

Emerging Trends in Medical Imaging for Precision Evaluation of Crohn's Disease: A Critical Review

Authors:

Simran Tariq¹, Ather Ali¹, Anamika Tiwari¹, Amit Pratap Singh Chouhan¹, Ankush Verma¹, Vandana Singh^{2*}

¹Department of Radiology, Sharda School of Allied Health Sciences, Sharda University.

²Department of Microbiology, Sharda School of Allied Health Sciences, Sharda University.

*Corresponding Author:

Vandana Singh

Department of Microbiology, Sharda School of Allied Health Sciences, Sharda University.

Article Received: 14-May-2024

Revised: 04-June-2024

Accepted: 24-June-2024

ABSTRACT:

Crohn's disease is particular kind of an inflammatory intestinal or bowel disease (IBD) which causes persistent swelling or inflammation of digestive tract or lining. It can be any part of gastrointestinal path, which involves mouth up to anus, might experience inflammation. Chron's disease typically affects the terminal ileum and colon. It cannot be reversed or cured once it has started in a patient, although the symptoms can be managed with medicine. Early warning indications include tiredness, fever, appetite loss, pain in the abdomen, joint pain, red skin pimples, and in most cases, those with Crohn's disease there is presence of Fistula, abscess, or strictures. Although it can arise at any age, the most common age range is between 15 and 35. When assessing Crohn's disease, the capabilities of several imaging techniques are crucial. We make use of imaging techniques like CT, MRI, PET, PET/MRI, and CT/MRI as well as other imaging modalities. A CT scan can assess gut participation and extra luminal pathology, such as abscesses, GI tract blockages, and fistulas between the GI tract and any other body part or cavity of body. MRI is now the main tool used to assess CD. MRI frequently shows little bowel motion. In individuals with IBD, PET scans are utilized to assess the locations of active inflammation. For optimum results, a PET scan is paired with an MRI or CT scan. CD can be prevented naturally by eating a balanced diet low in fat and high in fibre, refraining from smoking, managing stress, and engaging in regular exercise.

Keywords: Crohn's Disease, Gastro-intestinal Tract, Inflammatory Bowel Disease, Auto-immune disease, terminal ileum, Fistula, Stricture, Abscess.

INTRODUCTION:

A scientist namely Dr. Burrill Crohn first picked out Crohn's disease in 1932 after discovering a link among inflammation in the intestines and a specific type of arthritis. The illness was first referred to as "regional ileitis" before being dubbed "Crohn's disease" in his honour. An inflammatory ailment that can affect any area of gastrointestinal (GI) tract, which includes whole esophagus to stomach and also small intestines, large intestines, rectum, and anus, can be called as Crohn's disease (CD). The inner layer of digestive tract becomes inflamed as a result of this chronic illness. It is an autoimmune illness, which means that normal tissues and cells in the GI tract are wrongly attacked by the body's immune system. It is form of inflammation in bowel which can result in intestinal obstructions, ulcers, and fistulas, which can cause abdomen pain, diarrhoea, losing weight, appetite loss, bleeding via rectum, and malnutrition. Patient's signs and medical history, as well as testing in the

laboratory, endoscopy, imaging tests, and biopsy, are frequently used to make diagnoses of Crohn's disease. Additionally, CD can cause extra-intestinal symptoms such skin rashes, eye inflammation, and joint pain. Around the world, CD is becoming more common, and the number of Americans who have the disorder is thought to be as high as 2 million. In order to give the best care possible for CD, it is crucial to identify and monitor the condition. Although CD can affect anybody, it is more prevalent in adults around the years of twenty and forty. Individuals of Northern European ancestry and those with a family record of the disease are more likely to experience it.(Roda *et al.*, 2020)

Non-invasive imaging tests including CT, MRI, and PET scans are secure and easily tolerated by patients. Because the symptoms of Crohn's disease frequently resemble those of other illnesses, a proper diagnosis can be challenging. The breadth and seriousness of the disease can be assessed, aeffectiveness of the treatment

is assessed as well, using an imaging investigations which includes MRI, computed tomography (CT), and PET scans. These methods analyse the diagnostic precision of these imaging methods for Crohn disease and potential for early detection and treatment of Crohn disease. It is an important thing to think about benefits and drawbacks of each technique and how they might be used to produce the most precise evaluation of CD activity..(Roda *et al.*, 2020)

There are various manifestations of Crohn's disease: When just the colon or intestines having larger lumen,

are affected, the condition is called as Crohn colitis as well as granulomatous colitis, however when only the small intestine is affected, the condition is known as Crohn enteritis. The last part of small intestine is called the ileum, is area that is most frequently impacted by Crohn's disease. Crohn ileitis is the name for an active condition or pathology in this region and It is known as Crohn enterocolitis (or ileocolitis) when both the small and large intestines are affected. (Atreya *et al.*, 2022)

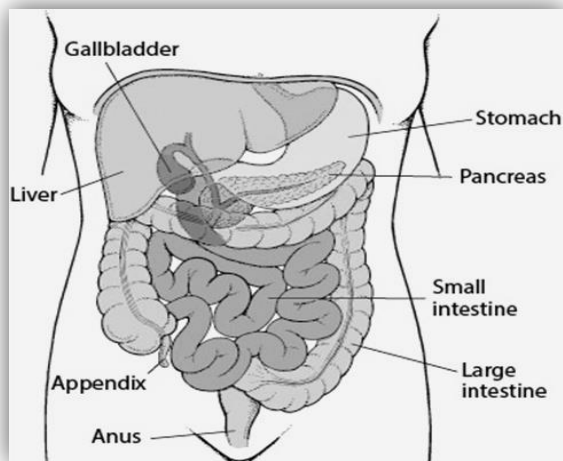


Fig.1 Abdominal organs(Roda *et al.*, 2020)

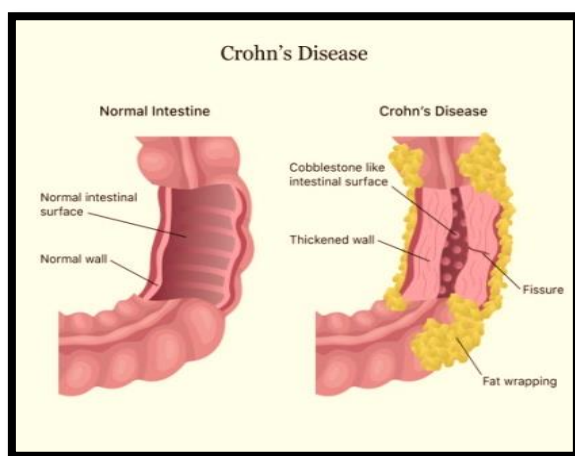


Fig.2 Normal intestine and intestine with crohn’s disease (Bettenworth *et al.*, 2019)

Anatomy of intestines:

The digestive system includes the intestines, which are in charge of absorbing nutrients from meals and removing waste. The small intestinal tract and the large intestinal tract are the two primary types of intestines.

Small intestine:

Duodenum, Ileum and jejunum, are main three segments that make up small sized intestine. Stomach passes half crushed food to duodenum, the initial

section of small intestine. Majority of the nutrients that come from food are absorbed by jejunum, that makes second segment of small sized intestines. Small lumen intestine's ileum, which is its last section, is where the last of the body's nutrients, such as bile salts and vitamins B12, are absorbed. Villi, which are many folds in the small intestine's walls, improve the intestinal surface area used for absorption. Blood and lymphatic vessels can be found inside each villus, which aid in the delivery of vital nutrients through them to other parts of the body.(En, 2002)

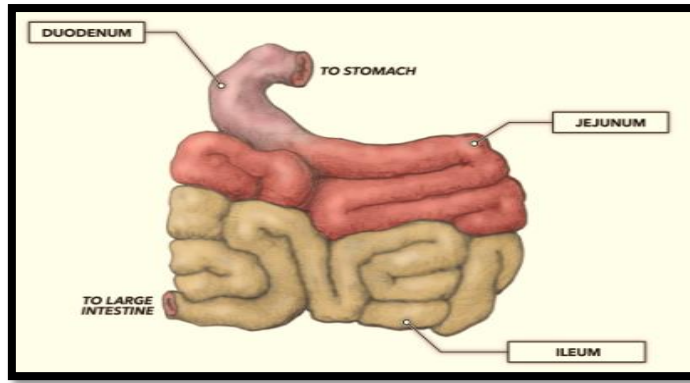


Fig.3 Showing Small Intestine (Bettenworth *et al.*, 2019)

Large intestine:

Ascending colon, first part, transverse colon, second part, third part that is descending colon, and final part that is sigmoid colon are the four segments that form large intestines, generally known as colon. The large intestine takes the digestive waste from the small intestine, eliminates the water and electrolytes, and then secretes solid faeces. Although the big intestine has more circumference as that of small intestine, it

has smoother, less-folded walls. Additionally, it has a lot of bacteria that aid in the digestion of undigested food and the production of vital vitamins such as vitamin K and several B vitamins. The large intestine's rectum, which is the last segment, retains the final product of food which is of no use and is complete wastage till that is expelled through body by the help of an opening in the body which is called as anus. (En, 2002).

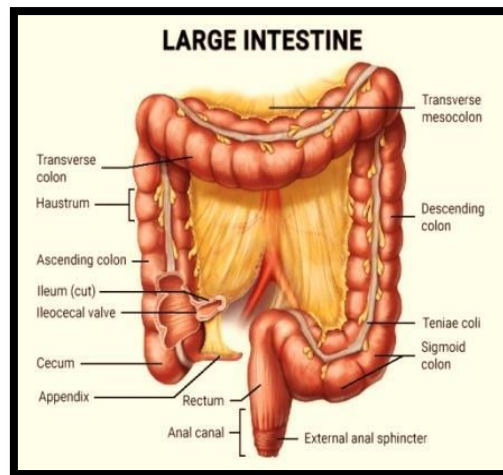


Fig.4 Showing Large Intestine (Bettenworth *et al.*, 2019)

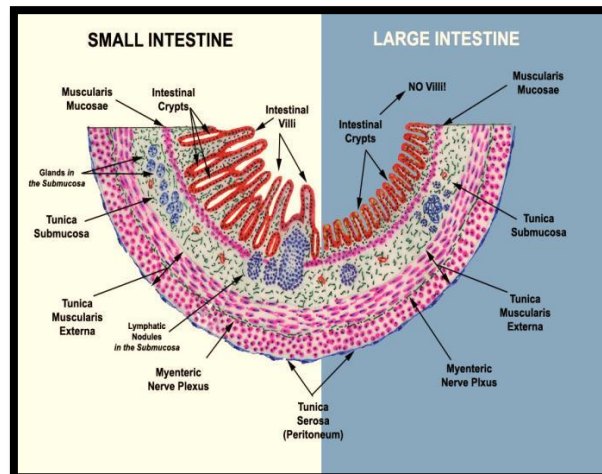


Fig.5 Difference in the structure of small intestine and large intestine (Atreya *et al.*, 2022)

Types: Crohn's Disease:

Chron's disease is classified into two major types: Ileocolitis and Colitis.

