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REVIEW ARTICLE **OPEN ACCESS**

A Review on Novel Biomarkers for Inflammatory Bowel Disease

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ABSTRACT
Inflammatory bowel disease is a chronic condition that affects the lives of millions of humans worldwide. It is often difficult to diagnose IBD and differentiate it from other GIT diseases. There is no gold standard diagnostic test for IBD. Although colonoscopy, endoscopy, serological, fecal, and histopathological studies exist for diagnosis, most of them are invasive and may complicate the patient's condition. Initially, the area of biomarkers for IBD was underexplored, but with a better understanding of the disease etiology, novel biomarkers are emerging that can be of diagnostic value. This review focuses on those novel biomarkers and highlights their potential in precisely diagnosing IBD.
Keywords: *IBD, Inflammatory bowel disease, Novel non-invasive Biomarkers, Urinary biomarkers for IBD, Fecal biomarkers for IBD, Fecal Calprotectin, Micro RNA's.*

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INTRODUCTION

Inflammatory bowel disease is a chronic condition that is characterized by moderate to severe inflammation of GIT. Depending on the site and severity of inflammation, IBD is categorized into two disease entities, Crohn's disease, and ulcerative colitis (1). Crohn's disease can affect any part of GIT between mouth and anus, but most often, it affects the small intestine before the colon. Also, Inflammation in Crohn's disease is discontinuous and may reach the deeper layer of the intestines (2) whereas UC affects specifically the colon and rectum, and inflammation is restricted to the innermost lining of the intestines(3). Some common manifestations of IBD include persistent diarrhoea, abdominal pain, hematochezia, weight loss, and fatigue (4). The usual diagnosis of IBD includes a preliminary stool and serological tests, followed by confirmatory endoscopy, colonoscopy, biopsies, or radio imaging (5).The plethora of diagnostic tests can help to diagnose IBD, but it is often difficult to differentiate IBD from other disease conditions. This is because of the shared symptoms, and much similar clinical and radiological findings of IBD and other GIT diseases or disorders. For instance, Diverticulitis (inflammation of diverticula) shows similar manifestations as active Crohn's disease (6). The initial signs and symptoms, and radiological findings can be similar in both conditions. To differentiate IBD from diverticulitis, colonoscopy is done which is invasive and may carry the risk of perforation (6). Also, around 10% of IBD patients are misdiagnosed with irritable bowel syndrome (7). The endoscopic findings of infections with Shigella or Campylobacter organisms may be identical to that seen with Ulcerative Colitis (8). Ileitis is otherwise unrelated to Crohn's disease but due to infections or drugs, may be misdiagnosed as IBD(9). The currently existing tools, diagnostic tests, and biomarkers for IBD are invasive, not so precise and often confused with IBD as other diseases. Several promising novel (10) fecal biomarkers for IBD have been named. However, none of the currently described markers are disease-specific, so the search for better biomarkers of IBD continues (10). Several other novel biomarkers are currently being studied that will help to diagnose IBD with minimal invasion and discomfort to the patient.

FAECAL BIOMARKERS:

When it comes to non-invasive and promising biomarkers for IBD, faeces is a favourable source. Faecal biomarkers are biproducts of inflammatory responses in the intestines (11). The logic behind using faecal biomarkers is that faeces directly pass through the intestines, hence may contain several markers of intestinal inflammation(12). These faecal biomarkers act as surrogates for traditional diagnostic methods like endoscopy, radiography, and histopathology (13). Several of the novel faecal biomarkers are as follows

Faecal calprotectin (FC):

Faecal calprotectin is a calcium and zinc binding protein present in neutrophils (1). Neutrophils being the primary defenses released by the body(2), migrate to the site of chemo-attractants to disintegrate and release their cytosolic contents(3). Out of total cytosolic protein content of neutrophils, calprotectin accounts for as much as 60% (4). And the total amount of calprotectin reflects the number of participating neutrophils in inflammation(3), which is especially beneficial in diagnosing IBD. Further, FC is resistant to bacterial degradation during passage through the GI tract and remains stable for upto 7 days making it easier to be measured(5,6). FC can be measured by two conventional methods, one is enzyme-linked immunosorbent assay [ELISA], and the other is fully quantitative rapid tests and semi-quantitative point-of-care tests (POCTs)(7). Since fecal calprotectin is being correlated with the level of IBD, the test results should be interpreted in the context of a cut-off value, below which the test is considered negative (7). The cut off values may vary from one study to another. Usually, the cutoff values is fixed at 50µg/g(8). In a specific study, a significant difference in Faecal Calprotectin cutoff was found ranging from 50 to 918µg/g. Faecal Calprotectin cut-off value for the initial diagnosis of IBD or active disease status ranged from 50 to 800 µg/g. A cut-off level of 50–250 mg/g differentiated patients of IBD from IBS. Cut-off level of FC for the prediction of remission ranged from 250 to 918 µg/g and that for prediction of relapse ranged from 50 to200 microgram/gram(9). This variability in cutoff can be due to several factors including method of testing, age, lifestyle, and other inflammatory diseases(9–11). Despite these variations, FC can help to differentiate IBD and IBS(12), between active and inactive IBD(26), to assess disease activity(27) etc.

