Pediatr Surg Int (2016) 32:465–470
DOI 10.1007/s00383-016-3880-7

ORIGINAL ARTICLE

The value of contrast studies in the evaluation of bowel strictures after necrotising enterocolitis

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Accepted: 12 February 2016 / Published online: 25 February 2016

Abstract
Purpose Strictures of the bowel are a frequent complication post-necrotising enterocolitis (NEC). Contrast studies are routinely performed prior to stoma closure following NEC. The aim of this study was to evaluate the ability of these studies to detect strictures and also directly compare them to operative and histological findings.
Methods Two hundred and fourteen neonates who had a diagnosis of NEC (Bell stage 2 or greater) in a single unit (2007–2011) were analysed. Their case notes, radiology, and histology were reviewed.
Results One hundred and sixteen neonates underwent an emergency laparotomy and 77 had stomas fashioned. Sixty-six patients had a contrast study prior to stoma closure (distal loopogram 18, contrast enema 37, both studies 11). Colonic strictures were reported in 18 patients and small bowel strictures were reported in two patients. Fourteen of these colonic strictures were confirmed at operation and on histology but three colonic strictures were missed on contrast studies; one patient had had both contrast studies and the other two only a distal loopogram. Two small bowel strictures reported were confirmed and an additional small bowel stricture missed on distal loopogram was also detected at the time of operation. The incidence of post-op strictures was 19 out of 68 patients (27.9 %) and 16 (84.2 %) of these strictures were found in the colon. Contrast enemas had a much higher sensitivity for detecting post-NEC colonic strictures than distal loopograms; 93 versus 50 %, respectively; however, they are more likely to give a false positive result and therefore their specificity is lower; 88 versus 95 %, respectively.
Conclusion Colon is the commonest site for post-NEC stricture and contrast enema is the study of choice for detecting these strictures prior to stoma closure.

Keywords Necrotising enterocolitis · Stricture · Contrast study

Introduction

Necrotising enterocolitis (NEC) is the most common gastrointestinal emergency requiring surgery during the neonatal period. Its clinical presentations are characterised by feeding intolerance, abdominal distension, bloody stools, cardiorespiratory compromise and severe haemodynamic instability [1].

NEC is a growing problem as a result of an increased incidence of premature deliveries [2] and improved survival for extremely low birth weight premature neonates [3, 4]. For those neonates who survive the acute illness with or without surgery, some will go on to develop intestinal obstruction secondary to NEC related strictures. Contrast studies are performed prior to stoma closure or in neonates who develop signs of intestinal obstruction. In this study, we review our experience of contrast studies at detecting post-NEC strictures in surgically treated neonates.

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Methods

Neonatal data collection

Patients admitted to the Neonatal Intensive Care Unit (NICU) at Chelsea and Westminster Hospital NHS Trust were recorded prospectively on the South East Neonatal Database (SEND) since March 2003. All consecutive records of patients with a diagnosis of NEC on SEND over a 5 year period (January 2007–December 2011 inclusive) were retrieved and analysed. These patients were double-checked against a separate prospectively collected surgical database of patients with NEC. Case notes, radiological and histological findings were noted. All patients who underwent surgery for NEC were included and patients with another diagnosis at operation were excluded from the study.

The dataset collected for each patient was: sex, weight and gestation at birth, weight and gestation at initial operation, initial operative findings and procedure (bowel resection, primary anastomosis, stoma formation), contrast studies performed (distal loopogram, contrast enema or both), strictures detected on contrast study, age at stoma closure, strictures detected at further operation, histological confirmation of the stricture and overall mortality.

Contrast studies

The contrast studies performed to confirm or rule out the stricture were: contrast enema, distal loopogram or both. The contrast enema was performed by placing a Foley catheter in the rectum without inflating the balloon. Half strength Omnipaque 300 (300 mg/mL) was instilled via the catheter and patient position was moved accordingly to help displace the contrast around the colon while screening.

The distal loopogram was performed through the mucous fistula if present and patent. Again half strength Omnipaque 300 (300 mg/mL) was instilled using a Foley catheter of appropriate size without inflating the balloon. If the mucous fistula was found to have been closed spontaneously or difficulty to instil any contrast then the procedure was abandoned and a contrast enema was performed if it was not performed initially.

