Inflammatory Bowel Disease: Serologic Markers and Pharmacogenomic and Metabolic Assessment of Thiopurine Therapy

Number: 0249

Policy

*Please see amendment for Pennsylvania Medicaid at the end of this CPB.

I. Aetna considers TPMT gene mutation or TPMT phenotypic assays (e.g., Prometheus TPMT Genetics, Prometheus TPMT Enzyme) medically necessary prior to initiation of 6-mercaptopurine or azathioprine therapy. Only 1 genotypic or phenotypic assay of TPMT activity is necessary per member per lifetime. TPMT gene mutation assays and TPMT phenotypic assays are considered experimental and investigational for all other indications because their effectiveness for indications other than the one listed above has not been established.

II. Aetna considers NUDT15 (nudix hydrolase 15) gene analysis medically necessary to identify member at risk of thiopurine-induced toxicity prior to initiation of...
thiopurine therapy (i.e. azathioprine, mercaptopurine, or thioguanine). Aetna considers NUDT15 testing experimental and investigational for all other indications because its effectiveness for indications other than the one listed above has not been established.

III. Aetna considers testing for anti-chitobioside carbohydrate antibodies (ACCA), anti-laminaribioside carbohydrate antibodies (ALCA), anti-mannobioside carbohydrate antibodies (AMCA), anti-chitin IgA (Anti-C), and anti-laminarin IgA (Anti-L), anti-neutrophil cytoplasmic antibodies (ANCA), anti-Saccharomyces cerevisiae antibodies (ASCA), anti-outer membrane porin C (OmpC) antibodies, anti-CBir1 flagellin (anti-CBir1) antibodies, and I2 antibodies experimental and investigational to diagnose inflammatory bowel disease, to distinguish ulcerative colitis from Crohn's disease, and for all other indications because their effectiveness has not been established.

IV. Aetna considers anti-smooth muscle antibodies (ASMA) experimental and investigational to diagnose inflammatory bowel disease or to distinguish ulcerative colitis from Crohn's disease because its effectiveness for these indications has not been established. (Note: ASMA may be medically necessary to diagnose autoimmune hepatitis).

V. Aetna considers measurements of 6-thioguanine nucleotide (6-TGN) and 6-methylmercaptopurine nucleotide (6-MMPN) (e.g., Prometheus Thiopurine Metabolites) medically necessary to monitor compliance in those not responding to 6-mercaptopurine and azathioprine therapy and to assess suspected toxicity.
VI. Aetna considers fecal measurement of calprotectin medically necessary for the management of inflammatory bowel diseases (e.g., Crohn's disease, ulcerative colitis) and for distinguishing inflammatory bowel diseases from irritable bowel syndrome. Aetna considers fecal calprotectin experimental and investigational for other indications because its clinical value has not been established.

VII. Aetna considers fecal lactoferrin medically necessary for distinguishing inflammatory bowel diseases (Crohn's disease, ulcerative colitis) from irritable bowel syndrome. Aetna considers fecal lactoferrin experimental and investigational for evaluation of infectious diarrhea, Clostridium difficile infection, and all other indications.

VIII. Aetna considers NOD2/CARD15 genotyping experimental and investigational because its clinical value has not been established.

IX. Aetna considers CD14 gene C-260T polymorphism testing, fucosyltransferase 2 gene (rs601338) variant testing, glutathione S-transferase M1 (GSTM1) null genotyping, interleukin-10-1082A/G polymorphism testing, Prometheus Crohn's Prognostic, Prometheus IBD sgi diagnostic panel and the Prometheus IBS diagnostic panel (including BDNF [brain-derived neurotrophic factor], GRO-α [growth-regulated oncogene-alpha], IL-1β [interleukin -1 beta], IL-6, IL-8, macrophage inflammatory protein-1β (MIP-1β), NGAL [neutrophil gelatinase-associated lipocalin], TIMP-1 [tissue inhibitor of metalloproteinase-1], tTG [anti-human tissue transglutaminase IgA], and TWEAK [TNF-related weak inducer of apoptosis]) experimental and
investigational for the diagnosis and management of inflammatory bowel diseases because their clinical values have not been established.

X. Aetna considers pre-operative serologic screening to identify individuals at increased risk of recurrence of Crohn's disease experimental and investigational because the effectiveness of this approach has not been established.

XI. Aetna considers the following tests experimental and investigational because their clinical values have not been established.

- Crohn's disease peptide antibody testing
- ECM1 and Stat-3 testing for ulcerative colitis
- eXaIBD test (a quantitative PCR test for 6 genes [BLCAP, UBE2G1, GPX1, RAP1A, CALM3 and NONO])
- *Firmicutes and Bacteroidetes* (F/B) ratio stool test (e.g., Salveo Diagnostics)
- IBSDetex test (an ELISA test for cytolethal distending toxin B antibody and vinculin antibody) / ibs-smart for irritable bowel syndrome
- Measurements of DNA, mRNA and protein biomarkers for predicting therapeutic response in inflammatory bowel disease
- Measurement of serum mannose-binding lectin
- Myeloperoxidase antibody testing for inflammatory bowel disease
- Proteinase-3 antibody testing
- Raman spectroscopy for inflammatory bowel disease
- Serum amyloid A as a biomarker of disease activity in Crohn's disease
• Whole blood gene expression analysis in the evaluation of Crohn's disease and ulcerative colitis

See also CPB 0341 - Infliximab (../300_399/0341.html)(for measurements of serum levels of infliximab and antibodies to infliximab), and

CPB 0715 - Pharmacogenetic and Pharmacodynamic Testing (../700_799/0715.html)

CPB 0717 - Analysis of Volatile Organic Compounds (../700_799/0717.html)

Background

Serologic Markers of Inflammatory Bowel Disease

A serology panel including anti-neutrophil cytoplasmic antibodies (ANCA), anti-Saccharomyces cerevisiae IgG and IgA antibodies (ASCA), and anti-OmpC antibodies (outer membrane porin from E. coli) are marketed by Prometheus Laboratories (San Diego, CA) as the IBD First Step. This panel has not been shown to have levels of specificity sufficient to distinguish ulcerative colitis (UC) from Crohn's disease (CD) in indeterminate cases.

Research into the pathogenesis of inflammatory bowel disease in the areas of mucosal immunology, genetics, the role of bacterial products, and mediators of tissue damage has identified new sets of "subclinical" serological markers known as anti-neutrophil cytoplasmic antibodies (ANCA). ANCA have also been found to be associated with Wegener's granulomatosis and other forms of systemic vasculitides, and more recently with sclerosing cholangitis and other autoimmune liver diseases.
“Atypical” ANCA yielding a perinuclear staining pattern (pANCA) with alcohol-fixed neutrophils is primarily found in patients with UC; pANCA has been found to be detectable in 50 to 80% of patients with UC, and 10 to 40% of patients with CD. Anti-Saccharomyces cerevisiae antibody (ASCA) is primarily detected in patients with CD; ASCA has been found to be detectable in 46 to 70% of patients with CD and 6 to 12% of patients with UC.

These tests, however, have insufficient sensitivity to diagnose UC or CD. In a paper for the North American Society for Pediatric Gastroenterology and Nutrition, Griffiths concluded that “the relatively low sensitivities of serology for [Crohn's disease] and [ulcerative colitis] as documented in all studies argue against there being any greater value of ASCA/ANCA as routine or first-line screening tests for [inflammatory bowel disease] in comparison to clinical acumen and the equally sensitive (albeit less specific) measurement of acute phase reactants. Moreover, the need for performance of definitive radiologic and endoscopic studies to guide therapy by defining the extent and nature of inflammatory bowel diseases (IBD) will not be averted by positive serologic tests.” Gupta et al (2004) examined the concordance of serologic testing for inflammatory bowel disease with clinical diagnosis established by traditional testing in children. The investigators found that the sensitivity of serologic testing is insufficient to replace traditional studies when evaluating children for inflammatory bowel disease. The investigators evaluated the results of ANCA and ASCA testing in 107 children who had serologic testing for inflammatory bowel disease (IBD) at their center, and compared these results with their clinical diagnosis. The investigators calculated that the sensitivity, specificity, positive and negative predictive values of serologic testing for ulcerative colitis were 69.2, 95.1, 90.0 and 87.1%, respectively, and for CD were 54.1, 96.8, 90.9 and 80.8% respectively. The investigators concluded that “[t]he low sensitivity, especially for Crohn’s disease, precludes the
possibility that the IBD Diagnostic System can replace traditional studies when evaluating for inflammatory bowel disease."

Some investigators have proposed using these serologic tests to differentiate CD from UC (e.g., Kornbluth and Sachar, 2004). Differentiation of CD from UC is clinically problematic only when inflammation is confined to the colon. A number of studies have reported that IgA and IgG ASCA titers are significantly greater and highly specific for CD, and that and that pANCA positivity is highly specific for UC. However, there is much less published information concerning the subgroup of IBD patients with colitis only, where differentiation of UC from CD is clinically problematic. One investigator reported ASCA positivity in only 47% of 17 patients with Crohn’s colitis. Another investigator found only 32% of 37 patients with Crohn’s colitis were ASCA positive and pANCA negative. Conversely, studies have found that the majority of Crohn’s patients positive for pANCA have a UC-like presentations (Bentley et al, 2001; Ruemmele, 1998; Vasiliaskas et al, 1996). Griffiths explained, “hence, the usefulness of serology is less (where it is needed most), given the higher prevalence of pANCA positivity and the lower prevalence of ASCA positivity in CD confined to the colon”.

Similarly, whether or not ASCA/ANCA measurement may be helpful in classifying otherwise ‘indeterminate’ colitis cannot as yet be ascertained. Only a few patients have been studied, and follow-up is too limited. In the only prospective study of serologic testing in indeterminate colitis, Joosens et al (2002) examined the results of serologic testing for ASCA or ANCA and final diagnosis of CD or UC after 6-year follow-up of 97 patients with indeterminate colitis. The largest group (47) of subjects were negative for both ANCA and ASCA; 3 of these had a final diagnosis of CD, 4 had a final diagnosis of UC, and 40 had a final diagnosis of indeterminate colitis. Of 26 subjects who were ASCA-positive and ANCA-negative, 8 had a final diagnosis of CD after 6 years follow-up, 2 had a final
diagnosis of UC, and 16 remained with a diagnosis of indeterminate colitis. Of 20 subjects who were ASCA-negative and ASCA-positive, 4 had a final diagnosis of CD, 7 had a final diagnosis of UC, and 9 had a final diagnosis of indeterminate colitis. Only 4 of the 97 subjects were positive for both ANCA and ASCA; 2 of these had a final diagnosis of CD, 1 had a final diagnosis of UC, and 1 remained with a final diagnosis of indeterminate colitis. Thus, about one-third (31%) of subjects who were ASCA-positive and ANCA-negative progressed to CD during the 6-year follow-up period, and about one-third (35%) of subjects who were ASCA-negative and ANCA-positive progressed to UC during the 6-year follow-up period. Joosens et al (2002) calculated that, thus far, the sensitivity of ASCA+/ANCA- for CD was 66.7% and the specificity is 77.8%, and the sensitivity of ASCA-/ASCA+ for UC is 77.8% and the specificity is 66.7%. Noting that these calculations exclude subjects who remained with the diagnosis of indeterminate colitis, a technology assessment of serologic testing for IBD by the Institute for Clinical Systems Improvement noted that only a “small number” (21) of subjects were included in this analysis of sensitivity and specificity. Based on their analysis of this prospective study and other published studies of serologic testing in indeterminate colitis, the ICSI concluded that the clinical utility of serologic testing in indeterminate colitis has not been established. It has also been noted that this study does not provide direct evidence of improvement in clinical outcomes by basing the management of persons with indeterminate colitis on serologic testing.

ANCA and ASCA testing has not been proven to be useful in selecting therapeutic interventions. “Although this would be desirable, there is no evidence as yet that serological test results can be used to predict the likelihood of therapeutic response to specific interventions,” Griffiths explained. In a prospective clinical study of CD patients, Esters et al (2002) found no significant relationship between these serologic markers and response to anti-tumor necrosis factor (TNF) therapy.
In addition, studies have not demonstrated correlation of ANCA or ASCA with disease activity, duration of illness, extent of disease, extra-intestinal complications, or surgical or medical treatment in patients with IBD. The Institute for Clinical Systems Improvement (ICSI) (2002) technology assessment of serologic testing for IBD concluded “[t]he clinical utility of serological testing is not yet established for the diagnosis of inflammatory bowel disease in patients presenting with symptoms suggestive of IBD” and “[t]he clinical utility of serological testing is not yet established for differentiating between UC and CD in patients with inflammatory bowel disease”.

Additional assays have been developed to use in conjunction with ANCA and ASCA in an effort to improve the diagnostic capabilities of serologic testing. OmpC IgA is an autoantibody to outer membrane porin to E. coli included in the Prometheus serology panel to enhance detection of CD (Landers et al, 2002). I2 is an IgA antibody that has been detected in patients with CD. The I2 serologic response recognizes a novel homologue of the bacterial transcription-factor families from a Pseudomonas fluorescens associated sequence (Sandborn, 2004). However, there are no studies of the clinical utility of anti-OmpC and I2 IgA antibodies in distinguishing CD from UC in persons with IBD whose diagnosis cannot be established by standard methods.

