubble” sign
Obstruction in the duodenum

Malrotation
Midgut Volvulus
Malrotation

- 1 in 500 live births
- Failure of normal embryologic rotation of bowel

Normal intestinal rotation
Long mesenteric pedicle

Non-rotation
Short mesenteric pedicle
Midgut Volvulus
Malrotation

• 75% in newborn period and 90% in infancy
• Classic presentation is **new onset bilious vomiting**
• Unclear clinical picture
  – Non-bilious emesis
  – GI bleed due to intermittent volvulus
  – Failure to thrive
Malrotation - US

• Role of US is disputed
  » Evaluate for malrotation on HPS studies for emesis in neonates and infants

• SMA / SMV relationship

• Position of the 3rd portion of duodenum
Malrotation US
SMA / SMV relationship

- Linear Transducer (5-12 MHz)
- Transverse midline just below the pancreas
  - Trace SMV draining into splenic vein
  - Evaluate position relative to SMA

- **Normal** – SMV to the right of SMA
- **Malrotation** – SMV directly anterior (above) and left of SMA
  - Due to failure of normal counterclockwise rotation of bowel
Normal SMA / SMV relationship

Transverse midline level of pancreas and below

Normal – SMV to the right of SMA
1 month old male with intermittent vomiting - r/o HPS

- Malrotation – SMV directly anterior (above) and left of SMA
Malrotation US
SMA / SMV relationship

- SMA / SMV relationship low sensitivity and specificity for malrotation
- Normal relationship does not exclude malrotation
  - False negative – 2- 33%
  - False positive - 21%

Zerin et al. Radioloy 1992; 183 (3):693-694
Malrotation US
Position of 3\(^{rd}\) portion of duodenum

- Normal – 3\(^{rd}\) portion of duodenum is retromesenteric - between SMA and aorta
- Normal retromesenteric position of duodenum rules out malrotation
- Utility of this sign is controversial (we do not rely on it)

Malrotation with mid gut volvulus – US

- “Whirlpool sign” – midgut volvulus – Surgical Emergency!
- SMV and jejunal veins circling around SMA

Marine et al. Semin Ultrasound CT MRI 2014; 35:555-570
Malrotation

- US in infant for vomiting (HPS)
- SMA / SMV relationship is abnormal
- Get upper GI to rule out malrotation
- If whirlpool sign – Malrotation w/ midgut volvulus – emergent UGI and Surgery – bowel ischemia
Case

1 year old male w/ intermittent abdominal pain and diarrhea since 2 days.
1 year old male w/ intermittent abdominal pain and diarrhea since 2 days
1 year old male w/ intermittent abdominal pain and diarrhea since 2 days

Donut or target sign

Lymph node
Lead point

Color Doppler

Mesenteric vessels entering the intussuscepiens

Intussusception
Intussusception

- Children between 6 months – 2 years of age
- Classic clinical triad
  - Acute colicky abdominal pain
  - Bloody stools – “currant jelly” stools
  - Palpable abdominal mass or vomiting
- 20% with intussusception may be pain free at diagnosis
- Only 30%– 68% - w/ suspicious clinical signs have intussusception
- Imaging is required – US mainstay for diagnosis
  - Sensitivity – 97.9%, Specificity – 97.8%, Negative predictive value – 99.7%

Intussusception

- Intussusception is “telescoping” or invagination of bowel into itself
- “Intussuscepiens” – receiving loop containing
- “Intussusceptum” – donor loop
  - Intussusceptum has two components
    - Central entering limb of bowel
    - Edematous returning limb more peripherally
  - Mesentery is dragged between the 2 limbs +/- lymph nodes
Intussusception US

Intussuscepiens (receiving loop) contains intussuceptum – donor loop
Intussusceptum - two components
E – entering limb
R – returning limb
M – mesentery dragged between two limbs

Short axis US image ileo-colic intussusception - “Donut” sign

Cogley et al. Radiographics 2012; 32:651-665
US Intussusception - Technique

• Linear array transducer (5-12 MHZ)
• RLQ – Cecum is the starting point – majority ileocolic
• Trace the colon from cecum to rectum
  – Probe held in transverse position w/ additional views as required
    – “target” or “donut” sign of intussusception
  – Longitudinal – confirm bowel within bowel
• Panoramic
• Color Doppler
  – Vessels with mesentery in bowel lumen
  – Assess viability of bowel
6 month old female with bloody diarrhea

Color Doppler Transverse RUQ

- Free fluid
- Distended bowel loops
- Intussusceptum entering intussuscepiens w/ mesenteric vessels
Intussusception
“Lead point”