1. Ileocolitis:

Both the small intestines (ileum) and large intestines (colon) are both inflamed in the most prevalent form of Chron's disease, known as ileocolitis. Crohn's disease most frequently manifests as ileocolitis. Ileitis: the lining of small sized intestine (ileum) swells so becomes inflamed. Innermost layer of gut develops aphthous ulcers, which are tiny, dispersed, shallow crater-like patches (erosions). In more extreme situations, deeper and wider ulcers can

form, leading to stiffness and scarring as well as possible intestinal constriction and obstruction. Deep ulcers have the potential to pierce the gut wall, causing peritonitis and infection of the organs nearby as well as the abdominal cavity. It can be accompanied with reddish sensitive skin nodules, joint, spine, eye, and liver inflammation, as well as symptoms including pain in the abdomen, diarrhoea, weight loss, exhaustion, anaemia, and fever. X-rays, MRIs, CTs, and colonoscopies are frequently used to make diagnoses. Anti-inflammatory, immune-suppressing, or antibacterial drugs are used as part of the treatment. In severe circumstances, surgery may be required. (Pariente *et al.*, 2011).

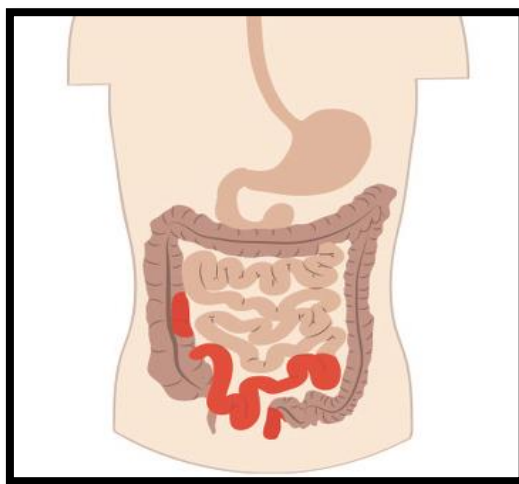


Fig.6 Location of Ileocolitis in small intestines and large intestines(Pariente *et al.*, 2011)

2. Colitis:

Chron's disease can manifest as colitis, a less prevalent type of the condition that only affects the colon. Abdominal discomfort, bloody diarrhoea, fever, exhaustion, a persistent urge to urinate (tenesmus), dehydration, and anaemia are some of the symptoms that are linked to it. The majority of the time, colitis's root cause is unknown. Colitis can be brought on by parasitic or viral infections, bacterial food poisoning like Crohn disease may be ulcerative colitis or ischemic colitis, radiation colitis, in infants, pseudomembranous colitis brought on by the infection with *Clostridium difficile* (now known as *Clostridiodes difficile*).

The main purpose of a sigmoidoscopy with flexibility or colonoscopy is to assess colitis. A flexible tube is placed through the rectum during this procedure to inspect the colon. During the examination, biopsies are performed. Biopsies could reveal inflammatory-related alterations. This aids in identifying the origin of colitis. Non-invasive methods used to screen for inflammation, damage, and any form of obstruction include abdominal CT, abdominal MRI, and abdominal PET. Additionally, barium enema is used to identify the pathology. (Pariente *et al.*, 2011)

Prognosis:

Depending on the underlying cause it is evaluated Crohn's disease as well as ulcerative colitis can both typically be managed with medication. Ulcerative colitis is a chronic disorder with no known treatment. Surgery to remove the colon can be used to treat it if it cannot be controlled. With the right medications, colitis caused by viruses, bacteria, and parasites can be treated. Antibiotics used appropriately can usually treat pseudomembranous colitis.

Complications:

Having bleeding bowel motions Colon perforation, toxic megacolon, and sore (ulcer).

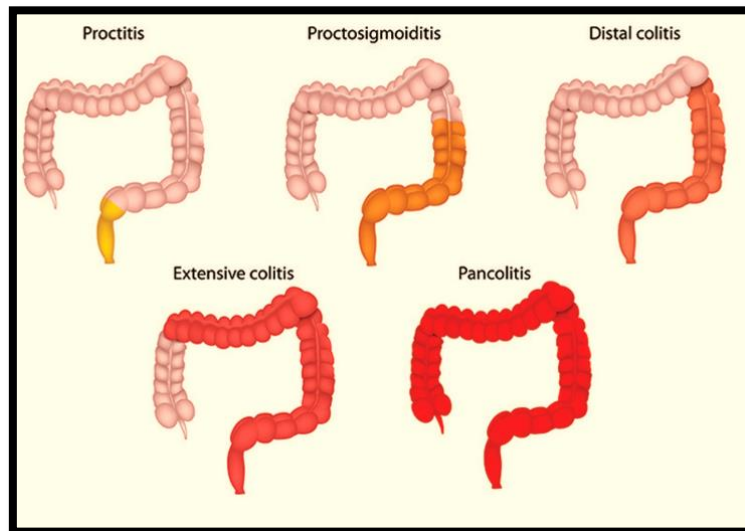


Fig.7 Types of colitis according to the part being affected(Pariente *et al.*, 2011)

➤ **Subtypes of Chron’s Disease:**

In addition to ileocolitis and colitis, Chron’s disease can also be classified into several subtypes, based upon destination and seriousness of inflammations in lining of intestines either small or large ones.

Ileitis:

Ileitis is a kind of Chron's disease that only affects the small intestine and is characterised by inflammation. To be more specific, the word describes the inflammation of the ileum, which is the lower or terminal part of small intestines. The regional ileitis or Crohn's disease, is a particular and more severe type of inflammation affecting the large as well as the small

intestines. Ileitis can generally affect people of all sexes and ages, however it most frequently affects people between years of 20 and 50 age . Although symptom of Crohn's disease is extremely diverse, it primarily include chronic or irregular diarrhoea, sometimes bloody, which is accompanied by uncomfortable abdominal cramps. A high fever, weakness as such, loss of weight, and anaemia can happen as well and cause a patient's physical condition to progressively deteriorate. Additionally, obstruction or fistula (abnormal channels) between neighbouring gut loops might form. Ileitis's first acute bout can come on suddenly enough to be mistaken for appendicitis. (En, 2002).

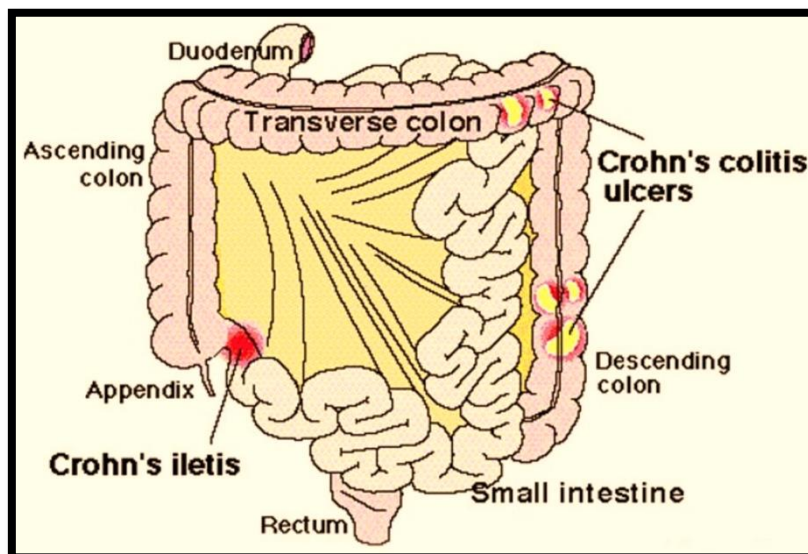


Fig.8 Crohn’s Ileitis (Pita and Magro, 2018)

The gut becomes thicker, its channel becomes narrower, and its lining becomes ulcerated as a result of Crohn's disease. Through X-ray assessment of the

small (in addition to maybe large) intestine, when the constriction and ulceration are obvious, the condition is diagnosed. The large intestine can also be examined

using a colonoscopy. To assess ileitis, non-invasive methods including CT, MRI, and PET are employed. Gastrointestinal infections, irritations, or blockages may result in simple ileitis. Most likely, immune system anomalies are what cause Crohn's disease. Very few patients having Crohn's disease will need surgery, either to repair problems like obstruction or fistula or to alleviate difficulties that do not improve with medication. Several medicines are successful in treating Crohn disease. (En, 2002)

Gastroduodenal Crohn's Disease:

An instance, Crohn disease known as gastroduodenal disease is characterised by inflammation action on stomach and duodenum, discomfort in abdomen, nausea, vomiting, weight loss, and anaemia are some of prime signs or symptoms of gastroduodenal Crohns disease. To further evaluate patient's signs , different techniques and imaging studies may be used.(Lightner, 2018)

Upper endoscopy:

This procedure involves inserting a small fiber-optic camera via the mouth to examine the oesophagus,

stomach, and duodenal. A biopsy is performed in addition to inspecting the GI tract tissues to assess the pathology, taking a tiny tissue sample for additional testing to validate the diagnosis.

Colonoscopy:

Although gastroduodenal Crohn's is seldom isolated, a colonoscopy, which involves inserting a flexible fiber-optic probe through the anus to inspect the colon, can be done to ascertain whether the lower GI tract is affected, is an option.

Computed Tomography (CT):

CT scan can be requested in order to find any region of inflammation, hemorrhage, or blockage in the intestines. There is also other imaging tests performed, including MRIs (magnetic resonance imaging). However, the most popular and often used methods for identifying gastroduodenal Crohn's disease continue to be an endoscope, colonoscopy, and CT scans.

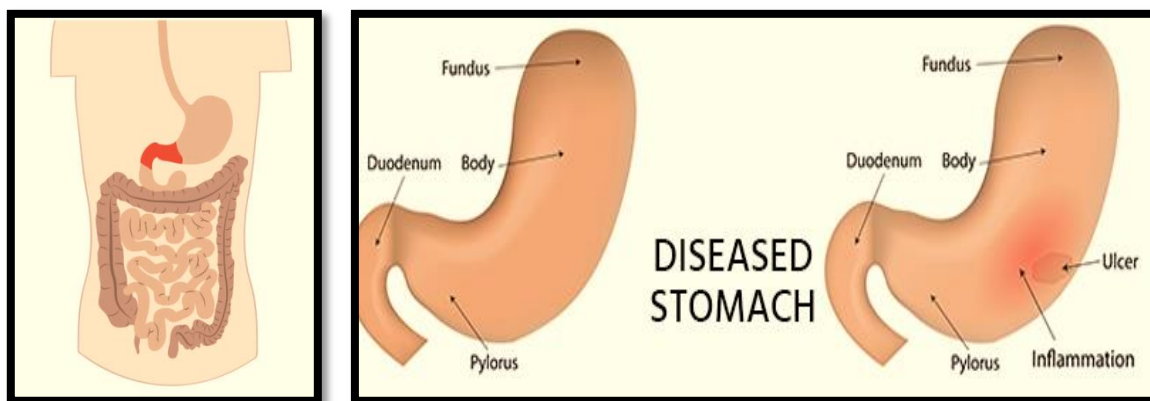


Fig.9,10 Gastroduodenal Crohn’s disease involves end part of stomach and starting part of duodenum (Lightner, 2018)

Jejunioileitis:

Chron's disease has a subtype known as jejunoileitis, which is characterised with inflammation of jejunum. Jejunoileitis signs or symptoms include anaemia, weight loss, diarrhoea, and stomach pain. It is a type of inflammatory intestine or bowel disease (IBD) in which a a set having disorders that are chronic and lifelong and currently incurable. (Al-Hawary, Kaza and Platt, 2013)

Complications:

Malnutrition: Nutritional deficits and malnutrition can affect a child's growth.