Faecal Micro RNA's:

MicroRNAs (miRNAs) are a class of non-coding RNAs that play important roles in regulating gene expression(28). They interact with the 3′ UTR of target mRNAs to suppress its expression(29). In several studies, differential expression of unique types of miRNA was found in IBD patients(30). One of the studies pointed out differential expression of 11 types of miRNA in which 3 miRNA's (miR-192, miR-375, miR-422b) levels were significantly decreased and 8 miRNA's (miR-16, miR-21, miR-23a, miR-24, miR-29a, miR-126, miR-195, let-7f) levels were significantly increased in active UC patients(30,31). Several other studies strongly suggest differential miRNA expression in IBD patients (32–36). In these studies, the miRNA expression was measured either by tissue biopsies or from peripheral blood which is invasive. As an alternative, the same miRNAs was measured in faeces in an independent study. In 52 adult patients suffering from Crohn's disease where miRNA was isolated from frozen faeces and profiled using small RNA sequencing and confirmed via Polymerase chain reaction. Also, their levels were correlated with CDAI (Crohn's Disease Activity Index) and CDEIS (Crohn's Disease Index of Severity) scores. Nine miRNAs were significantly increased and eight were significantly decreased. Three miRNAs (MiR-192-5p, miR-375, and miR-141-3p; $P<0.05$) were correlated with CDAI and CDEIS scores(37). This study provides evidence that the miRNA profile is altered in faaeces of IBD patients.

Measurement of faecal miRNA is not tedious but a straightforward process. miRNA can be easily extracted from feces by treatment with TRIZOL reagent, and by several kit methods. It can be detected and quantified by quantitative real time PCR (qPCR), microarray profiling, digital PCR (dPCR)(38).

But the real question is, which type of miRNA differential expression is specific for IBD and how specific and sensitive it will be to confirm the diagnosis.

URINARY BIOMARKERS:

Urinary proteomics is an advanced tool for detection of biomarkers. It is non-invasive and helps in early detection of multitude of diseases, especially urogenital diseases. There have been limited urinary biomarker studies for intestinal diseases, especially for IBD(39). Discovery of biomarkers for IBD through urine proteomics is quite challenging because the protein levels may vary from person to person depending upon their daily intake of fluids(40). To minimize this uncertainty, animal models were used to correlate the relationship between IBD and changes in urine(39).

In a particular study, Trinitrobenzene sulfonic acid (TNBS)-induced colitis rat model was used to detect the urinary protein changes. Nine biomarkers were uncovered out of which, three were previously known to be the biomarkers of IBD. They are Neutrophil gelatinase-associated lipocalin, Matrix metalloproteinase-8, Carbonic anhydrase 1. Other proteins such as glyceraldehyde-3-phosphate dehydrogenase, sodium-dependent neutral amino acid transporter B(0)AT3, neutral and basic amino acid transport protein rBAT, beta-mannosidase, as well as ribonuclease pancreatic gamma-type and collectrin showed significant change in their levels in the disease induced group. The study suggests that these proteins have the potential to be urinary biomarkers of inflammatory bowel disease(39).