Analysis

Sensitivities, specificities positive and negative predictive values of contrast enemas and distal loopograms were calculated. Other data were analysed using appropriate statistical testing based upon the normality of data distribution. Simple hypothesis testing (Mann–Whitney U test) were used to analyse ordinal continuous data. A probability value of <0.05 was considered statistical significant. All data were analysed using GraphPad Prism 5.0.

Results

A total of 214 consecutive patients with known NEC (Bell stage II or greater) were identified between January 2007 and December 2011. 116 neonates (63 male, 53 female; $p = \text{ns}$) had a laparotomy for acute NEC and 98 were managed conservatively.

26 patients had an open and close laparotomy for NEC totalis and died soon after surgery. They had a significantly higher gestation (30 + 4 weeks, $p < 0.05$) than the other groups of patients (Table 1). 13 patients (11 %) had bowel resection and primary anastomosis performed at the initial operation. 77 patients (66 %) had a stoma formed with or without a bowel resection. Nine neonates (8 %) died prior to stoma closure from recurrent NEC or other comorbidities. This group of patients had a significantly lower birth weight than the other groups (848 g, $p < 0.05$) (see Table 1). The remaining 68 neonates (59 %) underwent a stoma closure at an average of 71.5 days after the initial operation. There was no significant difference in gestation or weight at operation between the groups (Table 1).

Strictures reported on contrast studies

66 neonates out of 68 (97 %) underwent contrast study prior to their stoma closure (Fig. 1—example of normal study); 37 contrast enema, 18 distal loopogram and 11 had both studies performed. A distal loopogram was initially attempted in 4/37 patients who had contrast enema but was abandoned due to difficulty in cannulating the mucous fistula hence a contrast enema was performed instead. In remaining 2/68 patients stoma closure was expedited due to doubts of recurrent NEC in the presence of difficulty in managing the stoma; high stoma output in one and stoma retraction in the other. They had their stoma closure through a full laparotomy incision (no stricture was found at operation). Colonic strictures were detected in 18 patients. (Fig. 2) and two small bowel strictures were detected on distal loopogram. Four patients had colonic strictures seen on both forms of contrast study (Table 2). Six of the strictures caused a complete obstruction with no passage of contrast.

Strictures detected at operation

There were 16 true colonic strictures, 15 were detected at the time of stoma closure. The locations of these strictures were as follows: four ascending colon/hepatic flexure, three transverse colon/splenic flexure and seven descending colon and sigmoid, two patients had multiple colonic strictures. The contrast studies missed three colonic strictures (one patient on both distal loopogram and contrast enema, the other two patients on distal loopogram alone;

Table 1 Demographics details of four groups of neonates that underwent a laparotomy for NEC

	Primary anastomosis	Stoma formation later closed	Stoma formation with death prior to stoma closure	Open and close laparotomy	Total
Number of neonates (116 total)	13	68	9	26	116
Gestation at birth (weeks + days)	27 + 1	28 + 0	27 + 2	30 + 4*	28 + 1 (SD ± 3 + 1)
Corrected Gestation at operation (weeks + days)	29 + 4	32 + 2	30 + 4	32 + 6	32 + 0 (SD ± 4 + 0)
Birth weight (g)	1309	1080	848*	1285	1098 (SD ± 571)
Weight at operation (g)	1532	1541	1102	1416	1462 (SD ± 691)

