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Evaluation of Role of CT Enterography in the Diagnosis of Small Bowel Pathology

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KEYWORDS

CT Enterography(CTE), PEG electrolyte solution, Crohn's disease, tuberculosis, bowel adhesions.

ABSTRACT:

Background: Aim: This study prospectively evaluates the role of CT Enterography(CTE) in diagnosis of small bowel pathology.

Materials and Methods: This prospective observational study was conducted on 42 consecutive patients with suspected small bowel pathology. CTE was performed using polyethylene glycol(PEG) as oral neutral contrast agent. After ingestion of 2 L of PEG solution, plain and dual phase contrast CT scan was performed on all patients. Raw data and reconstructed images were studied on PACS workstation and degree of small bowel distension was assessed, abnormal small bowel was identified and studied in detail to arrive at a diagnosis. Statistical analysis was performed and sensitivity, specificity, PPV, NPV and accuracy were calculated by comparison of CTE with surgery and histopathology as Gold Standard.

Results: In our study,age of the patient ranged from 18 to 75 years,maximum number of subjects were between 21 and 40 years of age. Abnormal small bowel was diagnosed in 15/42 (35.7%) patients. CTE correctly diagnosed Crohn's disease in 5/6 cases (83%), small bowel adhesions in 4/4 cases (100%) and TB in 1/1 case (100%). We found that the overall accuracy of CTE in diagnosis of small bowel pathology was good. Sensitivity of CTE was found to be 100% for Crohn's, bowel adhesions and abnormal small bowel in general and specificity to be 97.06%, 100% and 96.30 % respectively.However, the sensitivity for tuberculosis was found to be low, only 50% while specificity was 100.0%. This was in comparison with reference standard of surgery and/ or histopathology.

Conclusion: CTE with large volume of PEG electrolyte solution as neutral oral contrast agent provides optimal luminal distension and adequate small bowel separation, thus enabling identification of mural changes, mucosal hyperenhancement, luminal as well as extraluminal abnormalities and active site of bleeding in cases of Gastro-intestinal bleed. In our study, we found CTE to be a highly sensitive and specific method for diagnosing small bowel pathology in accordance with other studies in the literature.

INTRODUCTION

Mesenteric small bowel continues to pose biggest challenge in bowel imaging despite advances in endoscopy and imaging techniques. This is mainly due to its length and redundancy. It approximately measures 11 feet long extending from pylorus to the Ileocaecal valve[1].

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Small bowel loops have narrow caliber and tend to overlap in the pelvis[1]. Until recently, Barium Meal Follow Through (BMFT) and Barium enteroclysis were the most popular Radiological examination in suspected small bowel pathology[1]. Conventional Computed Tomography(CT) performed with positive oral contrast like iodinated contrast is widely used in the evaluation of solid abdominal organs, bowel, lymph nodes, mesentery and retroperitoneum[1,2].The positive oral contrast, routinely used in abdominal CT, however, is partially absorbed and prevents uniform distension of bowel and also impairs the assessment of the bowel mucosa and lumen, preventing the visualization of abnormal mucosal enhancement and active contrast extravasation in the setting of obscure GI Bleeding. Enteroclysis techniques (CT/Barium enteroclysis) provide adequate luminal distension. However, they require intubation of jejunum, a procedure that is associated with patient discomfort, increased radiation dose, lengthy procedure time and the risk of perforation. Recently, CT and Magnetic resonance imaging (MRI) study of the small bowel using large volumes of oral contrast agent (CT Enterography (CTE) and MR Enterography (MRE)) ingested over a specified period of time is being increasingly used as an alternative to BMFT and Enteroclysis techniques. Enterography studies provide uniform and optimal bowel distension and separation of small bowel loops enabling evaluation of small bowel in its entirety, simultaneous evaluation of bowel wall thickness, luminal pathology, mucosal enhancement pattern and associated extraluminal findings in cases of small bowel pathology. Thus, CTE has better patient tolerance and reduced risks compared to Enteroclysis studies[1,2].

Different types of oral contrast agents are tried in CT studies for obtaining adequate small bowel distension and it has been concluded that neutral contrast agents are most suitable for achieving optimal bowel distension[3-7]. In our study, we used 2 litres of PEG electrolyte solution over a specified period of 45 minutes to 80 minutes time period to achieve adequate bowel distension.

There are currently very few studies in India evaluating the role of CTE in the evaluation of small bowel pathology[8]. This study is therefore proposed to prospectively evaluate the role of CTE in the diagnosis of small bowel pathology. Specific aims of this study is to prospectively evaluate the accuracy, sensitivity and specificity of CTE in detecting and characterizing small bowel diseases on CTE against a reference standard.

