The value of the routine ultrasound of abdomen in the early neonatal period

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The value of ultrasound in neonatal medicine

Ultrasound scanning is an imaging modality that continues to gain acceptance in pediatric and neonatal medicine.

Despite the early adoption in obstetrics and maternal-fetal medicine, the actual bedside implementation in neonatology has unfortunately been much slower.

Examples in neonatology where ultrasound scanning may continue to expand include central line placement, endotracheal tube localization, cardiac function assessment, bowel viability assessment, necrotizing enterocolitis and many other measurement of the organs in newborns.

Expanded training for neonatologists is required before widespread adoption occurs.

Abdominal ultrasound scanning

- Several diseases that occur frequently should be excluded by ultrasound examination.
- On the other hand, many of the suspected anomalies of the gastrointestinal system, can be confirmed and better visualized following the birth.
- Use of ultrasound imaging, however, will save time and reduce costs and can avoid exposure to radiation with no reduction in diagnostic accuracy.
- Misuse of ultrasound must be avoided, as it discredits the technique and the operator and wastes time and money

WHO Manual of diagnostic ultrasound, 2013

Ultrasound is the most commonly used method in the pediatric population, including the neonatal period, to investigate suspected abdominal diseases as it does not require radiation or iodine contrast or anesthesia, and it is easily performed at bed side.

Though it is a highly sensitive and easily accessible imaging mode, errors in abdominal ultrasound investigation result from many factors, including the knowledge of anatomic and pathophysiological differences, as well as of clinical symptoms and pathology at each stage of child development.

When a single ultrasound examination is performed in infants and newborns, it may be necessary to apply a wide range of different sensors for the most appropriate applications.

In addition to the knowledge of the ultrasound patterns of each disease, including the hepatobiliary and pancreatic ones, it is important to understand the normal appearance and variations to avoid interpretation errors.

Abdominal ultrasound can play a role both in the diagnostic and interventional process, and both in neonatal intensive care unit for pathologies that most typically involve premature infants and in a first level birth point.

- Neonatal abdominal ultrasound is usually performed as a follow up to further evaluate fetal abnormalities which were detected on prenatal ultrasound or in the course of investigating neonatal symptoms.

- The role of the prenatal ultrasound has evolved in its specificity (93-99%) and sensitivity (14-85%) for identification of fetal malformations over the last five decades and has partly contributed to the lowering of fetal mortality rates. More abnormalities are seen by the third trimester and a single early scan may miss some fetal anomalies. This implies that some abnormalities may still be missed antenatally.

- Most neonatal abdominal scans are performed to investigate neonatal symptoms. The role of ultrasound in this case is usually to confirm or exclude congenital or acquired, inflammatory or neoplastic lesions of abdominal organs.

Indicated ultrasound scanning in newborn

Solid abdominal organs (Liver, biliary tract, spleen)

- Ultrasound is the preferred initial imaging modality for evaluating the liver and biliary tract in children, especially newborns. Typical indications are hepatomegaly, jaundice, anomalous hepatic assessment, ascites, suspected liver abscess or liver mass.
- Ultrasound gives information on the size and structure of the liver and demonstrates both localized lesions and diffuse diseases.
- Doppler ultrasound is useful for locating vessels and for ensuring the permeability of the vascular structures. It is helpful for assessing the presence and direction of blood flow in the hepatic artery, hepatic veins and portal veins. Normal vascular flow patterns can be readily seen in children of all ages.

Liver length in midclavicular line in cm

Gestational age (weeks)	Number of patients	Mean length (+/- 1sd)	Min-max
24-31	29	3.7 (0.7)	2.8 – 5.8
32-35	33	4.6 (0.7)	3.2 – 6.2
36-37	35	5.4 (0.6)	3.5 - 6.3
38-41	153	5.5 (0.8)	3.9 – 7.8

Pancreas maximal diameter (sd)

Age	Head	Body	Tail
Newborn infants	1.0 (0.4)	0.6 (0.2)	1.0 (0.4)
1 month-1 year	1,5,(0.5)	0.8 (0.3)	1.2 (0.4)
1-5 year	1.7 (0.3)	1.0 (0.2)	1.8 (0.4)
5-10 year	1.6 (0.4)	1.0 (0.3)	1.8 (0.4)
10-19 year	2.0 (0.5)	1.1 (0.3)	2.0 (0.4)