Landers et al (2002) reported on serologic test results of a referral center population of 151 patients with CD. This study found that immune responses to specific antigens (ASCA, pANCA, OmpC, and I2) are not uniform among CD patients. ASCA was detected in 56 % of patients, OmpC in 55 % of patients, I2 in 50 % of patients, and ANCA in 23 % of patients. The investigators reported that 85 % of patients responded to at least 1 antigen and that only 4 % responded to all 4. This study did not demonstrate, however, how these serologic test results relate to clinical behavior and response to therapy. The authors stated that “[t]he relationship of these different
patterns of immune responses to clinical behavior is not yet clear." The authors concluded "[d]efining how these antibody reactivities relate to clinical behavior and response to therapeutic modalities will require larger numbers of phenotypically well-characterized patients."

Mow et al (2004) reported on the results of an hypothesis generating study, the aim of which was to determine whether Crohn's patients with predominant serum antibody reactivity toward bacterial antigens OmpC and/or I2 were more likely to achieve remission with antibiotics. Study subjects were patients with moderately active right-sided colonic and/or small bowel CD who were participating in an 8-week randomized clinical trial comparing the steroid budesonide with or without the antibiotics metronidazole and ciprofloxacin. Subject's serum was analyzed for ASCA, pANCA, anti-OmpC, and anti-I2 antibodies, and subjects were put into 1 of 4 "profile groups" (ASCA, pANCA, anti-OmpC/I2, and no or little antibody) depending upon the subjects' levels of antibody response. Twenty-five of 121 subjects were excluded from the analysis because their level of antibody response did not fit the 4 predominant profile groups. Only 2 subjects had an ANCA predominant profile, and these subjects were excluded from the analysis. In the steroid plus antibiotic group, 5 of 11 subjects (45.5 %) with predominant OmpC and I2 antibodies achieved remission, 5 of 16 subjects with predominantly ASCA antibody (31.3 %) achieved remission (similar to the overall remission rate), and 5 of 21 subjects (23.8 %) with little or no antibodies achieved remission. In the steroid only group, 7 of 16 subjects (43.8 %) with little or no antibodies achieved remission, 8 of 20 (40 %) with predominantly ASCA antibody achieved remission, and 3 of 10 (30 %) subjects with predominant OmpC and I2 antibodies achieved remission. Although there was a trend toward greater responsiveness to therapy that includes antibiotics in subjects with predominant OmpC and I2 antibodies, and a trend toward less responsiveness in subjects with little or no antibodies, these trends did not achieve statistical significance. The authors
concluded that this hypothesis-generating study provides preliminary evidence to suggest that serologic information about CD patients may be helpful in defining patients who would best respond to therapy. The authors noted, however, that, "[a]lthough these trends are provocative, they lack statistical significance." The authors concluded that "[p]rospective randomized placebo controlled trials that do not limit patient selection by disease location and do not have concomitant therapy are warranted to test this hypothesis."

Mow et al (2004) evaluated the sera of 303 patients with CD to determine whether expression of certain antibodies is associated with phenotypic manifestations. The investigators found that patients expressing I2 were significantly more likely to have fibrostenosing CD (64.4 % versus 40.7 %), and to require small bowel surgery (62.2 % versus 37.4 %). Patients with anti-OmpC were more likely to have internal perforating disease (50 % versus 30.7 %) and to require small bowel surgery (61.4 % versus 44.2 %). The investigators stated that these findings suggest an association between these immune responses and CD complications. The investigators concluded that "[i]n the future, knowledge of serological response may help the clinician determine the risk for more severe disease characteristics and predict disease behaviors. As a result, it may be possible to tailor therapy more effectively on the basis of specific serological responses. However, these findings must be confirmed by prospective studies that evaluate the presence of these antibody responses and the development of complicated small bowel disease phenotypes." An editorial accompanying this study explained that this study is limited by its retrospective nature (Vermeire and Rutgeerts, 2004): "Therefore, it is important that these findings first be confirmed in independent series and more importantly, that prospective studies with these markers be conducted to assess the risk of microbial responses on the development of strictures and perforations and subsequent need for surgery."
The flagellin-like antigen, CBir1, is associated with the presence of IBD. In particular, serum response to anti-CBir1 identifies the presence of CD and is associated with a subset of patients with this form of IBD. CBir1 is found in the C3H/HeJBir mouse model. It is believed that the Cdcs1 locus of the C3H/HeJBir mouse confers severe colitis associated with a decrease in innate immune function and an increase in adaptive T-cell responses to commensal bacterial products. No evidence-based clinical guidelines from leading medical professional organizations recommend the use of this marker.

Targan et al (2005) assessed serum response to CBir1 flagellin in CD patients and compared this response to responses defined previously to ASCA, I2, OmpC, and pANCA, and determined anti-CBir1-associated phenotypes. A total of 484 sera from the Cedars Sinai Medical Center repository, previously typed for anti-Saccharomyces cerevisiae antibody, anti-I2, anti-OmpC, and pANCA were tested for anti-CBir1 by enzyme-linked immunosorbent assay, and results were evaluated for clinical phenotype associations. The presence and level of immunoglobulin G anti-CBir1 were associated with CD independently. Anti-CBir1 was present in all antibody subgroups and expression increased in parallel with increases in the number of antibody responses. pANCA+ CD patients were more reactive to CBir1 than were pANCA+ UC patients. Anti-CBir1 expression is associated independently with small-bowel, internal-penetrating, and fibrostenosing disease features. Levels of anti-CBir1 are increased in 50 to 55% of patients with CD. The authors concluded that serum responses to CBir1 independently identify a unique subset of patients with complicated CD.

Dubinsky et al (2006) examined the association of immune responses to microbial antigens with disease behavior and prospectively determined the influence of immune reactivity on disease progression in pediatric CD patients. Sera were collected from 196 pediatric CD cases and tested for immune
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responses: anti-I2, anti-OmpC, anti-CBir1, and ASCA using enzyme-linked immunosorbent assay (ELISA). Associations between immune responses and clinical phenotype were evaluated. A total of 58 patients (28 %) developed internal penetrating and/or stricturing (IP/S) disease after a median follow-up of 18 months. Both anti-OmpC (p < 0.0006) and anti-I2 (p < 0.003) were associated with IP/S disease. The frequency of IP/S disease increased with increasing number of immune responses (p trend = 0.002). The odds of developing IP/S disease were highest in patients positive for all 4 immune responses (odds ratio [OR] (95 % confidence interval [CI]): 11 (1.5 to 80.4); p = 0.03). Pediatric CD patients positive for greater than or equal to 1 immune response progressed to IP/S disease sooner after diagnosis as compared to those negative for all immune responses (p < 0.03). The authors concluded that the presence and magnitude of immune responses to microbial antigens are significantly associated with more aggressive disease phenotypes among children with CD. This was the first study to prospectively demonstrate that the time to develop a disease complication in children is significantly faster in the presence of immune reactivity, thus predicting disease progression to more aggressive disease phenotypes among pediatric CD patients.

In a review on serological markers in IBD, Bossuyt (2006) stated that several antibodies have been associated with IBD, the 2 most comprehensively studied being autoantibodies to neutrophils (atypical pANCA) and ASCA. New microbial target antigens such as OmpC, I2, and the flagellin CBir1 have been described in patients with CD. There is evidence that the number and magnitude of immune responses to different microbial antigens are associated with the severity of the disease course. However, this should be confirmed by additional studies.

Benor et al (2010) compared the predictive values of the Prometheus Inflammatory Bowel Disease (IBD) Serology 7 (IBD7) panel (Prometheus Laboratories, San Diego, CA) with
the predictive values of routine blood tests in a population of children referred for initial evaluation of suspected IBD. Medical records of pediatric patients referred for evaluation of IBD for whom IBD7 testing was performed at Prometheus Laboratories between January 2006 and November 2008 were reviewed. Patients underwent diagnosis by pediatric gastroenterologists on the basis of clinical, radiologic, endoscopic, and pathologic evaluations. A total of 394 records were identified. These investigators excluded 90 records on the basis of age of greater than 21 years, previous diagnosis of IBD, or unclear diagnosis. The prevalence of IBD in this cohort was 38%. The sensitivity, specificity, positive predictive value, negative predictive value, and kappa value for the serological panel were 67%, 76%, 63%, 79%, and 42%, respectively, compared with values for a combination of 3 abnormal routine laboratory test results of 72%, 94%, 85%, 79%, and 47%. The anti-flagellin antibody assay, the newest assay added to the panel, had sensitivity of 50% and specificity of 53%. Repeat serological testing failed to produce consistent results for 4 of 10 patients. The authors concluded that despite its recent inclusion of the anti-flagellin assay, the IBD7 panel has lower predictive values than routine laboratory tests in pediatric screening for IBD.

In summary, the testing for ANCA, ASCA, OmpC antibodies, I2 antibodies, and anti-CBir1 antibodies appears to be a promising approach to diagnose IBD, and to distinguish UC from CD.

Anti-glycan antibodies are also serological markers that are reportedly being utilized for testing in IBD. These markers are directed against microbial carbohydrate antigens and it’s purported that these markers are useful in the differentiation of CD versus UC. Anti-glycan antibodies include: anti-chitin (Anti-C), anti-chitobioside (ACCA), anti-laminaribioside (ALCA), anti-laminarin (Anti-L), anti-mannobioside (AMCA), and anti-smooth muscle antibody (ASMA), which detects autoantibodies directed against smooth muscle.
The anti-smooth muscle antibody (ASMA) test detects autoantibodies directed against smooth muscle. While this test has been employed in the management of patients with autoimmune hepatitis and cirrhosis, its use in the diagnosis of IBD has not been established.

The North American Society for Pediatric Gastroenterology, Hepatology, and Nutrition and the Crohn’s and Colitis Foundation of America’s consensus conference report on differentiating UC from CD in children and young adults (Bousvaros et al, 2007) stated that the clinical value of serology in patients with indeterminate colitis (IC) remains a topic of research, and further investigation should ascertain, among other areas, the role of surrogate laboratory markers (e.g., genetics, microbiology, and serology) in distinguishing these entities. A proposed algorithm to aid clinicians in differentiating UC from CD does not include serological testing.

Mokrowiecka et al (2009) stated that the role of pANCA and ASCA assessment in IBD diagnosis and differentiating is still imprecise and controversial. These researchers determined the accuracy of pANCA and ASCA in patients with IBD subgroups. The study was performed in 125 patients: 71 patients with UC, 31 with CD and 23 with IC. Control group consists of 45 patients with functional intestinal disorders; pANCA and ASCA (IgA and IgG) were measured with ELISA, using commercial antibody panel. In UC patients the prevalence of pANCA was 68 %, which was significantly higher than in CD -- 29 %. ASCA were found significantly more often in CD -- 80.6 % than in UC patients -- 26.8 %. Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of pANCA for UC diagnosis was 68 %, 84 %, 75 % and 78 %; and ASCA for CD: 81 %, 78 %, 45.5 % and 95 %, respectively. The combined use of these 2 markers gave changes in diagnostic accuracy: pANCA+/ASCA- in UC: 42 %, 100 %, 100 % and 43 %, and for pANCA-/ASCA+ in CD: 52 %, 98.6 % 94 % and 82 %, respectively. The authors concluded that the specificity of
these combined markers tends to be higher than sensitivity, what made them more useful in the differentiation of the IBD subtypes rather than population screening. The characteristic IC serotype pANCA(-)ASCA(-) leads to further controversies about origin of this IBD subtype.

The American College of Gastroenterology practice guidelines for management of CD in adults (Lichtenstein et al, 2009) stated that serological studies evaluating ASCA, ANCA, anti-CBir1, anti-OmpC are evolving to provide adjunctive support for the diagnosis of CD; however, they are not sensitive or specific enough to be recommended for use as a screening tools.

Lembo and colleagues (2009) stated that currently, no single serum biomarker can reliably differentiate irritable bowel syndrome (IBS) from other functional gastrointestinal disorders or organic diseases of the gastrointestinal tract. These researchers attempted to develop and validate a diagnostic test using serum biomarkers to detect IBS. A total of 10 serum biomarkers (ANCA, ASCA-IgA, BDNF [brain-derived neurotrophic factor], CBir1, GRO-α [growth-regulated oncogene-alpha], IL-1β [interleukin-1 beta], NGAL [neutrophil gelatinase-associated lipocalin], TIMP-1 [tissue inhibitor of metalloproteinase-1], ITG [anti-human tissue transglutaminase IgA], and TWEAK [TNF-related weak inducer of apoptosis]) were selected from a potential panel of 140 for their ability to differentiate IBS from non-IBS disease in blood samples from patients with IBS, other gastrointestinal disorders and healthy volunteers. A predictive modelling tool was developed to assess patterns and relationships among the 10 serum biomarkers that best differentiated IBS patients from healthy controls and patients with non-IBS gastrointestinal disease. This model was tested in a different cohort of patients and healthy controls (n = 516) to determine the predictive accuracy of differentiating IBS from non-IBS. The sensitivity and specificity of the 10-biomarker algorithm for differentiating IBS from non-IBS was 50 % and 88 %, respectively. The positive
predictive value was 81 %, and the negative predictive value was 64 % at 50 % IBS prevalence in the validation cohort. Overall accuracy was 70 %. The value of this panel of biomarkers in the management of patients with IBS needs to be validated.

