INTRODUCTION

The small bowel, affected by a host of pathologic conditions can be difficult and challenging to image because of its length and tortuous course. However the small bowel imaging is evolving. There was a time when small-bowel follow-through (SBFT) was the primary and only method of diagnosing diseases of the small bowel. In recent years, there has been availability of a variety of techniques such as ultrasound (US), contrast enhanced ultrasound (CEUS), computed tomography (CT), magnetic resonance imaging (MRI), computed tomography enteroclysis/enterography (CTEc)/CTEg), magnetic resonance enteroclysis/enterography (MRec/MReg) and small bowel endoscopy methods including capsule endoscopy. Digital subtraction angiography (DSA) for diagnostic purposes has in the majority of indications been replaced by CT angiography (CTA) while DSA is reserved for guidance of interventional procedures. New ultrafast techniques in MRI & Magnetic resonance angiography (MRA) using IV contrast medium are able to compete with CTA.

IMAGING MODALITIES

The different modalities in small bowel imaging are;
1. Small-bowel follow-through.
2. Enteroclysis.
3. Ultrasound, Contrast-entranced ultrasound and new ultrasound imaging modalities.
4. CT enteroclysis, CT enterography.
5. MR Enteroclysis /MR Enterography.

1. Small-bowel follow-through (SBFT)
Historically SBFT has been the standard radiologic approach used to assess patients with small bowel disease. There has been a slow and steady decline in the volume of barium studies as a whole, but the numbers of barium small bowel studies remain unchanged. In one survey, it was found out that volume of SBFT examinations was as large as or larger than the volume of SBFT examinations 5 years earlier. The dedicated SBFT has been replaced to a lesser degree by abdominal CT, MR and capsule endoscopy. It is a safe, cost-effective diagnostic test for patients with a gamut of GI conditions. Barium studies have a clear advantage over endoscopy for evaluating submucosal and extrinsic mass lesions and assessing GI function & motility. A properly conducted SBFT is a useful imaging test for CD, malabsorption, jejunal diverticulosis and other abnormalities. In daily clinical practice, the SBFT still has its place in the evaluation of the small bowel and is usually a relatively quick, non-invasive and inexpensive test to perform.

2. Enteroclysis(Conventional Enteroclysis)(CE)
In this method a nasojejunal tube under fluoroscopic guidance is introduced, getting the tip of the tube right in the duodeno-jejunal flexure. Administration of 200-250ml of barium suspension followed by 0.5% methyl cellulose through the tube is performed manually or by an automatic pump. The balloon can be administered to the duodenum to prevent reflux into the stomach. Enteroclysis or conventional enteroclysis (CE) enables optimal distension of individual small-bowel loops, to produce a trans-radiant effect for better visualization of subtle abnormalities. Enteroclysis is useful for diagnosing low-grade small bowel
obstruction, small bowel neoplasm, occult GI bleeding, celiac disease and Meckel’s diverticulum. Enteroclysis has been shown to be highly accurate, with a sensitivity of 93% and specificity of 97% in diagnosing small bowel diseases & permits detection of partly obstructive or non-obstructive lesions that may not be demonstrated with cross-sectional imaging techniques. The principal disadvantage is the limited indirect information on the state of bowel wall and extramural extension and its effectiveness may be hindered owing to overlapping bowel loops. CE is the most efficient diagnostic modality in evaluating cases of postoperative obstruction etiology, location and determination the degree of obstruction.

3. Ultrasound(US), Contrast-entranced ultrasound(CEUS) and newer ultrasound imaging modalities

Always challenging because of the gas content of the small bowel, this method is favored in pediatric gastroenterology. However US needs experienced sonographers and good co-operation with clinicians. It has the advantage of being cheap, portable, flexible and user and patient friendly. The strength of the US examination is high flexibility, repeatability, low patient risk and price in combination with good spatial and excellent temporal resolution. Gut wall masses may be intraluminal, mural or exophytic, all with or without ulceration. Intraluminal gut masses are frequently hidden by gas or luminal content. Intraperitoneal masses of varying morphology, which do not clearly arise from the solid abdominal viscera or lymphnodes, should be considered to have a potential gut origin. The role of US in the evaluation of GI tract neoplasms is similar to that of CT scan.

**CEUS** uses contrast agents of micro-bubbles made of phospholipid cells with a gaseous content. The simplest way of applying US contrast is to examine the intestinal wall 30 sec after injection with Doppler.

**Ultrasound Enteroclysis (USE)** using tap water and filling small bowel through nasojejunal tube, seems to have become the standard examination of patients with unclear conventional ultrasound. The most important fact is that, this examination significantly decreases the radiation dose while maintaining high sensitivity. This is very important in patients with CD who require repeated examinations life-long. This examination is much easier to standardize than the conventional US.