MATERIALS AND METHODS

Patients and control subjects

We conducted a single centre, prospective observational study for a duration of 1 year (from June 2013 to May 2014) on 42 consecutive patients referred to the department of Radiodiagnosis, Columbia Asia Referral hospital, Bangalore with suspected small bowel pathology. The age group of our patients ranged from 18 to 75 years. All patients with clinical suspicion of small bowel pathology irrespective of age were included in the study. Those with high grade, acute intestinal obstruction, pregnant patients, those with history of allergy to iodinated contrast, those with history of severe drug allergy, those with serum creatinine > 1.5 mg/dL and those who could not drink more than 1 L of oral contrast were excluded from the study. The patients were instructed to be nil by mouth for solids for atleast 4 hours prior to the start of CTE. All patients were instructed to drink 2 L of neutral oral contrast (PEG electrolyte solution) over 45 to 80 minutes time period. At the end of contrast ingestion, routine CT abdomen was performed and the patient was kept under observation for atleast 1 hour before leaving the hospital. Written informed consent was obtained from all patients. The study was conducted after obtaining approval of the study protocol from Institutional Review Board and Ethics committee.

Image Acquisition

64-slice CT scanner (Toshiba Aquilion) was used for performing CTE studies. At the end of oral contrast ingestion (over 45 to 80 minutes time period) a plain CT scan of abdomen was performed followed by dual-phase CT scan.150 mL of intravenous (IV) Omnipaque (300 mg/mL) was injected at the rate of 4 to 4.5 mL/ second using a pressure injector followed by saline flush. Bolus tracking method was used for acquisition of arterial and enteric phases; the trigger was placed on the descending thoracic aorta, arterial phase acquired after 15 to 20 seconds delay and enteric phase was acquired after 45 seconds delay.

Post processing

Images were acquired in the axial plane in a cephalocaudal direction, extending from lung bases superiorly to symphysis pubis inferiorly, during a single breath hold. Raw data were generated in axial planes and

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later reconstructed in coronal and sagittal planes with 3 mm slice thickness and reconstruction interval of 1 to 1.5 mm. Images were
reviewed on picture archiving and communication system.

Image Analysis

The degree of small bowel distension was assessed on coronal images by dividing the abdominal cavity into four quadrants: right upper, left upper, right lower, and left lower quadrants. The maximum diameter of small bowel lumen (inner-to-inner wall) was measured in five different loops in each of the four quadrants. If 4 or more measurements in a quadrant measured ≥ 1.8 cm, it was considered as "adequate luminal distension". (Figures 1-3)

Data were tabulated and analyzed using statistical methods.

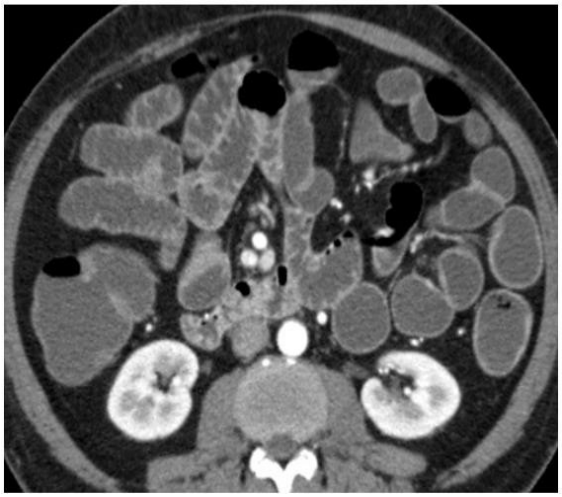
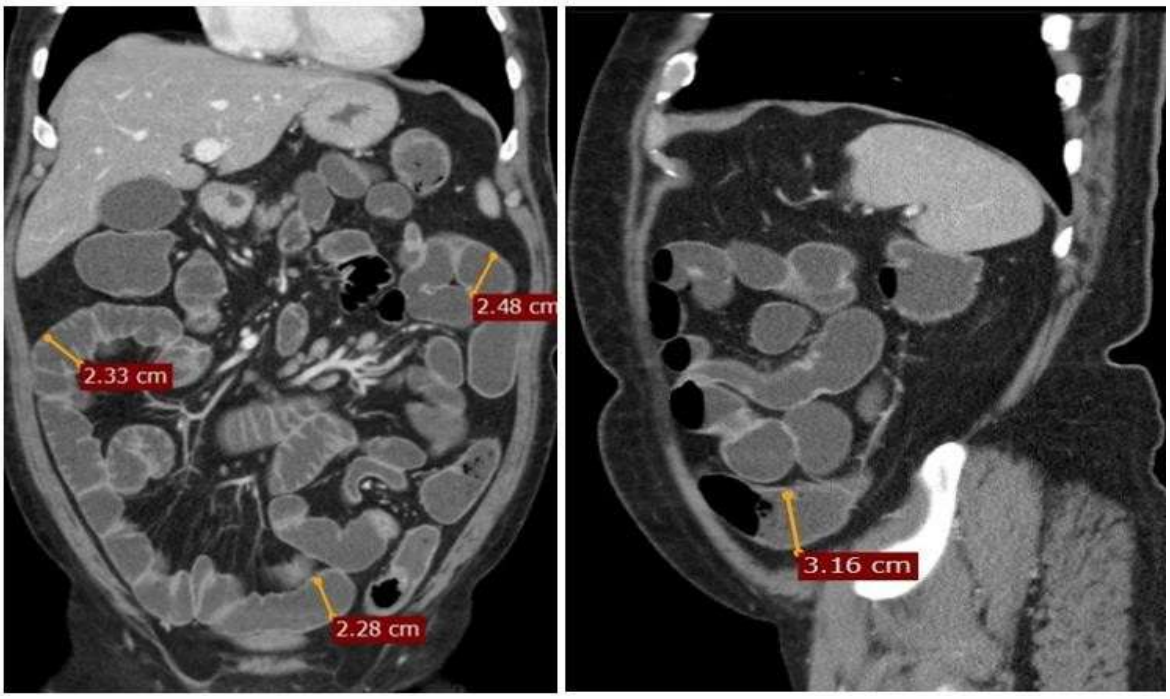


