Neonatologist performed point-of-care bowel ultrasound: Is the time right?

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Abstract

Introduction: This review acquaints neonatal clinicians using point-of-care ultrasound with a range of pathological bowel ultrasound findings, with the aim to promote utility of this skill as a diagnostic assessment tool in diseased neonatal intestinal states.

Overview: A range of normal and pathological bowel ultrasound findings are illustrated with case examples from our neonatal intensive care unit. The technical challenges of lack of familiarity with sonographic appearance of bowel (healthy and diseased), occurrence of gas artefacts and requirements of high-resolution linear transducer probes are described to allow the development of skills amongst neonatologists trained in point-of-care ultrasound. Plain abdominal radiography continues to remain the standard investigation to differentiate benign bowel states such as continuous positive airway pressure (CPAP) belly syndrome in preterm infants from life-threatening pathological intestinal states such as necrotising enterocolitis. Although plain radiography is the gold standard modality in the evaluation of neonatal diseased bowel states, real-time point-of-care bowel ultrasound performed in conjunction can provide valuable information on bowel peristalsis, bowel wall thickness and bowel vascularity. Abnormal configuration of superior mesenteric vessels on colour Doppler can alert the clinician to the diagnosis of neonatal intestinal malrotation-a time critical emergency.

Conclusion: Further research is needed to explore true-negative and true-positive predictive values of bowel ultrasound. However, with expansion of knowledge, appropriate training of techniques, neonatologists will be able to enhance their diagnostic acumen by performing point-of-care bowel ultrasound in conjunction with plain radiography in the evaluation of broad array of neonatal intestinal states.

Keywords: neonatologists, bowel ultrasound, point of care.

Introduction

The potential for use of bowel ultrasonography (BUS) in the evaluation of paediatric diseased bowel states has been well recognised. Whilst plain abdominal radiography is the gold standard modality for diagnosis, monitoring and guiding management of suspected diseased bowel state in neonates, there is a growing interest in the utility of BUS. The use of BUS in the diagnosis of necrotising enterocolitis (NEC) has steadily increased worldwide over the last 12 years, particularly in the hands of the radiologists.¹ There is compelling evidence demonstrating diagnostic ultrasound findings in NEC

correlating with clinical presentation and pathological bowel findings intraoperatively.^{2,3}

In 2011, neonatal clinician-performed ultrasound (CPU) was formalised in Australia and New Zealand in association with The Australian Society of Ultrasound in Medicine (ASUM). Neonatal trainees undergo rigorous hands-on training in performing cranial and cardiac ultrasound for 2 years or more to obtain certification in clinician-performed ultrasound (CCPU).⁴ Point-of-care ultrasound, performed by trained neonatologists, now has an established role in the clinical management of sick neonates. Whilst assessment of functional changes in cardiac state, intracranial structural injuries such as intraventricular haemorrhage using point-of-care ultrasound is well established, knowledge of point-of-care BUS is a growing area of interest amongst neonatologists.

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Identifying gastrointestinal obstruction or perforation presents as critical, time-sensitive scenarios for neonatal clinicians. Also, a common scenario faced by neonatologists is the occurrence of abdominal distension, feed intolerance in preterm infants on respiratory support with continuous positive airway pressure (CPAP) ventilation. This benign gaseous abdominal distension is called CPAP belly syndrome⁵ and often necessitates differentiation from life-threatening bowel conditions such as NEC. The use of point-of-care abdominal ultrasound can be a very valuable clinical tool in these scenarios. BUS can enhance diagnostic accuracy of diseased neonatal bowel states in conjunction with clinical assessment and findings from plain abdominal radiography.