All data normally distributed (D'Agostino–Pearson normality test) so mean given

Asterisk are $p < 0.05$

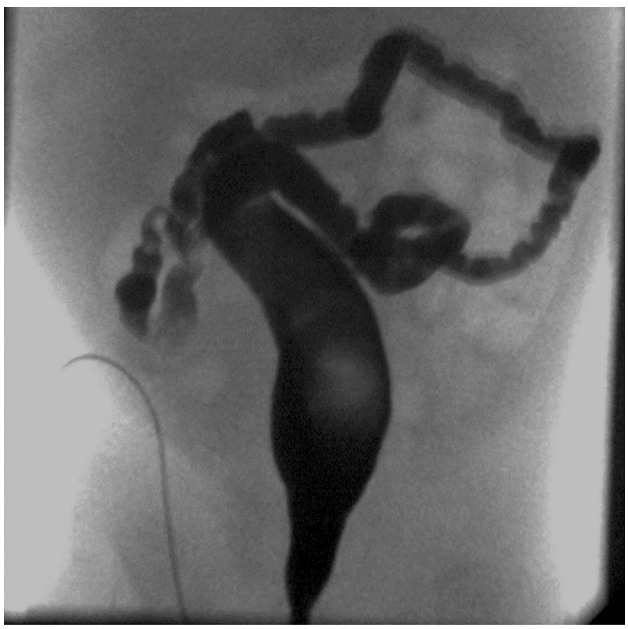

Fig. 1 Normal contrast enema, no stricture found at operation

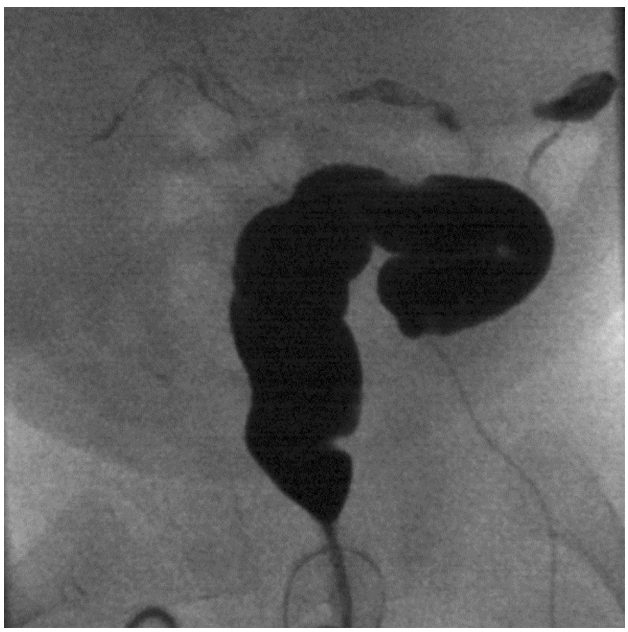

Fig. 2 Contrast enema showing a long stricture in the descending colon and transverse colon

Fig. 3); two of these patients had them detected at the time of operation (transverse colon and hepatic flexure). Unfortunately one patient who had a limited stoma closure following a clear distal loopogram deteriorated soon after the onset of feeding. After confirming the presence of a stricture at the hepatic flexure on a subsequent contrast enema, he was taken back to theatre where the stricture was resected and a primary anastomosis was performed. This patient then developed an anastomotic stricture a month later and underwent further surgery but died 8 days later after never recovering from the operation. Only three patients were found to have small bowel strictures at the time of stoma closure. Two of these had been detected on a distal loopogram and one was detected at operation. Overall there were total five patients with reported strictures on contrast studies but not confirmed at the time of operation (four on contrast enema, one loopogram; Fig. 4).

All 16 colonic and three small bowel strictures were confirmed on histology. They had varying degrees of mucosal, submucosal and muscularis involvement with presence of fibrosis and granulation tissue.

None of the 13 patients who had a resection and primary anastomosis for limited NEC died or developed a stricture. No contrast study was performed in any of these patients. Three out of 98 conservatively managed NEC later required resection and anastomosis for post-NEC strictures.

Contrast enemas had a much higher sensitivity for detecting post-NEC colonic strictures than distal

Table 2 Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) for detecting colonic strictures post-NEC for both distal loopograms and contrast enemas

	Total	Colonic strictures detected	False positive	False negative	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Combined studies	66	18	5	3	81	90	72	94
Distal loopogram	29	4	1	3	50	96	75	88
Contrast enema	48	18	4	1	93	88	76	97