Portal Vein diameter in mm

Age (years)	Mean (mm)	Limits of error
0	4.5	3.0 – 6.3
1	5.7	3.6 – 7.8
2	6.5	4.2 – 8.8
3	7.0	5.5 – 8.5
4	6.8	5.5 – 8.2
5	7.0	5.2 – 8.7
6	7.7	5.0 – 10.3
7	7.7	4.8 – 10.6
8	7.2	5.3 – 9.0
9	7.6	5.7 – 9.5
10	8.2	5.0 – 11.3
11	8.7	6.1 – 11.3
12	9.5	6.7 – 12.1
13	9.2	6.9 – 11.4
14	9.0	6.2 – 12.0
15	10.2	9.0 - -11.5
16	11.0	7.8 – 14.2

Spleen length in neonates in cm

Gestational age (weeks)	Number of patients	Mean length (+/- 1sd)	Min-max
24-31	29	2.4 (0.4)	1.6 - 3.2
32-35	34	2.8 (0.5)	1.7 - 4.0
36-37	35	3.3 (0.4)	2.6 - 4.2
38-41	155	3.4 (0.5)	2.4 - 4.9

Gallbladder volume in ml

	Term neonates	Preterm neonates
No. of observations	46	50
At birth	1.1 (0.2 – 2.4)	0.7 (0.1 – 1.2)
6-hours after birth	1.0 (0.2 – 2.2)	0.6 (0.1 – 1.5)
After regular feeding		
No. of observations	46	294
3-hours fasting	0.08 (0 – 0.2)	0.08 (0 – 0.2)
6-hours fasting	0.7 (0.1 – 1.3)	0.3 (0.1 – 0.9)

Biliary atresia

- Biliary atresia consists of an absent or severely deficient extrahepatic biliary tree, which affects 1 in 10 000 neonates.
- On sonography, both biliary atresia and neonatal hepatitis syndrome can show normal or increased echogenicity of the liver parenchyma.
- Is this incidence high enough to perform routine US after the birth? Are there clear clinical signs to indicate US scanning?

Routine US in newborns

- There are only few studies conducted as routine US scanning after the birth in unselected population of patients.
- In these retrieved studies, there were 3-5.9% abnormal scans seen in neonates. More than 95% were in kidneys, either as ectopic/pelvic kidney or severe ureteropelvic junction obstructions. Mostly were suspected in utero.
- Therefore, these results didn't identify the need for routine US scanning of the retroperitoneal space.
- Also, there are conflicting reports on the optimal time to perform a postnatal abdominal scan for urological abnormalities after birth, ranging 48 to 72 hours after the birth, due to relative oliguria in the first 72 hours of life which may lead to wrong estimation of the degree of hydronephrosis.

Abnormal adrenal masses

- The incidence of adrenal masses on imaging has been put at between 0.6 to 1.3% and is higher with abdominal CT scan than with prenatal US scan of the pregnant women.