BUS studies in adult patients have shown that diseased bowel is easier to image than healthy normal bowel.⁶ Similar findings have been reported in diseased neonatal bowel states such as NEC.^{2,3} In diseased neonatal bowel states, often motility is decreased, bowel wall thickened, which appears larger and easier to see. Familiarity with the sonographic appearance of the normal bowel pattern, meticulous use of technique (e.g. use of high-resolution linear transducer probes) and using techniques to obscure the gas artefacts are essential to identify pathological appearance of the bowel on ultrasound. Despite these challenges, real-time BUS provides crucial information on bowel peristalsis, vascularity, bowel wall thickness, the presence of free fluid within the abdominal cavity, all of which can help differentiate healthy from diseased bowel state and without any ionising radiation effects.

The objective of this review was to firstly discuss BUS as a clinical tool in neonatal bowel assessment. Secondly, we describe a range of pathological BUS findings obtained when performing point-of-care BUS in our Neonatal Intensive Care Unit for a range of acute intestinal emergencies.

Technical aspects for performing BUS

One of the technical challenges in performing BUS in neonates is the difficulty in evaluating bowel in its physiological state. Ongoing enteral feeds with the use of respiratory support such as CPAP in preterm infants often result in reverberation gas artefacts. These artefacts appear as transverse lines on the imaging screen obscuring the sonographic appearance of the bowel. Clear anatomical appearance of the bowel is often difficult to obtain until these gas shadows resolve. Gentle compression of the abdominal wall using the transducer probe and repositioning the infant to the lateral side can improve bowel visibility.

Meticulous technique and following a structured protocol are vital to reproduce the imaging findings and maintain reliability. Recently, Faingold (2018) published on the technical aspects of performing abdominal ultrasound and colour Doppler assessment of bowel viability in NEC, providing a comprehensive description of the technique and sharing his practical experience.¹

High-resolution liner probes 12–20 MHz are desirable to perform BUS. In our cases, BUS was performed using the

15 MHz linear transducer probe to obtain grey scale images of the bowel, portal venous gas, free fluid within abdominal cavity and locate the superior mesenteric vessels. Colour Doppler assessment was then performed to determine bowel vascularity and confirm the anatomical location of the superior mesenteric vessels.

Appearance of normal neonatal BUS pattern

The normal bowel appearance

The normal sonographic appearance of the bowel also called as the 'gut signature' describes typically the appearance of alternating hyperechoic and hypoechoic layers on ultrasound imaging that arise from its highly stratified histological appearance of the bowel wall. Anatomically, these layers from innermost to outermost are superficial mucosa (echogenic); muscularis mucosa (hypoechoic); submucosa is the thickest layer (echogenic); muscularis propria (hypoechoic); and the outermost layer serosa (echogenic).^{6,7} Sonographic pattern recognition of the normal gut signature distinguishes bowel from the adjacent structures. Disruption of this sonographic pattern aids in the diagnosis of bowel pathology. Normal neonatal bowel appearance (gut signature) shows a particularly prominent hypoechoic halo, which is thought to represent the muscularis propria. Highly echogenic dots seen within the lumen of the bowel are produced due to the presence of intraluminal gas which is a normal finding within the bowel lumen. Although there are five layers of the bowel wall described in the literature, only three layers are usually identifiable on BUS in a neonate, the most prominent being the hypoechoic layer formed by the muscularis propria (Figure 1).

Bowel wall thickness

Bowel wall thickness varies with gestational age.⁷ Faingold *et al.* (2005) reported bowel wall measurements ranging from 1.1 to 2.6 mm in 30 infants (gestational age 24–41 weeks) with healthy bowel.⁸ Bettina Bohnhorst (2013)⁹ reported similar findings of normal bowel wall measurements ranging from 1.3 to 2 mm in healthy preterm infants. Bowel wall thinness <1 mm is highly suggestive of bowel ischaemia in diseased infants with NEC.¹⁰ A recent meta-analysis by Cuna *et al.* (2018) described cut-off values to define bowel wall thickening as >2.5 to >2.7 mm in various studies.¹¹

We conclude then that normal bowel wall thickness ranges from 1 to 2.6 mm. Bowel wall measurements of >2.6 mm would classify as thickened, and any measurement <1 mm would classify as thinned, both suggesting pathological bowel states. Bowel wall thinning <1 mm results from ischaemia or necrosis.¹¹ In neonates, thickening of the bowel wall >2 mm should be considered suspicious; this thickening is usually accompanied by an increase in echogenicity. Bowel wall measurements should be taken in relaxed bowel segments (Figure 2).

