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Original Article

ABDOMINAL ULTRASONOGRAPHY AND RADIOGRAPHY DIAGNOSIS IN PRETERM NECROTIZING ENTEROCOLITIS

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Abstract

Introduction: **Necrotizing enterocolitis (NEC) is a major cause of neonatal morbidity and mortality.**

To explore whether abdominal ultrasound (AUS) provide additional information over plain radiography in cases of necrotizing enterocolitis (NEC).

Materials & Methods: **This study is a prospective study of 30 premature neonates with NEC in our neonatal intensive care unit between September 2013 and November 2014. Fifteen premature control neonates were also included in the study.**

Results: **Patients were classified into two groups: the first group with suspected NEC (stage I) (n = 14) and the second with definite NEC (stage II or III) (n = 16). In group I abdominal ultrasound (AUS) revealed intramural air (n = 9) and portal venous gas (PVG) (n = 1) while plain radiography showed only gaseous distension. In group II, intramural air (n = 10), PVG (n = 2), free fluid (n = 6) focal fluid (n = 1) and free air (n = 6) detected by AUS compared to pneumatosis intestinalis (PI) (n = 2) PVG (n = 1) and free air (n = 5) by plain radiography. Additionally bowel wall thinning was detected in 2 neonates of group I and 3 of group II.**

Conclusion: **Our results suggest AUS to be superior to plain radiography in early detection of complication as intestinal perforation by eliciting PVG and fluid collection and so early surgical management. Therefore this may decrease morbidity and mortality rates.**

Keywords: Necrotizing enterocolitis; Abdominal ultrasound radiography; NEC sonogrraphic findings

Introduction

Necrotizing enterocolitis (NEC) is a common gastrointestinal emergency of unknown etiology that primarily affects preterm infants in neonatal intensive care units (NICU)[1]. The incidence of NEC ranges between 3% and 28%, with an average of 6–10% in neonates weighing less than 1500 g[2]. The diagnosis of NEC must be based on both clinical signs and symptoms and findings on abdominal radiographs. NEC may have a wide range of clinical symptoms including feeding intolerance and abdominal distension and it may be indistinguishable from neonatal sepsis[3]. Abdominal radiography has been the standard method for detecting and monitoring NEC. The radiological signs in early NEC are dilated tubular appearing bowel loops[4]. However, just as the early radiographic findings of NEC are non-specific, so are the advanced findings[3]. There are cases where the abdominal radiograph may show no bowel gas[5]. In others, necrotic bowel and perforation may occur without any radiographic signs[4]. In these circumstances a diagnosis of NEC based on clinical and radiographic findings only is insufficient. Abdominal ultrasonography (AUS) provides a more detailed understanding of the state of the bowel in patients with NEC and may thus make management decisions easier and potentially change outcome[6]. In this study we aimed to prospectively analyze abdominal sonographic findings of premature infants with NEC to investigate whether AUS is superior to abdominal plain radiography in the diagnosis of NEC.

Materials and methods

Thirty neonates with an early diagnosis of NEC hospitalized in our NICU at National Center for Maternal and Child Health hospital were prospectively evaluated between september 2013 and November 2014.

We included 15 premature neonates who had no gastrointestinal symptoms or radiographic abnormalities as control group for the evaluation of the sonographic findings of the normal bowel wall.

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In neonates with NEC, the disease stage was determined by physicians in the NICU according to modified Bell's staging criteria[7], and so were prospectively analyzed into neonates with an early diagnosis of suspected (stage I) or definite (stages II or III) NEC. The modified Bell's staging criteria[7] are a clinical classification and management tool for NEC in which a composite of clinical signs and symptoms (e.g., abdominal distension, bloody stools, or hypotension), biochemical parameters (e.g., thrombocytopenia or neutropenia) and radiographic signs (e.g., pneumatosis intestinalis (PI) or pneumoperitoneum) are used to grade the severity and aid in the reporting of NEC. Clinical findings were evaluated by the same physician throughout the study.