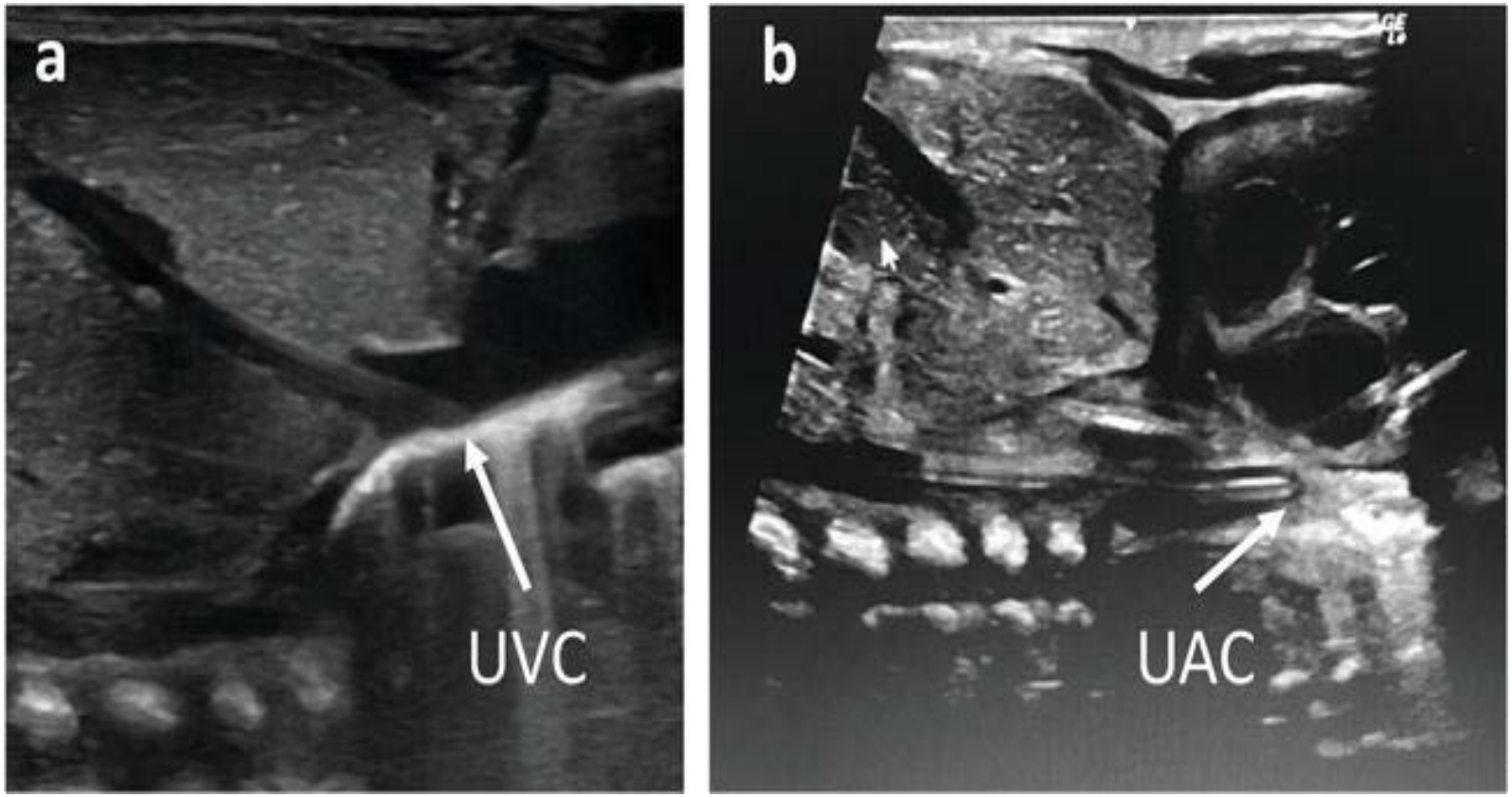
- Adrenal tumors and adrenal hemorrhage can be diagnosed with USS and it has been reported that prenatal US diagnosis of neuroblastoma results in a higher survival rate as it is identified at an early stage. It is seen in about 1.9 per 1000 live births, usually presenting between day 2 and day 7 of life. It is more commonly seen in neonates than in children or adults because the neonatal gland is about two times larger and therefore prone to hypotension and asphyxia.

- Serial imaging with ultrasound until complete resolution is advised for these cases

- US is the examination of choice in neonates with suspected adrenal hematoma. Initial US typically shows a complex, echogenic mass with inferior displacement of the kidney if the bleed is large. Over time, the mass becomes smaller, cystic and echolucent over a period of weeks. It may also subsequently develop calcifications. The US appearance is however variable and may disappear by six months.