In a review on the importance of early diagnosis in patients with IBS, Halpert (2010) stated that the diagnosis of IBS is challenging because symptoms can vary between patients and overlap with those of other disorders. This investigator examined the current diagnostic approach in IBS and discussed new tools that may improve diagnostic confidence earlier in the process. The author noted that accumulating evidence suggests that fecal and/or serum biomarkers may be helpful in differentiating IBS from non-IBS disorders. These tools may help minimize unnecessary testing and diagnostic delays. As biomarkers are further studied and developed, they are likely to become an integral part of the diagnosis of IBS and reduce the potential for incorrect diagnosis and treatment delays.

Dotan (2010) stated that IBD are chronic intestinal disorders where, in genetically susceptible hosts, an intestinal microorganism triggers an over-reactive immune response. Antibodies against luminal antigens are specifically associated with CD. In addition to the previously described ANCA, ASCA, OmpC, I2 and CBir1 Flagellin, new anti-glycan antibodies were recently added to the armamentarium of serologic markers in IBD. The anti-glycan antibodies are directed against laminaribioside, chitobioside, mannobioside and mannan residues and are designated anti-laminaribioside carbohydrate antibodies (ALCA), anti-chitobioside carbohydrate antibodies (ACCA), anti-mannobioside carbohydrate antibodies (AMCA) and gASCA, respectively. Anti-laminarin IgA (Anti-L), and anti-chitin IgA (Anti-C) are new members of this family. Laminarin and chitobioside are capable of stimulating the innate immune system, thus the finding of antibodies against these glycans suggests a connection between the adaptive and innate arms.
of the immune response in CD patients. The contribution of serologic markers, specifically the anti-glycan antibodies, to IBD diagnosis may be in differentiating IBD from other gastrointestinal diseases, and between CD and UC, in better classifying undetermined colitis and for decision-making prior to proctocolectomy in UC patients. The anti-glycan antibodies are specifically important in ASCA-negative CD patients. Correlation between serologic markers and genetic variations may contribute to re-classifying IBD into new and more homogeneous subclasses. Their significance in diagnosing populations at risk, such as unaffected relatives of IBD patients and CD patients prior to diagnosis, is under current investigation.

Lettesjo et al. (2006) examined if inflammatory markers could be detected in feces from patients with IBS and collagenous colitis (CC), and elucidated if such analyses could be used as non-invasive tools to distinguish between these disorders. Stool samples were obtained from 18 patients with CC, 46 patients with IBS and 20 healthy controls (HC). Eosinophil protein X (EPX), MPO, tryptase, interleukin-1 beta (IL-1beta) and tumor necrosis factor alpha (TNFalpha) were measured in supernatants from processed feces using immunoassays. EPX levels were enhanced in feces from CC patients (median 3.8 microg/g (0.47 to 16.2)) compared to patients with IBS (0.44 microg/g (0.25 to 1.8)), p < 0.001, and HC (0.46 microg/g (0.21 to 1.3)), p < 0.001. In addition, MPO was increased in CC patients (11.7 microg/g (2.0-124)) compared to IBS patients (1.7 microg/g (0.81 to 5.2)), p < 0.01, and HC (2.5 microg/g (1.1 to 6.3)), p < 0.05. Tryptase was found in 9/18 patients with CC, 6/46 with IBS and 1/19 HC. IL-1beta was only enhanced in 2/11 CC patients and TNFalpha was not detected in any sample. The authors concluded that increased levels of EPX, MPO and tryptase were observed in stools from CC patients, whereas the levels in IBS patients did not differ from healthy controls. These findings suggested that
fecal markers could be used as part of the clinical work-up to determine which patients should be biopsied and evaluated for CC.

A recent review by Navaneethan et al (2009) on laboratory tests for ilieal pouch-anal anastomosis noted the need for further studies validating the role of anti-CBIR1 as a laboratory marker to predict pouchitis, and concluding that serologic tests are primarily for research purposes.

Booth et al (2011) noted that the evidence for testing TPMT enzymatic activity or genotype before starting therapy with thiopurine-based drugs is unclear. These investigators examined the sensitivity and specificity of TPMT genotyping for TPMT enzymatic activity, reducing harm from thiopurine by pre-testing, and the association of thiopurine toxicity with TPMT status in adults and children with chronic inflammatory diseases. MEDLINE, EMBASE, the Cochrane Library, and Ovid HealthSTAR (from inception to December 2010) and BIOSIS and Genetics Abstracts (to May 2009) were used for this review. Two reviewers screened records and identified relevant studies in English. Data on patient characteristics, outcomes, and risk for bias were extracted by one reviewer and independently identified by another. A total of 54 observational studies and 1 randomized, controlled trial were included. Insufficient evidence addressed the effectiveness of pre-testing. Genotyping sensitivity to identify patients with low and intermediate TPMT enzymatic activity ranged from 70.33 % to 86.15 % (lower-bound 95 % CI: 54.52 % to 70.88 %; upper-bound CI: 78.50 % to 96.33 %). Sparse data precluded estimation of genotype sensitivity to identify patients with low to absent enzymatic activity. Genotyping specificity approached 100 %. Compared with non-carriers, heterozygous and homozygous genotypes were both associated with leukopenia (OR, 4.29 [CI: 2.67 to 6.89] and 20.84 [CI: 3.42 to 126.89], respectively). Compared with intermediate or normal activity, low TPMT enzymatic activity was significantly associated with myelotoxicity and
leukopenia. The authors concluded that insufficient evidence addresses the effectiveness of TPMT pre-testing in patients with chronic inflammatory diseases -- insufficient evidence demonstrating that this strategy is effective in reducing harm or is superior to the established clinical standard of hematological monitoring.

The new PROMETHEUS IBD sgi Diagnostic is the 4th-generation irritable bowel disease (IBD) diagnostic test and the first and only test to combine serologic, genetic, and inflammation markers in the proprietary Smart Diagnostic Algorithm for added diagnostic clarity. This test aids healthcare providers in differentiating IBD versus non-IBD as well as CD versus UC in 1 comprehensive blood test. This assay includes 9 serological markers including the proprietary Anti-Fla-X, Anti-A4-Fla2, anti-CBlr1, anti-OmpC, and DNAse-sensitive pANCA that helps identify patients with IBD and utilizes Smart Diagnostic Algorithm Technology to improve the predictive accuracy. Genetic susceptibility influences immune responses and this assay includes evaluation of ATG16L1, STAT3, NKX2-3, and ECM1. Inflammatory markers include VEGF, ICAM, VCAM, C-reactive protein (CRP), SAA. While most other labs only offer assay values, PROMETHEUS IBD sgi Diagnostic provides added clarity in diagnosing IBD, UC, and CD.

One of the references cited in the Prometheus website was a study on genetics of the ulcerative colitis by Thompson and Lees (2010). The authors concluded that "[t]hese advances will not in short term provide additional diagnostic or prognostic value. There is also no reason necessarily why polymorphisms that contribute to disease susceptibility should predict disease course, and almost certainly have no bearing on treatment response and intolerance. Prospective studies are required to address the genetic contributions to these clinically important areas, and will become a major focus in the next few years".

Proprietary
Adler et al (2011) noted that CD is often purely inflammatory at presentation, but most patients develop strictures and fistulae over time (complicated disease). Many studies have suggested that nucleotide-binding oligomerization domain 2 (NOD2) mutations are associated with a varying but increased risk of complicated disease. An accurate and sufficiently powerful predictor of complicated disease could justify the early use of biological therapy in high-risk individuals. These researchers performed a systematic review and meta-analysis to obtain accurate estimates of the predictive power of the identified mutations (such as p.R702W, P.G908R, and p.Leu1007fsX1008) in NOD2 for the risk of complicated disease. An electronic search of MEDLINE, Embase, and Web of Science identified 917 relevant papers. Inclusion required specification of genetic mutations at the individual level and disease phenotypes by Vienna classification (inflammatory (B1), stricturing (B2), and fistulizing (B3)). A total of 49 studies met these criteria, which included 8,893 subjects, 2,897 of whom had NOD2 mutations. Studies were weighted by median disease duration. Studies not providing duration data were weighted at the level of the study with the shortest disease duration (3.9 years). The relative risk (RR) of the presence of any NOD2 mutant allele for complicated disease (B2 or B3) was 1.17 (95% confidence interval (95% CI): 1.10 to 1.24; p < 0.001). P.G908R was associated with an RR of complicated disease of 1.33 (95% CI: 1.11 to 1.60; p = 0.002). NOD2 did not predict peri-anal disease (p = 0.4). The RR of surgery was 1.58 (95% CI: 1.38 to 1.80; p < 0.001). There was substantial heterogeneity across all studies (I(2) = 66.7%). On the basis of logistic regression of these data, the sensitivity of any mutation in predicting complicated disease was 36% and specificity was 73%, with the area under the receiver operating characteristic curve 0.56. The authors concluded that the presence of a single NOD2 mutation predicted an 8% increase in the risk for complicated disease (B2 or B3), and a 41% increase with 2 mutations. Surgery risk is increased by 58% with any NOD2 mutation, whereas peri-anal disease was unchanged. The predictive power
associated with a single NOD2 mutation is weak. The RR of any NOD2 mutations for complicated disease was only 17% across 36 studies. However, the presence of two NOD2 mutations had 98% specificity for complicated disease. These data provide insufficient evidence to support top-down therapy based solely on single NOD2 mutations, but suggest that targeted early-intensive therapy for high-risk patients with two NOD2 mutations might be beneficial, if prospective trials can demonstrate changes in the natural history in this subset of patients.

Bi et al (2011) stated that UC and CD are 2 distinct forms of IBD that can overlap radiologically, endoscopically, and pathologically. This difficulty complicates surgical options. The development of new technologies providing accurate diagnosis of IBD is needed. Raman spectroscopy is a non-invasive method that uses the intrinsic properties of tissue and that tissue's vibrational energy in reaction to light. These investigators hypothesized that Raman spectroscopy can detect the structural and compositional changes that occur in the tissue during the development of IBD, and thus may offer increased diagnostic certainty in the differentiation between CD and UC. Fresh frozen colon tissue biopsies from patients with UC (n = 12) and with CD (n = 9) were measured in-vitro using a custom-designed Raman fiber-optic probe. For spectra collection, the probe was placed in gentle contact with the mucosa surface for 3 seconds, with excitation power at 150 mW. Five spectra were acquired from each biopsy to increase the signal-to-noise ratio and to ensure repeatability of data collection. Mean spectra were analyzed for peak difference and molecular origin. Significant difference was observed between the spectra from each disease in the spectral regions assigned to nucleic acid, phenylalanine, and lipids. Tissue samples from patients with UC demonstrated higher content of lipid and lower amount of phenylalanine and nucleic acid. These characteristic Raman features could serve as spectral markers that can potentially be applied to distinguish UC and CD. The authors concluded that this study
presented the only application of Raman spectroscopy in the diagnosis of IBD. The feasibility of this technique in differentially detecting molecular alterations in UC and CD has been demonstrated, indicating the potential to improve diagnostic accuracy of IBD.

Wang et al (2012) noted that the gene encoding CD14 has been proposed as an IBD-susceptibility gene with its polymorphism C-260T being widely evaluated, yet with conflicting results. These researchers investigated the association between this polymorphism and IBD by conducting a meta-analysis. A total of 17 articles met the inclusion criteria, which included a total of 18 case-control studies, including 1,900 UC cases, 2,535 CD cases, and 4,004 controls. Data were analyzed using STATA software. Overall, association between C-260T polymorphism and increased UC risk was significant in allelic comparison (OR = 1.21, 95% CI: 1.02 to 1.43; p = 0.027), homozygote model (OR = 1.44, 95% CI: 1.03 to 2.01; p = 0.033), as well as dominant model (OR = 1.36, 95% CI: 1.06 to 1.75; p = 0.016). However, there was negative association between this polymorphism and CD risk across all genetic models. Subgroup analyses by ethnicity suggested the risk-conferring profiles of -260T allele and -260 TT genotype with UC in Asians, but not in Caucasians. There was a low probability of publication bias. The authors concluded that expanding previous results of individual studies, these findings demonstrated that CD14 gene C-260T polymorphism might be a promising candidate marker in susceptibility to UC, especially in Asians.

Zhu et al (2013) stated that a large number of studies have shown that the interleukin-10 (IL-10)-1082A/G polymorphism is implicated in susceptibility to IBD. However, the results are inconsistent. These investigators performed a meta-analysis to estimate the association between -1082A/G polymorphism in the IL-10 gene and IBD susceptibility. A total number of 18 case-control studies including 17,585 subjects were identified. No association was found between -1082A/G polymorphism
and UC susceptibility. However, increased risk of CD was associated with -1082A/G polymorphism in the dominant genetic model (GG+GA versus AA: OR = 1.22, 95 % CI: 1.02 to 1.46, p = 0.028) and the heterozygote comparison (GA versus AA: OR = 1.28, 95 % CI: 1.05 to 1.55, p = 0.015). The authors concluded that the results of this meta-analysis provided evidence for the association between IL-10-1082A/G polymorphism and susceptibility of CD. However, they noted that due to several limitations in the present study, well-designed epidemiological studies with large sample size among different ethnicities should be performed in the future.

