



MULTIPHASE CT ENTEROGRAPHY AS A DIAGNOSTIC TOOL IN THE EVALUATION OF SMALL BOWEL PATHOLOGY

Radiodiagnosis

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ABSTRACT

CT Enterography provides adequate luminal distension and separation of small bowel loops, enabling high diagnostic accuracy for small bowel pathology. In our study we have imaged 42 cases with suspected small bowel pathology using oral and intra venous contrast agent. The aim of our study was to evaluate the role of CT Enterography in the diagnosis of small bowel diseases against a reference standard, usefulness in the follow up of Crohn's disease for activity of the disease and suspected complications, and also in localizing GI bleeding sites. CT Enterography is highly sensitive and specific method of diagnosing small bowel pathology in suspected cases. Patterned approach for evaluating small bowel abnormality helps to narrow the differential diagnosis. CT Enterography is useful in demonstrating extraenteric complications of Crohn's disease and accurately determine the severity and extent of disease.

KEYWORDS

CT Enterography (CTE), Barium Meal Follow Through (BMFT), Small bowel diseases, Crohn's disease.

INTRODUCTION:

Despite advances in endoscopic techniques, the mesenteric small intestine continues to pose a diagnostic challenge, eluding imaging virtue of its length, poorly distended lumen, tortuosity and deep location within the peritoneal cavity. The mesenteric small intestine has a variable length, measuring approximately 11 feet beginning at the pylorus and extending up to the Ileocaecal valve¹. The positions of the jejunum and ileum are relatively constant with the left upper quadrant of the abdominal cavity occupied by jejunum and right lower quadrant occupied by ileum. However, in the presence of intestinal obstruction, the small bowel becomes more tortuous, longer and wider with crowding of jejunal and ileal loops in the pelvis.

Currently, fluoroscopic imaging including Barium meal follow through (BMFT), Enteroclysis and Computerized Tomography (CT) are the most commonly performed imaging examinations in suspected or known cases of small bowel disease^{1,2}. While BMFT is easily performed, well-tolerated, low cost, dynamic and non-invasive, cross-sectional imaging like Computerized tomography (CT) and Magnetic resonance imaging (MRI) can provide advantages in the form of multi-planar imaging, excellent soft tissue contrast and demonstration of the entire bowel wall.

Small Bowel Barium Enteroclysis is a type of Barium Meal Follow Through examination performed following jejunal intubation, but is less commonly used because of the technical expertise required to intubate the jejunum and the low patient tolerance.

Conventional CT performed with positive oral contrast like barium or iodinated contrast is widely used in the evaluation of solid abdominal organs, bowel, lymph nodes, mesentery and retroperitoneum. 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. CT Enteroclysis is a new technique that provides adequate luminal distension with complete visualization of the mucosal enhancement pattern and the source and site of active contrast extravasation through combined use of neutral / negative oral contrast along with conventional iodinated IV contrast. CT Enteroclysis requires intubation of the jejunum beyond the ligament of Trietz, a procedure that is associated with patient discomfort, increased radiation dose, lengthy procedure time and the risk of perforation.

Recently, CT and MRI of the small bowel distended by contrast delivered orally (CT and MR Enterography) have been advocated as an alternative to jejunal intubation methods of luminal contrast delivery (CT and MR Enteroclysis) in view of greater patient tolerance and reduced risks. In CT Enterography, complete evaluation of the small bowel is possible with the use of neutral oral contrast that distends lumen and intravenous iodinated contrast that enhances the wall, allowing assessment of lumen, wall thickness and pattern of wall enhancement.

There are currently very few studies in India evaluating the role of CT Enterography in the evaluation of small bowel pathology and Crohn's disease in specific. This study is therefore proposed to prospectively evaluate the role of CT Enterography in the diagnosis of small bowel pathology.

Aims and Objectives:

1. To prospectively evaluate the role of CT Enterography in the diagnosis of small bowel diseases.
2. To prospectively evaluate the accuracy, sensitivity and specificity of CT Enterography in detecting and characterizing small bowel diseases against a reference standard.
3. To prospectively evaluate the role of CT Enterography in the follow-up of Crohn's disease for activity of the disease and suspected Enterography complications.
4. To evaluate the sensitivity and specificity of CT Enterography in localizing the sites of GI bleeding, particularly occult/ chronic GI blood loss.