Figure 1: Axial CTE image showing optimal bowel distension



Figures 2 and 3: Coronal and Sagittal CTE images showing optimal bowel distension

Statistical Analysis

Descriptive and inferential statistical analyses were performed. Results on continuous measurements are expressed in the form of mean ± standard deviation (min–max) and results on categorical measurements are expressed in the form of percentage (%). Significance of study parameters on categorical scale was calculated using Chi-square/Fisher's exact test.

Statistical software: SAS 9.2, SPSS 15.0, Stata 10.1, MedCalc 9.0.1, Systat 12.0, and R environment

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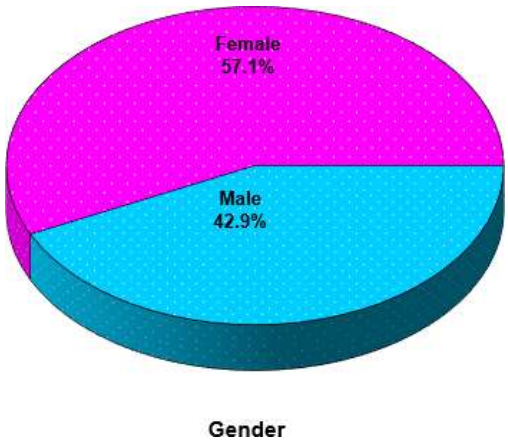
ver.2.11.1 are the statistical softwares used for analysis of the data. Graphs, tables and charts are generated using Microsoft Word and Excel.

RESULTS

All 42 patients underwent CTE study after ingestion of 2 L of oral PEG solution over a period of 45 to 80 minutes time duration. Few of them complained mild nausea.None of them had serious side effects. Out of the 42 subjects, 24(57.1%) were females and 18 (42.9%) were males. In our study population, the age ranged between 18 and 75 years with a mean age of 40.6 years; maximum number of subjects were between 21 and 40 years(Tables 1and 2, Graphs 1 and 2).

Table 1: Gender distribution of patients studied

Gender	No. of patients	%
Female	24	57.1
Male	18	42.9
Total	42	100.0

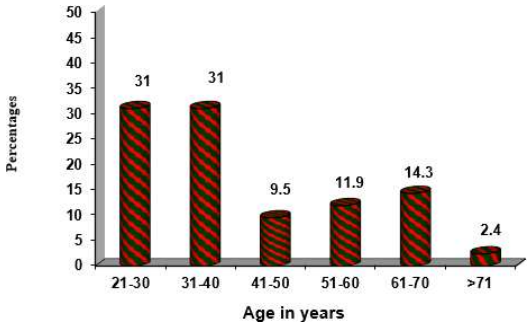


Graph 1: Gender distribution

Table 2: Age distribution of patients studied

Age in years	No. of patients	%
21-30	13	31.0
31-40	13	31.0
41-50	4	9.5
51-60	5	11.9
61-70	6	14.3
>71	1	2.4
Total	42	100.0

Mean ±SD: 40.69 ±15.01



Graph 2: Age distribution

Findings on CT Enterography

15(35.7%) out of 42 CTE studies demonstrated abnormal small bowel findings. 27(64.3%) out of 42 studies showed normal appearance of small bowel. Out of 15 CTE studies with abnormal small bowel findings,7 patients were diagnosed as Crohn's disease, 5 patients were diagnosed to have post operative small bowel adhesions. 1 out of 5 patients with small bowel adhesions also showed features of acute appendicitis and he was a known case of Chron's disease. One patient was diagnosed to have short segment jejunal intussusception with increased jejunal folds and suspected to have jejunitis /inflammatory bowel disease on CTE. One patient was diagnosed as inflammatory bowel disease or lymphoma.One patient had features suggestive of ileocecal tuberculosis (Table 3, Graph 3)