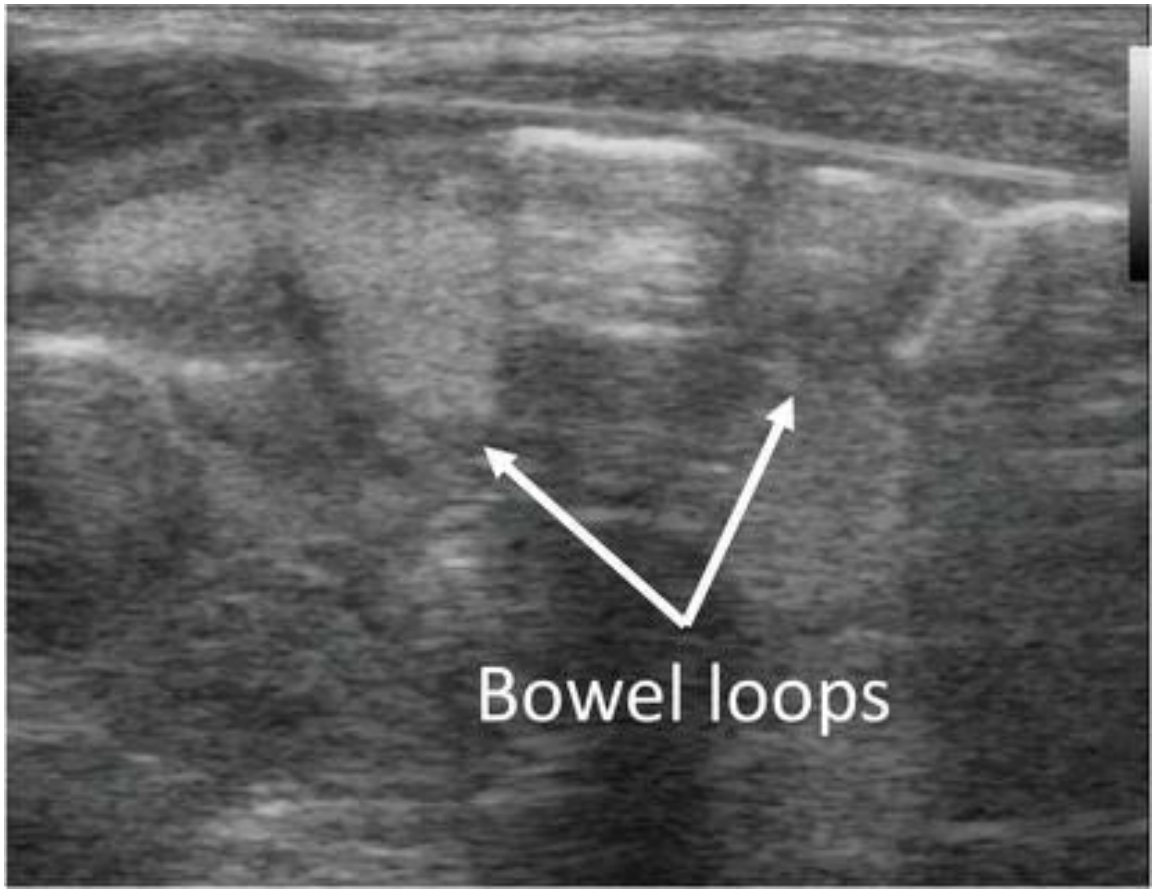
Central catheters

- Central vascular catheters such as umbilical arterial catheters (UAC), umbilical venous catheters (UVC), and peripherally inserted central catheters (PICC) are the most common central catheters placed in the sick neonate. Any neonate born at less than 32 weeks gestation will have at least one of these catheters during their admission for nutrition and/or medications.
- In most units all of these lines are placed blindly, and confirmed with a single radiograph. UVC tip localization by standard radiography is imprecise. In one study approximately 30% of the radiographs were read as normal but actually had the UVC tip in the right atrium when checked with US.
- Radiographic localization of UVC on anterior–posterior (AP) is difficult to place in ideal position because of the attachment of the diaphragm and lateral chest radiograph is preferred.
- Therefore, it is indicated to perform US for confirming proper placement of CVC because it reduces the exposure of ionizing radiation.