Figure 1: (a) Illustration of the Layers of Normal Bowel Wall. (b) Normal BUS Image in 38-week Infant on Day 2 of Life. The Hypoechoic Layer Represents Muscularis Propria. (c) Normal BUS Image in 26-week Infant on Day 6 of Life Showing Highly Echogenic Dots within the Bowel Representing Normal Intraluminal Gas.

Peristalsis on BUS

Bowel motility dysfunction remains a major concern in preterm neonates. Examination using traditional auscultation of bowel in neonates is limited by examiner skill, inability to reproduce and objectivity of assessing peristalsis quality. Recently, it has been feasible to use automated assessment of bowel sounds using digital stethoscopes for extended periods to assess gut peristalsis. However, noise interference is a limitation of this method.^{12,13} Ultrasound is a valuable tool in the detection of bowel peristalsis. Normal bowel peristalsis appears more than 10 times per minute⁹ and can be visualised in real time as a 'worm-like motion'. This characteristic opening and closing of the bowel lumen 'swirling movement' displacing the echogenic dots within the lumen seen in real-time represents normal bowel peristalsis on BUS and is often easily appreciated despite gas artefacts.

Vascularity on BUS

Real-time BUS has the added advantage of assessing bowel wall vascularity, which cannot be assessed on plain abdominal radiography. Faingold *et al.*⁸ assessed bowel wall perfusion (BWP) by counting the number of dots on colour Doppler (CD) signal/cm square and forming standardised squares on areas of interest on the bowel images using a four-quadrant approach. Normal BWP was classified as 1–9 CD signal dots detected per square cm. Bowel wall perfusion is considered to be present when these CD signals are reproducible or confirmed on pulsed Doppler waveforms.¹ BWP is interpreted to be absent when no CD signal is detected at the slowest possible velocity.⁹ The slowest possible velocity on Colour Doppler reported in the study by Faingold *et al.* was 0.029 m/s.⁸ Interpretation of absent colour Doppler signal, suggestive of avascular bowel wall, is potentially prone for observer error. Reduction to the lowest possible velocity on the colour Doppler is crucial to confirm this finding. Considering that oxygenation and perfusion are both likely to be reduced in the event of absent bowel wall perfusion; no study so far has compared absent bowel wall perfusion to regional oxygen saturation using near-infrared spectroscopy (NIRS) to detect intestinal viability. The absence of BWP as evidenced by no CD signals on Doppler Ultrasound, in the hands of an experienced operator using standardised techniques, is highly suggestive of severe intestinal disease.

Appearance of neonatal BUS pattern in some of the acute intestinal diseased states

Identifying developmental obstructions of the intestine is a diagnostic challenge to the neonatologist with a myriad of possible underlying pathologies ranging from complete to incomplete obstructions such as stenosis, atresia and malrotation resulting in volvulus.

Figure 2: (a, b) Bowel Ultrasound Image Showing Bowel Wall Thickening and Thinning.

Intestinal atresia

BUS can be utilised in the early diagnosis of intestinal atresia as natural contrast (air) is not present in the bowel at birth. A transit time of about 3 h is usually required for gas to traverse the small intestine and approximately 8–9 h for the gas to appear in the sigmoid colon. Movement of gas through the intestines takes several hours to generate a contrast with fluid levels (air-fluid levels) to be apparent on plain abdominal radiographs in order to make a diagnosis of intestinal obstruction.¹⁴ Most plain abdominal radiographs appear as gasless abdominal films in neonates with intestinal obstruction, as opposed to air-fluid levels seen in paediatric patients pathognomonic of intestinal obstruction. On a plain abdominal radiograph, significant ascites also appears as a gasless abdomen (Figures 3 and 4).