FATTY-ACID BINDING PROTEINS (FABP'S)

Fatty-acid binding proteins are small cytosolic proteins present in all the major organs like liver, intestines, pancreas, kidney, lungs, heart, and brain(41). At present, nine FABP's are known each with their unique function(42) But, all of them are mainly involved in lipid metabolism(43,44). The major FABP's that are abundantly found and to be highlighted are I-FABP (intestinal- Fatty acid binding protein) and L-FABP (Liver- Fatty acid binding protein). These are present in gastrointestinal tract especially in the enterocytes of jejunum, duodenum and to a lower extent in ileum(45). These two proteins especially I-FABP was found to be helpful in detecting intestinal injury. Any damage to the epithelial cells causes its release into circulation and eventually its concentration rises which can be detected easily from plasma(46). In a pilot study, several urinary biomarkers for Crohn's disease were studied one of which is I-FABP. It was measured from the urine of young adults with active CD. After putting the subjects on exclusive enteral nutrition (EEN) therapy, the pre and post therapy levels of I-FABP were monitored. It was found that Urinary I-FABP : Creatinine levels were significantly reduced after 8weeks of therapy, suggesting that I-FABP is a potential marker for measuring the disease activity in CD patients(47). In another study, I-FABP was measured in 41 patients with active CD, 33 patients with CD remission, and 37 healthy controls. Level of I-FABP was measured from serum sample and was found to be significantly higher in patients with active CD than in CD remission patients and healthy individuals. Also, a positive correlation was revealed between I-FABP and CDAI(Crohn's disease activity index), I-FABP and CRP (C- reactive protein) levels(48). Another study conducted with 47 CD patients shows a correlation in the levels I-FABP and TNF-α after anti TNF-α antibody (infliximab) therapy. The levels of both were high prior to treatment and significantly reduced after 3 administrations of infliximab. This suggests that I-FABP can be used as a prognostic marker for CD patients (49). All this data suggests that I-FABP is a promising biomarker for prognosis in patients with IBD. However more studies need to be conducted in larger population to confirm the potential of I-FABP to become a marker for IBD.

CONCLUSION

Inflammatory Bowel disease is a chronic, life-threatening condition. It is categorized into several disease entities like Crohn's, ileitis, ulcerative colitis, Crohn's colitis, etc. Many a times, patients suffering from any of these diseases may manifest similar type of symptoms. Solely diagnosing the disease based on symptoms and scoring them is not always enough. Hence, several other techniques like endoscopy, colonoscopy, biopsy are being used. These techniques are invasive and may worsen the condition of the patient. Hence there is a high need for non-invasive techniques that may precisely diagnose IBD with utmost sensitivity. Non-invasive biomarkers have the potential to change the fate of IBD diagnosis and treatment.

Research gap:

The condition and severity of Inflammatory Bowel Disease varies in different individuals, it may be symptomatic and severe, or maybe asymptomatic also with only a few manifestations. The condition may be severe, acute, asymptomatic, symptomatic, or chronic, no single marker seems to be sensitive, diagnostic and prognostic IBD-specific indicator. In the light of this, there is a need for felicitous biomarkers that can help to diagnose IBD precisely.

Novelty: This review covers novel biomarkers that can be used to diagnose IBD.

REFERENCES

1. Guan Q. A Comprehensive Review and Update on the Pathogenesis of Inflammatory Bowel Disease. Journal of Immunology Research. 2019;2019.
2. Strober W, Fuss I, Mannon P. The fundamental basis of inflammatory bowel disease. The Journal of Clinical Investigation [Internet]. 2007 Mar 1 [cited 2022 Apr 3];117(3):514–21. Available from: http://www.jci.org
3. CDC -What is inflammatory bowel disease (IBD)? - Inflammatory Bowel Disease - Division of Population Health [Internet]. [cited 2022 Apr 2]. Available from: https://www.cdc.gov/ibd/what-is-IBD.htm
4. Szigethy E, McLafferty L, Goyal A. Inflammatory bowel disease. Child Adolesc Psychiatr Clin N Am [Internet]. 2010 Apr [cited 2022 Apr 2];19(2):301–18. Available from: https://pubmed.ncbi.nlm.nih.gov/20478501/
5. How is IBD Diagnosed? | Crohn's & Colitis Foundation [Internet]. [cited 2022 Apr 2]. Available from: https://www.crohnscolitisfoundation.org/what-is-ibd/diagnosing-ibd
6. Peppercorn MA. The overlap of inflammatory bowel disease and diverticular disease. J Clin Gastroenterol [Internet]. 2004 [cited 2022 Apr 4];38(5 Suppl 1). Available from: https://pubmed.ncbi.nlm.nih.gov/15115922/
7. Card TR, Siffledeen J, Fleming KM. Are IBD patients more likely to have a prior diagnosis of irritable bowel syndrome? Report of a case-control study in the General Practice Research Database. United European Gastroenterology Journal [Internet]. 2014 Dec 1 [cited 2022 Apr 4];2(6):505. Available from: /pmc/articles/PMC4245306/