Kovacs and associates (2013) stated that mannose-binding lectin (MBL) is a pattern-recognition molecule of the innate immune system and may be involved in the pathogenesis of IBD. These researchers evaluated the prevalence of MBL deficiency in a cohort of patients with pediatric-onset IBD and examined if it is associated with the clinical manifestations, serum antibody formation, or genetic factors. This prospective study included 159 pediatric patients (mean age of 14.0 years) with IBD (107 patients with CD and 52 patients with UC). Furthermore, 95 controls were investigated. Serum samples were determined for MBL by ELISA and for serologic markers (ASCA and pANCA) by indirect immunofluorescent assay. NOD2/CARD15 variants were tested by PCR/restriction fragment length polymorphism. The MBL serum concentration was significantly lower in IBD patients (both with CD and UC) compared to controls (IBD, p = 0.007; CD, p = 0.04; UC, p = 0.004). Prevalence of low MBL level (less than 500 ng/ml) was significantly higher in both CD and UC groups compared to controls (p = 0.002 and p = 0.006). Furthermore, low MBL level was associated with isolated ileal involvement (p = 0.01) and MBL deficiency (less than 100 ng/ml) with male gender (p = 0.004) in patients with CD. These investigators failed to confirm any correlation between MBL deficiency and serum autoantibodies or NOD2/CARD15 variants. The authors
concluded that these findings suggested that low MBL associated with pediatric-onset IBD and ileal CD may be considered an additional marker of the IBD pathogenesis.

Moreover, an UpToDate review on “Clinical manifestations, diagnosis and prognosis of Crohn’s disease in adults” (Peppercorn, 2013) does not mention measurement of mannose-binding lectin as a management tool.

Mitsuyama and colleagues (2014) stated that various non-invasive tests have been studied to screen for patients with CD, and were found to have limited accuracy and sensitivity, particularly in Asian populations. These investigators explored the possible diagnostic utility of antibodies to the CD peptide (ACP) in patients with CD. In a multi-center study using ELISA, serum ACP levels were determined in 196 patients with CD, 210 with UC, 98 with other intestinal diseases, 132 with other inflammatory diseases, and 183 healthy controls; and then examined for correlation to clinical variables. The diagnostic utility of ACP was evaluated by ROC analysis and compared with ASCA. Levels of ACP were significantly elevated in the CD patients, but not in the other groups that included UC, other intestinal diseases, other inflammatory diseases and the healthy controls. Among these other groups, ACP levels were not significantly different. In the CD patients, ACP had a higher sensitivity and specificity (63.3 % and 91.0 %, respectively) than ASCA (47.4 % and 90.4 %). Levels of ACP were negatively associated with disease duration, but not with Crohn’s Disease Activity Index (CDAI), disease location, or medical treatment. The authors concluded that ACP, a newly proposed serologic marker, was significantly associated with CD and was highly diagnostic. Moreover, they stated that further investigation is needed across multiple populations of patients and ethnic groups, and more importantly, in prospective studies to ascertain the clinical value of ACP.
Furthermore, an UpToDate review on “Clinical manifestations, diagnosis and prognosis of Crohn’s disease in adults” (Peppercorn, 2013) does not mention measurement of antibodies to the CD peptide as a management tool.

Adedokun et al (2014) analyzed data collected during the Active Ulcerative Colitis Trials (ACT-1 and ACT-2) to assess relationships between serum concentrations of infliximab and outcomes of adults with moderate-to-severe UC. These investigators compared serum concentrations of infliximab with outcomes of 728 patients with moderately-to-severely active UC who participated in ACT-1 or ACT-2; efficacy data were collected at weeks 8, 30, and 54 (for ACT-1 only). Relationships between serum concentration of infliximab and efficacy outcomes were assessed using trend, logistic regression, and receiver operating characteristic curve analyses. They also evaluated factors that affected the relationship between exposure and response. Median serum concentrations of infliximab at weeks 8, 30, and/or 54 were significantly higher in patients with clinical response, mucosal healing, and/or clinical remission than in patients who did not meet these response criteria. There were statistically significant relationships between quartile of infliximab serum concentration and efficacy at these time points (p < 0.01). Infliximab therapy was effective for a smaller proportion of patients in the lowest quartile, and these patients had lower serum levels of albumin and a higher incidence of antibodies to infliximab than patients in other quartiles. Although the relationship between exposure to infliximab and response varied among patients, approximate serum concentrations of 41 μg/ml infliximab at week 8 of induction therapy and 3.7 μg/ml at steady-state during maintenance therapy produced optimal outcomes in patients. The authors concluded that serum concentrations of infliximab are associated with efficacy in patients with moderate-to-severe UC; however, complex factors determine the relationship between exposure to this drug and response. They stated that a prospective evaluation
of the value of measuring serum concentrations of infliximab should be performed before these data can be included in patient management strategies.

An UpToDate review on “Clinical presentation and diagnosis of inflammatory bowel disease in infants, children, and adolescents” (Higuchi and Bousvaros, 2016) states that “The anti-OmpC antibody has been identified as a potential serologic marker of IBD. The OmpC is an outer membrane porin, E. coli protein that is immunoreactive to P-ANCA monoclonal antibodies. In a study of 198 children, anti-OmpC was detected in 25% of patients with CD (n = 81), 11% of patients with UC (n = 54), and 5% of controls (n = 63). Because anti-OmpC was positive in 9 children with IBD who were not detected by ASCA (IgA and IgG) or P-ANCA, the addition of anti-OmpC to these antibody assays increased the sensitivity from 63 to 70%, but decreased the specificity from 97 to 94%”.

Pre-Operative Serologic Screening to Identify Patients at Increased Risk of Recurrence of Crohn's Disease

Hamilton and colleagues (2017) stated that disease recurs frequently after CD resection; and the role of serological antimicrobial antibodies in predicting recurrence or as a marker of recurrence has not been well defined. In this study, a total of 169 patients (523 samples) were prospectively examined, with testing peri-operatively, and 6, 12 and 18 months post-operatively. Colonoscopy was performed at 18 months post-operatively. Serologic antibody presence (pANCA, ASCA IgA/IgG, anti-OmpC, anti-CBir1, anti-A4-Fla2, anti-Fla-X) and titer were tested. Quartile sum score (range of 6 to 24), logistic regression analysis, and correlation with phenotype, smoking status and endoscopic outcome were assessed. Patients with greater than or equal to 2 previous resections were more likely to be anti-OmpC positive (94% versus 55%, greater than or equal to 2 versus less than 2, p = 0.001). Recurrence at 18 months was associated with anti-Fla-X
positivity at baseline (49 % versus 29 %; positive versus negative, p = 0.033) and 12 months (52 % versus 31 %, p(14)
Patients positive (n = 28) for all 4 antibacterial antibodies (anti-CBir1, anti-OmpC, anti-A4-Fla2 and anti-Fla-X) at baseline were more likely to experience recurrence at 18 months than patients negative (n = 32) for all 4 antibodies (82 % versus 18 %, p = 0.034; OR 6.4, 95 % CI: 1.16 to 34.9).

The baseline quartile sum score for all 6 anti-microbial antibodies was higher in patients with severe recurrence (Rutgeert's i3 to i4) at 18 months, adjusted for clinical risk factors (OR 1.16, 95 % CI: 1.01 to 1.34, p = 0.039); smoking affected antibody status. The authors concluded that anti-Fla-X and presence of all anti-bacterial antibodies identified patients at higher risk of early post-operative CD recurrence. They stated that serologic screening pre-operatively may help identify patients at increased risk of recurrence. These preliminary findings need to be validated by well-designed studies.

Serum Amyloid A as a Biomarker of Disease Activity in Crohn's Disease

Yarur and co-workers (2017) noted that serum amyloid A (SAA) is an acute-phase protein, but its role as a biomarker of disease activity in CD is unclear. These researchers evaluated the correlation between SAA, inflammatory cytokines, and mucosal inflammation in patients with CD and examined if this marker might be useful in patients who do not have elevated CRP levels despite having active disease. This was a cross-sectional study that included patients with CD who underwent colonoscopies for assessment of disease activity. Predictive variables were recorded at the time of the procedure and included demographics, phenotype of disease, medications, and collection of serum for cytokine analysis (SAA, CRP, intercellular adhesion molecule-1, vascular cell adhesion molecule-1, and interleukins 8, 1β, and 6). The primary outcome was the presence of mucosal healing (MH) (absence of macroscopic and microscopic inflammation). A
total of 94 patients were included; 68 (72.3 %) had not achieved MH; SAA, CRP, intercellular adhesion molecule, and interleukin-6 levels were significantly lower in those patients with MH; SAA was the only test that performed well in the sensitivity/specificity analysis (ROC: 0.81, p = 0.046). A high SAA was able to identify 70 % of the patients with a normal CRP but active inflammation. The authors concluded that high circulating SAA levels can correlate with lack of MH and may be used as a surrogate marker for disease activity, even in those patients in whom CRP levels do not correlate with disease activity. These preliminary findings need to be validated by well-designed studies.

Furthermore, UpToDate review on “Clinical manifestations, diagnosis and prognosis of Crohn disease in adults” (Peppercorn and Kane, 2016) and “Clinical presentation and diagnosis of inflammatory bowel disease in children” (Higuchi and Bousvaros, 2016) do not mention serum amyloid A as a marker.

Whole Blood Gene Expression Analysis

Barnes and associates (2015) noted that despite significant improvements in the understanding CD and UC in recent years, questions remain regarding the best approaches to assessment and management of these chronic diseases during periods of both relapse and remission. Various serologic biomarkers have been used in the evaluation of patients with both suspected and documented IBD, and while each has potential utility in the assessment of patients with IBD, potential limitation remain with each method of assessment. Given these potential shortcomings, there has been increased interest in other means of evaluation of patients with IBD, including an expanding interest in the role of gene expression profiling. Among patients with IBD, gene expression profiles obtained from whole blood have been used to differentiate active from inactive CD, as well as to differentiate between CD, UC, and non-inflammatory diarrheal
conditions. There are many opportunities for a non-invasive, blood based test to aid in the assessment of patients with IBD, particularly when considering more invasive means of evaluation including endoscopy with biopsy. Furthermore, as the emphasis on personalized medicine continues to increase, the potential ability of gene expression analysis to predict patient response to individual therapies offers great promise. The authors concluded that while whole blood gene expression analysis may not completely replace more traditional means of evaluating patients with suspected or known IBD, it offers significant potential to expand the knowledge of the underlying genes involved in the development of these diseases. The main drawbacks of this study were: (i) the majority of the studies evaluating the use of whole blood gene expression analysis in the evaluation of patients with IBD have examined small populations. These small study populations may result in evaluations of heterogeneous patient groups, including patients with varying degrees of disease activity. This introduced heterogeneity into the ultimate population of cells used for the sample analysis, and thus larger studies are needed for further exploration, and (ii) when target genes have been identified in IBD and other inflammatory conditions, difficulty in the evaluation of which genes represent underlying etiologies and which represent consequences of the disease remained.

Immunological Biomarkers (e.g., Interleukin-6 [IL-6], IL-8, and Macrophage Inflammatory Protein-1β [MIP-1β])

Pike and colleagues (2015) noted that there is a recognized need for biological markers to facilitate diagnoses of IBS and to distinguish it from other functional and organic disorders. As post-infectious IBS (PI-IBS) is believed to account for as many as 1/3 of all IBS cases, these researchers sought to identify differences in specific cytokines and serologic responses across patients with idiopathic IBS and PI-IBS and healthy controls. A total of 120 US military personnel were
identified from the Defense Medical Surveillance System-based International Classification of Diseases, 9th Revision, Clinical Modification (ICD9-CM) codes recorded during medical encounters and were grouped based on infectious gastro-enteritis (IGE) episode (shigella, campylobacter, salmonella, or an unspecified pathogen) followed by IBS, IBS without antecedent IGE, or IGE without subsequent IBS within 2 years of the IGE exposure. Sera from subjects were assayed for cytokine levels and antibodies against a panel of microbiome antigens. In total, 10 of 118 markers considered were shown to differ between IBS patients and healthy controls, including cytokines interleukin-6 (IL-6), IL-8, IL-1β, and macrophage inflammatory protein-1β (MIP-1β), as well as antibody responses to microbial antigens. Antimicrobial antibody response profiles also differed between PI-IBS cases compared with IBS cases without an antecedent episode of acute IGE. Comparisons also suggested that immunoglobulin A (IgA) and IgG profiles may point to pathogen-specific origins among PI-IBS cases. The authors concluded that taken together, these results provided further evidence as to the molecular distinctness of classes of IBS cases and that serum biomarkers may prove useful in elucidating their pathobiological pathways.

Fecal Markers of Inflammatory Bowel Disease

The fundamental pathological process behind IBD is intestinal inflammation. As the precise cause of IBD is not yet completely understood, current treatment strategies are aimed at reducing or eliminating the inflammation. Endoscopic examination and histological analysis of biopsy specimens remain the "gold standard" methods for detecting and quantifying bowel inflammation; however, these techniques are costly, invasive, and repeated examinations are unpopular with patients. Disease activity questionnaires and laboratory "inflammatory markers", although widely used, show an
unreliable correlation with endoscopy and histology. New
markers are needed for detecting and quantifying bowel
inflammation.

Calprotectin is a calcium- and zinc-binding protein of the S100
family derived mainly from neutrophils and monocytes. It is
excreted in excess in stools during IBD. Fecal calprotectin
level has been reported to parallel intestinal inflammation and
can predict relapse of UC (Hanai et al, 2004).

Fecal measurement of calprotectin is emerging as a tool for
the differential diagnosis of inflammatory (e.g., CD, UC) from
non-inflammatory gastrointestinal disease (e.g., IBS), for
monitoring patients' response to therapy and for predicting
recurrence of IBD.