Once NEC was suspected, plain abdominal radiography was performed immediately. Two views were obtained a frontal and a horizontal beam view. Sonographic examination was then performed in both patients (n = 30) and the controls (n = 15) by using LOGIQ 400 Pro Series, General Electric machine with 5 MHZ transducer, Korea. We scanned the abdomen transversely and longitudinally with mill compression to avoid pseudo pneumatosis intestinalis artifacts. Gray scale US evaluation included assessment of bowel wall echo texture for normal stratified bowel appearance or loss of "gut signature", measurement of wall thickness with calipers to assess bowel wall for thickening (>2.7 mm) and thinning (<1 mm). Penumatosis intestinalis, PVG, intra abdominal fluid and free air were also assessed. The liver and the portal venous structures were scanned using the standard planes in a real time mode[8]. The study was approved by the research ethics board at the hospital for sick children. Written informed consent was obtained from the parents of the neonates in the control groups.

Statistical analysis of the data was performed by using SPSS 15 software package under Windows 7® operating system. Qualitative data parameters were presented in the form of frequency and percent. All categorical data comparisons and associations were analyzed by either chi square test or Fisher exact test according to the nature of data. Quantitative data variables were described as mean, SD (standard deviation), median and IQR (interquartile range).

Results

Throughout the study period, 30 premature neonates were included with an early diagnosis of suspected (stage I) NEC (group I, n = 14) or definite (stage II or III) NEC (group II, n = 16). Fifteen premature neonates were included as a control group.

Group I included 14 neonates, whose mean gestational age was 30.36 ± 1.01 (range 29–32 weeks), and mean birth weight was 1.42 ± 0.12 (range 1200–1600 g). Group II included 16 neonates, whose mean gestational age was 30.44 ± 1.03 (range 21–32 weeks), and mean birth weight was 1.32 ± 0.16 (range 1100–1600 g). The control group included 15 neonates, whose mean gestational age was 30.67 ± 0.98 (range 29–32 weeks) and mean birth weight was 1.19 ± 0.10 (range 1000–1400 g) (Table I).

All of the neonates in the control group showed no gaseous distension by plain radiography except for 2 neonates, and all of them presented normal bowel echogenicity and appearance by AUS examination. Table 2 presents the plain radiographic and AUS findings in both patient groups with comparison between the groups seen in (Table 3). We can notice that AUS revealed PI in 9 patients (Fig. 1) and PVG in 1 patient of group I, though X-ray findings were negative in all patients of group I except for gaseous distension observed in 12 patients. In group II, the plain radiographic findings showed 2 neonates having PI, 1 neonate having PVG and 5 neonates having free air in contrast to 10 neonates with PI (Fig. 3 and Fig. 4), 2 with PV gas (Fig. 4), 6 with free air and 6 with free fluid (Fig. 4) and one with focal fluid collection by AUS. Bowel wall thickness was estimated by AUS in both groups, with thickened bowel wall seen in 3 (Fig. 2) and thinned in 2 of patients of group I (Fig. 1), while in group II, wall thickening was observed in 4 and thinning in 3 patients (Fig. 3).

Table-I

Comparisons between the three studied groups as regard gestational age and weight.

	Control group (n = 15)	Suspected group (n = 14)	Definite group (n = 16)	P value Control versus suspected	Control versus definite	Suspected versus definite
Gestational age	30.67 ± 0.98 (31; 29–32)	30.36 ± 1.01 (30; 29–32)	30.44 ± 1.03 (30; 29–32)	0.425	0.520	0.854
Weight	1.19 ± 0.10 (1.20; 1.0–1.4)	1.42 ± 0.12 (1.43; 1.2–1.6)	1.32 ± 0.16 (1.30; 1.1–1.6)	}*0.001	0.037	0.077

Table-II

Abdominal plain radiographic and ultrasonographic finding.

Abdominal plain radiography	Group I n=14	Group II n=16
Portal venous gas	-	1
Gaseous distension	12	15
Intramural air /PI/	-	2
Free intra abdominal air	-	5
Abdominal ultrasonography		
Bowel wall thickening	3	4
Bowel wall thinning	2	3
Bowel wall intramural air	9	10
Portal venous gas	1	2
Free intra-abdominal air	-	6
Free fluid	-	6
Focal fluid collection	-	1

Table-III

Comparisons between the three studied groups as regard X-ray and US findings.