a
UVC
b
UAC

Bowel

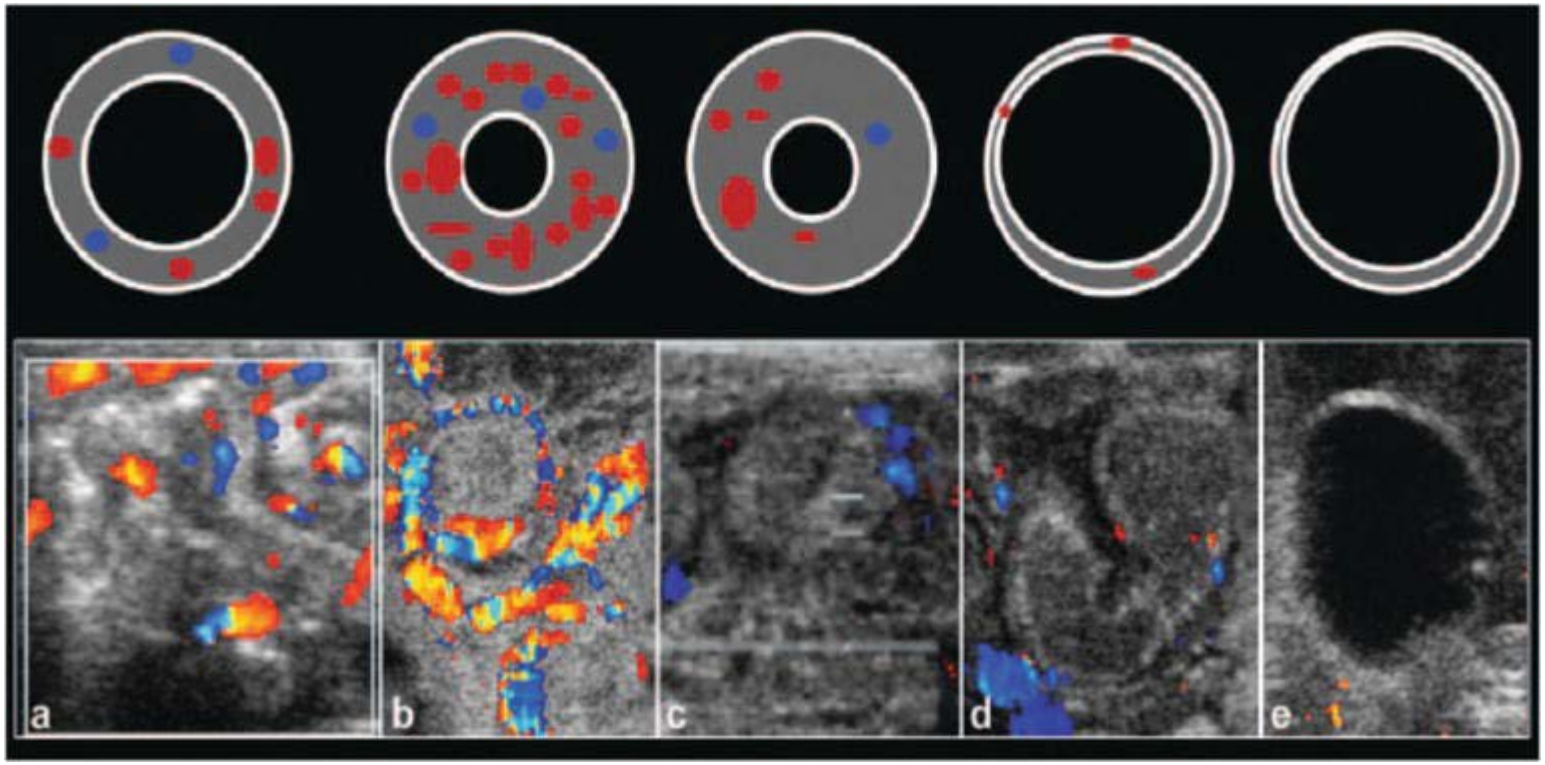
- The assessment of bowel by POCUS (Point of Care US) in neonates can show dynamic intestinal peristalsis as well as specify the physical nature and perfusion of bowel that can be used to assess bowel integrity and viability.
- Early recognition of the signs of impending bowel injury or the progression of bowel damage is essential. Intestinal peristalsis can be quantified by counting cumulative motility events over time to give an objective assessment of bowel movement.
- Identifying peristalsis can assist in the routine management of neonatal feeding or bowel assessment but more studies are required to validate its utility for clinical outcomes.
- Some other studies have demonstrated that gastroesophageal reflux can be evaluated by POCUS both identifying anatomic risk factors as well as visualizing the bolus but this has not gained traction in clinical practice yet.