The available literature reports high fecal calprotectin levels in
patients with active inflammation of the bowel. As such, it
differs from erythrocyte sedimentation rates and other tests
that are general markers of inflammation and not specific to
bowel inflammation. The fecal calprotectin test, however,
cannot distinguish among different causes of bowel
inflammation. Several diseases other than inflammatory bowel
disease, including colorectal neoplasia and gastrointestinal
infection, can also increase fecal calprotectin. Because fecal
calprotectin is a nonspecific marker of bowel inflammation,
endoscopic workup remains crucial to determine the
underlying cause of colitis.

In March 2006, the PhiCal (Genova Diagnostics) quantitative
ELISA test for measuring concentrations of fecal calprotectin in
fecal stool was cleared for marketing by the U.S. Food and
Drug Administration (FDA) through the 510(k) process.
Thus, the manufacturer was not required to provide the
evidence of efficacy necessary to support a premarket
approval application (PMA).
Studies have compared fecal calprotectin levels in patients with confirmed inflammatory bowel disease versus normal controls (Tibble, et al., 2000; Schoepfer, et al., 2010) or persons with irritable bowel syndrome (Schoepfer, et al., 2007). Joishy, et al., (2008) also had a control group of children with gastrointestinal symptoms, although the causes were not specified in detail in that report. Almost all of the studies published so far have been performed in prediagnosed groups of patients or in patients in whom the major clinical problem was to distinguish between Crohn's disease and irritable bowel syndrome. These studies did not consider the wide spectrum of other organic causes of chronic diarrhea that must be distinguished from inflammatory bowel disease.

Studies have reported correlations of fecal calprotectin levels with endoscopic, histologic, clinical and serum markers of inflammation in patients with confirmed diagnoses of inflammatory bowel disease (Tibble, et al., 2000; Bunn, et al., 2001; Gaya, et al., 2005; Sipponen, et al., 2008; Vieira, et al., 2009; Quail, et al., 2009; Fagerberg, et al., 2007). Sipponen, et al., 2010 examined correlations between fecal calprotectin and endoscopic response to therapy. Other studies (Kallel, et al., 2010; Gisbert, et al., 2009) examined correlations between fecal calprotectin levels and relapse. However, the usefulness of these findings in the management of patients with inflammatory bowel disease has not been shown. There is a lack of clinical outcome studies of the use of fecal calprotectin in lieu of a standard workup for inflammatory bowel disease. Although some authors claim that fecal calprotectin can be used to avoid invasive testing, there are a paucity of studies demonstrating an actual reductions in number of invasive tests through use of fecal calprotectin measurement.

Berni et al (2004) examined fecal calprotectin values in different pediatric gastrointestinal diseases (n = 281; age ranging from 13 to 216 months) comparing them with those obtained in healthy children (n = 76; age ranging from 13 to 209 months). These investigators concluded that fecal
calprotectin is a sensitive, but not disease specific, marker to easily detect inflammation throughout the whole gastrointestinal tract. It may help in identifying an organic disease characterized by intestinal mucosa inflammation and in the differential diagnosis of functional bowel disorders. Wassell et al (2004) posited that a single measurement of fecal calprotectin may help gastroenterologists in the differential diagnosis of CD and IBS.

Tibble et al (2000) examined if measurement of intestinal permeability and inflammation could predict relapse of IBD. Forty-three patients with CD and 37 with UC in clinical remission provided a stool sample to be assayed for calprotectin and patients with CD additionally underwent a small intestinal permeability test. Relapse was defined using clinical disease activity indices. Twenty-five (58 %) patients with CD and 19 (51 %) with UC had a relapse over the 12-month period. Median calprotectin levels in the relapse groups (122 mg/L for CD, 123 mg/L for UC; normal less than 10 mg/L) differed significantly (p < 0.0001) from those of the non-relapse groups (41.5 mg/L for CD, 29.0 mg/L for UC). At 50 mg/L, the sensitivity and specificity of calprotectin for predicting relapse in all patients with IBD were 90 % and 83 %, respectively. Permeability in the CD patients who relapsed (median, 0.075; normal less than 0.04) differed significantly (p = 0. 004) from that in the non-relapse group (median, 0.038). At the level of 0.05, the sensitivity and specificity of permeability in predicting relapse were 84 % and 61 %, respectively. The authors concluded that fecal calprotectin may be useful in predicting clinical relapse of disease activity in patients with CD and UC, whereas small intestinal permeability may be a useful predictor of relapse in patients with small intestinal CD.

Although the study by Tibble et al (2000) suggested that high fecal calprotectin levels may identify IBD patients in remission who are at risk for early relapse, there are reports that there may be differences in relapse prediction in patients with CD compared to those with UC.
Costa et al (2005) examined if the predictive value of fecal calprotectin is different in CD and UC. Seventy-nine consecutive patients with a diagnosis of clinically quiescent IBD (38 CD and 41 UC) were followed for 12 months, undergoing regular clinical evaluations and blood tests. A single stool sample was collected at the beginning of the study from each patient and the calprotectin concentration was measured by a commercially available enzyme linked immunoassay. In CD, median calprotectin values were 220.1 microg/g of stool in those patients who relapsed during follow-up, and 220.5 microg/g in non-relapsing patients (p = 0.395). In UC, median calprotectin values were 220.6 microg/g and 67 microg/g in relapsing and non-relapsing patients, respectively (p < 0.0001). The multi-variate Cox regression model, after adjustment for possible confounding variables, showed a 2- and 14-fold increase in the relapse risk, respectively, in those patients with CD and UC in clinical remission who had a fecal calprotectin concentration higher than 150 microg/g. The authors concluded that fecal calprotectin proved to be an even stronger predictor of clinical relapse in UC than in CD, which makes the test a promising non-invasive tool for monitoring and optimizing therapy.

In a commentary on the role of biomarkers for predicting relapse in patients with IBD, Pardi and Sandborn (2005) stated that based on the studies of Tibble et al (2000) as well as Costa et al (2005), fecal calprotectin appears to be a relatively sensitive and specific marker of the risk of relapse for UC. It also appears to be a sensitive marker of relapse risk in CD but the data on specificity are conflicting at this juncture. However, these data need to be interpreted carefully since the number of studies is small, and in both studies using calprotectin to predict relapse risk, most patients were on medical therapy. Calprotectin may behave differently in patients who are not on therapy. Thus, before fecal calprotectin or any other biomarker of inflammatory activity in
the gastrointestinal tract can be incorporated into routine clinical practice, other studies in larger and diverse groups of patients will be needed to further clarify its role.

In the guidelines for chronic diarrhea compiled at the request of the British Society of Gastroenterology, Thomas et al (2003) stated that stool markers of gastrointestinal inflammation such as calprotectin are of considerable research interest. However, these tests have not been introduced into clinical practice. Moreover, in a review on the diagnostic and therapeutic strategies in the IBD, Cremonini and Talley (2004) stated that the usefulness of fecal tests such as calprotectin to exclude organic bowel disease is not adequately established. Furthermore, the use of calprotectin is not mentioned in the practice parameters on the management of CD in adults by the American College of Gastroenterology (Hanauer et al, 2001) and the practice guideline on the management of UC by the Society of Surgery of the Alimentary Tract (2001).

D'Inca et al (2008) evaluated the role of calprotectin tests in predicting clinical relapse in IBD patients. A total of 97 patients with UC and 65 with CD in clinical remission were prospectively included in the study. A 10-g stool sample was collected for calprotectin assay. The cut-off level was set at 130 mg/kg of feces. Patients were followed-up for 1 year after the test or until relapse. The cumulative proportion of relapses was estimated by the Kaplan-Meier analysis. Statistics for equality of survival distribution were tested using the log-rank test. The calprotectin test was positive in 44 UC patients and 26 of them relapsed within 1 year, while 11 of 53 UC patients with a negative calprotectin test relapsed within the same time frame. Thirty CD patients had a positive calprotectin test and 13 of them relapsed within 1 year, as did 7 of the 35 with a negative test result. A significant correlation emerged between a positive calprotectin test and the probability of relapse in UC patients (p = 0.000). In CD patients, only cases of colonic CD showed a significant correlation between a positive calprotectin test and the probability of relapse, i.e., 6
colonic CD patients were positive for the calprotectin test and
4 relapsed (p = 0.02). The authors concluded that measuring
calprotectin may help to identify UC and colonic CD patients at
higher risk of clinical relapse. The author also noted that while
the marker has an impressive profile in discriminating organic
versus functional intestinal diseases, its role in monitoring IBD
remains promising but still unclear. These investigators are
currently evaluating the usefulness of calprotectin levels for
predicting relapses in a more careful manner by measuring
calprotectin every 3 months, and are also planning to verify the
usefulness of this marker in monitoring response to
treatments.

Gisbert and McNicholl (2009) noted that fecal calprotectin has
been proposed as a non-invasive surrogate marker of
intestinal inflammation in IBD. Close correlation between fecal
calprotectin concentration and fecal leukocyte excretion
quantified with (111)indium has been described. Fecal
calprotectin has a good diagnostic precision for separating
organic and functional intestinal diseases. However, the
specificity for the diagnosis of IBD is lower than desirable, as
several diseases other than IBD -- specially colorectal
neoplasia and gastrointestinal infection -- can also increase
fecal calprotectin. High concentration of calprotectin in feces
is a strong argument to carry out a colonoscopy in order to rule
out the presence of IBD or other organic pathologies.
Parallelism between fecal calprotectin levels and IBD activity
has been confirmed, although this fecal marker appears to
better reflect the disease activity in UC than in CD. Fecal
calprotectin's capacity to predict IBD relapse is promising. It
has been suggested that, in IBD patients receiving treatment,
a normalization or decrease in fecal calprotectin
concentrations is an accurate indicator of endoscopic healing.
Greater fecal calprotectin concentration has been shown in
asymptomatic first-degree relatives of patients with IBD,
suggesting that there is a high prevalence of sub-clinical
intestine inflammation in them.
One of the proposed uses of this test is to evaluate patients presenting with gastrointestinal symptoms, where irritable bowel syndrome (a noninflammatory condition) and inflammatory bowel disease (Crohn's disease or ulcerative colitis) are in the differential. A metaanalysis from the Netherlands (van Rheenen, et al., 2010) examined studies of the potential use of fecal calprotectin for inflammatory bowel disease screening. The pooled analysis showed that a normal fecal calprotectin test result reduced the probability of inflammatory bowel disease in adults to 3 percent; however the confidence intervals were wide, ranging from 1 percent to 11 percent. The test did not perform as well in children, where a normal fecal calprotectin test reduced the probability of inflammatory bowel disease to 15 percent, with confidence intervals ranging from 7 percent to 28 percent. The investigators calculated false negative results in 6 percent of adults and 8 percent of children. Based upon this analysis, it has been suggested that adults with a normal fecal calprotectin can forgo endoscopy, and be treated presumptively as having irritable bowel syndrome. Based upon that assumption, the authors presenting a modeling scenario where they estimated that screening by measuring fecal calprotectin levels would result in a 67% reduction in the number of adults requiring endoscopy. This is a modeling estimate, based upon an assumption that all adults with a normal fecal calprotectin test would forgo endoscopy. Based on this analysis, there has been some support in Europe for the use of fecal calprotectin in this way. A guideline on irritable bowel syndrome from the World Gastroenterology Organisation that lists markers of inflammation ("e.g., faecal calprotectin") in the workup of persons suspected of having irritable bowel syndrome.

This metaanalysis by Van Rheem, et al. (2010) of fecal calprotectin presents a number of limitations. One has to do with the wide confidence intervals of the estimates. For adults, the upper end of the confidence interval is 11 percent, and for children, the upper end of the confidence interval is 28
percent. Thus, for adults, the actual proportion of adults with a normal fecal calprotectin may be more than 10 percent. The wide confidence intervals are a reflection of the heterogeneity of the results of the studies included in the review. The substantial differences in the estimates of the accuracy of fecal calprotectin testing among studies means that there is substantial uncertainty on the true diagnostic performance of this test. A critique of this metaanalysis by the Centre for Reviews and Dissemination (2010) stated that the authors of the metaanalysis, while recognizing the heterogeneity of study results, failed to do a statistical analysis of the heterogeneity, and that the substantial heterogeneity of study results suggests that pooling of the results into a single metaanalysis may have been inappropriate. In reviewing the conclusions of this study, one commentator (Rex, et al., 2010) questioned whether, in the United States, given the current medical legal environment, a gastroenterologist would be willing to forgo endoscopy knowing that there may be an 11 percent chance that they will misdiagnose a person with inflammatory bowel disease as having irritable bowel syndrome. Rex (2010) stated that, in the United States, given the medical legal burden to exclude inflammatory bowel disease, gastroenterologists would be unlikely to forgo endoscopy because of this imprecision. In addition, endoscopy detects more than just inflammatory bowel disease, and can detect other conditions, such as diverticulosis, that may be in the differential or contribute to the patient's symptoms.

The authors of this metaanalysis (Van Rheem, et al., 2010) stated that the estimates of test performance for this indication have been in referral populations and not in primary care. The absence of information on the performance of the fecal calprotectin test in the primary care population was also the conclusion of a recent Cochrane review. The test performance may be very different in primary care, given the differences in disease spectrum in the primary care population compared to the population of patients that are seen in secondary or tertiary care settings. For example, the
prevalence of inflammatory bowel disease would be expected
to be much lower in the primary care population, and one
would expect to have a higher prevalence of acute
inflammatory bowel disorders that may lead to falsely positive
results. Thus, the results of this metaanalysis cannot be
extrapolated for use in primary care.