Inclusion criteria:

All patients referred to the radiology department at Sree Gokulam Medical College for CT Abdomen and pelvis with suspected small bowel pathology during the period from January 2019 to December 2019.

Exclusion criteria:

- Pregnancy
- History of contrast allergy or severe drug allergy
- Renal insufficiency, S. Creatinine level > 1.5 mg/dl
- Clinical suspicion of high grade/acute intestinal obstruction
- Inability to ingest > 1L of oral contrast.

MATERIALS AND METHODS:

Our study is a prospective observational study performed in 43 consecutive patients referred to the Radiology Department of Sree Gokulam Medical College with suspected small bowel pathology during the period from January 2019 to December 2019. The patients were instructed to remain nil oral for solid food for at least 3-4 hours prior to the start of CT Enterography. Written informed consent was obtained from all patients after informing them about the CT Enterography procedure and the importance of adequate distension of the small bowel. Patients were requested to drink 2 L of oral contrast (mannitol) over a period of 60 to 90 minutes. The patients were taken onto the CT table and the scan were performed on 128 slice MDCT GE Optima Scanner. Using a pressor injector, 1.5ml/kg of iodinated contrast material is injected at the rate of 4ml/second, followed by saline flush at the same injection rate. A dual phase CT scan was performed after an unenhanced CT scan. Bolus tracking method was used for acquisition of arterial and enteric phases and images were acquired in the axial plane in a cephalocaudal direction, during one breath hold. Raw data was generated in axial planes with 3mm thickness, later reconstructed in coronal and sagittal planes and images were transferred to PACS for review. All images were reviewed on a BARCO 5 mega pixel image viewer.

Step 1: Quantitative Analysis of the Degree of Small Bowel Distention

On coronal images, the abdominal cavity was divided into four quadrants, right upper, left upper, right lower and left lower quadrants. The maximum diameter was measured from inner to inner walls, 3 measurements were taken in each quadrant and mean distension was recorded separately for each of the quadrants. Luminal distension was said to be 'adequate'^{3,4} if the diameter ≥ 1.8 to 2 cm. If greater than 90% of the small bowel was adequately distended, the CT Enterography examination was given a distention score of 4 (optimal); if 70%–90% of the small bowel was adequately distended, the examination received a distention score of 3 (good); if 40%–69% was adequately distended, the examination received a score of 2 (moderate); and if there was less than 40% adequate distention, the examination received a distention score of 1 (mild).

Step 2: Identification of Abnormal Small Bowel and Pattern-based Diagnosis

A segment of small bowel was deemed abnormal if wall thickness ≥ 3.0 mm. Once an abnormal small bowel loop is identified; the following features described by Macari et al⁶ were used to narrow the differential diagnosis.

Enhancement pattern: homogeneous/ heterogeneous/ target

Length of involvement: short segment/long segment

Degree of thickening

Bowel wall attenuation

Location of lesion along the course of small bowel: proximal / distal

Location of lesion in the wall of small bowel: mucosa/ submucosa/ serosa

Associated abnormalities in the mesentery and vessels

Bowel wall attenuation was assessed according to the method described by Baker et al¹¹, all the measurements were made by placing ROI on the bowel wall and maximum attenuation recorded. Enhancement was defined as 'mild' if it was equal to that of the muscle, 'moderate' if just more than muscle and 'marked' if obviously more than muscle⁵.

Step 3: Record Ancillary Findings

Statistical Methods:

Descriptive and inferential statistical analyses were done on the data collected and tabulated. Results on continuous measurements are presented as Mean SD (Min-Max) and results on categorical measurements are presented in Number (%).

RESULTS:

A total of 43 CT Enterography examinations were performed. One subject was excluded from the study as she developed severe vomiting during ingestion of oral contrast and was unable to ingest more than 1L. 42 patients were therefore included in the analysis.

Population characteristics:

Gender and Age distribution

Of the 42 subjects, 24(57.1%) were females and 18(42.9%) were males. Age ranged between 20 and 80 years with a mean age of 40.6 years; maximum number of subjects were between 23 and 40 years.