	Control group (n=15)	Suspected group (n = 14)	Definite group (n = 16)	P value		
				Control versus suspected	Control versus definite	Suspected versus definite
X-ray						
Gaseous distension	2/15	12/14	15/16	<0.001	<0.001	0.586
Pneumatosis	0/15	0/14	2/14	-	0.484	0.485
Free air	0/15	014	5/11	-	0.043	0.045
Portal venous gas	0/15	12/14	15/16	-	1.000	1.000
US						
Intramural air	0/15	9/5	10/6	<0.001	<0.001	1.000
Increased wall thickness	0/15	3/14	4/12	0.100	0.101	1.000
Decreased wall thickness	0/15	2/12	3/13	0.224	0.226	1.000
Portal venous gas	0/15	1/13	2/14	0.483	0484	1.000
Ascites	0/15	0/14	6/10	-	0.018	0.019
Free air	0/15	0/14	6/10	-	0.018	0.019

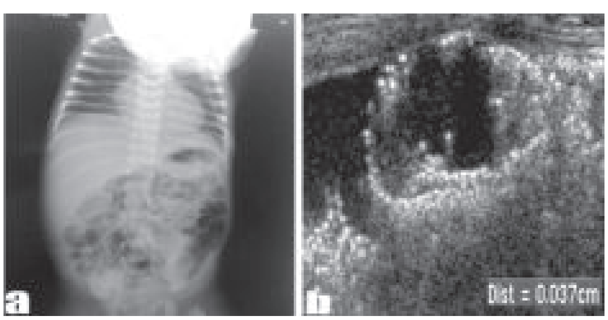

Fig. 1: A case of early necrotizing interocolitis; a neonate ±31 weeks, with congenital heart disease, formula feeding. (a) X-ray shows just distended loops of intestine. (b) Sonogram shows distended loop, hyperechogenic foci and thinning of the wall.

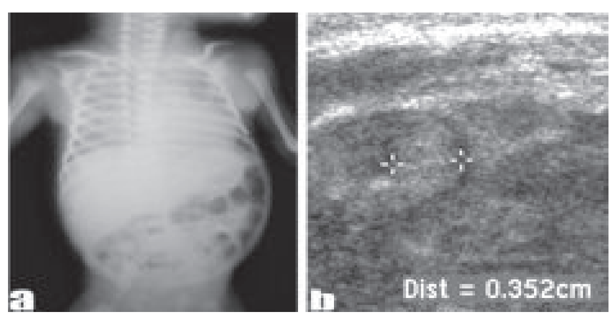

Fig. 2: A case of early necrotizing interocolitis; a neonate ±30 weeks, preterm with formula feeding. (a) X-ray shows distended loops of intestine. (b) Transverse sonogram of the right flank shows collapsed loops of bowel with thickened echogenic wall.