• Most childhood intussusceptions are idiopathic
  – Hypertrophied lymphoid tissue
  – Reduced by air or contrast enema
  – Recur 10-15%

• 5% have underlying “lead point” – or mass
  – Meckel’s diverticulum, duplication, polyp, tumor

• Lead point common
  – Neonates < 30 days old
  – Older children > 5 years old

• “Lead point” can cause recurrent intussusception, require surgery
11 year old with acute abdominal pain, bloody diarrhea r/o appendicitis/inflammatory bowel disease

US right lower quadrant / pelvis

Intussusception – Surgery - Meckel’s diverticulum as lead point
Intussusception - Mimics

• Small bowel intussusception
  • Small less than 2 cm
  • Do not involve cecum – much central
  • Asymptomatic – occasionally incidental
  • Reduce spontaneously

• Thickening of cecum
  – Inflammatory bowel disease
  – Infection/ inflammation etc.
Case

13 year old male, acute onset right lower quadrant pain since 2 days, leukocytosis
13 yr. old male, acute onset right lower quadrant pain since 2 days, leukocytosis

Distended blind bowel loop draping over iliac
13 yr. old male, acute onset right lower quadrant pain since 2 days, leukocytosis

Diameter 1.15cm

Transverse RLQ

appendicolith
13 yr. old male, acute onset right lower quadrant pain since 2 days, leukocytosis

Non-compressible bowel loop
13 yr. old male, acute onset right lower quadrant pain since 2 days, leukocytosis

Longitudinal RLQ

appendicolith
Blind ending loop - appendix
Power Doppler - hyperemia

Acute appendicitis w/ appendicolith
Appendicitis

- Most common condition requiring emergent surgery in childhood
- 60,000-80,000 children get treated for appendicitis in US each year
- 5-15 years of age
- Obstruction of lumen > distension > elevated pressure across wall > decreased mural perfusion > (appendectomy) > gangrene and perforation
Appendicitis

- Classic presentation- periumbilical pain that migrates to RLQ – McBurney’s point
- Anorexia, elevated white count, low grade fever
- Higher prevalence of ruptured appendicitis in children
  - 1/3 have atypical clinical findings
  - Younger children can not describe symptoms
- US is primary imaging modality for appendicitis in children
Appendicitis – US Technique

• Operator dependency major issue in US evaluation for appendicitis
• US sensitivity 88%, specificity 94%
• Technical factors
  – Obesity
  – Severe tenderness – unable to adequately compress
  – Marked gaseous distension of bowel loops
Appendicitis – US Technique

- High resolution Linear-array transducer (5-12 MHz)
- Ask the child “where does it hurt?” – starting point
- Graded compression
  - Displace bowel
  - Differentiate normal collapsible bowel from inflamed appendix
- Landmarks
  - Cecum, iliac vessels, psoas muscle
- Color Doppler – hyperemia
US Normal Appendix

- Variable success rate
- Blind ending tip
- Outer diameter 6mm or less
- Partially compressible lumen

Longitudinal Gray scale US
Blind ending bowel loop – Normal appendix
Appendicitis US Findings

- Outer wall diameter appendix **greater than 6mm under compression** - most accurate sign

- Positive and negative predictive value of 98%

![Image of ultrasound findings for acute appendicitis with and without compression]
Appendicitis US Findings

- Other less sensitive and specific signs
  - Hyperemia of the appendiceal wall
  - Presence of appendicolith
    - Associated with earlier and higher rate of perforation
  - Echogenic inflamed periappendiceal fat
Appendicitis US Findings

- Appendix may not be identified with rupture
- Clinical history to reach diagnosis
- Differentiate from other conditions with RLQ pain such as IBD, infections etc.
4 yr. old, RLQ pain, fever, leukocytosis

- If diagnosis remains equivocal CT should be performed to avoid unnecessary surgery

Crohn’s Disease
17 yr. old male with known Crohn’s Disease with severe, acute abdominal pain
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US mid line; RLQ

- Thick walled bowel loops
- Thickened Hyperechoic mesentery
- Abscess
17 yr. old male with known Crohn’s Disease with severe, acute abdominal pain

Axial CT abdomen
With contrast

Coronal CT Abdomen
w/ contrast

Thickened bowel loops w/ septated abscess
Crohn’s Disease
US in Inflammatory Bowel Disease