Necrotising enterocolitis

A plain abdominal radiograph with detection of pneumatosis intestinalis in the clinical setting of feed intolerance raises the

suspicion of NEC. In this clinical setting, detection of free abdominal air heralds the possibility of intestinal perforation. BUS findings in conjunction with plain abdominal radiographs are valuable in the early detection of NEC severity. Real-time BUS can provide information on the presence of bowel thickening, thinning, portal venous gas, pneumatosis intestinalis, increased bowel wall echogenicity, disturbances in BWP and the presence of free fluid or air. The presence of three out of these seven sonographic features has a sensitivity of 0.82 and specificity of 0.78 in the diagnosis of NEC.³ BUS is a valuable tool in complicated cases of NEC which have a poor response to medical treatment with non-specific plain abdominal radiographs. One such scenario is extreme preterm infants presenting with NEC without the presence of pneumatosis on plain abdominal radiography (Figure 9). In a recent review by Staryszak *et al.*,¹⁰ the pathognomonic sign of NEC which is pneumatosis intestinalis was seen more frequently on BUS (44%) than plain abdominal radiographs (11%). Absent bowel wall perfusion seen on Doppler may suggest severe NEC.³ This

Figure 3: (a) Plain Abdominal Radiograph Performed on a 27-week Preterm Infant at 48 h of Life for Abdominal Distention. The Plain Radiograph Image Showing Non-specific Dilatation of the Bowel Loops. (b) Bowel Ultrasound Performed Concurrently Showed a Localised Bowel Segment with Loss of Gut Signature with Significant Dilatation and Thinning of the Surrounding Bowel Loops. There was Free Fluid Noted in the Abdominal Cavity. This Patient was Diagnosed with Ileal Atresia on Diagnostic Laparoscopy, Underwent Surgical Resection of the Atretic Segment with End to End Ileal Anastomosis.

Figure 4: (a) Plain Abdominal Film Showing Loss of Normal Distribution of the Bowel Gas Pattern with Few Abnormally Distended Sausage-shaped Bowel Segments. (b) Real-time BUS Shown Significant Dilatation and Thinning of the Bowel Loops Surrounding the Atretic Segment with Loss of Normal Gut Signature. (c) Significant Dilatation and Thinning of the Surrounding Bowel Loop. The Echogenic Dots with Dilated Bowel Lumen Represent Intraluminal Gas which is Normal. This Patient was Confirmed to have Ileal Atresia on Laparotomy.

sonographic appearance of thinned out bowel wall with absent vascular flow may herald the onset of spontaneous intestinal perforation, an indication for surgical intervention. Increased bowel wall perfusion, seen during bowel inflammation, produces specific hyperaemic flow patterns based on the area of increased vascularity such as mucosal folds of the small intestine (zebra pattern CD signals); subserosal lines and mesenteric artery (Y-shaped CD signals); and circumferential flow across the entire bowel wall (ring-shaped CD signals).² Free air seen on abdominal ultrasound is suggestive of intestinal perforation (Staryszak *et al.*) (Figure 5).¹⁰

Pneumatosis intestinalis (PI)

PI is the pathognomonic sign of NEC where gas bubbles are seen trapped along subserosal and submucosal layers. This gas is delivered by bacterial fermentation of the intestinal contents within the lumen due to stasis and the movement and trapping of this gas into the injured bowel wall generates PI. The presence of PI would alert the clinician to the diagnosis of NEC; however, PI is also seen in other neonatal intestinal pathologies such as meconium ileus, malrotation with volvulus and aganglionic segment in Hirschsprung's disease.¹⁵ On BUS, PI is seen as highly echogenic dots within the bowel wall with a variable amount of intramural gas ranging from a few foci to involvement of the entire circumference of the bowel ('circle sign').