8. Papadakis KA, Tabibzadeh S. Diagnosis and misdiagnosis of inflammatory bowel disease. Gastrointestinal Endoscopy Clinics [Internet]. 2002 Jul 1 [cited 2022 Apr 4];12(3):433–49. Available from: http://www.giendo.theclinics.com/article/S1052515702000053/fulltext
9. Dilauro S, Crum-Cianflone NF. Ileitis: When It is Not Crohn's Disease. Current Gastroenterology Reports 2010 12:4 [Internet]. 2010 Jun 8 [cited 2022 Apr 4];12(4):249–58. Available from: https://link.springer.com/article/10.1007/s11894-010-0112-5
10. Duvoisin G, Lopez RN, Day AS, Lemberg DA, Gearry RB, Leach ST. Novel Biomarkers and the Future Potential of Biomarkers in Inflammatory Bowel Disease. Mediators of Inflammation. 2017;2017.
11. Liu F, Lee SA, Riordan SM, Zhang L, Zhu L. Global Studies of Using Fecal Biomarkers in Predicting Relapse in Inflammatory Bowel Disease. Frontiers in Medicine. 2020 Dec 17;7:1012.
12. Ministro P, Martins D. Fecal biomarkers in inflammatory bowel disease: how, when and why? https://doi.org/101080/1747412420171292128 [Internet]. 2017 Apr 3 [cited 2022 May 10];11(4):317–28. Available from: https://www.tandfonline.com/doi/abs/10.1080/17474124.2017.1292128
13. Ruscio M di, Vernia F, Ciccone A, Frieri G, Latella G. Surrogate Fecal Biomarkers in Inflammatory Bowel Disease: Rivals or Complementary Tools of Fecal Calprotectin? Inflamm Bowel Dis • [Internet]. 2018 [cited 2022 May 11];24(1). Available from: www.ibdjournal.org|78
14. Pathirana WPNGW, Paul Chubb SA, Gillett MJ, Vasikaran SD. Faecal Calprotectin. The Clinical Biochemist Reviews [Internet]. 2018 [cited 2022 May 12];39(3):77. Available from: /pmc/articles/PMC6370282/
15. Rosales C. Neutrophil: A cell with many roles in inflammation or several cell types? Frontiers in Physiology. 2018 Feb 20;9(FEB):113.
16. Bjarnason I. The Use of Fecal Calprotectin in Inflammatory Bowel Disease. Gastroenterology & Hepatology [Internet]. 2017 Jan 1 [cited 2022 May 12];13(1):53. Available from: /pmc/articles/PMC5390326/
17. Røseth AG, Fagerhol MK, Aadland E, Schjønsby H. Assessment of the Neutrophil Dominating Protein Calprotectin in Feces: A Methodologic Study. https://doi.org/103109/00365529209011186 [Internet]. 2009 [cited 2022 May 12];27(9):793–8. Available from: https://www.tandfonline.com/doi/abs/10.3109/00365529209011186
18. Røseth AG, Fagerhol MK, Aadland E, Schjønsby H. Assessment of the Neutrophil Dominating Protein Calprotectin in Feces: A Methodologic Study. https://doi.org/103109/00365529209011186 [Internet]. 2009 [cited 2022 May 16];27(9):793–8. Available from: https://www.tandfonline.com/doi/abs/10.3109/00365529209011186
19. Raman M. Testing for Chronic Diarrhea. Advances in Clinical Chemistry. 2017 Jan 1;79:199–244.
20. Faecal calprotectin diagnostic tests for inflammatory diseases of the bowel Diagnostics guidance. 2013 [cited 2022 May 15]; Available from: www.nice.org.uk/guidance/dg11