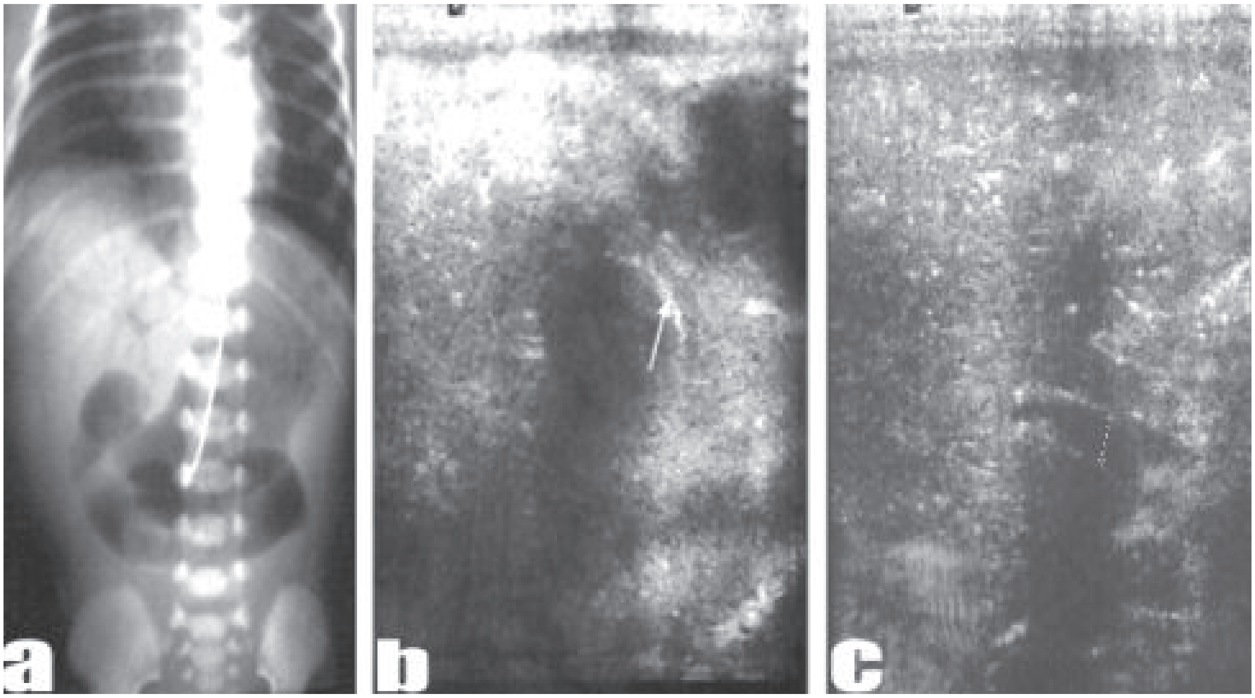

Fig.-3: *A case of late necrotizing interocolitis; a neonate ±31 weeks, with congenital heart disease, formula feeding. (a) X-ray shows portal venous gas. (b) Sonogram shows thinning of intestinal wall (0.7 mm) with hyperechoic foci in the wall. (c) Sonogram shows air bubbles at portal vein branches. PV diameter = 0.22 mm.*

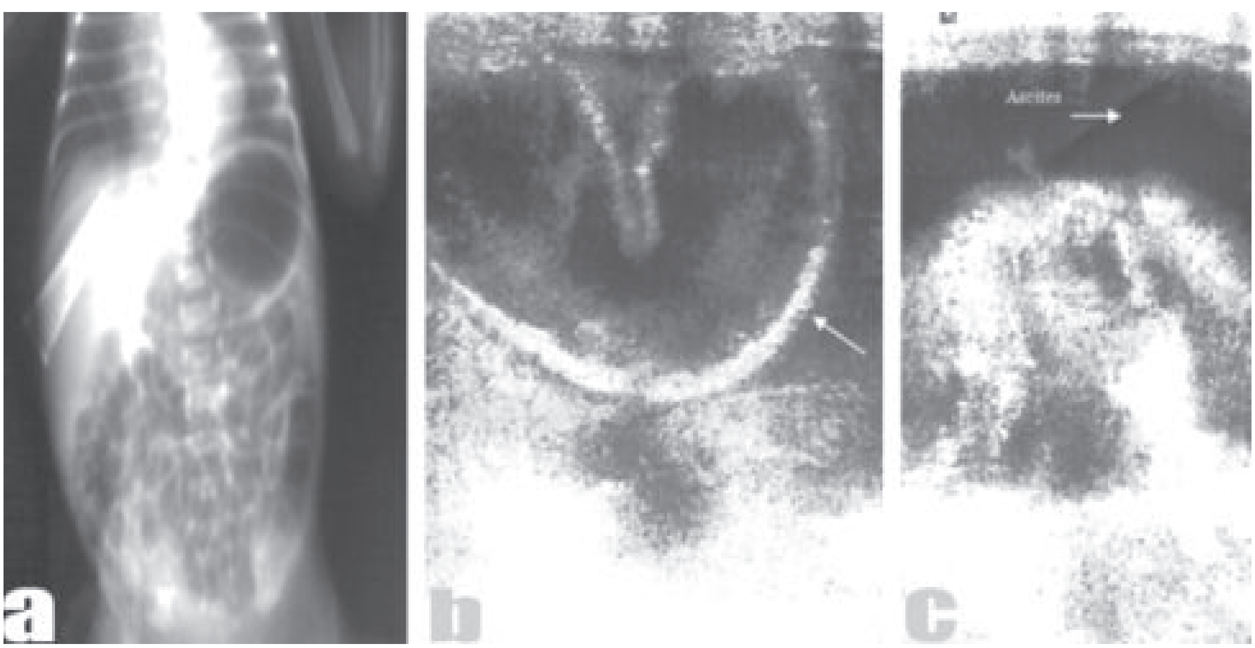

Fig.-4: *A case of late necrotizing interocolitis; a neonate ±30 weeks, with hypoxic ischemic encephalopathy, with formula feeding. (a) Plain X-ray showing gaseous distension. (b) Sonogram shows sever gaseous distension with bright echoes in the intestinal wall. (c) Free ascites between the anterior abdominal and intestinal wall, between intestinal loops.*