There is an absence of evidence to support the use of fecal
calprotectin testing to guide the management of patients with
inflammatory bowel disease. There are no current guidelines
from leading medical professional organizations that
recommend the use of fecal calprotectin for this purpose.
Guidelines from the World Health Organization (2015), in a
section on diagnosis of inflammatory bowel disease, state that
fecal calprotectin "could be very helpful in developing
countries." The guidelines state that fecal calprotectin is not
necessary for diagnosis if endoscopy available, but may help
select for further investigation including with endoscopy in
countries with limited (medium) resources. A Crohn's disease
evaluation and treatment tool from the American
Gastroenterological Association (Sandborn, et al., 2014)
includes measurement of fecal calprotectin among a series of
tests in the workup of inflammatory bowel disease, but has no
recommendations for use of this test in guiding
management. The FDA-approved labeling of products used to
treat inflammatory bowel disease do not discuss the use of
fecal calprotectin for this purpose. There is a lack of reliable
evidence from clinical studies where fecal calprotectin is used
to guide management. There is a need for clinical studies of
the use of fecal calprotectin demonstrating that, compared to
standard of care management without fecal calprotectin, the
use of fecal calprotectin results in better clinical outcomes,
fewer endoscopies, or some other important clinical
outcome. Current evidence for fecal calprotectin to
guide management describes the test performance in guaging
inflammation in persons with inflammatory bowel disease; this
type of evidence is hypothesis generating, and suggests that
fecal calprotectin has promising potential for this use.
Abej et al (2016) sought to determine the relationship between fecal calprotectin and imaging studies and other biochemical inflammatory markers and the impact of fecal calprotectin measurements on decision-making in inflammatory bowel disease (IBD) patient management in usual clinical practice. Investigators enrolled 240 persons with inflammatory bowel disease in a cross-sectional study conducted at a single center in Canada. The correlation between fecal calprotectin values and other markers for disease activity such as serum albumin (alb), hemoglobin (Hg), and C-reactive protein (CRP) and diagnostic imaging or colonoscopy was examined. Fecal calprotectin ≥ 250mcg/g of stool was considered a positive result indicating active IBD. A total of 183 stool samples (76.3%) were returned. Positive fecal calprotectin was associated with colonoscopy findings of active IBD ($P < 0.05$), low albumin ($P < 0.05$), anemia ($P < 0.01$), and elevated CRP ($P < 0.01$). A positive fecal calprotectin test was not significantly associated with radiologic evidence of active disease. There was no significant difference for fecal calprotectin results by outcomes on small bowel evaluation among the 21 persons with small bowel CD. Most persons (87.5%) with normal fecal calprotectin and no change in therapy remained in remission during subsequent 3 months; however, followup time was short and lacked controls. The authors noted, in addition, that "it is difficult to discern what role the FCAL result had in the clinicians not pursuing investigations or therapy changes as opposed to their management consideration being based on a composite of other testing, as well." Other limitations noted by the authors was that the same testing was not undertaken in all subjects to fully determine the correlations between the fecal calprotectin and various outcomes, especially cross-sectional imaging. The authors found that a positive fecal calprotectin often triggered a clinical response, either more investigations or a change in therapy. But, not having done imaging in all subjects, they were not able to discern how many false negative fecal calprotectin tests were represented within their sample.
Noting that there are limited studies that have looked at the physician experience and perspective of the use of fecal calprotectin, Rosenfeld et al. (2016) conducted a survey to evaluate the perspective of gastroenterologists affiliated with the University of British Columbia, Canada, regarding the impact of fecal calprotectin on the management of patients with inflammatory bowel disease (IBD). Patients with known IBD or symptoms suggestive of IBD for whom the physician identified that fecal calprotectin would be clinically useful were recruited. Physicians completed an online “pre-survey” outlining their rationale for the test. After receipt of the test results, the physicians completed an online “post-survey” to portray their perceived impact of the test result on patient management. Clinical outcomes for a subset of patients with follow-up data available beyond the completion of the “post-survey” were collected and analyzed. The primary outcome was the frequency with which the fecal calprotectin result resulted in a change in the management of the patient as indicated by the pre- and post-surveys. Secondary outcomes included the deferral of colonoscopies as a result of the fecal calprotectin level, the proportion of events for which the physician found the fecal calprotectin level to be useful in the care of the patient and the association of the fecal calprotectin result to subsequent clinical, endoscopic and/or radiological outcomes. The primary outcome of change in management was analyzed according to a positive result being > 250 μg/g in addition to > 100 μg/g, given the heterogeneity in the indication for fecal calprotectin in the study cohort as well as the uncertainty in the current literature relating to what is considered a “positive” and “negative” fecal calprotectin. Of 373 test kits distributed, 290 were returned, resulting in 279 fully completed surveys. One hundred and ninety patients were known to have IBD; 147 (77%) with Crohn’s disease, 43 (21%) ulcerative colitis and 5 (2%) IBD unclassified. Indications for fecal calprotectin testing included: 90 (32.2%) to differentiate a new diagnosis of IBD from irritable bowel syndrome (IBS), 85 (30.5%) to distinguish symptoms of IBS from IBD in those known to have IBD and 104 (37.2%) as an
objective measure of inflammation. Survey respondents indicated that fecal calprotectin levels resulted in a change in management 51.3% (143/279) of the time which included a significant reduction in the number of colonoscopies (118) performed (P < 0.001). Overall, 97.5% (272/279) of the time, the physicians stated that they found the test sufficiently useful that they would order it again in similar situations. Follow-up data was available for 172 patients with further support for the clinical utility of fecal calprotectin provided. The authors noted that the limitations of this "pilot study" include potential bias created by patient inclusion being solely dependent on the discretion of the involved physician. The authors stated that this accordingly has contributed to a heterogeneous patient population and is reflective of the limited guidance regarding the most appropriate use of fecal calprotectin. Other limitations of the study included the lack of validation of the study survey and failure to return about 20 percent of fecal calprotectin sample. The authors noted that, finally, at the time of initial study design, a fecal calprotectin level of 250 μg/g was considered appropriate for analysis of outcomes; however at the time of follow-up analysis, a level of 100 μg/g was considered more appropriate. The authors noted the need for additional investigations in the "grey zone" between 100 and 250 μg/g.

The authors (Rosenfeld, et al., 2016) noted that this study had several drawbacks: (i) potential bias created by patient inclusion being solely dependent on the discretion of the involved physician. This accordingly has contributed to a heterogeneous patient population and was reflective of the limited guidance regarding the most appropriate use of FC at the time of study design, (ii) given this was a real-life study, there was also unavoidable potential for inclusion of patients with co-existing undiagnosed conditions that could influence the FC level such as colonic polyps or additional immunologically driven digestive disorders, (iii) more than 20% of patients did not return FC samples. However, such
patients were similarly distributed across the indications for the test suggesting that this did not influence the patient's decision to carry out the test, (iv) it is acknowledged that questionnaires were not previously validated although a degree of quality control was performed during the study to ensure that the surveys accurately reflected the clinical practice of the doctors, with initial perusal of 20 surveys, and then a further follow-up of 210 patients. The considerable duration of follow-up possible for the latter patients did enable adjustment for variation between what had been indicated by the physician on the post-survey response and what actually occurred, and (v) at the time of initial study design, a FC level of 250 μg/g was considered appropriate for analysis of outcomes, however at the time of follow-up analysis in 2015, a level of 100 μg/g was considered more appropriate. The “grey zone” between 100 and 250 μg/g and the accompanying need for additional investigations, particularly in IBD was highlighted in the recently published clinician guide to using FC to identify and monitor disease activity in IBD.

In a retrospective cohort study from Canada, El Mataray et al (2017) stated that "data on the impact of fecal calprotectin directing management in an IBD population, especially in children, are sparse." The investigators measured fecal calprotectin, clinical activity indices, and blood markers in children with established diagnoses of inflammatory bowel disease (IBD). Pearson correlation coefficient analysis was performed to examine association between fecal calprotectin and other markers. Decisions based on fecal calprotectin measurements were prospectively documented and participants were evaluated 3 to 6 months later. When patients were asked to bring stool samples, pediatric gastroenterologists were asked to complete a questionnaire. Other investigations such as hemoglobin, serum albumin, and CRP were known to physicians who made no changes in treatment at that time point. The clinicians were asked to
decide if they would do any additional investigations (mainly colonoscopy) or any changes in therapy, based only on the fecal calprotectin results. Clinicians were given specific options to choose from for treatment escalation in case fecal calprotectin comes back as positive. Once the fecal calprotectin results were known, any investigations and treatment changes were documented and patients were followed up for 3–6 months. Clinical activity indices were measured in the follow-up visits. A total of 115 fecal samples were collected from 77 children with IBD [median age 14, interquartile range (IQR) 11–15.6 years, 42 females, 37 with Crohn’s disease]. The authors reported that fecal calprotectin measurements had “fair” correlation with clinical disease activity indices ($r = 0.483$, $P < 0.05$), Physicians Global Assessment of disease activity (PGA) ($r = 0.40$, $P < 0.05$), erythrocyte sedimentation rate (ESR) ($r = 0.40$, $P < 0.05$), low hemoglobin ($r = -0.40$, $P < 0.05$), with less correlation with low serum albumin ($r = -0.3$, $P < 0.05$) but no correlation with c-reactive protein (CRP) ($r = 0.1$, $P = 0.3$). Correlation was limited ($r = 0.256$, $P = 0.006$) with endoscopic activity as only 14 children had colonoscopy within 4 weeks of fecal calprotectin measurement. The authors reported that only 14 (12%) out of 115 samples resulted in colonoscopy as guided by physicians’ discretion. The authors posited that this may have been when physicians felt that fecal calprotectin value was equivocal between 100 and 250, but data to that effect were not presented. Two colonoscopies were in fecal calprotectin negative and 12 in the fecal calprotectin positive group. The authors stated that, for the rest of the cohort [101 (88%) samples], decisions on treatment (escalation or no treatment) were based solely on fecal calprotectin measurements. Sixty four out of 74 (86%) samples with positive FCal measurements were associated with treatment escalation that resulted in improvements in clinical activity indices, while in the FCal negative group, 34 out of 41 (83%) measurements were associated with no change in treatment. The authors noted that limitations of the study include the retrospective design and small sample size.
especially for those who had colonoscopy. As colonoscopy was not performed in all subjects, the investigators were unable to discern how many false negative fecal calprotectin measurements were represented within the sample. Another limitation was a lack of measurements of fecal calprotectin in the follow-up visits after implementing changes in therapy but the study outcome was intended to be clinical activity indices. The authors concluded, however, that 'nonetheless, the study adds significantly to the current literature as little is known about the impact and outcome of FC measurements in pediatric IBD clinical practice.'

Henderson and colleagues (2014) stated that fecal calprotectin (FC) is increasingly used during the diagnosis of inflammatory bowel disease (IBD), out-performing blood markers during investigation in children. Tests that reduce endoscopy rates in children with suspected gut inflammation would be beneficial. These investigators determined the usefulness of FC in children undergoing their primary investigation for suspected IBD by systematic review and meta-analysis. An electronic search was performed with keywords relating to IBD and calprotectin in multiple electronic resources from 1946 to May 2012; a hand search was also performed. Inclusion criteria were studies that reported FC levels before the endoscopic investigation of IBD in patients less than 18 years old. Studies were evaluated using the Quality Assessment of Diagnostic Accuracy Studies tool, and a meta-analysis was performed using a hierarchical summary receiver operating curve model. A total of 8 papers met the inclusion criteria (6 prospective and 2 retrospective case-control studies); methodological quality was determined in detail for each study. The 8 studies presented FC levels at presentation in 715 patients, 394 pediatric IBD patients, and 321 non-IBD controls. Pooled sensitivity and specificity for the diagnostic utility of FC during the investigation of suspected pediatric IBD were 0.978 (95 % confidence interval (CI): 0.947 to 0.996) and 0.682 (95 % CI: 0.502 to 0.863), respectively; the positive and negative likelihood ratios were 3.07 and 0.03, respectively. The authors
concluded that FC has a high sensitivity and a modest specificity during the diagnosis of suspected pediatric IBD. Moreover, they stated that further work is required to determine the effect of FC levels on endoscopy rates and its role during the re-evaluation of those with confirmed disease.

Also, an UpToDate review on “Clinical manifestations, diagnosis and prognosis of Crohn’s disease in adults” (Peppercorn, 2013) states that “Testing for fecal calprotectin may help identify patients with intestinal inflammation, though it is not routinely done in clinical practice”.