Fistulas: Inflammatory abscesses or fistulas can develop in the abdomen. A canal that forms between two organs to connect them is known as a fistula. Based on wherever the fistula connects, there are numerous different varieties. Approximately 1 in 3 Crohn's patients eventually have fistula development.

Strictures: Due to scar tissue from chronic inflammation, the colon's wall may thicken with time. As a result, the intestine may become partially or completely obstructed, slowing or halting the passage of food or faeces through the intestines. Complete intestinal obstructions are potentially fatal and frequently call for surgery.

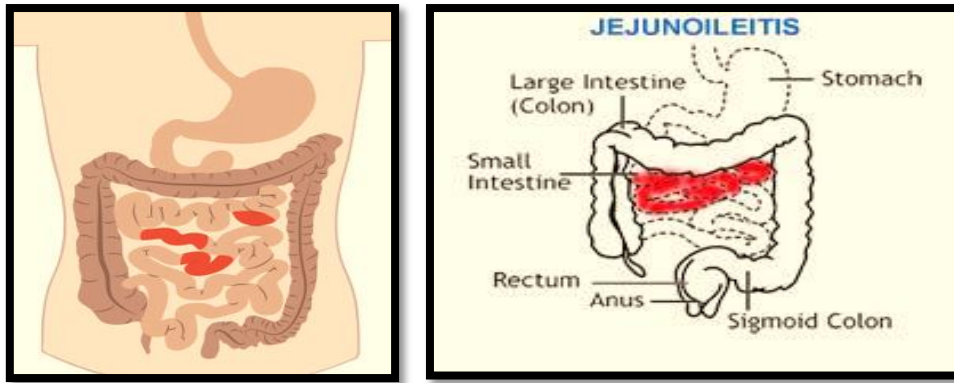


Fig.11, 12 Images showing Jejunoileitis (Signore *et al.*, 2017)

Ileocecum crohn’s disease:

Ileocecal is final portion of ileum, or small diameter intestines, and the beginning of cecum, or large intestine are both prone to inflammation in Crohn's disease, a kind of Chron's disease. the signs of ileocecal Abdominal discomfort, diarrhoea, weight loss, exhaustion, anaemia, and bottom right side of the abdomen are all symptoms of Crohn's disease,

particularly after eating. Crohn's disease showing its effect in the ileum is frequently referred to as "terminal ileal", because it affects the terminus, or terminal, of ileum. Ileocecal Crohn's is the name given to the condition if it impacts the very start of the large bowel. One among the most popular kinds of CD is this one.(Wagner *et al.*, 2018)

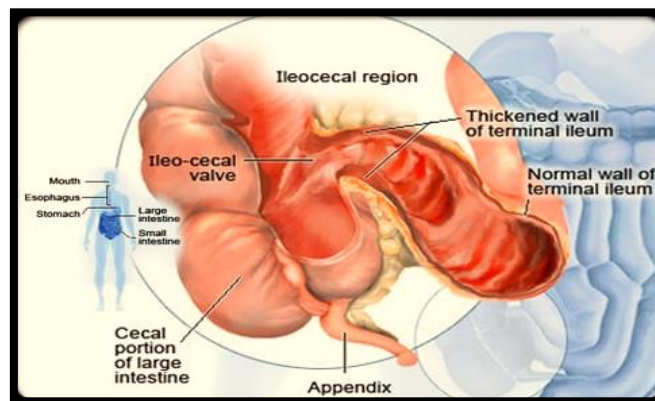


Fig.13 Thickened wall of Ileocecal region(Wagner *et al.*, 2018)

Granulomatous Crohn's Disease (CGD):

Granulomatous Granulomas, or cell clusters, are an indicator of one type in Crohn's disease, that attacks intestines. Nausea, abdominal pain with diarrhea so having weight loss, which results in different malfunction and anaemia are all signs of granulomatous crohn's disease. Granulomas thought having distinguishing characteristic of a CD microscopic diagnosis, yet they are only seen in 40–60% of surgically removed bowel portions in CD patients. A histological structure of a tissue reaction called granulomatous inflammation arises after cell damage. There are many different circumstances that can lead to granulomatous inflammation, including infections, autoimmune diseases, toxic substances, allergic reactions, pharmacological interactions, and cancer. Some strains of bacteria and fungus are resistant to the phagocytes, immune system cells, in

people with CGD. Long-lasting (chronic) and recurrent (recurrent) infections are brought on by this condition. Oftentimes, the disease is identified quite early on in childhood. Diagnoses for milder versions may occur in adolescence or even as an adult. A stem cell transplant may be able to treat CGD. (Steckstor *et al.*, 2013).

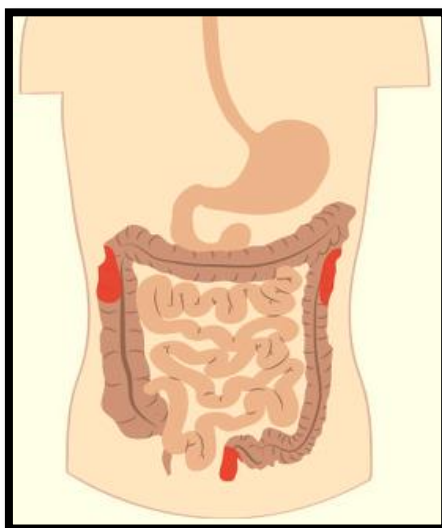


Fig.14 Usual Location of Granulomatous Crohn's Disease (Steckstor *et al.*, 2013)

Fistulising crohn's disease:

A kind in Crohn's disease known as fistulising disease is characterised by the development of fistulas (irregular linkages between organs or arteries). Fistulizing Crohn's disease symptoms include anaemia, weight loss, diarrhoea, and abdominal pain. Fistula formation is predisposed by Crohn's disease's transmural inflammatory process. Fistulas are a symptom that the transmural infection has reached the nearby organs, tissues, or skin. Fistulas are categorised according to where they are located and how they link to adjacent organs.

1. Fistulas are classified as **internal** if they open into neighbouring mesentery or external if they open into nearby enteroenteric, enterovesical, ileocolic, gastrocolic, or rectovaginal organs.

2. **External** fistulas that end on the patient's body's surface, such as enterocutaneous, parastomal, or perianal.

People having Crohn's disease, abscesses and fistulas may coexist or one may come after the other. These 2 patho-physiologies are not fully known, however it is thought that they share some similarities. External fistulas are frequently accompanied by localised discomfort, drainage, and the potential for abscess formation (most frequently enterocutaneous or perianal). Internal fistulas, however, may not be symptomatic and go unnoticed. Internal fistulas can be "major" like an ileoileal or ileocecal fistula, which typically do not cause significant symptoms and are frequently asymptomatic or "minor" (like gastro-colic fistula, that has the ability to trigger **short gut syndrome** by eliminating the vast majority of luminal gastrointestinal tract). (Lung and Ng, 2017).

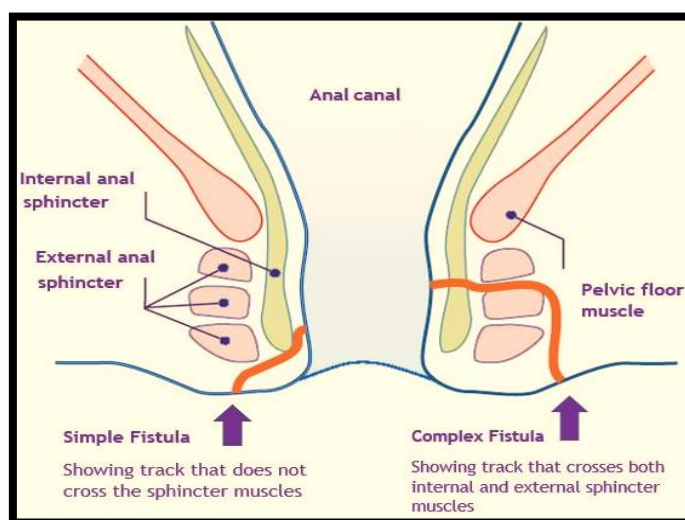


Fig.15 Fistulising Crohn's disease(Lung and Ng, 2017)

Perianal Crohn's Disease:

Inflammatory action of the tissues surrounding the anus is a characteristic of disease variant referring to perianal Crohn's disease. Around the anus, itching, redness, and swelling are signs in perianal disease. Symptoms, being present in this kind of disease namely perianal Crohn disease are felt around the anus, include heightened bowel urgency, bowel incontinence, anal bleeding, itching or soreness in the anus, and mucus or pus-like discharge. Over time, peripheral Crohn's disease may cause more symptoms. Treatment can help perianal Crohn's disease symptoms and lower the likelihood of these symptoms.

Advanced symptoms of perianal Crohn's may include:

Advanced perianal Crohn's symptoms can include:

1. Abscess: A bacterial infection causes an abscess, which is a tiny pocket filled with pus. It may develop in the gut wall.
2. Ulcer: Any open wound on the surface of the skin is referred to as an ulcer.
3. Skin tag: Skin tag involves a little expansion of extra skin.
4. Fissure: Fissure is break or tear in your anal canal's lining.
5. Fistula: Fistula is passageway that develops between two organs. This connects the organs and may result in a number of issues.
6. Rectal stricture: Stricture develops when persistent inflammation-induced scar tissue completely or partially obstructs the anal or rectal opening. Strictures frequently call for surgery. (Lung and Ng, 2017).

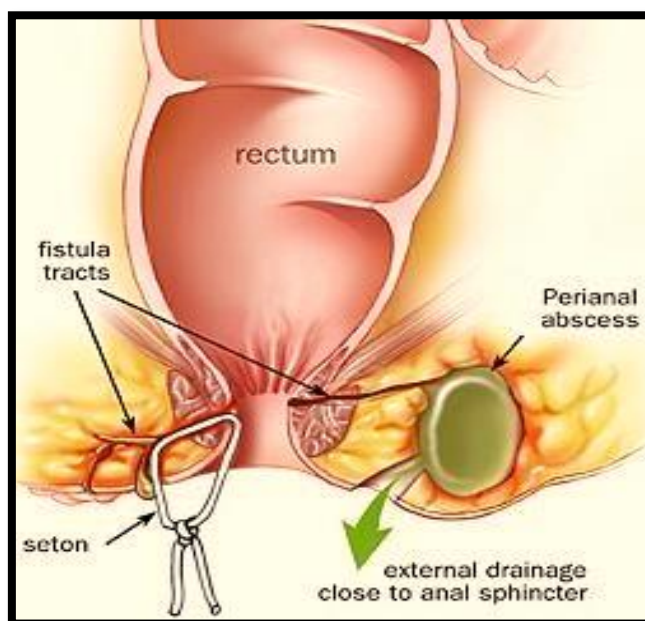


Fig.16 Perianal Crohn's Disease(Lung and Ng, 2017)

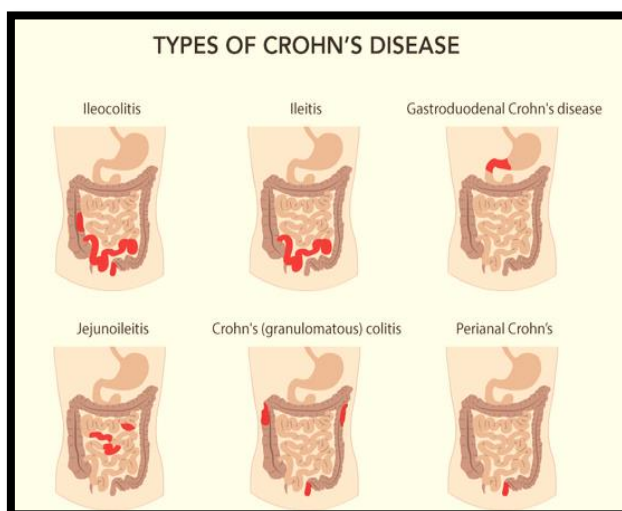


Fig.17 Different images showing different locations of Crohn's disease (Lung and Ng, 2017)

Role of Medical imaging used in evaluation of Crohn's disease:

Endoscopy:

Along with additional tests like blood testing, bowel tests, and imaging tests, endoscopy is a typical diagnostic method used to identify Crohn's disease. A tiny, flexible tube having a camera on the end is introduced through the mouth or an opening in the skin during an endoscopy and guided along the digestive system. This enables the physician to collect tissue samples for subsequent examination and visually inspect the digestive tract lining. Endoscopy helps in

evaluation of Crohn's disease seriousness and helps pinpoint the location and degree in inflammation. Additionally, it can be used to track the success of therapy and spot any side effects like fistulas or strictures. For Crohn's disease, endoscopy procedures such as upper endoscopy, colonoscopy, and sigmoidoscopy are used to check esophagus up to stomach, as well as top part of small diameter intestine, as well as large intestine so bottom section in small intestines. Various forms of endoscopy can be performed to diagnose and treat Crohn's disease depending on the specific circumstances. (Benitez *et al.*, 2013).