**US Enterography** with small bowel prepared by drinking 500-1000ml of water has better patient acceptance in follow-up of inflammatory diseases.

**Endoscopic Ultrasound (EUS)** in patients in whom an invasive procedure is necessary, endoscopic ultrasound with biopsy or even local resection is possible.

**Newer Modalities of US in Small Bowel Imaging:** The newer modalities such as hydrosonography, allergosonography, elastography, strain rate imaging, endoscopic sonography and nutritional imaging are also available and some of these have shown clinical benefit while others are under research & development to establish their role in the diagnostic repertoire.  

4. Computed Tomography(CT), CT enteroclysis (CTEc), CT enterography (CTEg)

The introduction of helical CT technology in 1989 and subsequently multidetector CT has changed small bowel imaging. CT has become a routine examination in the evaluation of gastrointestinal disorders because of rapid execution, its accuracy with axial images and multiplanar reconstruction. Multislice CT has improved image quality and has reduced scan times. Abdominal CT without enteroclysis/enterography is performed after ingestion of oral positive (iodine solution or barium solution) or neutral (water) contrast agent before examination. CT enteroclysis (CTEc) can be performed by using either positive enteral contrast agent without intravenous contrast agent. CTEc combines the advantage of CT and CE into one technique. CT enterography (CTEg) is an alternative technique to CTEc, where small-bowel filling is achieved with oral hyperhydration with at least 1500-2000ml of oral contrast agent. In a prospective comparison between MR enteroclysis (MREc) and CTEc, the latter showed higher sensitivity and inter-observer agreement for imaging signs of small-bowel disease. The sensitivity of CTEc for bowel wall thickening, abnormal bowel wall enhancement and adenopathy was 89%, 79% and 64% respectively. For the same signs, the sensitivity of MREc was 60%, 56% and 19% respectively. CTEc is the only study that has been found reliably to help exclude small-bowel strictures prior to capsule study. In a study of 56 patients with known CD, CTEc and wireless capsule endoscopy(WCE) both depicted a substantial number of terminal ileal crohn’s lesions, unlike those for jejunal lesions. There are some disadvantages of CTEc, the discomfort associated with nasojejunal tube placement which may be improved with local sedation and smaller tubes. The addition of CT to enteroclysis increases the cost of the procedures, and exposure of patients and staff to radiation. CTEg is recommended for
revealing congenital lesions. In patients with CD, CTEg is increasingly used to detect enteric inflammation in addition to extra-enteric complications. A lot of reports has confirmed the effectiveness of CTEc in the diagnosis of small-bowel neoplasms because of its ability to characterize the small bowel wall, its mesentery and the liver. More accurate determination of primary or metastatic lesions involving the small bowel is possible with CTEc compared with conventional CT. However, if the indication is pain or small-bowel obstruction, CT will usually be the first-line examination.

5. MR Enteroclysis (MRec)/MR Enterography (MReg)
The introduction of MRI has created an important tool for small bowel imaging too. MRI is the preferred diagnostic procedure, due to absence of radiation, excellent soft tissue resolution, its easy comparability and follow-up during whole life. In MRec, administration of 1500-2000 ml of PEG solution through the tube manually or with automatic pump is performed. Intraluminal contrast agents can be administered per orally (MReg) or through nasojejunal tube. MReg with oral contrast can be used as a diagnostic tool for evaluation of the small bowel in patients with CD and has the potential to replace CE as follow up. The most important clinical application of MRec and MReg is evaluation of CD, other form of inflammatory diseases, malabsorption syndromes, small-bowel tumors and intestinal obstruction. Another indication for MRec and MReg are the malabsorption syndrome, Whipple disease and celiac sprue but definitive diagnosis is based on biopsy. The role of MRec and MReg in detection of small bowel neoplasms has not been fully established at present, based on the limited experience with these rare tumors. MRec & MReg are very effective in diagnosing small bowel obstruction and in the cause of the obstruction-postoperative adhesions, postradiation enteropathy, peritoneal carcinomatosis, Meckel’s diverticulum, polyps and polyposis syndromes, benign/malignant stenosis.

6. Endoscopic techniques in small bowel disorders

**Esophagogastroduodenoscopy (EGD):** EGD is the initial test for revealing duodenal disorders such as ulcers, inflammation, reflux, intraluminal tumors, potential sources of obscure gastrointestinal bleeding (OGIB). Insertion of fiber-optic endoscope through the mouth is comfortable for small bowel biopsies (suspicion of celiac sprue). The jejunum and distal part of small bowel are invisible because of the limited endoscope length.