Table 3: SMALL BOWEL findings on CTE

SMALL BOWEL findings	No. of patients (n=42)	%
Normal small bowel	27	64.3
Abnormal small bowel	15	35.7
Crohn's	7	16.7
Bowel adhesions	5	11.9
Ileocaecal TB	1	2.4
Inflammatory bowel disease /Lymphoma	1	2.4
Transient jejunal intussusception	1	2.4

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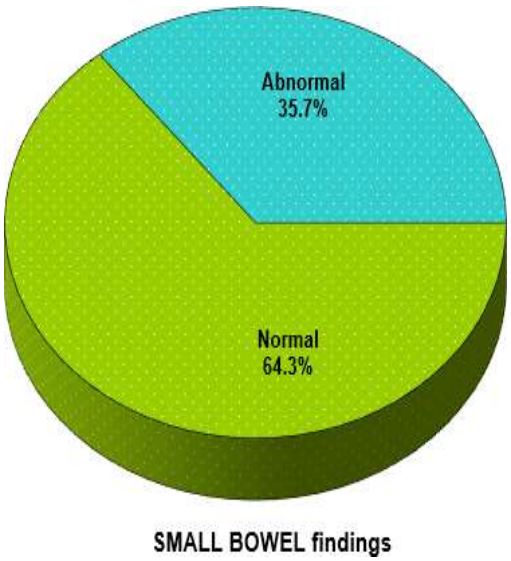


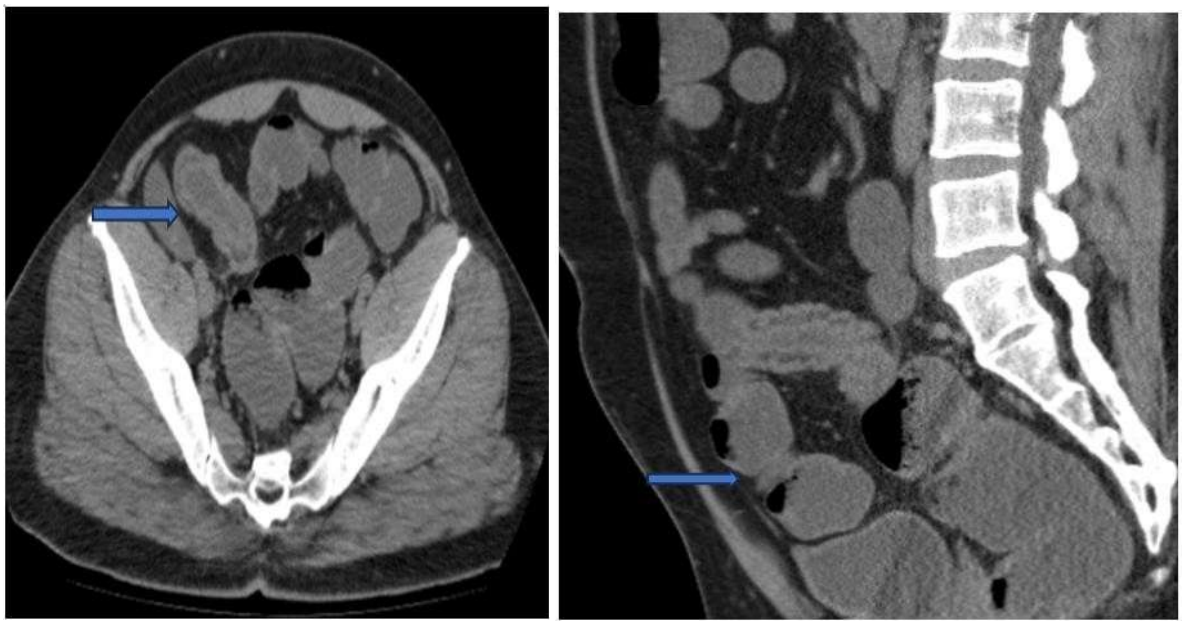
Graph 3: Small Bowel Findings

Follow up

We found CTE to be a highly sensitive and specific method of diagnosing small bowel pathology with 100% sensitivity and 96.3% specificity. Positive predictive value is 90.91%, negative predictive value is 100% and accuracy was found to be 97.30%.

Compared with reference standard of surgery and/ or histopathology, CTE correctly diagnosed Crohn's disease in 5/6 cases (83%), small bowel adhesions in 4/4 cases (100%) and TB in 1/1 case (100%). Out of 7 cases diagnosed as Crohn's disease on CTE, 5 were proven as Crohn's disease on biopsy; one case was proven to be tuberculosis on surgical resection and biopsy; one case did not undergo colonoscopy or biopsy. 4 out of 5 patients diagnosed to have post operative small bowel adhesions on CTE, were confirmed on laparoscopy. One patient did not undergo surgery.