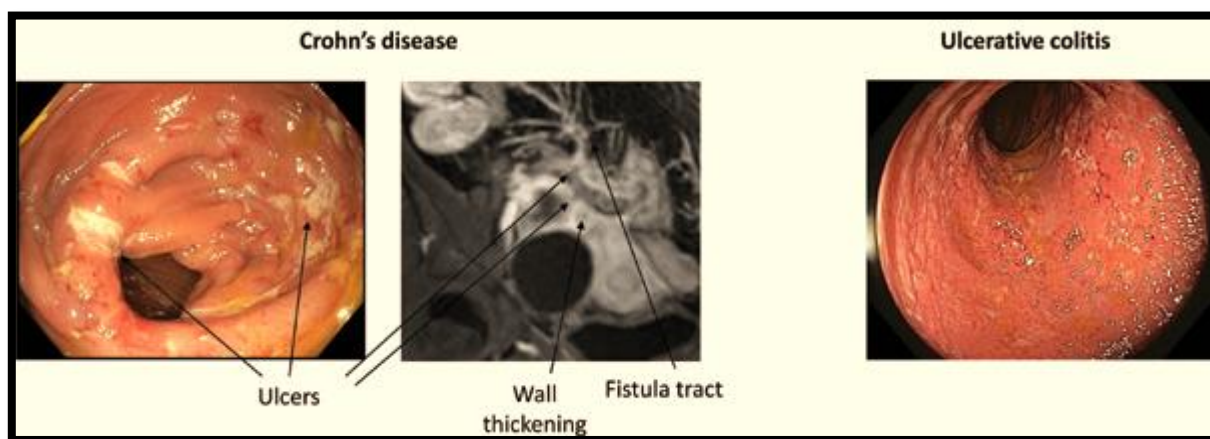


Fig.18 Endoscopy showing Crohn's Disease (Benitez *et al.*, 2013)

Endoscopy with biopsy:

During the endoscope, the physician may remove biopsies, or small tissue samples, from regions that seem inflamed or abnormal. These biopsies are read via microscopy so as to evaluate degree or level of severe inflammation and to verify the medical diagnosis of Crohn's disease. Endoscopy combined

biopsy can also assist in locating any Crohn's disease-related complications, like fistulas or strictures, and track the efficacy of treatment over time. Overall, the use of endoscopy with biopsy in diagnosing and treating Crohn's disease results beneficial and efficient. (Benitez *et al.*, 2013).

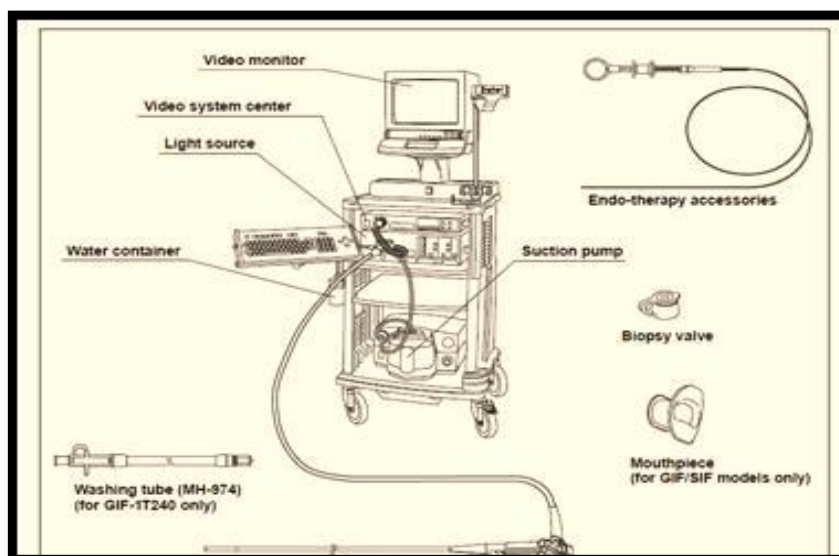


Fig.19 Endoscopy with biopsy (Benitez *et al.*, 2013)

Ultrasound (USG):

A type of diagnostic imaging called ultrasound can be used to assist identify Crohn's disease. High-frequency waves of sound are employed during an ultrasound to provide images of the inside organs and tissues. This can assist in identifying regions of inflammation, thickness, or narrowing in the intestines' walls, which are typical indicators of disease. When looking into Crohn disease consequences such bile duct inflammation or small intestine obstruction, ultrasound

can be especially helpful. It is additionally feasible to keep track of how well a treatment is working and to see if the condition has changed over time. It's crucial to remember that ultrasonography may not always offer accurate diagnosis and that additional imaging procedures might be required. The best tests will be chosen by doctor based on your particular circumstances. (Bruining *et al.*, 2018).

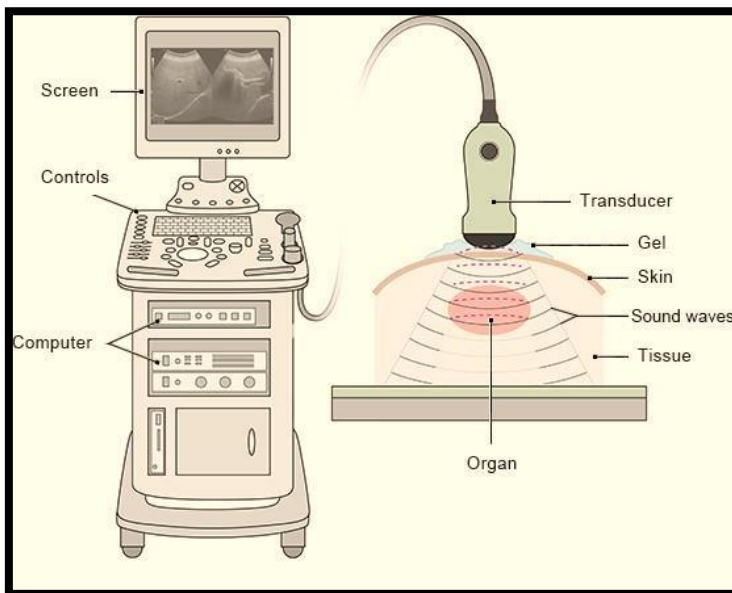


Fig.20 Ultrasonography system(Bruining *et al.*, 2018)

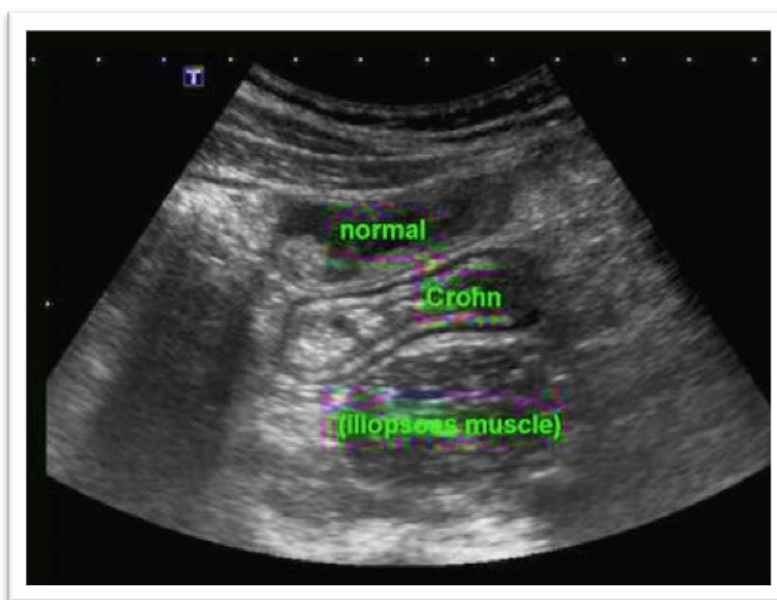


Fig.21 USG showing crohn's disease(Bruining *et al.*, 2018)

CT Scan:

X-rays are used in a CT scan, a form of imaging research, to produce a fine-grained cross-sectional picture of the body. CT enterography is used to diagnose Crohn's illness. It is non-invasive process that is frequently used to check the pelvis and abdomen for

indications of Crohn's disease. The CT scan can find abscesses, strictures, fistulas, ulcerations, and inflammation. The structure of the small intestine and other organs in the belly and pelvis can be seen in great detail thanks to CT scans, which are non-invasive. The location, size, and sequence of

inflammatory conditions, along with the severity of tissue damage, can all be better understood by doctors using a CT scan to determine the disease's extent. Since CT may identify symptoms of an active disease, such as small-intestinal thickness, mesenteric thickening, and mesenteric fat stranding, so it is very useful in diagnosing Crohn's disease. Combining CT with additional imaging modalities improves the accuracy in diagnosing Crohn's disease. Additionally, using intravenous contrast agents and 3-dimensional reconstruction techniques improves CT accuracy. Due to its good availability and superior contrast resolution, CT is the imaging method that is most frequently utilised for the examination of CD. Detecting and quantifying disease activity such as difficulties with abscesses, strictures and fistulae, are among the benefits of CT in CD evaluation.(Al-Hawary, Kaza and Platt, 2013)

Typically, a radiologist will examine the pictures to search for indications of Crohn's Disease, such as intestinal constriction, ulcers, and regions of inflammation or scarring. Potential problems like abscesses, fistulas, and obstructions can be found using the CT scan. A CT scan is used for purposes other than diagnosis. They may also be employed to support therapy selection decisions.

Advantages: Benefits: The primary benefit of CT scans is their capacity to present a thorough image of the region that has been impacted. The scan is frequently used to assess the severity of the disease because it can pick up on minute details that might not be seen on a conventional X-ray. Additionally, CT scans can be completed quickly, easily, and without any additional preparation.

Disadvantages: Radiation is used in CT scans, which can damage the body and raise the chance of cancer. A contrast dye must also be injected prior to the scan, which could have negative side effects include nausea and allergic responses. The primary drawback of CT is its incapacity to tell active illness from scarring. Additionally, due to the size of the small bowel, CT cannot be used to diagnose small bowel Crohn's disease.