Thus, the wall of the bowel cannot be clearly defined. PI in NEC, seen as echogenic dots along the side of the bowel wall, does not change with position. This can be tested by gently applying pressure on the transducer probe over the abdominal wall. Intraluminal gas will move and can be easily displaced by applying gentle pressure. This differentiates the fixed echogenic dots seen in PI (intramural gas) from intraluminal gas. Detection of PI is time sensitive. PI is present only for few hours during the disease process in NEC and may not be seen in advanced NEC as the disease progression worsens.¹⁶ Follow-up BUS can be performed in the assessment of PI. This has the advantage of preventing radiation exposure from repeated plain abdominal radiography assessments. Kim *et al.* (2005)¹⁷ reported that PI was detectable in 100% of their 40 patients with early NEC (Bell stage 1) using BUS with no PI seen on plain radiographs. Thus, although PI is seen more impressively on plain abdominal radiograph compared to BUS, PI visibility is improved by real-time BUS in the detection of early NEC (Figure 6).

Portal venous gas

Portal venous gas (PVG) is produced when the entrapped intramural gas escapes through the portal vein only to get trapped in the portal microcirculation. Similar to intramural gas, this finding is also time sensitive and can be seen as bubbles

Figure 5: (a, b) Bowel Colour Doppler (CD) Study Images in a 24-week Infant Diagnosed to have NEC Requiring Surgical Intervention on day 24 of Life. Increased Bowel Wall Perfusion seen During Bowel Inflammation in NEC Producing the Specific Hyperaemic Flow Pattern Y-shaped CD Signals. (c) Bowel Colour Doppler Study Image in a 27-week Infant Diagnosed to have NEC Requiring Surgical Intervention on day 33 of Life Showing Increased Bowel Wall Perfusion. (d) Bowel Colour Doppler Study Image in the Same 27-week Infant Diagnosed to have NEC Requiring Surgical Intervention on Day 33 of Life Showing Increased Bowel Wall Thickening and Increased Vascularity. (e) Normal Bowel Wall Perfusion on Colour Doppler.

Figure 6: (a, b) Demonstration of Intramural Gas (Pneumatosis Intestinalis) on Bowel Ultrasound. Intramural Gas Seen as Multiple Echogenic Dots Varies Between a Few Foci to Involvement of the Whole Circumference of the Bowel Wall known as the ‘circle sign’.

(echogenic dots) migrating rapidly through the portal vein on real-time BUS. In the diagnosis of NEC, most studies report sensitivity of detection of portal venous gas ranging from 2.6%

Figure 7: (a) Plain Abdominal Film Showing Portal Venous Gas. (b) Normal Hepatic Echotexture on Ultrasound. (c) Extended Portal Venous Gas in the Smaller Branches of the Portal Vein Appearing as Dendriform Granular Echogenicities in the Liver Parenchyma ‘Trapped Microbubbles’. This Gas can be Impressively Visualised Rapidly Tracking Upwards through the Portal Vein On Real-time Ultrasound, Trapping of this Gas Produces the Echogenic Dots within the Liver Parenchyma.

Figure 8: BUS Image in the Same 27-week Infant Diagnosed to have NEC Requiring Surgical Intervention on Day 33 of Life Showing Increased Bowel Wall Thickening (Bowel Wall Thickness Measured 3.2 mm).

to 58% on plain abdominal radiographs vs. 16%-45% on BUS (Figure 7).⁹

Bowel wall thickness and thinness

The sonographic appearance of bowel wall thickness (>2 mm) pathologically correlates with mucosal haemorrhage and oedema and is often associated with increased bowel wall echogenicity. Bowel wall thinness <1 mm, however, pathologically correlates with ischaemia and or necrosis and may alert to the sequelae of impending intestinal perforation (Figures 8 and 9).