Findings on CT Enterography:

15 out of 42 patients (35.7%) had abnormal small bowel findings on CT Enterography with 100% sensitivity and 96.4% specificity for the detection of small bowel pathology using surgery and/or histopathology as the reference standards. Positive predictive value was 92.31% and negative predictive value was 100%. CT Enterography demonstrated features suggestive of Crohn's disease in 7(16.7%) patients, small bowel adhesions were diagnosed in 5(11.9%) patients, ileocaecal tuberculosis in 1(2.4%) patient, inflammatory pathology / lymphoma in 1(2.4%) patient and jejunitis with intussusception in 1(2.4%) patient.

27(64.3%) studies showed normal appearance of small bowel. Abnormal small bowel was diagnosed in 15(35.7%) studies. Two of these patients, one diagnosed as Crohn's and other with appendicitis with small bowel adhesions did not undergo further follow up, surgery or biopsy. One patient who was diagnosed as Crohn's was proven to be tuberculosis on HPE. 5 out of 7 patients diagnosed as Crohn's disease on CT Enterography were confirmed as Crohn's on biopsy, 1 patient

was proven to be tuberculosis on surgical resection and biopsy. 4 out of 5 patients diagnosed to have postoperative small bowel adhesions on CT Enterography, were confirmed on laparoscopy. One patient who was diagnosed to have short segment jejunal intussusception with jejunitis underwent extended enteroscopy, had no evidence of intussusception. Jejunal mucosa appeared normal as confirmed on biopsy. Intussusception seen in all the phases of our CT Enterography study could be representing spontaneously reducible type of intussusception.

Patterned approach to abnormal small bowel:

Abnormal small bowel was identified by wall thickness ≥ 3.0 mm. Once an abnormal small bowel loop was identified, the following 7 criteria described by Macari et al⁶ were used to narrow the differential diagnosis:

Table 1: Patterned approach to small bowel pathology

Criteria	Crohn's disease (n=5)	Intestinal tuberculosis (n=2)	Jejunitis (n=1)	Small bowel adhesions (n=5)
Location of lesion along the course of small bowel, whether proximal / distal	Distal ileum=5	Proximal (jejunum)=1 Distal ileum=1	Proximal	Ileum=5 Adjacent to previous incision site
Location of lesion in the wall of small bowel- mucosa, sub mucosa or serosal	Mural=5	Mural=1 Serosal=1	Mural	-
The length of involvement- focal/segmental/diffuse segment	Focal=2 Segmental=3	Focal=1 Segmental=1	Focal	Segmental
Degree of thickening- mild/moderate /marked	Mild=1 Marked =4 Symmetrical	Moderate=2 Symmetrical	Moderate Symmetrical	-
Enhancement pattern - homogenous / heterogeneous / target	Target=3 Homogenous=2*	Target=2	Heterogeneous	-
Associated abnormalities in the mesentery and vessel	Creeping fat, comb sign=5 Skip lesions=2 Enhancing appendix=3	Necrotic lymph nodes, hepatomegaly=1 Desmoplastic reaction, tethering of bowel loops=1	Intussusception	-

*Recurrent Crohn's disease.

Role of ancillary findings in diagnosis of small bowel pathology on CT Enterography 11(73.8%) out of 15 patients with small bowel pathology demonstrated ancillary findings outside the intestinal lumen in the adjacent mesentery, vessels, lymph nodes and solid organs which aid in final diagnosis.

1(6.66%) patient with bowel wall thickening in the ileocaecal junction, ascending colon, right half of transverse colon and dilatation of terminal ileum was associated with hepatomegaly, necrotic mesenteric lymph nodes, engorged vasa recta which was diagnosed as intestinal tuberculosis.

1(6.6%) patient with jejunal wall thickening and mural hyper enhancement demonstrated desmoplastic reaction with tethering of adjacent bowel loops, was diagnosed as Crohn's on CT Enterography which was confirmed as intestinal tuberculosis (dry type) on surgery and biopsy.