11 patients had both forms of study

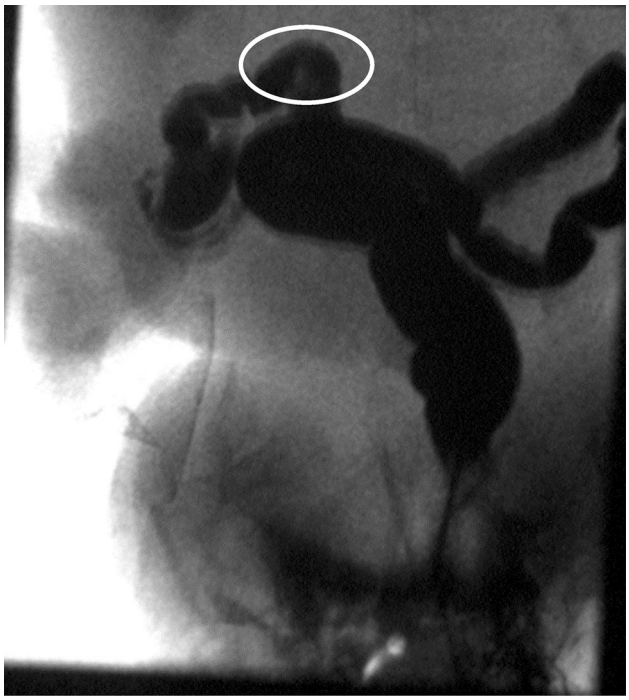

Fig. 3 False negative—contrast enema reported as normal but found stricture at operation (marked out with *circle*)

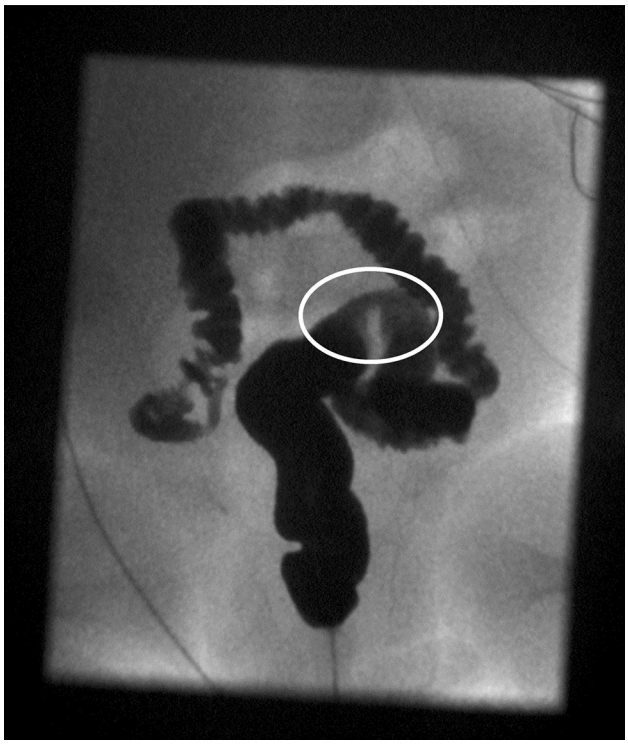

Fig. 4 False positive—contrast enema reported a stricture but not found at operation (marked with a *circle*)

loopograms; 93 versus 50 %, respectively, however they are more likely to give a false positive result and therefore their specificity is lower; 88 versus 96 %, respectively (Table 2).

Discussion

Our retrospective study is the first to compare fluoroscopic test characteristics of the contrast enema and distal loopogram for diagnosing post-NEC colonic strictures prior to stoma closure. Our data suggest that contrast enemas have a sensitivity of 93 % and specificity of 88 %; versus distal loopograms which have a sensitivity of 50 % and specificity of 96 %.

The overall incidence of stricture formation in neonates who had undergone stoma formation after NEC laparotomy in this series is 27.9 % (19/68 patients). However, the incidence of colonic stricture is 23.5 % (16 patients) and small bowel stricture is only 4.4 % (3 patients). This is similar to the incidence reported in other series [4, 5]. The pathogenesis of intestinal strictures following NEC is similar to ischaemic colitis in adults. They result from a reparative proliferative process following intestinal ischemia [6].

Missed intestinal strictures following NEC has consequential morbidity and mortality such as life-threatening sepsis, perforation or death [7, 8]. All surviving surgical NEC infants with stoma undergo a contrast study at our

institution prior to stoma closure. Infants in this study received an assortment of contrast studies (distal loopogram, contrast enema or both) depending on whether there was a patent mucous fistula or surgeon/radiologist preference. There are no set guidelines as to the type of study they should have. All infants receive a dose of intravenous antibiotics (benzyl penicillin, metronidazole and gentamicin unless previous culture sensitivities demonstrate resistance). This is in order to limit translocation and deterioration post-contrast studies due to sepsis [9].