In our study, we observed mural changes and mucosal hyperenhancement in 8 out of 15 patients with positive small bowel findings. On CTE,7 out of 8 patients demonstrated symmetrical wall thickening while 1 patient had asymmetrical wall thickening. 5 out of 7 patients with symmetrical involvement were proven to be Crohn's on histopathology. One out of other two patients was diagnosed as tuberculosis on HPE and other suspected as inflammatory bowel disease /lymphoma on CTE was confirmed as chronic inflammatory bowel disease on HPE. One patient who had asymmetrical wall thickening did not undergo further evaluation. (figures 4 - 11).



Figures 4 and 5: Axial and sagittal non enhanced CTE images demonstrating stratified wall thickening/mural stratification(thick arrows) in a proven case of Crohn's disease.

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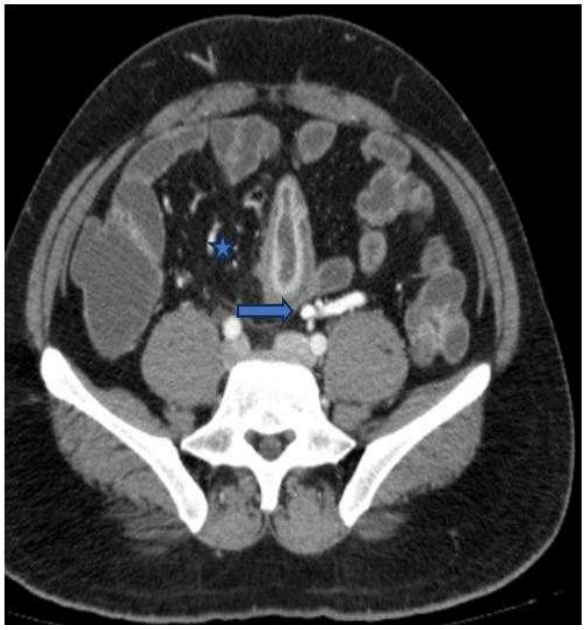

Figure 6: Axial CTE image(enteric phase) demonstrating mural stratification, mucosal hyperenhancement with target pattern of enhancement(thick arrow) and creeping fat sign(*) in a proven case of - Crohn's.

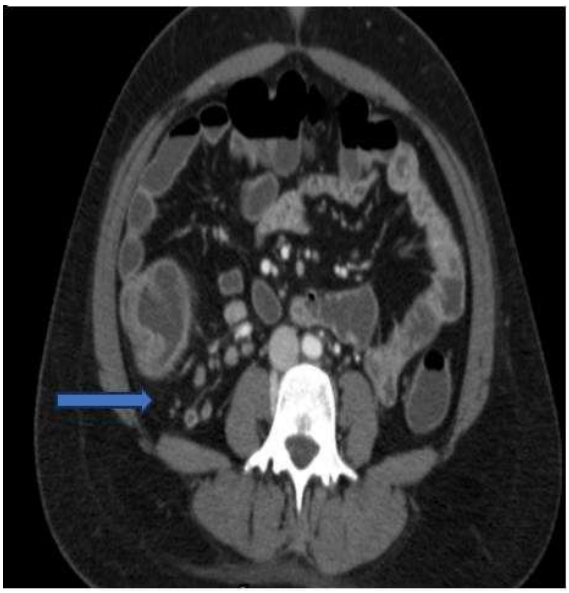

Figure 7: Axial CTE image (enteric phase) demonstrating asymmetrical wall involvement (thick arrow) and necrotic mesenteric lymph nodes in suspected case of Crohn's on CTE. On HPE, it was proven to be tuberculosis.

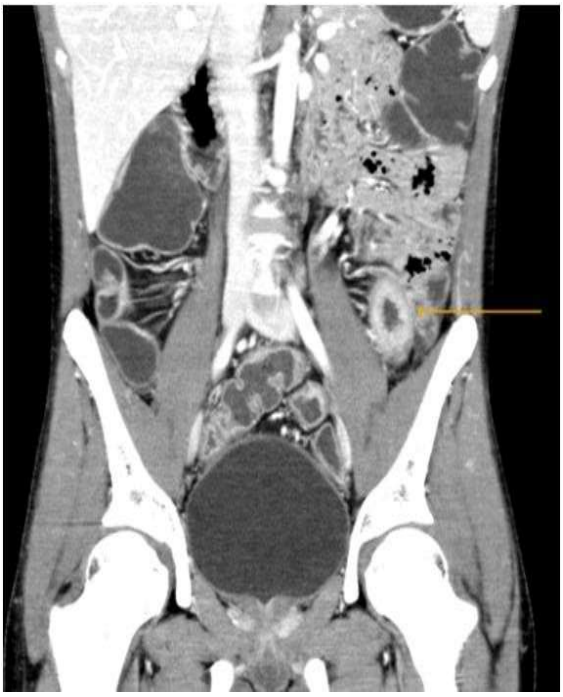

Figure 8: Coronal CTE image (enteric phase) demonstrating symmetrical wall involvement (thin arrow) in a known case of Crohn's with recurrence.