Table-IV

Diagnostic performance of diagnostic parameters of both X-ray and US techniques.

	X-ray			US		
	Pneumatosis	Free air	PV gas	Intramural air	Free air	PV gas
TP	2	5	1	10	6	2
TN	15	15	15	15	15	15
FP	0	0	0	0	0	0
FN	14	11	15	6	10	14
Sensitivity	12.50%	31.25%	6.25%	62.50%	37.50%	12.50%
Specificity	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
PPV	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
NPV	51.72%	57.69%	50.00%	71.43%	60.00%	51.72%
DA	54.84%	64.52%	51.61%	80.65%	67.74%	54.84%

Table -IV compares the sensitivity, specificity, positive predictive values and negative predictive values of plain radiography and ultrasound in detecting PI, PVG, and free intra abdominal air. The sensitivity of AUS in detecting PI, PVG and free air was higher than that of plain radiography. The highest sensitivity was seen with the finding of intramural air as detected by AUS (62.5%). This was followed by that of free intra abdominal air (37.5%) and PVG (12.5%) compared to 12.5%, 31.25%, and 6.25% for PI, free air and PVG respectively by plain radiographic findings.

Discussion

Necrotizing enterocolitis is one of the most common causes of gastrointestinal morbidity in neonatal intensive care units. The etiology is multifactorial, with prematurity and hypoxia having a significant role in disease development. In case of clinical suspicion for NEC, abdominal plain film is the primary modality for diagnosis, which may confirm the diagnosis in definite and advanced stages. Early in the disease process radiological findings include distension of bowel loops and loss of the mosaic pattern of the loops of bowel is often seen. Later on, pneumatosis intestinalis occurs with an incidence over 19%. The pattern varies from localized cystic collection of air to diffuse linear collections that outline an area of the bowel wall. Intramural gas is a non-specific radiological sign that may precede clinical signs[4]. In some occasions abdominal gas may be absent on abdominal radiographs and if associated with an unclear clinical picture a diagnostic confusion results that call for AUS[5]. The major advantages of abdominal ultrasound over abdominal radiography are its ability to detect abdominal fluid, free abdominal air even a small amount and portal venous gas. Abdominal ultrasound can also assess bowel wall thickness, echogenicity, peristalsis as well as bowel wall perfusion 1 and 9.

Intramural air is seen in the abdominal sonograms of neonates with NEC as echogenic dots or dense granular echogenicities[9]. In our study, PI was detected in 2 neonates with definite NEC (group II) on plain radiography while 10 neonates of this group showed intramural air by AUS. These findings suggest plain radiography to be not effective as AUS in demonstrating PI. This suggestion contradicts with that suggested by Bunomo[3], that PI by plain radiography has been routinely used for the diagnosis of NEC.

Extension of intramural gas into the veins of the bowel wall finally passes into the portal venous system. At gray-scale AUS, PVG may be seen in the main portal vein and its branches as intramural echogenic foci moving with the blood flow. Sharma et al.[10] reported that PVG may be detected in about 10% of premature infants with NEC. In the study by Bomelburg et al.[11], they reported that AUS was able to aid in the diagnosis of NEC prior to radiography by demonstrating PVG, however, absence of PVG on AUS did not exclude NEC. In another study, Dordelmann et al.[12] evaluated 352 neonates for PVG by sonography. They concluded that screening for PVG by sonography was a useful, easily and quickly performed bedside test with a high specificity (86%) but low sensitivity (45%). In our study PVG was detected sonographically in 13% of the neonates in group II with low sensitivity (12.5%). However, the specificity of sonographically detected PVG for a diagnosis of definite NEC was calculated to be 100%, it had a positive predictive value of 100% and a negative predictive value of 54.8%. These results are somewhat close to those of Dilli et al.[12] where in their study, PVG was detected sonographically in 17% of infants in group II with low sensitivity, yet the specificity was calculated to be 97%, positive predictive value 83.3% and a negative predictive value of 56.8%. These data suggest AUS to be superior to plain radiography in demonstrating PVG.