Colonic strictures accounted for 84.2 % (16 colon, 3 small bowel) of all post-NEC strictures in this series. This is in accordance with that reported in the literature [10–12]. The colon is also more difficult to visualise at the time of stoma closure than small bowel due to it being fixed to the retroperitoneum. It is therefore very important to get detailed imaging of the colon prior to stoma closure in order to reduce unnecessary bowel dissection and to minimise the chances of missing these strictures during surgery. Contrast enemas have a much better sensitivity than distal loopograms for detecting these colonic strictures. This is in accordance with a previous study, which demonstrated contrast enemas (76 % sensitivity; 82 % specificity) were superior to upper gastrointestinal small bowel follow-through studies for detecting any strictures, but particularly colonic [13]. Contrast enemas, however, did not detect any ileal strictures. Even with an incompetent ileocaecal (IC) valve the amount of contrast making it to the small bowel is usually not enough to rule out any small bowel strictures confidently. The distal loopogram detected two of the three ileal strictures, therefore if the mucous fistula is at considerable distance from the IC valve, a distal loopogram may also be a useful investigation in addition to the contrast enema to detect strictures both in the small and large bowel.

This series has shown that strictures were more common in the descending and sigmoid colon which can easily be delineated on contrast enema. Two of the three colonic strictures that were missed by the contrast enema in this series were at the hepatic flexure and proximal part of the transverse colon. Furthermore there were four false positive diagnosis of colonic strictures on the contrast enema which were not confirmed at the laparotomy. Therefore, it is very important to get good contrast images delineating the entire colon. This can reduce the chances of missing these colonic strictures as these are also particularly difficult to visualise at surgery due to post-NEC adhesions affecting that area. This can be achieved if the contrast is instilled under sustained pressure to create uniform distension of the colon. However, areas still suspicious of strictures should be explored at the surgery to prevent further operations.

We do not perform routine contrast studies on patients with non-operatively managed NEC unless if there are clinical symptoms and signs suggestive of partial or complete intestinal obstruction. Some groups advocate doing them routinely [8, 14] on medically managed infants whilst others found a high false positive rate and therefore a potential risk for a negative laparotomy [15]. Only three out of 98 (3 %) medically managed patients developed signs suggestive of NEC strictures. These were diagnosed by contrast enemas as colonic strictures and were confirmed at surgery and later on histology.

Harberg et al. performed a resection and primary anastomosis in 27 patients and found an overall survival of 89 % with no postoperative strictures or anastomotic leaks encountered [16]. Other groups support its use [17, 18] although Cooper et al. retrospectively reviewed 143 babies who had a resection for NEC. 27 patients had a primary anastomosis. 14 of these infants died and at autopsy three of seven were found to have anastomotic leaks. They concluded there was no advantage to the more traditional approach of resection and stoma formation [19]. In the current series resection and primary anastomosis was performed in only 11 % of cases with limited disease. Routine contrast studies were not carried out and none of these patients developed any signs suggestive of stricture formation or leak.

The overall incidence of NEC totalis (12 %) is high in comparison to other series [20, 21]. Patterns in referral and clinical decision making will have an important impact on NEC outcomes. The majority of neonates at our tertiary surgical institution are transferred in from elsewhere. The approach at our centre is to offer surgery to all neonates with NEC regardless of how critically ill they are.

Limitations of this study include its retrospective nature although checking our patients against two prospectively collected databases reduced our numbers of potentially missed patients. As a result of this study, together with the radiologists, we now have updated our intranet neonatal guidelines stating that contrast enema is the study of choice prior to reversal of post-NEC stoma although in proximal stomas distal loopogram may still be indicated. Fluoroscopic studies are dynamic, operator-dependent and best interpreted at the time of the study. We used the original radiology report. Inter-observer variability occurs between radiologists; however, this is realistic to clinical practice. Other methods such as magnetic resonance imaging for diagnosing post-NEC strictures still needs to be explored to minimise the amount of ionising radiation these neonates receive.

Conclusion

The colon is the commonest site for post-NEC stricture and contrast enema is the study of choice for detecting these strictures prior to stoma closure. Distal loopogram can also

be a useful study for detecting small bowel strictures distal to the mucous fistula. We recommend that all the bowel is inspected closely and instilled with saline particularly the colon at the time of stoma closures if there is any suspicion of a colonic stricture.

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