Free abdominal air and free abdominal fluid

The presence of free abdominal air on plain abdominal radiographs is diagnostic of bowel perforation. Free air on BUS is seen as bright echogenicity between the abdominal wall and the anterior surface of the liver obscuring the normal views. This requires meticulous placement of the transducer on the abdominal wall with least compression, so as not to displace the free air. The presence of localised fluid collection or echogenic material seen between the bowel loops on sonography is highly suggestive of bowel perforation, an indication for surgical intervention.

Malrotation and volvulus

Malrotation is a congenital malformation with incidence estimated to be present in one in 500 live births. Seventy-five per

Figure 9: (a) Plain X-Ray Showing Paucity of Gas with no Evidence of Pneumatosis Intestinalis in 24-week Infant Diagnosed to have NEC Requiring Surgical Intervention on Day 24 of Life. (b, c) BUS Performed at the Time of Plain Radiograph Assessment as Shown in Figure a Detected Significant Dilatation of the Intestinal Loops with no Visible Peristalsis and Absent Bowel Wall Perfusion.

cent present in the neonatal period with midgut volvulus.¹⁸ Malrotation is caused when normal rotation and fixation of the gut have been arrested or deviated at various developmental stages in early embryological period. Intestinal malrotation can go unnoticed and predispose the infant to have a narrow base midgut mesentery resulting in twisting of the bowel loop around itself and occurrence of volvulus. This results in arterial strangulation with resultant gut ischaemia. Delay in diagnosis can result in necrotic bowel requiring surgical resection. The need for frequent paediatric surgical reviews and opinion from experienced radiologists may warrant transfer of the neonatal patient to a surgically specialised centre to rescue ischaemic bowel loops. Point-of-care BUS conducted by neonatologists allows more rapid assessment and diagnosis to allow timely surgical decompression of twisted bowel loops and restoration of the bowel wall perfusion.

The diagnosis of malrotation is conventionally made on Upper Gastrointestinal (GI) contrast study, to demonstrate abnormal configuration of duodenal C-loop or duodenojejunal flexures located on the right side of the vertebral bodies.¹⁹ On sonography, the normal anatomy of the superior mesenteric vessels is seen as the superior mesenteric vein (SMV) lying left and superior of the superior mesenteric artery (SMA).²⁰ That is, the SMV lies at 11 o'clock position to the SMA. Chao *et al.*²¹ studied the sensitivity and specificity of detection of intestinal malrotation and volvulus on BUS. Their study results demonstrated a 100% sensitivity in detecting neonatal intestinal malrotation based on the inversion of the SMV and SMA (with no SMV seen at 11 o'clock position to the SMA), whilst the whirlpool sign (SMV winding around the SMA) had a sensitivity of 86% and specificity of 92% in the detection of volvulus. It is imperative to note that a normal anatomical configuration of the SMA and SMV does not exclude malrotation; however, their abnormal anatomical configuration is diagnostic. Characteristic signs of midgut volvulus include duodenal dilatation with distal tapering, fixed midline bowel on contrast study and the whirlpool sign with dilatation of the SMV on sonography (Figures 10 and 11).²¹

Although plain abdominal radiography in preterm infants with bile stained aspirates showing normal gas pattern can be reassuring, the most common finding on plain radiography in neonate with malrotation is normal bowel gas pattern.¹⁸ BUS can be used to determine the position of the superior mesenteric vessels and their relationship to the third portion of the

Figure 10: (a) Plain Abdominal Radiograph Showing a Distended Gastric Bubble with Paucity of Gas Beyond the Gastric Bubble in a 36-week Infant Diagnosed with Malrotation on Laparotomy. (b) Normal Anatomical Orientation of the Superior Mesenteric Vessels. The Superior Mesenteric Vein Seen at 11 o'clock Position to the Superior Mesenteric Artery. (c) Colour Doppler Study Showing the Superior Mesenteric Vein Swirling Around the Superior Mesenteric Artery, the 'Whirlpool Sign' Diagnostic of Malrotation.