21. Pathirana WPNGW, Paul Chubb SA, Gillett MJ, Vasikaran SD. Faecal Calprotectin. The Clinical Biochemist Reviews [Internet]. 2018 [cited 2022 May 16];39(3):77. Available from: /pmc/articles/PMC6370282/
22. Suchismita A, Gandhi AJI. IDDF2019-ABS-0129 Optimal cut-off value of fecal calprotectin for the evaluation of inflammatory bowel disease: an unsolved issue? Gut [Internet]. 2019 Jun 1 [cited 2022 May 16];68(Suppl 1):A85–6. Available from: https://gut.bmj.com/content/68/Suppl_1/A85
23. Poullis A, Foster R, Shetty A, Fagerhol MK, Mendall MA. Bowel Inflammation as Measured by Fecal CalprotectinA Link between Lifestyle Factors and Colorectal Cancer Risk. Cancer Epidemiology, Biomarkers & Prevention [Internet]. 2004 Feb 1 [cited 2022 May 16];13(2):279–84. Available from: https://aacrjournals.org/cebp/article/13/2/279/256586/Bowel-Inflammation-as-Measured-by-Fecal
24. Burri E, Beglinger C. The use of fecal calprotectin as a biomarker in gastrointestinal disease. http://dx.doi.org/101586/174741242014869476 [Internet]. 2014 Feb [cited 2022 May 16];8(2):197–210. Available from: https://www.tandfonline.com/doi/abs/10.1586/17474124.2014.869476
25. Walsham NE, Sherwood RA. Fecal calprotectin in inflammatory bowel disease. Clinical and Experimental Gastroenterology [Internet]. 2016 Jan 28 [cited 2022 May 16];9:21. Available from: /pmc/articles/PMC4734737/
26. Noninvasive Markers in the Assessment of Intestinal Inflamma... : Official journal of the American College of Gastroenterology | ACG [Internet]. [cited 2022 May 16]. Available from: https://journals.lww.com/ajg/Abstract/2008/01000/Noninvasive_Markers_in_the_Assessment_of.25.aspx
27. Schoepfer AM, Beglinger C, Straumann A, Trummler M, Vavricka SR, Bruegger LE, et al. Fecal calprotectin correlates more closely with the simple endoscopic score for crohn's disease (SES-CD) than CRP, blood leukocytes, and the CDAI. American Journal of Gastroenterology [Internet]. 2010 Jan [cited 2022 May 16];105(1):162–9. Available from: https://journals.lww.com/ajg/Fulltext/2010/01000/Fecal_Calprotectin_Correlates_More_Closely_With.27.aspx
28. O'Brien J, Hayder H, Zayed Y, Peng C. Overview of microRNA biogenesis, mechanisms of actions, and circulation. Frontiers in Endocrinology. 2018 Aug 3;9(AUG):402.
29. Ha M, Kim VN. Regulation of microRNA biogenesis. Nature Reviews Molecular Cell Biology 2014 15:8 [Internet]. 2014 Jul 16 [cited 2022 May 19];15(8):509–24. Available from: https://www.nature.com/articles/nrm3838
30. Dalal SR, Kwon JH. The Role of MicroRNA in Inflammatory Bowel Disease. Gastroenterol Hepatol (N Y) [Internet]. 2010 Nov [cited 2022 May 19];6(11):714–22. Available from: https://pubmed.ncbi.nlm.nih.gov/21437020/
31. Wu F, Zikusoka M, Trindade A, Dassopoulos T, Harris ML, Bayless TM, et al. MicroRNAs are differentially expressed in ulcerative colitis and alter expression of macrophage inflammatory peptide-2 alpha. Gastroenterology [Internet]. 2008 [cited 2022 May 19];135(5). Available from: https://pubmed.ncbi.nlm.nih.gov/18835392/