Bowel loops

Necrotizing enterocolitis (NEC)

- Necrotizing enterocolitis (NEC) is the most common and frequently dangerous gastrointestinal emergency the neonatal intensive care unit (NICU). The risk increases with degree of prematurity, in those with low birth weight and severely asphyxiated neonates . Despite significant advances in neonatal care, mortality in NEC remains high (between 20 and 60% in a group of most immature neonates) and maintained at the same level.
- Traditionally, the gold standard for imaging evaluation of the neonatal intestine is the intestinal gas pattern on plain abdominal radiographs; however interpretation can be challenging with intestinal gas pattern being nonspecific, and significant overlap between radiographic signs of NEC and other intestinal pathology.

- Recently, there has been growing evidence that with real-time ultrasound, intramural air and portal gas can be better detected than with x-ray.
- Furthermore, dedicated ultrasound examination may be of utility in the diagnosis and management of infants with necrotizing enterocolitis (NEC). Advantages of ultrasound include assessment of peristalsis, vascular perfusion, bowel-wall thickening, and abdominal fluid. Absence of ionizing radiation is an added benefit. Intra-abdominal fluid, both intraluminal or extraluminal is also visible.
- With color Doppler specific suspicious loops of bowel can be interrogated to reveal if they are perfused or not which enables the identification of non-viable bowel with a high degree of certainty. The gradual progression of NEC can be identified by POCUS from the initial hyperemia and swelling of bowel wall to the dilatation with increased disease and then thinning of bowel wall with loss of perfusion or blood flow.
- However, data regarding the diagnostic validity and prognostic value of abdominal ultrasound are limited and often focused on a single finding rather than a combination of them. Therefore, the value of abdominal ultrasound in the diagnosis of necrotising enterocolitis has to be determined by further studies until its use can be generally recommended.



Sonographic appearance of NEC progression (figure from Epelman et al)

US in NEC

- Features that are key include:

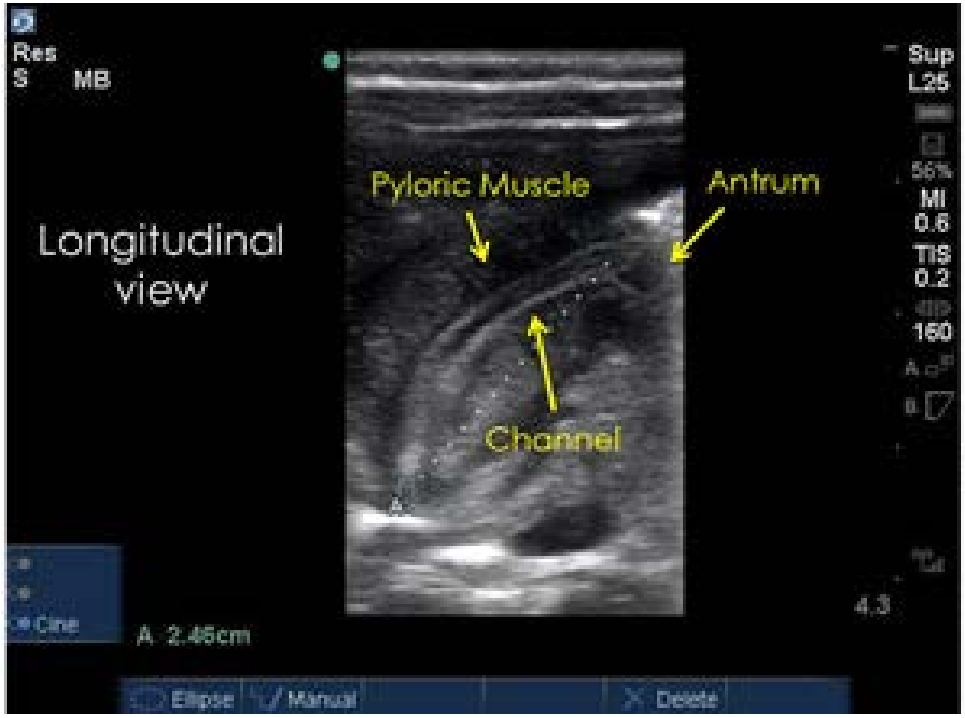
(a) bowel wall thickening >2.6 mm,
(b) increase in bowel wall echogenicity,
(c) portal venous air,
(d) pneumatosis Intestinalis and free air and
(e) intra-abdominal fluid.