3(20%) out of 15 patients with abnormal small bowel findings were associated with enhancing appendix, all 3 conditions diagnosed as Crohn's on CT Enterography and confirmed by biopsy. 3(60%) out of 5 patients of Crohn's disease were associated with enhancing appendix,

concluding that Crohn's disease can be frequently associated with enhancing appendix.

Creeping fat and comb sign were seen all 5(100%) patients of Crohn's disease, indicating that they are highly specific signs for Crohn's disease.

Another patient, a follow up case of known Crohn's disease demonstrated fistulous communication between strictured colon and umbilicus.

Summary of incidental findings (not related to small bowel):

14(33.3%) studies were found to be normal with no demonstrable small bowel pathology or another incidental findings in the abdomen and pelvis. 28(66.7 %) patients had incidental findings not related to small bowel.

Table 2: Incidental findings not related to small bowel

Findings not related to small bowel	No. of patients (n=42)	%
No pathology detected in CT Enterography	14	33.3
Abnormal	28	66.7
· Renal cysts	3	7.1
· Enhancing appendix	3	7.1
· Mesenteric lymphadenopathy	2	4.8
· Uterine fibroids	2	4.8
· Mild hepatomegaly	2	4.8
· Abdominal lymphadenopathy, massive splenomegaly with mild hepatomegaly	1	2.4
· Calcified mesenteric lymph nodes	1	2.4
· Distal CBD calculi	1	2.4
· Gastric lipoma	1	2.4
· Hypervascular hepatic lesions	1	2.4
· Osteitis/Osteomyelitis pubis, cholelithiasis	1	2.4
· Rectal stricture with multiple fistulous tracts to sigmoid colon and urinary bladder, presacral abscess ..TB/Crohn's	1	2.4
· Sigmoid colon growth	1	2.4
· Tiny left renal calculus	1	2.4

Critical incidental findings: 5(12%) out of 28 patients had critical incidental findings, which included sigmoid colon malignancy, rectal tuberculosis, sarcoidosis, appendicitis with abscess and small bowel adhesions and hypervascular hepatic lesions. Sigmoid colon malignancy, rectal tuberculosis, sarcoidosis were confirmed by biopsy while, the later two findings were not confirmed by biopsy or surgery.

Other investigations done:

Clinical records of the study subjects were reviewed before and after CT Enterography examination. 25(59.5%) out of 42 patients did not undergo any other small bowel examination. 17(40.5%) had undergone one or more of small bowel examinations like upper GI endoscopy, colonoscopy or Barium studies.

DISCUSSION

CT Enterography with large volume of oral contrast agent provided adequate luminal distension and separation of small bowel loops, enabling high diagnostic accuracy for small bowel pathology. We found CT Enterography 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. 35.7% of our patients had abnormal small bowel findings. These 15 patients demonstrated small bowel abnormalities that were consistent with Crohn's disease, TB, obstructive adhesions and intussusception.

Patterned approach to abnormal small bowel

We found that a patterned approach to evaluating small bowel abnormality as described by Macari et al⁵⁶ enabled us to narrow the differential diagnosis.

Features such as mural enhancement pattern, length of bowel involvement, degree of bowel wall thickening, type of thickening

(symmetrical or asymmetrical), location of lesion (proximal small bowel or distal small bowel) and location of lesion in the wall of small bowel (mucosal/submucosal/serosal) were used by Macari et al⁵ and Macari M⁶ et al for the evaluation of abnormal small bowel.

Once an abnormal small bowel loop was identified, the above mentioned 7 criteria were applied in our small number of positive patients to differentiate the differentials especially in suspected cases of Crohn's and tuberculosis:

Location of lesion along the course of small bowel - proximal/ distal:

Distal small bowel was affected in all 5 patients with Crohn's disease. Proximal small bowel was affected in 1 patient with TB while distal ileum and the ileocaecal junction were affected in the other patient with TB. Postoperative small bowel adhesions involved the ileum at the site of surgical incision.

Location of lesion in the wall of small bowel- mucosa, sub mucosa or serosal:

All 5 patients of Crohn's disease demonstrated mural involvement; mucosal involvement was seen in one case of TB while serosal involvement causing tethering of bowel loops was seen in the second patient with TB.