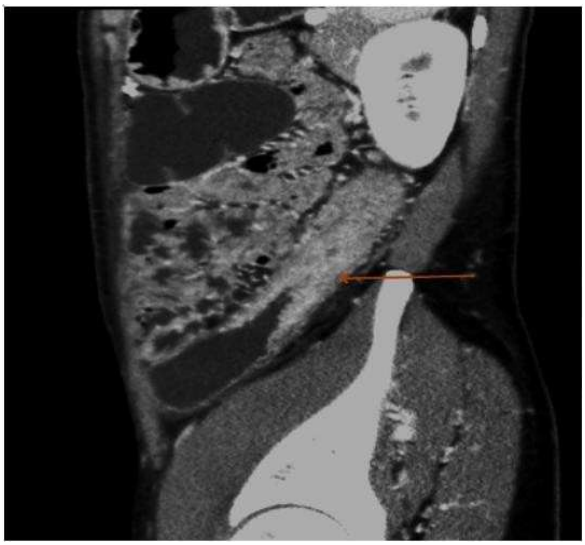

Figure 9: Sagittal CTE image (enteric phase) demonstrating Luminal narrowing /stenosis (thin arrow) in known case of Crohn's disease

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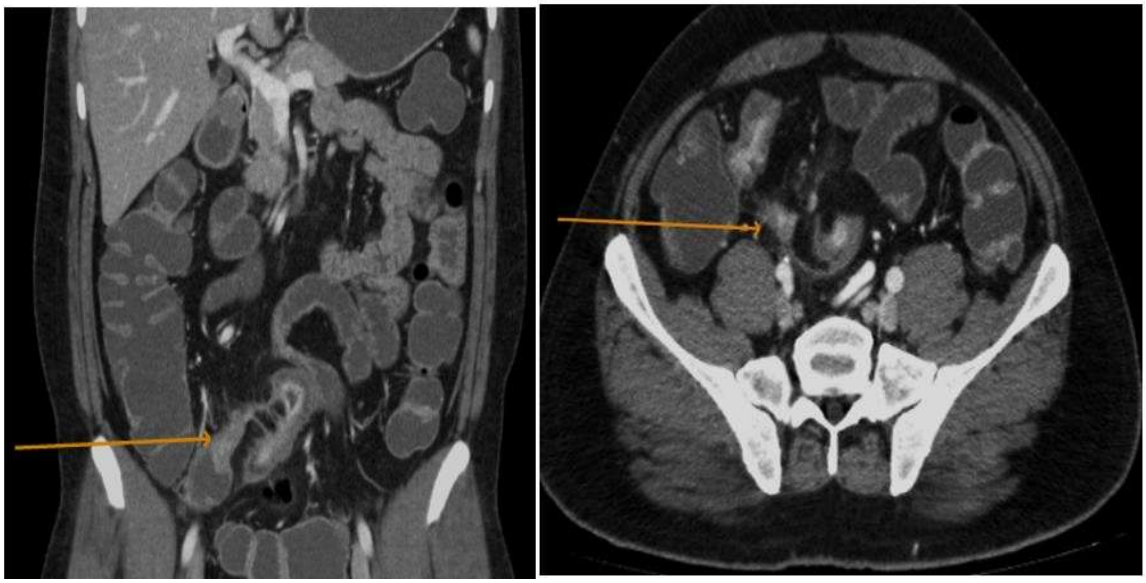

Figures 10, 11: Coronal and axial CTE images demonstrating enhancing appendix (thin arrow) with features of appendicitis in a proven case of Crohn's.

Crohn's disease: All the 5(100%) positive cases of Crohn's disease demonstrated mucosal hyperenhancement, comb's sign, creeping fat sign and mural stratification, all diagnosed to have active disease on biopsy, mucosal hyperenhancement and comb's sign, being the most specific signs of active disease as described in literature. Only 2(40%) out of 5 patients demonstrated skip lesions(table 5). One known case of Crohn's disease, presented with recurrent disease on CTE, demonstrating anastomotic site stenosis, mucosal hyperenhancement and mural thickening at the diseased site with dilatation of proximal bowel loops(Figures 4,5 and 6 and Table 5).

Table 5: Final Results on Crohn's cases, CTE findings : 5 Biopsy proven cases of Crohn's

CT findings: 5 Biopsy proven cases of crohn's	No. of patients (n=5)	%
Mural stratification	5	100.0
Mucosal enhancement	5	100.0
Comb sign	5	100.0
Creeping fat sign	5	100.0
Skip lesions	2	40.0

The overall accuracy of CT Enterography in diagnosis of small bowel pathology was good.