Lasson et al (2014) examined if the concentration of FC reflects the endoscopic findings 1 year after ileo-caecal resection and evaluated the variation of FC in individual patients during 6 months prior to the ileo-colonoscopy. A total of 30 patients with CD and ileo-caecal resection performed within 1 year were included. Stool samples were delivered monthly until an ileo-colonoscopy was performed 1 year post-operatively. One year after surgery the median values of FC were not significantly different between the patients in endoscopic remission (n = 17) and the patients with an endoscopic recurrence (189 (75 to 364) versus 227 (120 to 1,066) μg/g; p = 0.25). However, most patients with low values were in remission and all patients with high (greater than 600 μg/g) calprotectin values had recurrent disease. The variability of the FC concentration was most pronounced in patients with diarrhea. The authors concluded that they found no statistical difference in the concentrations of calprotectin between patients in endoscopic remission and patients with a recurrent disease 1 year after ileo-caecal resection for CD. However, among the minority of patients with low or high values, FC indicated remission and recurrence, respectively. There was significant variation of the FC concentrations over time, which affects the utility of calprotectin in clinical practice.
Noting that "the applications of FCAL in monitoring inflammation in IBD in clinical practice have not been standardized and the impact of addition of FCAL on the diagnostic and monitoring armamentarium in IBD is not well defined", Abej and co-workers (2016) examined the relationship between FC and imaging studies and other biochemical inflammatory markers and the impact of FC measurements on decision-making in IBD patient management in usual Canadian clinical practice. A total of 240 persons with IBD were enrolled. The correlation between FC values and other markers for disease activity such as serum albumin (alb), hemoglobin (Hg), and CRP and diagnostic imaging or colonoscopy was examined; FC greater than or equal to 250 µg/g of stool was considered a positive result indicating active IBD. A total of 183 stool samples (76.3%) were returned. The return rate in the pediatric and adult cohorts was 91% (n = 82) and 67.3% (n = 101), respectively (p < 0.0001). Positive FC was associated with colonoscopy findings of active IBD (p < 0.05), low albumin (p < 0.05), anemia (p < 0.01), and elevated CRP (p < 0.01). There was no significant difference for FC results by outcomes on small bowel evaluation among the 21 persons with small bowel CD. Most persons (87.5%) with normal FC and no change in therapy remained in remission during subsequent 3 months. The authors concluded that this study represented a snapshot of how FC testing is used in monitoring disease activity in IBD in clinical practice outside the context of clinical trials. They found that in a referral population of persons with IBD, positive FC was significantly associated with abnormal endoscopy, elevated serum CRP, low serum Hb, and low serum alb. While it was a small cohort that had imaging, FC results were not significantly associated with cross-sectional imaging evidence of disease activity, likely reflecting a weaker association with small bowel disease. They stated that the findings of this study confirmed that FC can be used as a surrogate marker for disease activity in IBD. However, clinicians are placing considerable faith in the test even though its role in small bowel CD requires further research.
The authors (Abej et al, 2016) stated that this study had one main drawbacks: the same testing was not undertaken in all subjects to fully determine the correlations between FC and various outcomes, especially cross-sectional imaging. However, at study outset, these investigators were particularly interested in determining how clinicians would use FC results. A positive FCAL often triggered a clinical response, either more investigations or a change in therapy. Unfortunately, not having done imaging in all subjects, the authors could not discern how many false negative FC tests were represented within their sample. Nonetheless, these findings showed how much faith clinicians have placed in FC based on the medical literature since all participating clinicians were utilizing FC for the first time in their practices.

In a retrospective cohort study from Canada, El-Matary and associates (2017) examined the impact of FC measurements on decision-making and clinical care of children with IBD; FC, clinical activity indices, and blood markers were measured in children with established diagnoses of IBD. Pearson correlation coefficient analysis was performed to examine association between FC and other markers. Decisions based on FC measurements were prospectively documented and participants were evaluated 3 to 6 months later. A total of 115 fecal samples were collected from 77 children with IBD [median age of 14 years, interquartile range (IQR) 11 to 15.6, 42 females, 37 with CD]; FC positively correlated with clinical activity indices ($r = 0.481, p < 0.05$) and erythrocyte sedimentation rate ($r = 0.40, p < 0.05$) and negatively correlated with Hb ($r = -0.40, p < 0.05$); 64 out of 74 (86 %) positive FC measurements (greater than or equal to 250 $\mu$g/g of stools) resulted in treatment escalation with subsequent significant clinical improvement while in the FC negative group, 34 out of 41 (83 %) measurements resulted in no change in treatment and were associated with remission on follow-up. The authors concluded that based on high FC, the majority of
children had treatment escalation that resulted in clinical improvement; FC measurements were useful and reliable in decision-making and clinical care of children with IBD.

The authors noted that this study had several drawbacks: (i) the retrospective design and small sample size especially for those who had colonoscopy. However, based on previous research, FC is known to strongly correlate with endoscopic disease activity and these researchers assumed that it did. Hence, the escalation of treatment in most participants with elevated FC levels regardless of whether a colonoscopy was performed or not, (ii) the study main objective was how FC measurements would impact on disease management. A positive FC most often triggered a clinical response; especially a change in therapy. As the authors did not do colonoscopy in all subjects they could not discern how many false negative FC measurements were represented within their sample. Nonetheless, these findings showed that the faith clinicians placed in the FC result was rewarded with good clinical outcomes, and (iii) a lack of measurements of FC in the follow-up visits after implementing changes in therapy but the study outcome was intended to be clinical activity indices. Nonetheless, the study added significantly to the current literature as little is known about the impact and outcome of FC measurements in pediatric IBD clinical practice.

Holtman and colleagues (2016) examined the diagnostic accuracy of symptoms, signs, non-invasive tests, and test combinations that can assist the clinician with the diagnosis of IBD in symptomatic children. These researchers performed a literature search of Medline and Embase. Two reviewers independently selected studies reporting on the diagnostic accuracy of tests for IBD, with confirmation by endoscopy and histopathology or clinical follow-up, in children with chronic gastrointestinal symptoms. Two reviewers independently extracted data and assessed study quality with the
QUADAS-2, an evidence-based quality assessment tool for diagnostic accuracy studies. A total of 19 studies were included (n = 2,806). Symptoms (abdominal pain, diarrhea, rectal bleeding, and weight loss) had pooled sensitivities ranging from 0.48 to 0.82 and specificities ranging from 0.17 to 0.78. Of all the blood markers, CRP (9 studies) and alb (6 studies) had the best performance, with pooled sensitivities of 0.63 (0.51 to 0.73) and 0.48 (0.31 to 0.66), respectively, and specificities of 0.88 (0.80 to 0.93) and 0.94 (0.86 to 0.98). Assessment of FC (10 studies) had a pooled sensitivity of 0.99 (0.92 to 1.00) and a specificity of 0.65 (0.54 to 0.74). One limitation was that none of the studies was conducted in non-referred children. The authors concluded that in children whose pediatrician is considering an endoscopy, symptoms are not accurate enough to identify low-risk patients in whom an endoscopy can be avoided. They stated that FC, CRP, and alb findings are potentially of clinical value, given their ability to select children at low risk (negative FC test result) or high risk (positive CRP or alb test result) for IBD. Moreover, they stated that further research should examine the accuracy of sequential testing strategies and the added values of tests beyond signs and symptoms focusing on FC, CRP, and alb; and before tests or a diagnostic strategy can be recommended in non-referred, low-risk children, high-quality studies are needed in this setting.

Koulaouzidis et al (2016) noted that accurate inflammation reporting in CE is important for diagnosis and monitoring of treatment of IBD; FC is a highly specific biomarker of gut inflammation. Lewis score (LS) was developed to standardize quantification of inflammation in small-bowel (SB) CE images. In a retrospective, multi-center study, these researchers investigated correlation between LS and FC in a large group of patients undergoing CE for suspected or known small-bowel IBD, and developed a model for prediction of CE results (LS) based on FC levels. A total of 333 patients were recruited; they had small-bowel CE and FC done within 3 months. Overall, correlation between FC and LS was weak (r_s: 0.232,
When 2 clinically significant FC thresholds (100 and 250 μg/g) were examined, the rs between FC and LS was 0.247 (weak) and 0.337 (moderate), respectively (p = 0.307). For clinically significant (LS greater than or equal to 135) or negative (LS less than 135) for SB inflammation, ROC curves gave an optimum cut-off point of FC 76 μg/g with sensitivity 0.59 and specificity 0.41. The authors concluded that LS appeared to show low correlation with FC as well as other serology markers of inflammation; and FC did not appear to be a reliable biomarker for significant small-bowel inflammation. Nevertheless, FC level greater than or equal to 76 μg/g may be associated with appreciable visual inflammation on small-bowel CE in patients with negative prior diagnostic work-up.

Ministro and Martins (2017) stated that over the past 30 years knowledge on fecal biomarkers (FM) has substantially increased. Nowadays these non-invasive inflammation markers are used in the daily management of IBD. The interest in investigating FM was motivated by the need of a simple, quick, disposable and less invasive marker of disease activity, which might remove the need for endoscopy when following-up with patients. These researchers reviewed the current literature for articles regarding the role of FM in IBD diagnosis, activity, flare prediction, medication and surgical treatment response as well as how FM may differ in adult and pediatric IBD patient populations. The authors stated that although FM is relevant in IBD patient follow-up, there isn’t enough data regarding FM reference values for different ages, different disease subtypes, disease localization/extension or response to therapy. Serial measurements of FM for each patient may be useful in accessing relapse in most patients. FM presented more consistent results when used as a predictive tool of relapse after ileocecal surgery in CD. The authors concluded that ongoing research will clarify FM role in decision-making IBD daily practice.
An UpToDate review on “Approach to the adult with chronic diarrhea in resource-rich settings” (Bonis and Lamont, 2017) states that “Calprotectin is a zinc and calcium binding protein that is derived mostly from neutrophils and monocytes. It can be detected in tissue samples, body fluids, and stools, making it a potentially valuable marker of neutrophil activity. Fecal calprotectin levels are increased in intestinal inflammation and may be useful for distinguishing inflammatory from non-inflammatory causes of chronic diarrhea. A meta-analysis of 13 studies of both adults and children with chronic diarrhea and/or suspected inflammatory bowel disease (IBD) who underwent endoscopy estimated sensitivity and specificity to discriminate IBD from other causes of symptoms. In adults, pooled sensitivity was 93% (95% CI 0.85 to 0.97) and pooled specificity was 96% (95% CI 0.79 to 0.99). In children and teenagers, sensitivity was similar (92%, 95% CI 0.84 to 0.96) but specificity was significantly lower (76%, 95% CI 0.62 to 0.86). The authors note that in settings with a low prevalence of IBD (such as among patients seen for abdominal pain or diarrhea in a primary care setting) the test might be most useful to help rule out IBD while in high prevalence settings (such as a gastroenterology clinic) the test might be most useful for ruling in IBD. However, test characteristics varied considerably among the studies included in the meta-analysis. Furthermore, diagnostic evaluation (including endoscopy) is sometimes needed even if IBD is not strongly suspected. Thus, fecal calprotectin can be considered as an adjunctive test in diagnostic evaluation of patients with chronic diarrhea. Other potential roles have also been proposed including in colorectal cancer screening and monitoring of activity in inflammatory bowel disease. However, its test characteristics are not yet sufficiently defined for routine clinical application for these indications.”

Benitez and García-Sanchez (2015) noted that IBD is a chronic and relapsing disorder that leads to an inflammation of the gastro-intestinal (GI) tract. A tailored therapy to achieve mucosal healing with the less adverse events (AEs) has
become a key issue in the management of IBD. In the past, the clinical remission was the most important factor to consider for adapting diagnostic procedures and therapeutic strategies. However, there is no a good correlation between symptoms and intestinal lesions, so currently the goals of treatment are to achieve not only the control of symptoms, but deep remission, which is related with a favorable prognosis. Thus, the determination of biological markers or biomarkers of intestinal inflammation play a crucial role. Many biomarkers have been extensively evaluated in IBD showing significant correlation with endoscopic lesions, risk of recurrence and response to treatment. One of the most important markers is FC. Despite calprotectin limitations, this biomarker represents a reliable and non-invasive alternative to reduce the need for endoscopic procedures; FC has demonstrated its performance for regular monitoring of IBD patients, not only to the diagnosis for discriminating IBD from non-IBD diagnosis, but for assessing disease activity, relapse prediction and response to therapy. The authors concluded that although, FC provides better results than other biomarkers such as CRP and ESR, these surrogate markers of intestinal inflammation should not be used isolation but in combination with other clinical, endoscopic, radiological or/and histological parameters enabling a comprehensive assessment of IBD patients.

Lehmann et al (2015) stated that CD and UC are characterized by periods of symptomatic relapse and remission. Diagnosis and assessment of IBD has so far been based on clinical evaluation, serum parameters, radiology and endoscopy. Fecal markers such as calprotectin or lactoferrin have emerged as new diagnostic tools to detect and monitor intestinal inflammation. These investigators listed the limitations of stool biomarkers: Calprotectin concentration depends on different physiological factors (e.g., age, clinical co-morbidities, and may also have considerable day-to-day variation). The distribution of calprotectin within a stool sample seems to be homogeneous. In a study by Naismith and colleagues in 143 consecutive patients with quiescent CD, the
interclass correlation of consecutive calprotectin samples was high (0.84) and only a minority of patients (16%) showed within-patient variability across 3 samples. However, considerable day-to-day variability of fecal calprotectin may exist. In a recent well-controlled study the coefficient of variation suggested a marked intra-individual variability of fecal calprotectin values but it is important to note that the variability was greatest in patients with high concentrations of calprotectin, questioning the clinical relevance of this finding. Only sparse and controversial data exist as to whether calprotectin levels are correlated to specific disease locations. Sipponen and colleagues found higher calprotectin concentrations in colonic compared with ileal CD. In contrast, Jensen and Bremner found similar calprotectin levels in patients with CD, irrespective of ileal, ileo-colonic or colonic disease. In UC, Ricanek and colleagues reported that the median calprotectin concentrations were higher in extensive and left-sided disease than in exclusive proctitis.