Enhancement pattern - homogenous / heterogeneous / target:

Target pattern of enhancement was seen in 3 out of 5 patients of Crohn's and both the patients of tuberculosis. Homogenous enhancement was seen in 2 out of 5 patients of Chronic / recurrent Crohn's. Target pattern of enhancement seen in 50% of patients with tuberculosis while homogenous enhancement was seen in the other.

The length of involvement- focal segmental / diffuse:

2 out of 5 patients of Crohn's disease and 1 patient with tuberculosis demonstrated focal involvement (< 5.0 cm) while segmental involvement was seen in 3 out of 5 patients of Crohn's and one patient of tuberculosis. Diffuse (>40 cm) involvement was not seen any of the case.

The degree of thickening- mild/moderate/marked :

4 out of 5 patients of Crohn's and both the patients with tuberculosis demonstrated moderate thickening, only one patient demonstrated mild thickening. All the patients showed symmetrical wall thickening.

Associated abnormalities in the mesentery and vessel:

3(60%) out of 5 patients of Crohn's disease were associated with enhancing appendix, creeping fat and comb sign were seen in all 5(100%) patients of Crohn's disease, indicating that they are highly specific signs for Crohn's disease. Another patient, a follow up case of known Crohn's disease demonstrated fistulous communication between strictured colon and umbilicus. Intussusception was associated with jejunitis seen in all the 3 phases (plain, arterial and venous phase). All 7 criteria described by Macari et al were fulfilled by all 5 proven cases of Crohn's. That is, distal small bowel involvement, length of involvement (focal in 2/5 or segmental in 3/5), moderate degree thickening, symmetrical wall thickening, mural involvement, target pattern of enhancement in acute Crohn's and homogenous pattern of enhancement in chronic Crohn's and associated findings like comb sign, creeping fat sign, all of which are proven to be strongly associated with Crohn's were also seen. 2/5 (40%) patients with Crohn's disease demonstrated skip lesions; Out of two patients of tuberculosis, one patient fulfilled all the 7 criteria as described above, while the other demonstrated atypical findings.

One typical case of tuberculosis showed distal small bowel involvement, mucosal involvement, symmetrical wall thickening, moderate degree wall thickening, target pattern of enhancement and associated findings like necrotic lymph nodes and hepatosplenomegaly. The other atypical case demonstrated proximal small bowel involvement, focal (< 5 cm) involvement and serosal involvement with tethering of bowel loops. This was wrongly diagnosed as Crohn's disease.

Thus, using the 7 criteria of patterned approach to abnormal small bowel, we could correctly diagnose 6/7 cases correctly. All 5 proven cases of Crohn's were correctly diagnosed as Crohn's on CTE (CT Enterography) and 50% of patients with tuberculosis fulfilled all the 7 criteria which enabled correct diagnosis on CTE, the other positive patient of tuberculosis was wrongly diagnosed as Crohn's on CTE.

Table 3: Approach to abnormal small bowel

Location of lesion	Location of lesion within bowel wall	Length of bowel involved (in cm)	Type of wall thickening	Degree of wall thickening	Pattern of enhancement	Other findings
Proximal: Adenocarcinoma	Mucosal: Crohn's TB	Focal (< 5): Inflammatory- Crohn's, TB Neoplastic-Metastases, GIST	Symmetrical: Smooth-Edema Hemorrhage Cellular infiltrates Nodular- Crohn's Mastocytosis Amyloidosis Giardiasis	Mild(4 mm) Hypoalbumin-aemia Infection	Target- Crohn's Infection Ischemia Radiation	Enlarged Lymph nodes Fat proliferation Engorged mesenteric vessels
Distal: Lymphoma GIST Carcinoid Crohn's TB	Submucosal: Edema Hemorrhage Vasculitis Ischaemia	Segmental(6-40) Ischaemia Infection Radiation Edema Crohn's Lymphoma	Asymmetrical Neoplasms	Moderate (5-9 mm) Crohn's Infection Inflammation Ischaemia	Homogenous- Lymphoma Chronic conditions: Crohn's Ischaemia Radiation	
	Serosal: Metastases Carcinoid Endometriosis	Diffuse(>40) Hypoalbuminaemia Ischaemia Vasculitis Angioedema		Marked (>10) Neoplasm	Heterogeneous Metastases GIST Endometriosis	