Figure 11: (a) Plain Abdominal Radiograph Showing Dilated Bowel Loops in the Right Upper Quadrant. This Infant was Diagnosed to have Volvulus on Day 2 of Life. (b) Concurrent BUS Image of the Same Distended Bowel Loop in Real-time Showed Dilated, Thinned Bowel Segment with no Visible Peristalsis.

duodenum. Normal orientation of the superior mesenteric vessels does not completely exclude malrotation but makes the diagnosis less likely.

CPAP belly syndrome

A particularly frequent clinical presentation to neonatologists' is the occurrence of CPAP belly syndrome.⁵ Benign gaseous distension of the bowel, due to CPAP support, exacerbates the physiological gastrointestinal dysmotility seen in preterm infants. Clinically, this presents as feed intolerance that is manifested in the form of abdominal distension and significant pre-feed aspirates, sometimes with bile. This clinical scenario necessitates urgent evaluation to rule out potentially life-threatening conditions such as NEC or volvulus. The characteristic features of CPAP belly syndrome on plain radiography include (i) Distended abdominal cavity (cross-diameter); (ii) Almost symmetrical polygonal gas/air spaces with thin walls spread homogeneously with the presence of rectal gas; (iii) Non-thickened bowel wall; and (iv) The absence of pneumatosis intestinalis, portal venous gas and non-moving (stagnant) parallel sausage-shaped loops. These findings are reassuring to the clinician, although often the findings are non-specific. In the context of feed intolerance, inconclusive plain radiology clinical decision to withhold feeds with potential antibiotic administration is justified. BUS can add to diagnostic accuracy in these clinical settings by differentiating healthy bowel that has normal gut signature, peristalsis and normal vascularity.

Conclusion

Surviving extremely low-birthweight infants have prolonged periods of noninvasive ventilation (nCPAP, biPAP) with varying degrees of gastrointestinal tract dysmotility, CPAP belly syndrome. Frequently, feed intolerance with low-grade bilious

aspirates triggers appropriate concerns of possible life-threatening pathological gastrointestinal diseases such as NEC or intestinal obstruction and the ability of the clinician to perform point-of-care BUS may enhance timely management. With expansion of knowledge and appropriate training of ultrasound techniques, neonatologists will be able to enhance their diagnostic acumen by performing point-of-care BUS in addition to plain radiography for a broad array of diseased bowel states in neonates.

Thus, to conclude, BUS has the added ability to measure bowel wall thickness, provide real-time evaluation of peristalsis, intestinal perfusion, free abdominal air/fluid and can detect pneumatosis intestinalis, portal venous gas and pneumoperitoneum similar to abdominal radiographs.

Future directions and research areas

Further studies to characterise bowel motility (swirls) using computerised vectorial analysis and measurements of vascularity by percentage (%) of colour pixels to luminance (intensity) of each colour pixel using novel computer-based software are underway to develop quantitative assessments (personal communication: Parson *et al.*, unpublished data, University Hospitals, Coventry and Warwickshire NHS trust hospitals). Such studies will determine bowel wall thickness and its variation with gestational age in healthy preterm infants with no diseased bowel states.

The role of BUS in reassuring the clinicians trained for point-of-care BUS to reassure with a diagnosis of CPAP belly syndrome as opposed to NEC will require further delineation.

We are undertaking a study to determine normal peristalsis in healthy preterm and term infants to define normal peristaltic movements—a sign of healthy bowel and comparing it with various methods to detect peristalsis clinically.

The objective of this review was thus to acquaint point-of-care neonatal clinicians with the range of normal and pathological BUS findings, the findings of which can be used to guide the need for any further acute medical or surgical intervention. The authors plan to examine in a prospective cohort study, the true-negative and true-positive predictive value of using point-of-care BUS to reassure clinicians of the low likelihood of diseased bowel states. Despite these challenges, it is feasible for neonatologists to enhance diagnostic accuracy of diseased neonatal bowel by using point-of-care BUS in conjunction with clinical assessment and performing plain abdominal X-rays.

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Conflict of interests

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