- US has emerging role
- Trend is to perform combination of US and MR enterography (MRE)
- US helpful
  - When MRE can not be performed – young age, sedation risk
  - Follow-up to MRE to assess treatment
  - Follow-up complications e.g. abscess
- CT is reserved for complications e.g. abscess in acute setting
Inflammatory Bowel Disease
US technique

• Curved low frequency and linear (12-15 MHz) transducer
  • Evaluate with low frequency transducer followed by Linear transducer
• Simultaneous anterior and posterior manual compression
  • Place hand behind patient and apply pressure upwards while pressing down with transducer
• Longitudinal and transverse scan through out colon - starting at terminal ileum - cecum to rectum
• Evaluate small bowel left upper quadrant, mid and lower abdomen
Inflammatory Bowel Disease
US technique

- Gray scale
- Cine clips – peristalsis
- Panoramic imaging – long segments
- Color Doppler - assess perfusion bowel
  - Low wall filter
  - Lowest PRF
- Spectral imaging – SMA
Normal terminal ileum – US

- Terminal ileum – 14 MHZ linear transducer

- 5 layers of bowel wall – gut signature
  1. Hyperechoic mucosal interface
  2. Hypoechoic mucosa
  3. Hyperechoic submucosa
  4. Hypoechoic muscularis
  5. Hyperechoic serosal surface

Inflammatory Bowel Disease
US Findings

- **Active disease**
  - Bowel wall thickening > 5mm
  - Loss of stratification of bowel
  - Bowel hyperemia
  - Non-compressible
  - Hypopersitaltic

- **Chronic disease**
  - Bowel wall thickening > 5 mm
  - Loss of stratification of bowel
11 year old boy with Crohn’s disease
Right lower quadrant pain

Gray Scale transverse image terminal ileum
Bowel wall thickening
Loss of stratification

Color Doppler Sagittal image terminal ileum
Hyperemia suggestive active disease

Anupindi et al. AJR 2014; 202:946-959
Crohn’s Disease
Extramural US findings

- Thickened, echogenic, hyperemic mesentery
  - (simulates creeping fat)
- Enlarged lymph nodes
- Disruption of bowel wall – phlegmon, abscess

Gray scale longitudinal image terminal ileum
Arrow-heads – thickened bowel
Arrows – thickened, echogenic mesentery

Anupindi et al. AJR 2014; 202:946-959
Complications of Crohn’s Disease

- **Strictures**
  - Look for transition from narrow to dilated bowel
  - Hyperperistalsis prestenotic component
  - Differentiate from inflammatory and fibrotic strictures - vascularity

- **Fistulas**
  - Difficult to diagnose w/ US

- **Abscess**
  - CT for diagnosis - US follow-up
  - Irregular aperistaltic hypoechoic collections

14 year old w/ Crohn’s disease

Longitudinal Gray Scale image terminal ileum
Transmural disease, disruption of wall
Early phlegmon formation

Anupindi et al. AJR 2014; 202:946-959
Case

IBD differential: other inflammations/infections

11 yr. old male w/ ALL, post bone marrow transplant with severe abdominal pain, diarrhea
11 yr. old male w/ ALL, post bone marrow transplant with severe abdominal pain, diarrhea
11 yr. old male w/ ALL, post bone marrow transplant with severe abdominal pain, diarrhea

- Marked bowel wall thickening
- Loss of gut signature
- Free fluid

US – Transverse RLQ

US – longitudinal
Ascending colon

CT Abdomen/pelvis

Wall thickening, enhancement cecum & ascending colon

Typhilitis
Case

6 year old with multiple joint pain, bluish purpuric rash, abdominal pain
6 year old with multiple joint pain, bluish purpuric rash, abdominal pain

Bowel wall thickening jejunum
Loss of architecture – gut signature

Jejuno-jejunal intussusception

Henoch Schonlein Purpura

Anupindi et al. AJR 2014; 202:946-959
Henoch Schonlein Purpura (HSP)

- Autoimmune vasculitis
- Bowel, skin, joints, kidneys
- US bowel
  - Bowel dilatation
  - Hypoperistalsis
  - bowel wall thickening, loss of gut signature
  - Transient small bowel intussusception
- DD from IBD – HSP usually involves stomach, duodenum, jejunum – upper abdomen, LUQ
Case

11 yr. old female with abdominal pain, r/o appendicitis
11 yr. old female with abdominal pain, r/o appendicitis

Recent immigrant to United States

What is the diagnosis? Ascariasis!
Conclusion

• US is the mainstay in diagnosis of HPS, intussusception and appendicitis in children

• Targeted US should be used beyond the established indications in other conditions such as NEC, IBD, HSP
Thank You!