Sensitivity of CT Enterography was found to be 100% for Crohn's, bowel adhesions and abnormal small bowel in general and specificity to be 97.06%, 100% and 96.30 % respectively. However, the sensitivity was found to be low, only 50% for tuberculosis while specificity was 100.0%(tables 6 and 7).

Table 6: Correlation of CTE with gold standard on Crohn's disease, bowel adhesions and abnormal small bowel in general : An observation

	True Positive	False Positive	False Negative	True negative	Total
CROHNS DISEASE ALONE	5	1	0	33	39
BOWEL ADHESIONS	4	0	0	35	39

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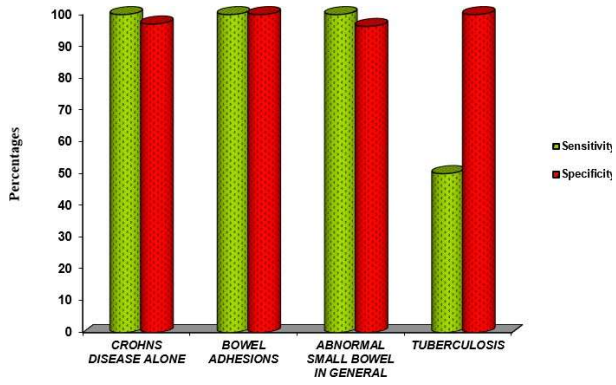
ABNORMAL SMALL BOWEL IN GENERAL	10	1	0	26	39
TUBERCULOSIS	1	0	1	37	39

*one case was diagnosed as Crohn's on CT Enterography, but proven as tuberculosis on biopsy.

Table 7: Correlation of CTE with gold standard on Crohn's disease, bowel adhesions and abnormal small bowel in general: Analysis

	Sensitivity	Specificity	PPV	NPV	Accuracy	P value
CROHNS DISEASE ALONE	100.00	97.06	83.33	100.00	97.44	<0.001**
BOWEL ADHESIONS	100.00	100.00	100.00	100.00	100.00	<0.001**
ABNORMAL SMALL BOWEL IN GENERAL	100.00	96.30	90.91	100.00	97.30	<0.001**
TUBERCULOSIS	50.00	100.00	100.00	97.37	97.44	<0.001**

* one case was diagnosed as Crohn's on CT Enterography, but proven as tuberculosis on biopsy.



Graph 4: CT Enterography comparison with reference standard in small bowel pathology: Analysis

DISCUSSION

Despite advances in endoscopy and gastrointestinal imaging techniques, the mesenteric small bowel continues to be the biggest challenge for clinicians and Radiologists. This is mainly due to its length, narrow caliber, coiled nature and superimposition of bowel loops in pelvis. Conventional cross sectional imaging studies (Contrast CT abdomen(CECT abdomen) and Contrast MRI abdomen(CEMR Abdomen) have largely replaced barium studies in evaluation of small bowel. Barium studies (BMFT and barium enteroclysis) are lengthy procedures, largely operator dependent and associated with barium related complications. Distension of small bowel is often non uniform and sub-optimal in barium studies, hence conventional cross sectional imaging studies have emerged as useful alternative to barium studies for small bowel imaging. Cross sectional studies help in simultaneous evaluation of mural, luminal and extraluminal pathology of intestines along with associated extraintestinal complication of small bowel disease. When used along with large volumes of oral contrast(either by Enterography and Enteroclysis techniques),they help to overcome the challenges caused by narrow caliber, redundancy and superimposition of small bowel loops and provide adequate luminal distension. CT and MR Enterography / Enteroclysis studies provide all the added advantages of conventional CECT/MR abdomen study along with optimal bowel distension. However, Enteroclysis technique needs intubation of the jejunum and is associated with patient discomfort, increased radiation dose and the risk of perforation. Recently, CECT and CE MRI study of the abdomen using large volumes of oral contrast agent (CT Enterography(CTE) and MR Enterography(MRE)) ingested over a specified period of time is being increasingly used as an alternative to BMFT, Enteroclysis and conventional cross sectional imaging studies. CTE and MRE have improved the diagnostic accuracy of cross sectional studies for small bowel pathology. They have better patient tolerance and reduced risks compared to enteroclysis studies[1,2].

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Oral contrast agents and Oral contrast ingestion time:

Different types of oral contrast agents - positive, negative and neural contrast agents are tried in CT abdomen studies for obtaining adequate small bowel distension. It has been concluded that neutral contrast agents are most suitable for achieving optimal bowel distension[3-7].