General Patient Preparation for CT scan:

History of patient is taken, contrast media allergies checked, whole procedure explained to patient, consent form signed from patient or attender, metallic objects removed from area of interest, if female patient ask for last menstrual period (LMP), hospital gown is provided to patient. Patient is advised to hold his breath during the procedure (if necessary).



Fig.22 Computed Tomography system (Al-Hawary, Kaza and Platt, 2013)

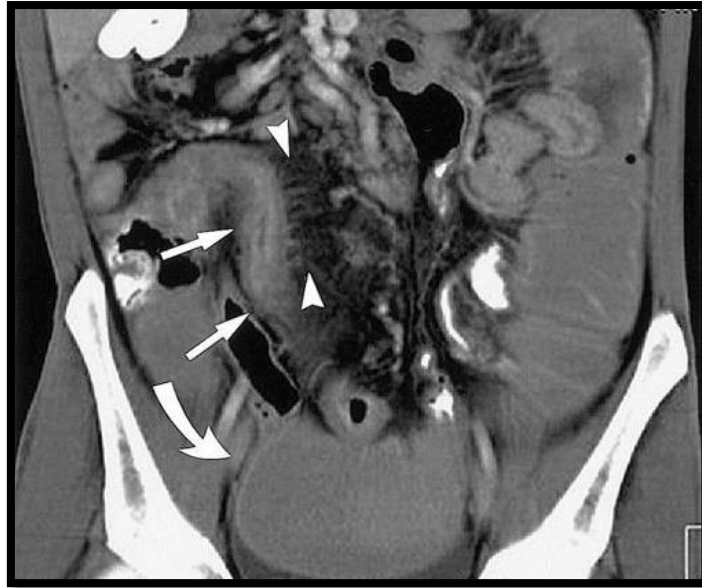


Fig.23 Coronal view of lower Abdominal region(Arrows showing abnormality) (Al-Hawary, Kaza and Platt, 2013)



Fig.24 Axial view showing traces of crohn's disease(Al-Hawary, Kaza and Platt, 2013)

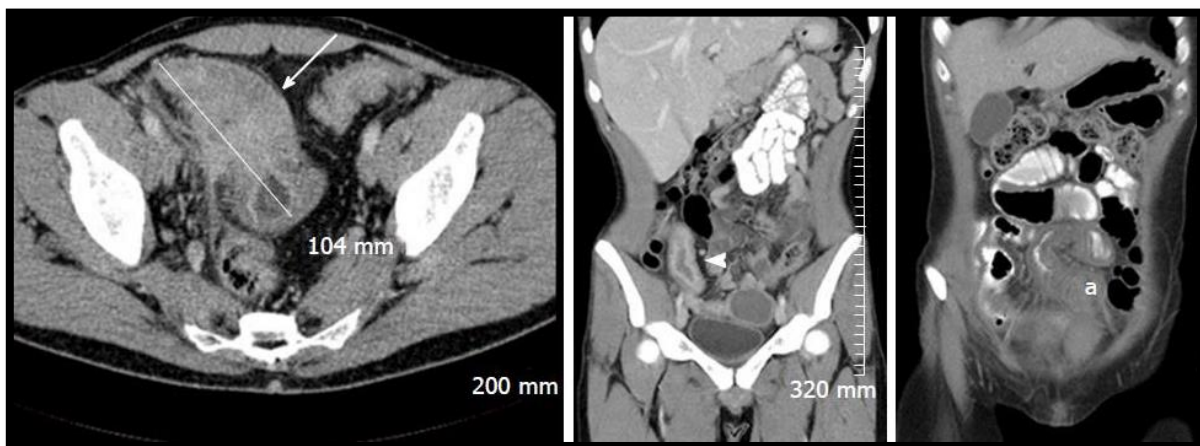


Fig.25 axial, coronal and sagittal views confirming pathology related to intestines (Benitez *et al.*, 2013)

MRI:

A specific kind of imaging test called an MRI combines powerful field of magnet with radio wave so that production of comprehensive pictures of human body. Its sensitivity is greater than other scans like CT scan so is capable of picking up on minor details like fistulas and micro-perforations. Additionally, it aids in determining the severity of the illness and associated repercussions. A common imaging technique for assessing people with Crohn's disease is magnetic resonance imaging (MRI) enterography. The small intestine and other organs can be seen in great detail on an MRI of the pelvic and abdomen. Doctors can use it to better comprehend the disease's scope and spot any potential problems. An MRI can be used to find

abscesses, ulcers, fistulas, ulcers, and areas of intestinal constriction. Additionally, is employed in tracking progression of the Crohn's disease over time. An MRI can be used to find abscesses, ulcers, fistulas, ulcers, and areas of intestinal constriction.(Bruining *et al.*, 2018)

General Patient preparation of MRI:

No metallic implants should be present in patient's body, all the metal objects with patient are removed outside the MRI room. History of patient is taken, contrast media allergies checked, immobilization devices used, consent form taken from patient or attender. Risk versus benefit is explained to patient.



Fig.25 Magnetic Resonance Imaging (MRI) machine (Makanyanga *et al.*, 2017)

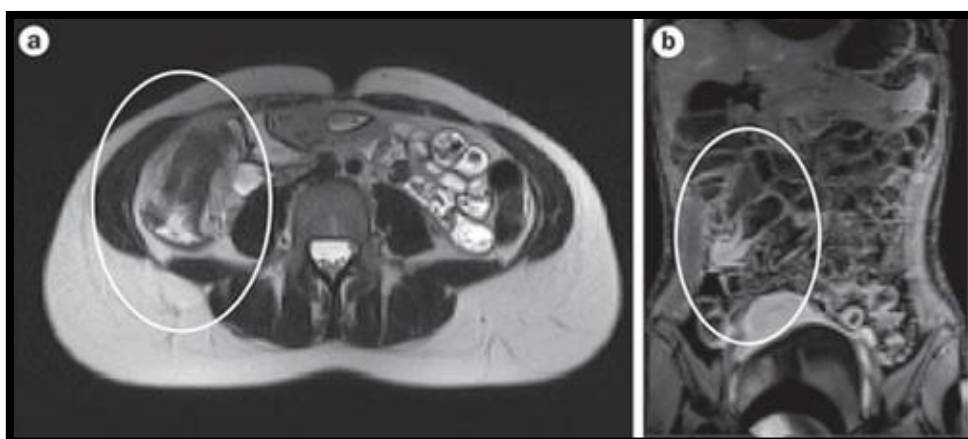


Fig.26 Magnetic Resonance Enterography showing axial and coronal view (Bruining *et al.*, 2018)

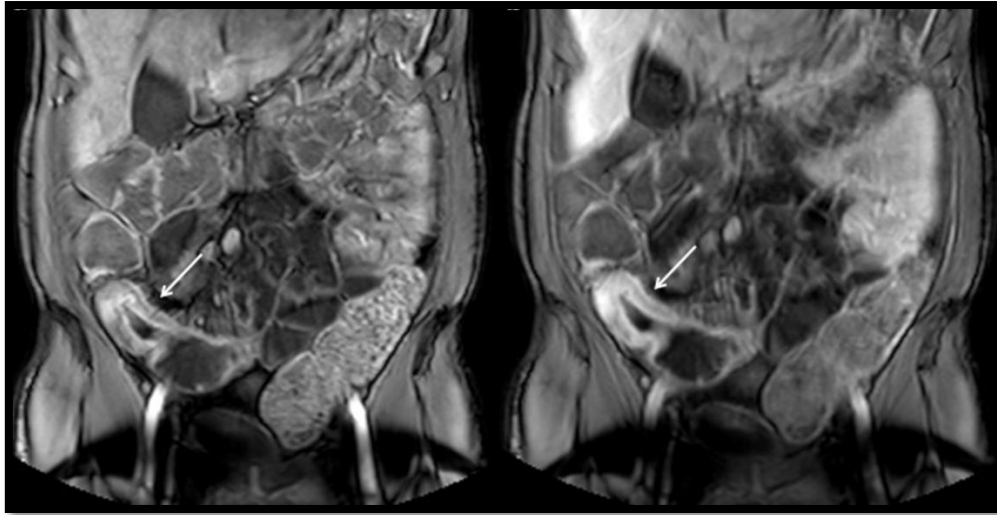


Fig.27 Arrow showing crohn's disease traces (Bruining *et al.*, 2018)

MRI Advancements in evaluation of Crohn's Disease:

Newer techniques including Dynamic studies like Contrast Enhanced Images called as DCE-MRI and others as well like Diffusion-Weighted Imaging (DWI), Perfusion MRI. There is also another one called as Magnet Resonance Spectroscopy (MRS) have significantly improved the use of MRI in Crohn's disease. These methods can offer more details regarding disease activity and aid in making therapy decisions. Additionally, hybrid imaging methods like PET/MRI are being investigated for the ability to offer more precise and in-depth details regarding Crohn's disease. MRI is a useful tool for diagnosing and tracking Crohn's disease overall. It can aid in enhancing patient outcomes and lowering disease-related morbidity and mortality. (Bruining *et al.*, 2018)

Mortality Imaging:

A highly effective technique for identifying active Crohn's disease is mortality imaging. It can quantify the level of inflammation and show whether there are inflammation disturbances to the gut wall. On T2-weighted images, the gut wall's signal strength indicates the extent of inflammation, with higher signal strength indicating active disease. Utilising MRI, this non-invasive imaging method evaluates the gastrointestinal tract's inflammatory activity. Mortality imaging has the ability to identify changes in the intestine's mucosal and submucosal layers, that can be used to both diagnose and track the progression of disease. Imaging of mortality may additionally be employed to assess how well a treatment is working. This method uses both T1 and T2 weighted images to distinguish between sites of inflammation and potential consequences such as abscesses and fistulas. A diagnostic method called mortality imaging is used to evaluate the severity of Chron's disease and find any potential underlying causes. (Schreyer *et al.*, 2005)

Diagnosis:

Chron's disease is diagnosed using mortality imaging, which looks into diseases like ulcers or inflammatory ones in small ones and large sized intestines.

Image acquiring methods are used to visualise the gastrointestinal system and spot any areas of inflammation or ulcers, including computer tomography (CT) and magnetic resonance image acquiring ones (MRI). Methods can also identify any adenomatous or dysplastic lesions that might be a sign of colorectal cancer. Mortality imaging can identify indications of inflammation as well as ulceration in another body parts, which includes lungs, liver, kidneys as well as chron's disease is a systemic disorder. (Schreyer *et al.*, 2005)

Prognosis:

Imaging of mortality may be employed to assess how serious Chron's disease is. Imaging characteristics like the existence of a fistula or stricture, for example, may signal a more severe disease state. The severity of the patient's gastrointestinal tract ulcers and inflammation can also be utilised to estimate the patient's prognosis. Imaging of mortality may be utilised as well to track the development of Chron's disease. For instance, alterations in the intestine's size or form may signal an increasing severity of the illness. (Schreyer *et al.*, 2005)

Treatment:

Imaging of mortality can be utilised to evaluate how well Chron's disease treatments are working. For instance, changes in the intestine's size or shape can be observed to assess the effectiveness of treatments like biologics, immunosuppressants, and anti-inflammatory therapies. Imaging can also be utilised to spot any treatment-related issues that might arise, like the emergence of fistulas or strictures.