**Push enteroscopy:** Push enteroscopy is an endoscopic procedure whereby a longer endoscope is inserted into the jejunum through the mouth to evaluate a larger segment of the small bowel. The indications are: looking for the source of OGIB, tumors, inflammation, celiac sprue. This endoscope has biopsy and therapeutic capability.

**Sonde enteroscopy:** Sonde enteroscopy involves the use of a long, flexible, fiber-optic instrument propelled through the small bowel by peristalsis, this procedure may allow for viewing the remainder of the small bowel. The sonde instrument relies on a balloon placed at the instrument’s tip. Peristalsis then advances the long flexible endoscope to the distal small bowel and the endoscopic examination is performed during withdrawal.

**Double-balloon enteroscopy:** This is a new endoscopic technique for evaluating the small bowel mucosa. This technique allows for more extensive examination of the small bowel and also has therapeutic capabilities. The technique for advancement uses a push and pull method with inflation and deflation of the balloons and telescoping of the intestine onto the over-tube. Double-balloon enteroscopy can be used to perform the full range of endoscopic therapies including biopsy, stricture dilatation, foreign body removal and argon plasma coagulation.

**Intraoperative enteroscopy:** Intraoperative enteroscopy during laparotomy may be used in patients with suspected OGIB. Endoscopic evaluation has been performed orally, rectally, or through enterostomies at the time of laparotomy.

**Ileocolonoscopy:** The colonoscope is 200 cm in the length and it is inserted rectally. Retrograde approach through ileocaecal valve to distal ileum allows evaluation of the most distal part of the small bowel. It has biopsy capability.

**Wireless capsule endoscopy (WCE)**
For this, the patient swallows a small capsule measuring 2.6cm in length by 1.1cm diameter which collects intraluminal images of the mucosa at a rate of two images per second. Capsule endoscopy is used when CD is suspected and ileocolonoscopy and SBFT are negative. It has also been used in chronic diarrhea, malabsorption and polyposis surveillance. However, capsule retention (by strictures) and localization may present problems and there is a significant false positive rate; approximately 14% of small bowel abnormalities on capsule endoscopy.
ANALYSING IMAGING PATTERNS IN SMALL BOWEL DISEASES

The small bowel can be affected by a wide range of pathological processes including inflammation, infection, malignancy, malabsorption, ischaemia, obstruction and malrotation. Although the techniques used to investigate the small bowel are changing, the basic principles of lesion analysis within the small bowel can be applied to all modalities - barium, US, CT, MR or endoscopy. The radiologist needs to assess for changes in caliber or contour, fold pattern, thickening or nodularity and the presence of focal lesions - single or multiple. CT/MR signs of CD include bowel wall thickening, hypervascularity - either of the bowel wall or in the adjacent mesentery ‘comb sign’: fatty proliferation of the mesentery, increased size and number of lymph nodes, fistulation and abscess formation. Analysing of the spectrum of changes in the small bowel fold pattern requires an assessment of the extent and distribution of the changes. Thickened folds can be due to a number of pathological processes including cellular infiltrate, bleeding into the bowel wall or edema. Fold thickening that is straight and diffusely distributed is seen in hypoalbuminaemia, portal hypertension and in gastroenteritis. Straight, segmental fold thickening has been termed ‘stack of coins’ and may be due to ischaemia, vasculitis, haemorrhage or radiation. This pattern of thickening has also been seen in graft-vs-host disease and in small bowel lymphoma. Where the fold thickening is irregular and segmentally distributed then the most obvious cause is CD. However, lymphoma, TB and Yersinia of the terminal ileum can also give this picture.

CONCLUSION

Small bowel imaging is changing and expanding but the underlying pathology remains the same. It is essential to understand the underlying condition before deciding an appropriate modality of imaging. A dedicated SBFT remains a useful and inexpensive imaging test for the diagnosis of many small bowel disorders and should not be discarded in favor of CT or MR unless there are specific indications for these investigations. US and MREg are method of choice for imaging small bowel diseases in pediatric populations. US and CEUS are methods of choice especially in inflammatory cases. Abdominal CT can reveal exactly: congenital lesions, hernias, polytraumatic abdominal conditions, obstructive small bowel diseases. Conventional enteroclysis is replaced with new cross-sectional imaging techniques like CTEc/CTEg or MRec/MREg. Comparing endoscopic and radiologic approach, radiologic techniques are less invasive for patients, they take less time to investigate with possibility of imaging the entire small bowel. Some of them do not have any radiation exposure (US, MR). Endoscopy is preferable as first line for ulcers and bleeding.

REFERENCES