Neutral oral contrast agents are preferred over positive oral contrast especially in suspected cases of Crohn's disease and obscure GI bleeding where mural enhancement and active contrast extravasation may be obscured by positive contrast in the lumen [9,10]. PEG electrolyte solution is a neutral contrast, commonly used as a colonoscopy preparatory agent. It is readily available, cost effective and has an agreeable flavour without known serious side effects. The attenuation is similar to water, enabling better delineation of mucosal and mural enhancement. PEG solution has also been shown to distend small bowel better than water or methylcellulose solution and as well as low density Barium [11.] In our study,we used 2 L of PEG solution, ingested over 45 to 80 minutes (1 hour 20 minutes) time period to achieve uniform and adequate small bowel distension. All 42 patients tolerated 2L of PEG electrolyte solution ingested over 45 to 80 minutes(1 hour 20 minutes) time period well and did not report any serious side effects. Similar study protocol was used by **Paulsen et al**[10] who used PEG solution as oral contrast agent and achieved uniform bowel distension after performing the scan at 1 hour 20 minutes. **Minordi et al** performed CTE using 2L of PEG as oral contrast agent ingested over 45 minutes time and achieved adequate small bowel distension [12].

Diagnostic accuracy:

CTE with large volume PEG electrolyte solution as neutral oral contrast agent provided adequate luminal distension and separation of small bowel loops, enabling high diagnostic accuracy for small bowel pathology. We found CTE to be a highly sensitive and specific method of diagnosing small bowel pathology demonstrating 100% sensitivity, 96.4 % specificity, 92.31% positive predictive value and 100% negative predictive value against a reference standard of surgery and/or histopathology. These results are similar to the study conducted by **Minordi et al** where sensitivity of PEG CTE was 93% and specificity was 94% for diagnosing small bowel pathology[12].

CTE in active Crohn's disease.

There are several studies proving that CTE is a very useful tool in the diagnosis and follow-up of Crohn's disease and for assessing disease activity, with sensitivity and specificity comparable with colonoscopy. In our relatively small number of patients with Crohn's disease, CTE was found to have 100% sensitivity and 97.2 % specificity against the reference standard of colonoscopy and biopsy. 4 of 5 Crohn's disease patients had colonoscopy findings similar to that seen on CTE. These results are similar to study by **OA Gamal Eldin et al** who performed CTE on 30 patients and found that the sensitivity and specificity of CTE for Crohn's disease was 100% and 100 % respectively[13].A similar result was observed by **Luciana et al** who compared CTE findings with clinical, laboratory and endoscopic data in patients with Crohn's disease. 14 out of 35 patients were positive for Crohn's disease with mural thickening and hyperenhancement seen in 100% of the cases[14]. A similar study by **Craig A. Solem et al** performed on 41 patients of Crohn's disease concluded that the sensitivity of CT Enterography was equal to that of capsule endoscopy(83%) and more than that of ileocolonoscopy(74%) and BMFT(65%)[15].

CTE in long term follow up of Crohn's disease In our study, most patients with suspected small bowel disease were between 21 and 40 years of age. CTE being non invasive and cost effective, can be used for long term assessment and follow-up of patients with established Crohn's disease. Literature review shows increased frequency of the disease in younger patients suggesting that the radiation risk is of major concern in Crohn's disease. The radiation dose in CTE is significantly lower compared to conventional CT particularly if used in conjunction with dose reduction techniques [16,17,18].

CTE in small bowel adhesions In our study, CTE was found to have sensitivity, specificity, positive predictive value, negative predictive value and accuracy of 100% each for diagnosis of small bowel adhesions. All 4 cases diagnosed as small bowel adhesions on CTE were confirmed at laparoscopy.These were similar to the study by **Cappell M S et al** who reported that CT Enterography is more accurate than Conventional CT Abdomen in the evaluation of small bowel obstruction. **Brian et al** in a review has commented that CT Enteroclysis is being replaced by CT Enterography in clinical practice and has become the investigation of choice in intermittent small

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bowel obstruction and in patients with past history of surgery[19-24].

CONCLUSION

CT Enterography with large volume PEG electrolyte solution as neutral oral contrast agent provides adequate luminal distension and separation of small bowel loops, enabling high diagnostic accuracy for small bowel pathology. In our study, we used PEG electrolyte solution as the neutral oral contrast agent ingested over 45 to 80 minutes time period in accordance with other studies in the literature[10,12,15]. We found CTE to be a highly sensitive and specific method of diagnosing small bowel pathology demonstrating 100% sensitivity and 96.4% specificity against a reference standard of surgery and/or histopathology. There are very few Indian studies evaluating the role of CTE in the diagnosis of small bowel pathology. Further research is needed in a large study population to compare the efficacy of different neutral contrast agents and confirm the usefulness of PEG electrolyte solution as optimal neutral contrast agent for CT/MR Enterography studies. Further studies with larger number of positive cases are required to assess the role of CT Enterography in the diagnosis of small bowel pathology in general, Crohn's disease and small bowel adhesions in specific.

Funding:

None.

Conflict of interest

None.

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