DWI (Diffusion-Weighted Imaging):

A type of MRI which can be used to detect and monitor changes in the structure of the intestines, is referred to as DWI.

Diagnosing Crohn's Disease Using DWI:

DWI is a form of MRI that measures water mobility in a tissue using an arrangement of hydro-protons and magnetic fields. DWI is particularly effective at identifying alterations in the intestine's structural integrity due to its elevated level of signal of water protons. DWI can identify alterations in the intestine's structure brought on by inflammation, ulceration, and intestine-narrowing. Additionally, it can reveal the existence of constrictions, which are regions of constriction brought on by fibrosis or scarring. Also, DWI can be used to distinguish between CD and other disorders such as ulcerative colitis.

In CD, DWI is often utilized to evaluate the level of intestinal inflammation and track the efficacy of treatment. Additionally, DWI can be utilized to find CD problems such as abscess, fistulas, and strictures. (Wagner *et al.*, 2018)

Management of Crohn's Disease Using DWI:

DWI can be done to make a diagnosis, monitor CD development, and assess the extent to which the medication is working. DWI can measure changes in the intestinal tract's size and shape as well as structural alterations brought on by inflammation. It can also be used to detect any CD issues such as abscesses, fistulas, and strictures. DWI can also be used to check the effectiveness of medications used to treat CD. By monitoring changes in the structural integrity of the gut over time, DWI can help determine whether a medication is beneficial in lowering inflammation and alleviating symptoms. (Makanyanga *et al.*, 2017).

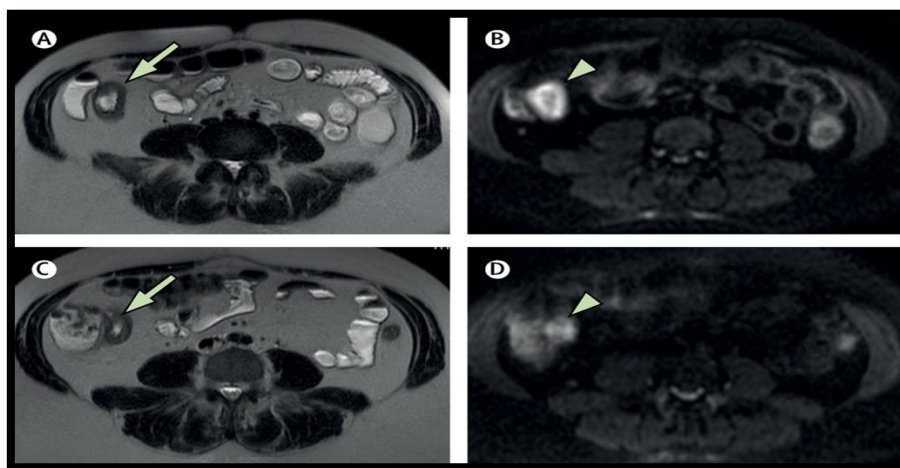


Fig.28 Diffusion weighted imaging (Makanyanga *et al.*, 2017)

Perfusion MRI in Chron's Disease:

Fortunately, advances in medical imaging have made diagnosis and treatment of Chron's disease easier and more effective. One such imaging technique is perfusion MRI, which can provide a detailed assessment of the anatomy as well as functioning of gastrointestinal tract.

Firstly understand the importance of understanding anatomy and physiology of gastrointestinal path. This path is made up of intestines (small ones) esophagus and stomach, as well as large intestines, or colon. The large intestine is the primary location of Chron's disease. This part of the gastrointestinal tract is necessary in absorbing water, nutrients as well from food that is being taken by human mouth. Large lumen intestines have 4 segments which are mentioned here, the cecum, descending colon, transverse colon, and ascending colon – each of which has a distinct function.

Perfusion MRI is a type of MRI that uses contrast material to measure the rate of blood flow to various

segments of gastrointestinal path. It is used for identifying areas having inflammation or obstruction, which can be indicative of Chron's disease. The contrast material is injected intravenously and then scanned. By analyzing the rate of blood flow to different parts of the gastrointestinal tract, doctors can identify areas of inflammation or obstruction. Additionally, perfusion MRI can help doctors identify areas of active inflammation, which can be targeted with specific treatments. This can help reduce symptoms and improve quality of life.

Perfusion MRI has also been used to monitor the response of Chron's disease to treatment. By comparing perfusion MRI scans taken before and after treatment, doctors can assess the efficacy of different treatment strategies. This can be particularly useful in deciding whether to continue a certain treatment or switch to another. (Sheedy *et al.*, 2017).

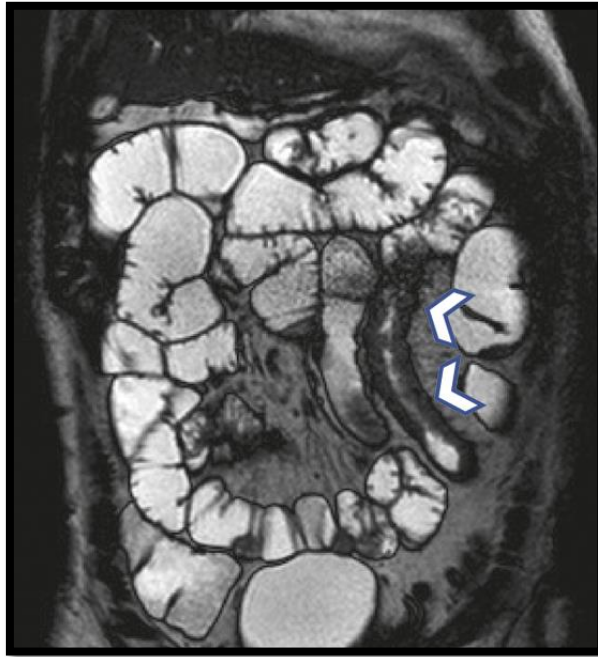


Fig.29 Magnetic Resonance perfusion (Sheedy *et al.*, 2017)

Magnetic Resonance Spectroscopy (MRS):

It is an imaging technique used to observe the chemical composition of tissue in the body. It works by measuring the resonance with radiofrequency pulses that cause the nuclei of atoms to produce a signal. This signal can then be interpreted to reveal the distribution of molecules in the tissue, which can then be used in diagnosing so monitoring varieties of disease, which includes Chron's disease. Chron's disease is inflammatory intestinal or bowel diseases (IBD) which results in affecting inner lining of digestive system. MRS has been used to detect an increase in inflammatory markers and to monitor the progression of the disease in Chron's disease patients. These markers include cytokines, which are proteins released by cells that have been activated by inflammation. An increased level of cytokines can indicate an active inflammatory process thus is useful in monitoring progressions of particular disease. MRS can be used to detect and monitor biochemical markers of inflammation in Chron's disease. The technique works by detecting the resonance of certain molecules in the body. These molecules are useful in measuring different level as particular biochemical markers, such as cytokines, chemokines, and other inflammatory mediators. MRS can also be used to measure the levels of certain bacterial populations in the gut, which can provide further insight into the underlying pathology of Chron's disease. (Wagner *et al.*, 2018)

Limitation of MRS:

MRS is not able to measure the levels of certain inflammatory mediators, such as cytokines, in the blood. It is also important to note that MRS is not able

to detect any structural changes in the gut that may be associated with Chron's disease.

Optical imaging:

Optical Imaging is a relatively new imaging modality that uses light of specific wavelengths to detect and image biological processes. Optical imaging can be used to detect and image inflammatory activity in Crohn's disease, as well as to monitor the response to treatment. Optical imaging can also be used to detect early stages of disease, before it is visible on other imaging modalities.

Molecular imaging:

Molecular Imaging of Crohn's disease has capability so that improvisation in understanding the disease is possible so leads to more precise diagnosis and more effective treatment. It also has the potential to provide early detection of disease activity, allowing for earlier therapeutic interventions that could improve patient outcomes. With further development and refinement, molecular imaging may become an essential tool for diagnosing and managing Crohn disease. (Wagner *et al.*, 2018)

Hybrid PET/MRI:

This technique is helpful in differentiating between Chron's disease and some other inflammation in bowel kind of disease, as well as to assess mucosal inflammation, bowel wall thickening, and other changes associated with Chron's disease. The technique can also be used to monitor Chron's disease activity, as well as to assess the efficacy of treatments. However, the technique is still relatively new and is not yet widely available. It is important that patients

understand the risks and potential benefits of PET/MRI before undergoing the procedure. It provides vast statistics regarding structures and functioning of gastrointestinal path, hybrid imaging PET/MR Imaging can help to identify changes in the structure or functioning that may indicate a response to treatment. This information can be used to determine if a treatment is working and if it needs to be adjusted or changed. (Signore *et al.*, 2017)

Advantages of MRI: The main advantage of MRI is its ability to provide a detailed picture of the affected area. Unlike a CT scan, an MRI does not use radiation, making it a safer option. It is also more sensitive than a CT scan and can detect small features which might not be possible to see on a traditional X ray.

Disadvantages in MRI: MRI scans can be expensive and may not be available at all medical facilities. The scan also requires the injection of a contrast dye, which can have side effects such as nausea and allergic reactions. Its limitations include its high cost and limited availability. MRI also needs patient to stay in particular small space for certain amount of time that causes patient discomfort.

PET Scan:

A PET (positron emission tomography) scan is obtained by injecting certain amount of radioactive substance which gives vast detailing in pictures acquired from the huamn body. It can detect

inflammation in the gastrointestinal tract and can be used to evaluate the extent of the disease and any complications. PET scanning is a kind of scanning which is used to evaluate Crohn’s Disease. It involves the use of a radioactive tracer for creating images with details of inside present organs with surrounding tissues. PET scan can help doctors better understand the extent of the disease, such as the location, size, and patterns of inflammation, as well as the degree of tissue damage. It is also used to identify any potential complications, such as abscesses, fistulas, and blockages. A PET scan can also help monitor the progress of Crohn’s Disease over time. It can help doctors determine if the treatment is working, and if any changes need to be made. PET is useful in diagnosing Crohn’s disease, because of having ability to detect signs of active disease, such as inflammation and tissue damage. (Signore *et al.*, 2017)

The accuracy of PET in diagnosis of Crohn’s disease is higher than other imaging modalities are used in combination. Additionally, the accuracy of PET increases with the use of intravenous contrast agents and with the use of 3-dimensional reconstruction techniques.

The main limitation of PET is its inability to differentiate between active disease and scarring. Additionally, PET is not suitable for evaluating small intestinal disease, as it is restricted by the size of the small bowel. (Signore *et al.*, 2017).

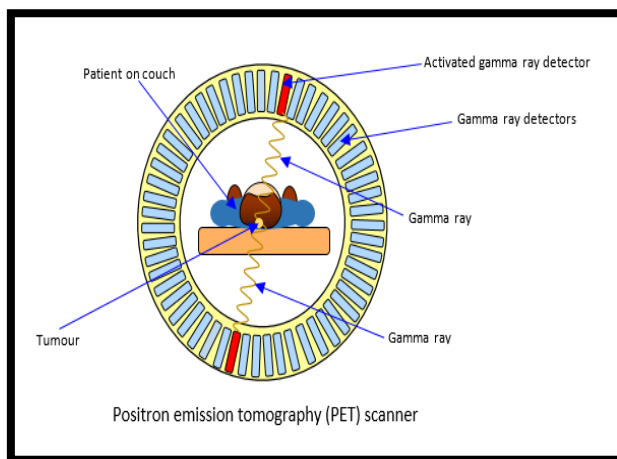


Fig.30 Positron Emission Tomography system

Advantages: The main advantage of PET scans is their ability to detect inflammation. They are also useful in evaluating the extent of the disease and any complications.