Free gas in the peritoneal cavity results from bowel perforation, which most commonly occurs in the distal ileum and proximal colon. It is the only universally accepted radiologic indication for surgical intervention[3]. Plain abdominal radiography has been the standard method for detection of the presence of free gas. In the current study, it was shown that AUS appears to be at least as sensitive as abdominal radiography for depicting free gas and, in certain circumstances, might even be more sensitive as illustrated by our six neonates in whom the AUS depicted free gas compared to five neonates detected by abdominal radiography. These findings are in accordance with those of Faingold et al.[1] who noted that free gas was present in 4 of 22 patients with NEC and this was apparent by both plain radiography and AUS. Very small amounts of gas can be most easily appreciated by hyperechoic foci with dirty shadowing between the anterior surface of the liver and the abdominal wall[6]. Also in the study of Silva et al.[13], two patients had free gas by AUS that was not detected on plain radiography.

Bowel perforation occurs in 12–31% of patients with NEC[14], and may lead to accumulation of free peritoneal fluid or focal fluid collection without evidence of free gas on plain radiography or even AUS[1]. Although there are signs on plain radiography which may suggest the presence of the fluid in the abdomen, it is depicted more accurately by AUS. Also focal fluid collections can be easily depicted by AUS which are rarely accurately demonstrated on abdominal radiography 6 and 13. The importance of AUS in this clinical setting was manifested in the current study where free fluid was detected in six cases by AUS with free air could be detected in four of them by plain radiography. There was a single case of focal fluid collection by AUS where plain abdominal radiography showed no evidence of mass effect in the case. This matches the results of Silva et al.[13], where 3 patients in their study showed focal collection by AUS with no leading sign on plain radiography.

Abdominal ultrasound is also important for determining which patients might have necrotic bowel prior to perforation[13]. A thin intestine is consistent with non-viable tissue and ultimately results in perforation[1]. Early detection of non-viable tissue might well influence surgical management and allow the surgical team to intervene in those patients prior to development of perforation, and therefore it may decrease the morbidity and mortality rates[13].

In our study, bowel wall thinning was noticed in two of suspected NEC group and three of definite NEC group, and all of them were referred to the pediatric surgeon to manage. In the study of Faingold et al.[1] bowel wall thinning was detected in two infants with definite NEC, where one of them died before the surgical intervention, while the other patient was managed surgically and then was discharged without any complication.

We found that AUS was beneficial in two clinical situations. The first one is in those patients in whom both the clinical and plain radiographic findings were non-specific while AUS revealed PVG and bowel wall thinning so these patients were counted as high risk for intestinal perforation though initially by the clinical and plain radiographic findings the diagnosis was indeterminate. Similarly, Franco and Ramji,[4] reported a case of pre-term infant in which the clinical signs were non-specific, and the plain abdominal radiography showed a gasless abdomen, but the sonogram was highly suggestive of necrotic bowel with perforation and abscess formation and the infant was referred for surgery which saved his life because of early intervention.

The second clinical situation was in those patients in whom NEC had been established as a diagnosis and AUS revealed additional findings as free air, free or focal fluid collection indicating that those patients might have already perforated though they had no evidence of free air on plain radiography. Early surgical intervention is life saving for those infants.

Conclusion:

Our results suggest AUS to be superior to abdominal plain radiography in demonstrating portal venous gas, free or focal fluid collection, bowel wall thinning and free air. Earlier detection of bowel wall thinning and PVG allow early surgical intervention prior to development of perforation and so decrease the morbidity and mortality rates. Moreover, early surgical management if echogenic focal fluid collection is observed by AUS in a clinically deteriorated NEC case may be life saving being an early sign of intestinal perforation. Therefore addition of AUS to plain radiography is valuable in managing patients with necrotizing enterocolitis.

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