32. Wu F, Zhang S, Dassopoulos T, Harris ML, Bayless TM, Meltzer SJ, et al. Identification of microRNAs associated with ileal and colonic Crohn's disease. Inflamm Bowel Dis [Internet]. 2010 Oct [cited 2022 May 19];16(10):1729–38. Available from: https://pubmed.ncbi.nlm.nih.gov/20848482/
33. Wu F, Guo NJ, Tian H, Marohn M, Gearhart S, Bayless TM, et al. Peripheral blood MicroRNAs distinguish active ulcerative colitis and Crohn's disease. Inflammatory Bowel Diseases. 2011 Jan;17(1):241–50.
34. Schaefer JS, Attumi T, Opekun AR, Abraham B, Hou J, Shelby H, et al. MicroRNA signatures differentiate Crohn's disease from ulcerative colitis. BMC Immunology. 2015 Feb 10;16(1).
35. Mohammadi A, Kelly OB, Smith MI, Kabakchiev B, Silverberg MS. Differential miRNA expression in ileal and colonic tissues reveals an altered immunoregulatory molecular profile in individuals with Crohn's disease versus healthy subjects. Journal of Crohn's and Colitis. 2019 Oct 28;13(11):1459–69.
36. Coskun M, Bjerrum JT, Seidelin JB, Troelsen JT, Olsen J, Nielsen OH. miR-20b, miR-98, miR-125b-1*, and let-7e* as new potential diagnostic biomarkers in ulcerative colitis. World Journal of Gastroenterology. 2013;19(27):4289–99.
37. Wohnhaas CT, Schmid R, Rolser M, Kaaru E, Langgartner D, Rieber K, et al. Fecal MicroRNAs Show Promise as Noninvasive Crohn's Disease Biomarkers. Crohn's & Colitis 360 [Internet]. 2020 Jan 1 [cited 2022 May 19];2(1). Available from: https://academic.oup.com/crohnscolitis360/article/2/1/otaa003/5735657
38. Rashid H, Hossain B, Siddiqua T, Kabir M, Noor Z, Ahmed M, et al. Fecal MicroRNAs as Potential Biomarkers for Screening and Diagnosis of Intestinal Diseases. Frontiers in Molecular Biosciences. 2020 Aug 7;7:181.
39. Qin W, Li L, Wang T, Huang H, Gao Y. Urine Proteome Changes in a TNBS-Induced Colitis Rat Model. Proteomics Clin Appl [Internet]. 2019 Sep 1 [cited 2022 May 7];13(5). Available from: https://pubmed.ncbi.nlm.nih.gov/31095872/
40. Decramer S, de Peredo AG, Breuil B, Mischak H, Monsarrat B, Bascands JL, et al. Urine in Clinical Proteomics. Molecular & Cellular Proteomics. 2008 Oct 1;7(10):1850–62.
41. Ho SSC, Keenan JI, Day AS. The Role of Gastrointestinal-Related Fatty Acid-Binding Proteins as Biomarkers in Gastrointestinal Diseases. Digestive Diseases and Sciences. 2020 Feb 1;65(2):376–90.
42. Storch J, Corsico B. The emerging functions and mechanisms of mammalian fatty acid-binding proteins. Annu Rev Nutr [Internet]. 2008 [cited 2022 Jul 20];28:73–95. Available from: https://pubmed.ncbi.nlm.nih.gov/18435590/
43. Thumser AE, Moore JB, Plant NJ. Fatty acid binding proteins: Tissue-specific functions in health and disease. Current Opinion in Clinical Nutrition and Metabolic Care. 2014 Mar;17(2):124–9.
44. Furuhashi M, Hotamisligil GS. Fatty acid-binding proteins: role in metabolic diseases and potential as drug targets. Nature Reviews Drug Discovery 2008 7:6 [Internet]. 2008 Jun [cited 2022 Jul 20];7(6):489–503. Available from: https://www.nature.com/articles/nrd2589
45. Pelsers MMAL, Namiot Z, Kisielewski W, Namiot A, Januszkiewicz M, Hermens WT, et al. Intestinal-type and liver-type fatty acid-binding protein in the intestine. Tissue distribution and clinical utility. Clinical Biochemistry. 2003 Oct 1;36(7):529–35.
46. Lau E, Marques C, Pestana D, Santoalha M, Carvalho D, Freitas P, et al. The role of I-FABP as a biomarker of intestinal barrier dysfunction driven by gut microbiota changes in obesity. Nutrition & Metabolism [Internet]. 2016 [cited 2022 Jul 20];13(1). Available from: /pmc/articles/PMC4851788/
47. Ho SS, Wall C, Gearry RB, Keenan J, Day AS. A Pilot Study Evaluating Novel Urinary Biomarkers for Crohn's Disease. Inflammatory Intestinal Diseases [Internet]. 2020 [cited 2022 Jul 20];5(4):212–20. Available from: https://www.karger.com/Article/FullText/510682
48. Sarikaya M, Ergül B, Doŧan Z, Filik L, Can M, Arslan L. Intestinal fatty acid binding protein (I-FABP) as a promising test for Crohn's disease: a preliminary study. Clin Lab [Internet]. 2015 [cited 2022 Jul 20];61(1–2):87–91. Available from: https://pubmed.ncbi.nlm.nih.gov/25807642/
49. Al-Saffar AK, Meijer CH, Gannavarapu VR, Hall G, Li Y, Tartera HOD, et al. Parallel Changes in Harvey-Bradshaw Index, TNF α, and Intestinal Fatty Acid Binding Protein in Response to Infliximab in Crohn's Disease. Gastroenterology Research and Practice. 2017;2017.

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