Disadvantages: PET scans use radiation, which can be harmful to the body and may cause increment in the chances of having cancer. Scan also requires injecting a radioactive substance, which can have side effects such as nausea and allergic reactions.

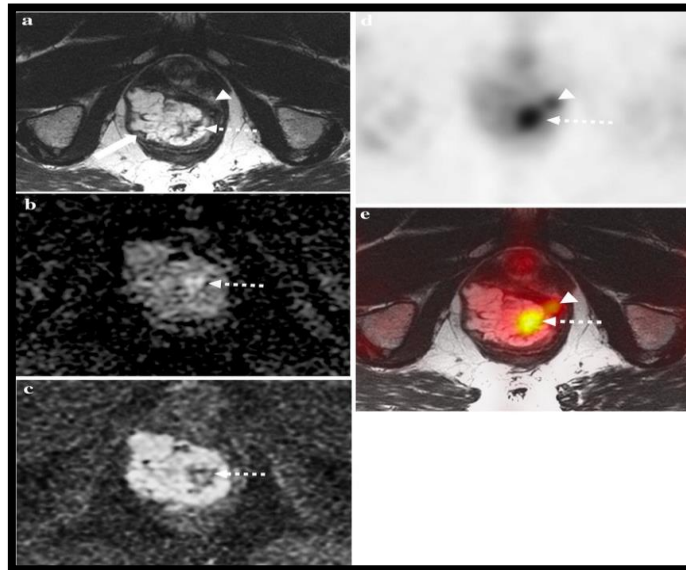


Fig.30 Fistula by PET Scan

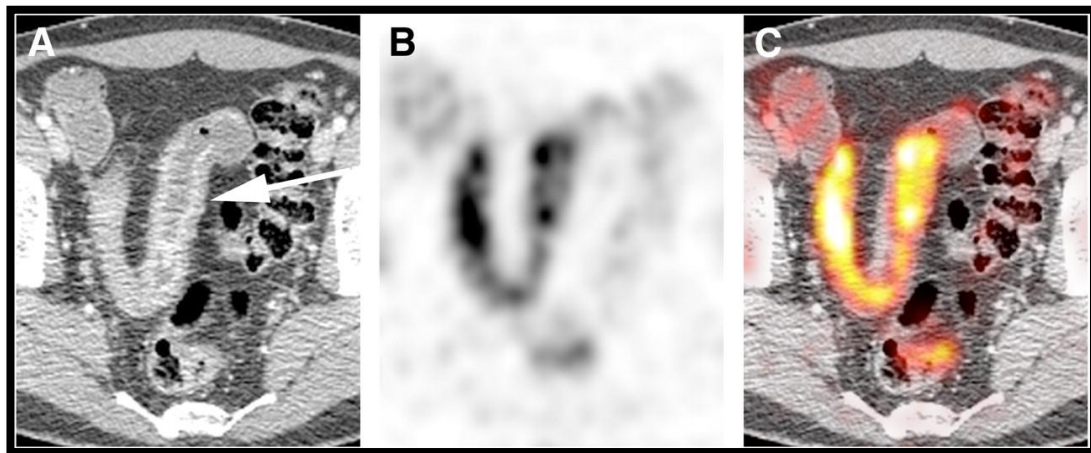


Fig.31 PET/CT SCAN ENTEROGRAPHY

Risk factors of Crohn’s Disease:

Particular reason for Crohn's disease is not discovered by doctors, certain risk factors are there which might cause increment in chances of having crohn’s disease. These include:

- Ages - People between the ages of 15 and 35 are most commonly affected by Crohn's disease.
- Genetics - Individuals are more prone to have the illness if their family has a history of it.
- Ethnicity - People of European, Jewish, or African-American heritage are more likely to have Crohn's disease.
- Smoking is a recognised risk factor for the onset of Crohn's disease.
- Diet - According to some research, consuming a lot of refined or sugar-laden foods may make you more likely to get the disease.

- Stress has been associated with a higher risk of getting Crohn's disease.

Symptoms:

From mild to severe, Crohn's disease symptoms may differ from one person to another person. Constant cramping and stomach pain, occasionally accompanied with bloody diarrhoea, are common symptoms. Patient has fatigue and loss of appetite, even there is unexplained weight loss. Fever, nausea and vomiting are most common symptoms. Sometimes rectal bleeding occurs and further results in anaemia. CD causes patient to feel incomplete evacuation after bowel movement. Skin rashes also occur and night sweats are also there with joint pain.

Evaluation of Crohn’s disease:

When evaluating Chron's disease, doctors will usually start with a physical exam. During this exam, a doctor

will ask certain questions about patient history with signs of difficulties he is facing. Additionally, a doctor will ask the patient to go laboratory checkup, like complete blood count and stool tests. These tests help in determining if there is an infection or inflammation in the intestine. The next step in the evaluation of Chron's disease is usually imaging, MRI, CT and PET scans are the most common imaging techniques used. These imaging techniques can be used to detect inflammation, structural abnormalities, and any blockages that may be causing symptoms. Additionally, PET scans can help determine how well a patient is responding to treatment.(Gibson *et al.*, 1991)

Once imaging has been completed, doctors may order a biopsy of the affected area. Biopsy includes taking a single small sized tissue sample from the intestine and thus is read under a microscope. So, helps in determining extent in damage to the intestine and can help provide a definitive diagnosis.

Treatment for Chron's Disease

The main goals of treating Chron's disease are to reduce inflammation and relieve symptoms. Treatment may involve 4 important measures:-

I. Medications:

Medications used to treat Chron's disease may include; Anti-inflammatory drugs (such as sulfasalazine, mesalamine, or corticosteroids) given to patient to reduce inflammation. Immunomodulators (such as azathioprine, methotrexate, or 6-mercaptopurine) can be given in certain conditions. Also biologic medications (such as infliximab, adalimumab, or golimumab) are provided. Antibiotics (such as metronidazole or ciprofloxacin) given to fight infection. Antidiarrheal medications (such as loperamide or diphenoxylate) given to prevent from excessive drainage of fluids. Pain medications (such as acetaminophen or ibuprofen) given to relieve the patient from pain

II. Dietary Changes:

Certain dietary changes may help reduce symptoms of Chron's disease. These are:
Eat small, in certain intervals, avoiding foods that cause signs (such as dairy products, caffeine, fatty foods, and processed foods), increasing fibre intake by eating more fruits, vegetables, legumes, and whole grains, drinking plenty of water and other fluids and eating probiotic-rich foods (such as yogurt, kefir, and fermented vegetables)

III. Lifestyle Modifications:

Making certain lifestyle changes may also help reduce symptoms of Chron's disease. Stress should be managed, exercise regularly; avoid smoking, take adequate sleep. Foods or beverages that trigger the condition should be avoided like alcohol. Joining a support group

will reduce anxiety and increase stability of patient.(Pita and Magro, 2018)

IV. Surgery:

Surgery is done in order to remove or get rid of the part which has inflammation.

The Main objective of medical imaging in evaluating Crohn's disease are:

1. **Diagnosis:** Medical imaging techniques are commonly used to help diagnose Crohn's disease. These imaging techniques can provide detailed images of the gastrointestinal tract, allowing doctors to identify the presence of inflammation, ulcers, strictures, or other abnormalities that are indicative Crohn disease.
2. **Disease Location with Extend:** Medical imaging can help evaluating location with extend of Crohn disease involvement in gastrointestinal tract. This information is crucial for treatment planning, as it helps doctors determine the appropriate treatment approach, such as medication therapy, endoscopic interventions, or surgery.
3. **Disease Activity:** Medical imaging can provide valuable information about the activity level of Crohn's disease. CT and MRI scans can show the presence and severity of inflammation in the gut wall, which can help doctors assess the disease activity and guide treatment decisions. This can aid in monitoring disease progression, response to treatment, and predicting disease recurrence.
4. **Complications Detection:** Medical imaging can help detect difficulties of Crohn's disease, like abscesses, fistulas, and strictures. These complications can have significant implications for treatment planning, and early detection through imaging can help prevent further complications and guide appropriate interventions.
5. **Surveillance and Monitoring:** Medical imaging is used for surveillance and monitoring of disease, especially with long-standing disease or increased risk for complications. Regular imaging can help track disease progression, assess response to treatment, and monitor for disease recurrence.
6. **Surgical Planning:** Medical imaging is essential for surgical planning in Crohn disease. CT and MRI scans gives detailing report of anatomy of the gastrointestinal path, which helps surgeons plan their approach, identify areas of concern, and minimize surgical risks.
7. **Patient Management:** Medical scanning is responsible for overall administration of Crohn's disease patients. It helps clinicians assess disease activity, response to treatment,

and monitor for complications, guiding the management plan and optimizing patient care.

In a nutshell, role of medical imaging for evaluation of Crohn's disease aims for providing accurate diagnosis, investigation of disease with location as well as extent, assess disease activity, detect complications, monitor disease progression, aid in surgical planning, and optimize patient management. It plays a critical part in multifaceted strategy for dealing with Crohn's disease, offering useful data for selecting treatments and enhancing patient outcomes.

SUMMARY:

The evaluation of the Crohn's disease using medical imaging has crucial aspect of the diagnostic and management process. Medical imaging techniques such as CT scans, MRI, small bowel series, ultrasound, endoscopy, and nuclear medicine play a vital role in visualizing the gastrointestinal tract and assessing the presence, location, and activity for Crohn disease.

Examination of methods with materials used to assess Crohn's disease through medical imaging emphasises the significance of choosing best form of imaging based on the clinical context and the available data. CT scans and MRI are commonly used for assessing the location, extent, and activity of Crohn's disease, as they provide detailed cross-sectional images of the gastrointestinal tract. Small bowel series and endoscopy are useful for evaluating the mucosal lining and detecting strictures or ulcerations. Ultrasound can be a useful initial imaging modality in certain situations, such as in pediatric patients or pregnant women. Nuclear medicine techniques can help assess inflammation or infection in the gut wall.

Patient preparation instructions, including fasting, bowel preparation, and contrast agent administration, may be necessary depending on the imaging modality used. Radiopharmaceuticals may be used in nuclear medicine scans, and intravenous contrast agents may be used in CT scans, MRI, and some nuclear medicine scans to enhance visualization.

It gives precise details regarding the location, magnitude, movement, and severity of the disease, medical imaging is extremely important in assessing Crohn's disease. The appropriate choice of imaging modality and proper patient preparation are important factors for accurate assessment. Identification, tracking, with treatment for Crohn's disease are aided by imaging procedures in combination with medical assessments along with additional diagnostic procedures, eventually leading to better care for patients. It is crucial to seek advice from a physician or a diagnostic professional to determine the best imaging strategy for each specific patient.