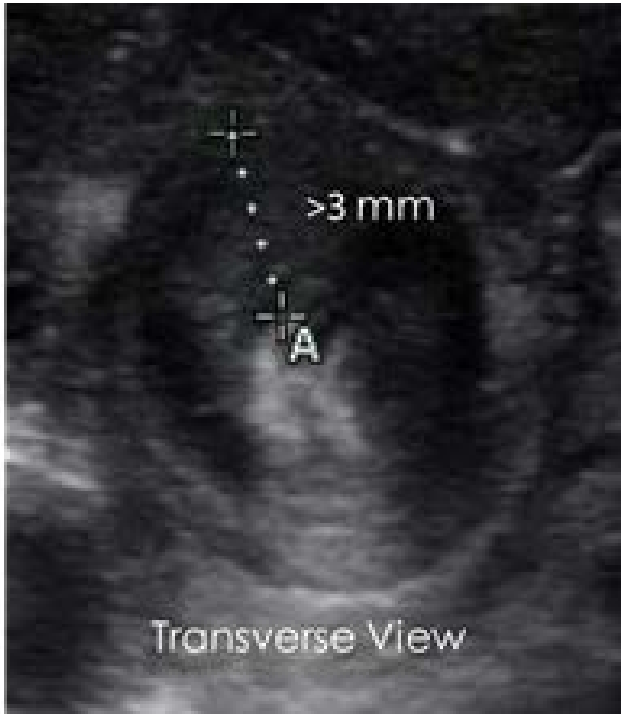
- Some limitations of ultrasound include that it is operator or skill dependent and this is a real time diagnosis which might create an obstacle for radiologists to evaluate the ultrasounds retrospectively and in turn underlines the need for neonatologists to be more familiar with this tool.

Infantile hypertrophic pyloric stenosis (IHPS)

- Infantile hypertrophic pyloric stenosis is the most common cause of vomiting in infants requiring surgical intervention. The disease is caused by a thickening and elongation of the pylorus, which leads to a pathologic narrowing of the pyloric channel with a resultant gastric outlet obstruction.
- Pyloric stenosis often is observed in infants between 2-8 weeks of age, with the highest prevalence between 3-5 weeks of age.
- Physical exam findings are not present, and ultrasound is necessary to confirm the diagnosis (a pyloric muscle thickness > 3 mm and a pyloric length > 15 mm).
- The sensitivity and specificity of ultrasound imaging in the diagnosis of IHPS is 98% and 100%, respectively, with a positive predictive value of 100% and negative predictive value of 90%

IHPS


Res
S MB
Sup
L25
56%
MI
0.6
TIS
0.2
160
Pyloric Muscle
Antrum
Longitudinal view
Channel
Cine
A 2.46cm
4.3
Ellipse
Manual
Delete