Crohn's disease

There are several studies proving that CT Enterography 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, CT Enterography was found to be an effective, non-invasive method of diagnosis, demonstrating 100% sensitivity and 97.2 % specificity against the reference standard of colonoscopy and biopsy. Positive predictive value was 83.3%, negative predictive value was 100% and accuracy was 97.30%. All 5 (100%) of our cases of Crohn's disease demonstrated mucosal hyper enhancement, comb sign, creeping fat sign and mural stratification. Only 2 (40%) of 5 patients demonstrated skip lesions while 3(60%) of 5 patients demonstrated an enhancing appendix. Creeping fat and comb sign were seen all 5(100%) patients of Crohn's disease, indicating that they are highly specific signs for Crohn's disease. 4 of 5 Crohn's disease patients had colonoscopy findings similar to that seen on CT Enterography, thus demonstrating that CT Enterography is comparable to ileocolonoscopy in the evaluation of this disease.

Enhancing appendix in Crohn's disease

Crohn's disease can involve the appendix and seen as a distended tubular structure with wall enhancement on CT Enterography. 3(60%) out of our 5 patients of Crohn's disease demonstrated an enhancing appendix. An enhancing appendix can therefore be a useful ancillary finding in suspected cases of Crohn's disease.

SBO Adhesions

CT Enterography is an excellent tool in diagnosis and grading of subacute intestinal obstruction caused by postoperative adhesions. In our study, CT Enterography correctly diagnosed and graded the single case of subacute intestinal obstruction caused by post-operative adhesions and did not wrongly diagnose any case of small bowel obstruction.

Ancillary findings in CT Enterography

CT Enterography is very simple noninvasive technique for overall evaluation of the abdomen and pelvis, including entire small bowel, portions of large bowel, solid organs, lymph nodes and mesenteric abnormalities that may be associated with small bowel pathology unlike BMFT which concentrates only on the intraluminal findings. 11(73.8%) out of 15 patients with small bowel pathology demonstrated ancillary findings outside the intestinal lumen in the adjacent mesentery, vessels, lymph nodes and solid organs which helped in final diagnosis. Ancillary findings like comb sign and creeping fat sign were seen in 100% of our patients with Crohn's suggesting strong association of these findings with Crohn's disease. Necrotic lymph nodes considered as highly specific for intestinal tuberculosis were found in 1 of 2 patients histopathologically proven to be tuberculosis. Thus, detection of ancillary findings increased the sensitivity, specificity and diagnostic accuracy of CT Enterography for small bowel pathology especially in differentiating the close differentials like Crohn's versus tuberculosis.

Role of incidental findings detected on CT Enterography

Although CT Enterography is a specific investigation, commonly indicated in suspected small bowel pathology, it can reveal many incidental unexpected findings. However, not all the incidental findings are clinically important and warrant further work up. In our study, 5 out of 28 patients demonstrated incidental findings that were clinically important and warranted further investigation and immediate medical attention. These critical findings included sigmoid colon malignancy, sarcoidosis and rectal tuberculosis all proven on biopsy.

CONCLUSIONS

CT Enterography can be used as the primary investigation tool in suspected small bowel pathology. With recent development of multi-detector CT, better spatial resolution and better multi-planar reconstructions, CT has become increasing popular in the evaluation of suspected small bowel pathology. Irrespective of the CT technique used, adequate bowel distension is mandatory since mural thickening is the hallmark of small bowel disease. CT Enterography with large volume of oral and intravenous contrast agent provides adequate luminal distension, separation of small bowel loops, evaluation of wall enhancement and thickness enabling high diagnostic accuracy for small bowel pathology. CT Enterography is useful in demonstrating extraenteric complications of Crohn's disease and accurately determine the severity and extent of disease. We used a "patterned approach for evaluating small bowel abnormality" to narrow the differential diagnosis along with ancillary findings in our study. Given its non-invasive and cost-effective nature, CT Enterography is particularly suitable for the long term assessment and follow-up of patients with established Crohn's disease especially when radiation dose can be significantly reduced with low-dose CT scanning techniques.

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