CONCLUSION:

To sum up, CT, MRI, and PET scans are crucial diagnostic and monitoring techniques for Crohn's

disease. These imaging tests can give precise pictures of the areas that are damaged and aid in separating Crohn's disease from other GI disorders. They can also be used to monitor the response to treatment and to assess for complications such as abscesses and fistulas. The patient's unique history of illness and condition, however, have the most role in choosing whichever radiological study is ideal in assessing Crohn's disease. PET is a nuclear medicine imaging technique that is increasingly used in CD due to its ability to detect inflammatory activity in the gastrointestinal tract. The advantages of PET in CD evaluation include its ability to accurately differentiate between active and inactive disease and to detect complications such as abscess and strictures. Its limitations include its high cost and limited availability. Overall, imaging methods in presence for Crohn's disease include CT, MRI, and PET scans. Nevertheless, they are unable to distinguish amongst disease progression along with wounds, therefore so are unsuitable for use in small intestine diagnosis. Chron's disease is a severe ailment which needs to be managed constantly. Working side by side with doctor will help in creating treatment strategy that is successful for patient. Numerous individuals having Chron's Disease may maintain healthy, active lives with the right care and lifestyle control.

REFERENCES:

1. Al-Hawary, M.M., Kaza, R.K. and Platt, J.F. (2013) 'CT Enterography: Concepts and Advances in Crohn's Disease Imaging', *Radiologic Clinics of North America*, 51(1), pp. 1–16. Available at: <https://doi.org/10.1016/j.rcl.2012.09.001>.
2. Atreya, R. *et al.* (2022) 'Ileal and colonic Crohn's disease: Does location makes a difference in therapy efficacy?', *Current Research in Pharmacology and Drug Discovery*, 3(December 2021), p. 100097. Available at: <https://doi.org/10.1016/j.crphar.2022.100097>.
3. Benitez, J.M. *et al.* (2013) 'Role of endoscopy, cross-sectional imaging and biomarkers in Crohn's disease monitoring', *Gut*, 62(12), pp. 1806–1816. Available at: <https://doi.org/10.1136/gutjnl-2012-303957>.
4. Bettenworth, D. *et al.* (2019) 'Assessment of

- Crohn's disease-associated small bowel strictures and fibrosis on cross-sectional imaging: A systematic review', *Gut*. BMJ Publishing Group, pp. 1115–1126. Available at: <https://doi.org/10.1136/gutjnl-2018-318081>.
5. Bruining, D.H. *et al.* (2018) 'Consensus Recommendations for Evaluation, Interpretation, and Utilization of Computed Tomography and Magnetic Resonance Enterography in Patients With Small Bowel Crohn's Disease', *Gastroenterology*, 154(4), pp. 1172–1194. Available at: <https://doi.org/10.1053/j.gastro.2017.11.274>.
 6. En, R.D.C.O.H. (2002) 'The quality of life in patients with Crohn's disease', *Alimentary Pharmacology and Therapeutics*, (May), pp. 1603–1609.
 7. Gibson, P. *et al.* (1991) 'Value of positive technetium-99m leucocyte scans in predicting intestinal inflammation', *Gut*, 32(12), pp. 1502–1507. Available at: <https://doi.org/10.1136/gut.32.12.1502>.
 8. Lightner, A.L. (2018) 'Duodenal Crohn's disease', *Inflammatory Bowel Diseases*. Lippincott Williams and Wilkins, pp. 546–551. Available at: <https://doi.org/10.1093/ibd/izx083>.
 9. Lung, P.F.C. and Ng, S.C. (2017) 'Editorial: challenges in the development of a magnetic resonance imaging index for fistulising Crohn's disease', *Alimentary Pharmacology and Therapeutics*. Blackwell Publishing Ltd, p. 696. Available at: <https://doi.org/10.1111/apt.14235>.
 10. Makanyanga, J. *et al.* (2017) 'MRI texture analysis (MRTA) of T2-weighted images in Crohn's disease may provide information on histological and MRI disease activity in patients undergoing ileal resection', *European Radiology*, 27(2), pp. 589–597. Available at: <https://doi.org/10.1007/s00330-016-4324-4>.
 11. Pariente, B. *et al.* (2011) 'Development of the Crohn's disease digestive damage score, the Lémann score', *Inflammatory Bowel Diseases*, 17(6), pp. 1415–1422. Available at: <https://doi.org/10.1002/ibd.21506>.
 12. Pita, I. and Magro, F. (2018) 'Advanced imaging techniques for small bowel Crohn's disease: what does the future hold?', *Therapeutic Advances in Gastroenterology*. SAGE Publications Ltd. Available at: <https://doi.org/10.1177/1756283X18757185>.
 13. Roda, G. *et al.* (2020) 'Crohn's disease', *Nature Reviews Disease Primers*, 6(1). Available at: <https://doi.org/10.1038/s41572-020-0156-2>.
 14. Schreyer, A.G. *et al.* (2005) 'Comparison of magnetic resonance imaging colonography with conventional colonoscopy for the assessment of intestinal inflammation in patients with inflammatory bowel disease: A feasibility study', *Gut*, 54(2), pp. 250–256. Available at: <https://doi.org/10.1136/gut.2003.037390>.
 15. Sheedy, S.P. *et al.* (2017) 'MR Imaging of perianal Crohn disease', *Radiology*. Radiological Society of North America Inc., pp. 628–645. Available at: <https://doi.org/10.1148/radiol.2016151491>.
 16. Signore, A. *et al.* (2017) 'Nuclear Medicine Imaging in Pediatric Infection or Chronic

- Inflammatory Diseases', *Seminars in Nuclear Medicine*. W.B. Saunders, pp. 286–303. Available at: <https://doi.org/10.1053/j.semnuclmed.2016.12.005>.
17. Steckstor, M. *et al.* (2013) 'Gastroduodenal Crohn's Disease', *Video Journal and Encyclopedia of GI Endoscopy*, 1(1), pp. 178–179. Available at: [https://doi.org/10.1016/S2212-0971\(13\)70074-8](https://doi.org/10.1016/S2212-0971(13)70074-8).
 18. Wagner, M. *et al.* (2018) 'Magnetic resonance imaging predicts histopathological composition of ileal Crohn's disease', *Journal of Crohn's and Colitis*, 12(6), pp. 718–729. Available at: <https://doi.org/10.1093/ecco-jcc/jjx186>.
 19. Deepak, P., Park, S.H., Ehman, E.C., Hansel, S.L., Fidler, J.L., Bruining, D.H. and Fletcher, J.G., 2017. Crohn's disease diagnosis, treatment approach, and management paradigm: what the radiologist needs to know. *Abdominal Radiology*, 42, pp.1068-1086.
 20. Halligan, S., Nicholls, S., Beattie, R.M., Saunders, B.P., Williams, C.B., Walker-Smith, J.A. and Bartram, C.I., 1995. The role of small bowel radiology in the diagnosis and management of Crohn's disease. *Acta Paediatrica*, 84(12), pp.1375-1378.
 21. Sinha, R., Murphy, P., Hawker, P., Sanders, S., Rajesh, A. and Verma, R., 2009. Role of MRI in Crohn's disease. *Clinical radiology*, 64(4), pp.341-352.
 22. Furman, M.S. and Lee, E.Y., 2020. Beyond Crohn Disease: Current role of Radiologists in diagnostic imaging assessment of inflammatory bowel disease transitioning from pediatric to adult patients. *Radiologic Clinics*, 58(3), pp.517-527.
 23. Nanakawa, S., Takahashi, M., Takagi, K. and Takano, M., 1993. The role of computed tomography in management of patients with Crohn disease. *Clinical imaging*, 17(3), pp.193-198.
 24. Dambha, F., Tanner, J. and Carroll, N., 2014. Diagnostic imaging in Crohn's disease: what is the new gold standard?. *Best Practice & Research Clinical Gastroenterology*, 28(3), pp.421-436.
 25. Gatta, G., Di Grezia, G., Di Mizio, V., Landolfi, C., Mansi, L., De Sio, I., Rotondo, A. and Grassi, R., 2012. Crohn's disease imaging: a review. *Gastroenterology research and practice*, 2012(1), p.816920.
 26. Minordi, L.M., Bevere, A., Papa, A., Larosa, L. and Manfredi, R., 2022. CT and MRI evaluations in Crohn's complications: a guide for the radiologist. *Academic Radiology*, 29(8), pp.1206-1227.
 27. Rubesin, S.E., Scotinotis, I., Birnbaum, B.A. and Ginsberg, G.G., 2001. Radiologic and endoscopic diagnosis of Crohn's disease. *Surgical Clinics of North America*, 81(1), pp.39-70.
 28. Rao, N., Kumar, S., Taylor, S. and Plumb, A., 2019. Diagnostic pathways in Crohn's disease. *Clinical Radiology*, 74(8), pp.578-591.
 29. Bruining, D.H. and Loftus, E.V., 2009. Crohn's disease clinical issues and treatment: what the radiologist needs to know and what

- the gastroenterologist wants to know. *Abdominal imaging*, 34, pp.297-302.
30. Horsthuis, K., Bipat, S., Stokkers, P.C. and Stoker, J., 2009. Magnetic resonance imaging for evaluation of disease activity in Crohn's disease: a systematic review. *European radiology*, 19, pp.1450-1460.
31. Conti, C.B., Giunta, M., Gridavilla, D., Conte, D. and Fraquelli, M., 2017. Role of bowel ultrasound in the diagnosis and follow-up of patients with Crohn's disease. *Ultrasound in Medicine & Biology*, 43(4), pp.725-734.
32. Cicero, G. and Mazziotti, S., 2021. Crohn's disease at radiological imaging: focus on techniques and intestinal tract. *Intestinal research*, 19(4), p.365.
33. Gallego, J.C. and Echarri, A., 2018. Role of magnetic resonance imaging in the management of perianal Crohn's disease. *Insights into imaging*, 9, pp.47-58.
34. Deepak, Parakkal, Joel G. Fletcher, Jeff L. Fidler, John M. Barlow, Shannon P. Sheedy, Amy B. Kolbe, William S. Harmsen et al. "Radiological response is associated with better long-term outcomes and is a potential treatment target in patients with small bowel Crohn's disease." *Official journal of the American College of Gastroenterology/ACG* 111, no. 7 (2016): 997-1006.
35. Yacoub, J.H., Obara, P. and Oto, A., 2013. Evolving role of MRI in Crohn's disease. *Journal of Magnetic Resonance Imaging*, 37(6), pp.1277-1289.
36. Furukawa, A., Saotome, T., Yamasaki, M., Maeda, K., Nitta, N., Takahashi, M., Tsujikawa, T., Fujiyama, Y., Murata, K. and Sakamoto, T., 2004. Cross-sectional imaging in Crohn disease. *Radiographics*, 24(3), pp.689-702.
37. Fraquelli, M., Colli, A., Casazza, G., Paggi, S., Colucci, A., Massironi, S., Duca, P. and Conte, D., 2005. Role of US in detection of Crohn disease: meta-analysis. *Radiology*, 236(1), pp.95-101.
38. Minordi, L.M., Scaldaferrri, F., Larosa, L., Marra, R., Giordano, F., Laterza, L., Scoleri, I., Poscia, A., Gerardi, V., Bruno, G. and Gaetani, E., 2015. Comparison between clinical and radiological evaluation before and after medical therapy in patients with Crohn's disease: new prospective roles of CT enterography. *La radiologia medica*, 120, pp.449-457.
39. Siddiki, H. and Fidler, J., 2009. MR imaging of the small bowel in Crohn's disease. *European journal of radiology*, 69(3), pp.409-417.
40. Villa, C., Pompili, G., Franceschelli, G., Munari, A., Radaelli, G., Maconi, G. and Cornalba, G.P., 2012. Role of magnetic resonance imaging in evaluation of the activity of perianal Crohn's disease. *European journal of radiology*, 81(4), pp.616-622.