>3 mm
A
Transverse View

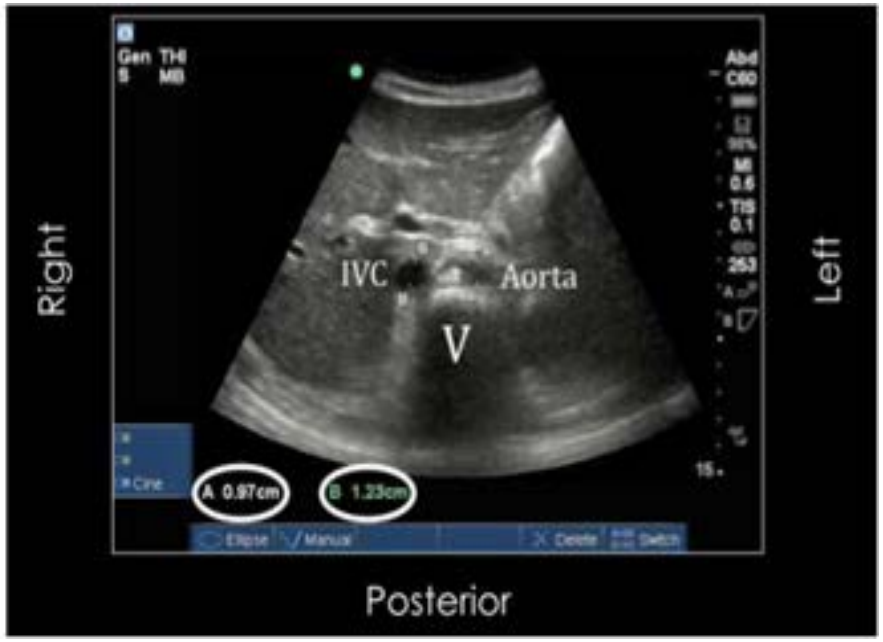
Inferior Vena Cava and Aorta

- According to the World Health Organization, one in 10 childhood deaths is attributed to diarrheal illness. Early identification of dehydration can prevent morbidity and mortality such as shock and death. Assessing volume status in children is challenging clinically. Many of the existing clinical dehydration scales, are suboptimal at identifying children with dehydration because of a lack of sensitivity.

- However, in the emergent setting, a pre-illness weight rarely is available. An accurate and efficient method to assess dehydration is vital to guide fluid resuscitation in critically ill children.

- Multiple researchers have assessed and found varying results as to whether IVC measurements can act as a proxy for clinical dehydration and response to fluid replenishment in children. Several indices have been studied, including the inferior vena caval index (IVCI), aorta/IVC cross-sectional area index (Ao/IVCA), and aorta/IVC diameter index (Ao/IVCD). The IVC/Ao index, inverse of the Ao/IVCD, one of the most commonly used metrics, is calculated using the maximal anterior-posterior diameter of the IVC


Anterior
Right
Left
IVC
Ao
V
Posterior


Right
IVC
Aorta
V
A 0.97cm
B 1.23cm
Left
Posterior

- The IVC/Ao ratio was found to be relatively consistent for normovolemic children, regardless of age and weight, but was reduced significantly in patients who were considered clinically dehydrated, and subsequently increased with IV hydration.

- The IVC/Ao cutoff ratio of 0.8 was shown to predict the severity of dehydration based on a ≥ 5% weight loss, with a sensitivity of 86% and a specificity of 56% and a positive predictive value of 56% and negative predictive value of 86%

Vomiting

- Vomiting is frequent in children, and imaging should be limited to infants with a potential organic cause, confirmed by a well-trained physician.

- Ultrasound examination must be the first imaging procedure used for vomiting infants. The cause depends on the age of the infant and the clinical and biological findings.

- Ultrasound must exclude surgical causes of vomiting, such as hypertrophic pyloric stenosis, hiatus hernia, gastro-oesophageal reflux, mechanical bowel obstruction and intussusception

Conclusion

- Ultrasound is instrumental in the diagnosis of many neonatal abdominal diseases and guides patient care. Emergency medicine physicians should have a foundation in the basics of point-of-care ultrasound.
- Being adept at using ultrasound is an invaluable skill in expediting patient care by providing a quick diagnosis and disposition while avoiding ionizing radiation.
- While ultrasound is a very effective and efficient means to diagnose neonatal abdominal pathologies, there are cautions and limitations for each exam to which providers must be attentive to.

- Therefore, as take home message should be the recommendation that **routine US of the abdomen in neonates during the early neonatal period is valuable for diagnosis and follow up of the progression of NEC, extensive vomiting, IVC and Ao measures and indices and UVC placement.**

- All other indications include use of abdominal US for confirmation/exclusion of prenatally seen abdominal anomaly as POCUS


Thank you for
your attention