Bodelier et al (2017) stated that monitoring mucosal inflammation in IBD is of major importance to prevent complications and improve long-term disease outcome. The correlation of clinical activity indices with endoscopic disease activity is, however, moderate. Fecal calprotectin is a better predictor of mucosal inflammation, but values between 100 and 250 µg/g are difficult to interpret in clinical practice. These investigators evaluated the occurrence of indefinite FC levels in a real-life IBD cohort and studied the additional value of a combination of biochemical markers and clinical activity indices. In total, 148 CD and 80 UC patients visiting the out-patient clinic were enrolled. FC, clinical disease activity scored by the Harvey-Bradshaw index or Simple Clinical Colitis Activity Index, and CRP were assessed. In a subset of patients, endoscopic activity was scored by the simple endoscopic score-Crohn's disease and Mayo endoscopic subscore. Clinical activity index, CRP, and FC were integrated in a combination score and compared with endoscopy. Indefinite FC values were present in 24% of CD and 15% of
UC. In the cohort of patients with endoscopy scores available, the combination score predicted endoscopic disease activity in CD with a sensitivity of 83% and specificity of 69% (PPV 58%, NPV 89%). In UC, this was 88 and 75% (PPV 93%, NPV 60%). The authors noted that despite the fact that the FC greater than or equal to 250 µg/g cut-off point showed good sensitivity and specificity for active disease in this endoscopy cohort, the reality in daily clinical practice is that a significant number of patients have "indefinite" FC values. All these patients in the authors' baseline cohort could, however, be classified as having active disease or remission with the combination score. These researchers concluded that in their real-life cohort of IBD patients, a substantial part of patients had indefinite FC values, which made active disease or remission difficult to predict. The combination of FC with clinical activity indices or CRP may improve the prediction of endoscopic active disease or remission in these patients. In daily clinical practice, the combination score instead of FC as a single non-invasive marker could be a practical tool for gastroenterologists to select patients that need treatment optimization or re-evaluation of disease activity, given the large number of patients with FC "gray zone" results between 100 and 250 µg/g. The combination score has shown potential as a non-invasive disease activity marker, but needs further validation in a second independent cohort of CD and UC patients with endoscopic disease activity as gold standard.

Heida et al (2017) stated that in asymptomatic patients with IBD, "monitoring" involves repeated testing aimed at early recognition of disease exacerbation. These researchers determined the usefulness of repeated FC measurements to predict IBD relapses by a systematic literature review. An electronic search was performed in Medline, Embase, and Cochrane from inception to April 2016. Inclusion criteria were prospective studies that followed patients with IBD in remission at baseline and had at least 2 consecutive FC measurements with a test interval of 2 weeks to 6 months. Methodological assessment was based on the second Quality Assessment of
Diagnostic Accuracy Studies (QUADAS-2) checklist. A total of 1,719 articles were identified; 193 were retrieved for full text review; 6 studies met eligibility for inclusion. The time interval between FC tests varied between 1 and 3 months. Asymptomatic patients with IBD who had repeated FC measurements above the study’s cutoff level had a 53 % to 83 % probability of developing disease relapse within the next 2 to 3 months. Patients with repeated normal FC values had a 67 % to 94 % probability to remain in remission in the next 2 to 3 months. The ideal FC cut-off for monitoring could not be identified because of the limited number studies meeting inclusion criteria and heterogeneity between selected studies. The authors concluded that 2 consecutively elevated FC values were highly associated with disease relapse, indicating a consideration to proactively optimize IBD therapy plans. Moreover, they stated that more prospective data are needed to examine if FC monitoring improves health outcomes.

Lee and colleagues (2019) evaluated the usefulness of FC as a biomarker for disease activity in patients with IBD using both ELISA and a quantitative point-of-care test (QPOCT). Fecal samples and medical records were collected from consecutive patients with IBD; FC levels were measured by both ELISA and QPOCT and patient medical records were reviewed for clinical, laboratory, and endoscopic data. A total of 93 patients with IBD were enrolled, 55 with UC and 38 with CD. The mean FC-ELISA levels were 906.3 ± 1,484.9 μg/g in UC and 1,054.1 ± 1,252.5 μg/g in CD. There was a strong correlation between FC-ELISA level and clinical activity indices (p < 0.05); FC-ELISA level was significantly lower in patients with mucosal healing (MH) compared to those without MH in UC (85.5 ± 55.6 μg/g versus 1,503.7 ± 2,129.9 μg/g, p = 0.005).

The results from the QPOCT corresponded well to those from ELISA. A cut-off value of 201.3 μg/g for FC-ELISA and 150.5 μg/g for FC-QPOCT predicted endoscopic inflammation (Mayo endoscopic subscore greater than or equal to 1) in UC with a sensitivity of 81.8 % and 85.8 %, respectively, and a specificity of 100 % for both. The authors concluded that these findings
indicated that FC is a reliable surrogate marker of endoscopic activity in IBD; FC could be especially useful in the prediction of endoscopic remission in patients with UC. Thus, FC has the potential to replace colonoscopy for the serial assessment of mucosal inflammation in IBD patients.

This study had several limitations. There was a lack of follow-up data for FC in these patients. In order to show the close correlation between FC and disease activity, FC data taken at different time-points with varying degree of disease activity in the same patient may be more useful and informative. The number of patients included in this study was relatively small. These researchers did not assess histological findings. The definition of MH is still controversial and some researchers suggested that MH should include not only endoscopic healing but also the histological absence of mucosal inflammation.

Recently, Theede et al illustrated that the FC level correlated with endoscopic and histologic inflammatory activity in 120 UC patients who had endoscopic and histologic features of mucosal healing (positive predictive value 0.71 and 0.75, negative predictive value 0.65 and 0.90). Thus, future studies should evaluate the relationship between FC and histologic inflammation. Since colonoscopy was performed in too few CD patients, the correlation between FC and endoscopic activity in CD could not be assessed. Higher fraction of the CD patients showed relatively low disease activity (CDAI less than 220). This uneven distribution could result in selection biases.

Boschetti et al (2015) stated that fecal calprotectin (fCal) is widely used as marker of gut inflammation and is strongly associated with the severity of endoscopic lesions in Crohn's disease (CD). The authors analyzed the relationships between levels of fCal and high-sensitivity C-reactive protein (hsCRP) and the presence and severity of postoperative endoscopic recurrence in asymptomatic CD patients (Harvey-Bradshaw index≤3). Blood and fecal samples were collected in consecutive asymptomatic CD patients (Harvey-Bradshaw
index 0.85 ± 0.19, mean ± s.e.m.) who had undergone an ileocolonic resection. hsCRP and fCal were measured and a routine ileocolonoscopy was performed within 18 months (median 7 months) from resection, to detect endoscopic recurrence according to the Rutgeerts score. Eighty-six patients were included in this prospective multicenter observational cohort. fCal concentrations differed significantly in patients with endoscopic recurrence when compared with those in endoscopic remission (mean ± s.e.m.: 473 ± 78 µg/g vs. 115 ± 18 µg/g; P<0.0001). The area under the receiver operating characteristic (ROC) curve to discriminate between patients in endoscopic remission and recurrence was 0.86 for fCal and lower for hsCRP (0.70). The best cutoff point for fCal to distinguish between endoscopic remission and recurrence was 100 µg/g as determined by the ROC curve, and its sensitivity, specificity, positive and negative predictive values (NPVs), as well as overall accuracy were 95%, 54%, 69%, 93%, and 77%, respectively. The authors concluded that measurement of fCal concentrations is a promising and useful tool for monitoring asymptomatic CD patients after ileocolonic resection. Taking into account the high NPV of fCal, a threshold below 100 µg/g could avoid systematic ileocolonoscopies in 30% of patients from this population.

Patel et al (2017) stated mucosal healing as measured by endoscopic activity is the therapeutic target for ulcerative colitis (UC) and associated with improved outcomes. The authors investigated the clinical utility of fecal calprotectin (FC) levels to predict depth of remission, including histological remission in patients with UC. The authors performed a retrospective chart review of patients with UC who underwent a full colonoscopy and FC measured within 6 weeks before colonoscopy at a tertiary inflammatory bowel disease center. Clinical, endoscopic, and histological disease activity was assessed by Patient Reported Outcomes (PRO2), Mayo endoscopic score (0-3), and Nancy score (0-4), respectively. Outcomes of interest included (1) deep remission (PRO2 remission and Mayo score 0) and (2) deeper remission (deep
remission plus Nancy score 0/1). Mann-Whitney U and Kruskal-Wallis tests and area under the curve-receiver operating characteristic curve analysis were used to evaluate accuracy of the predictive values. In 68 patients, increasing FC levels were significantly associated with disease extent ($P = 0.006$), Mayo score ($P = 0.001$), and Nancy scores ($P < 0.001$). Patients with Mayo score 0/1 and Nancy score ≤ 1 ($n = 20$) had significantly lower FC levels compared with Mayo 0/1 and Nancy ≥ 2 (31 versus 231; $P < 0.001$). FC level of ≤ 60 μg/g predicted deep remission (area under the curve = 0.92, sensitivity 86%, and specificity 87%) and deeper remission (area under the curve = 0.91, sensitivity 83%, and specificity 90%). The authors concluded that FC levels significantly correlated with endoscopic extent, mucosal healing, and histological activity, and reflect microscopic disease activity even in the face of macroscopic healing. An FC level of ≤ 60 μg/g robustly predicted depth of remission, suggesting that FC can be used instead of colonoscopy in a treat-to-target paradigm in patients with UC.

Ma et al (2017) stated the noninvasive biomarkers fecal immunochemical testing (FIT) and fecal calprotectin (FCP) are sensitive for prediction of mucosal inflammation in inflammatory bowel disease. However, neither test has yet been shown to independently and accurately predict mucosal healing (MH). The authors aimed to assess the specificity of noninvasive FIT and FCP for MH prediction. In this prospective cohort study of adult inflammatory bowel disease outpatients presenting for colonoscopy, stool samples for FIT and FCP were collected 48 hours before endoscopy. Using MH defined by Simple Endoscopic Score for Crohn's disease (SES-CD = 0), Rutgeert's score (i0), and the Ulcerative Colitis Endoscopic Index of Severity (UCEIS = 3), receiver operator characteristic curves were plotted, and sensitivity, specificity, positive and negative predictive values, and areas under the curve were calculated. Multivariate logistic regression analysis was used to develop a clinical model for noninvasively predicting MH. Eighty patients (40 Crohn's disease and 40 ulcerative colitis)
were enrolled. The specificities of FIT <100 ng/mL and FCP <250 μg/g for MH were 0.57 (95% confidence interval, 0.38-0.74) and 0.77 (0.57-0.89), respectively. Positive predictive values for MH for FIT <100 ng/mL and FCP <250 μg/g were 0.78 (0.64-0.87) and 0.77 (0.58-0.90), respectively. In multivariate modeling, combining FIT, FCP, and clinical symptomatic remission improved specificity for MH to 0.90 (0.72-0.97) with positive predictive values of 0.84 (0.60-0.96). Areas under the curve for FIT was higher for patients with ulcerative colitis (0.88) than for patients with Crohn's disease (0.69, P = 0.05). The authors concluded that FIT and FCP have similar performance characteristics for identifying MH. Combined, low FIT, low FCP, and clinical remission are specific for MH.

In the CALM study, Colombel et al (2018) stated biomarkers of intestinal inflammation, such as faecal calprotectin and C-reactive protein, have been recommended for monitoring patients with Crohn's disease, but whether their use in treatment decisions improves outcomes is unknown. The authors aimed to compare endoscopic and clinical outcomes in patients with moderate to severe Crohn's disease who were managed with a tight control algorithm, using clinical symptoms and biomarkers, versus patients managed with a clinical management algorithm. CALM was an open-label, randomised, controlled phase 3 study, done in 22 countries at 74 hospitals and outpatient centres, which evaluated adult patients (aged 18–75 years) with active endoscopic Crohn's disease (Crohn's Disease Endoscopic Index of Severity [CDEIS] >6; sum of CDEIS subscores of >6 in one or more segments with ulcers), a Crohn's Disease Activity Index (CDAI) of 150–450 depending on dose of prednisone at baseline, and no previous use of immunomodulators or biologics. Patients were randomly assigned at a 1:1 ratio to tight control or clinical management groups, stratified by smoking status (yes or no), weight (<70 kg or ≥70 kg), and disease duration (≤2 years or >2 years) after 8 weeks of prednisone induction therapy, or earlier if they had active
disease. In both groups, treatment was escalated in a stepwise manner, from no treatment, to adalimumab induction followed by adalimumab every other week, adalimumab every week, and lastly to both weekly adalimumab and daily azathioprine. This escalation was based on meeting treatment failure criteria, which differed between groups (tight control group before and after random assignment: faecal calprotectin ≥250 μg/g, C-reactive protein ≥5mg/L, CDAI ≥150, or prednisone use in the previous week; clinical management group before random assignment: CDAI decrease of <70 points compared with baseline or CDAI >200; clinical management group after random assignment: CDAI decrease of <100 points compared with baseline or CDAI ≥200, or prednisone use in the previous week). De-escalation was possible for patients receiving weekly adalimumab and azathioprine or weekly adalimumab alone if failure criteria were not met. The primary endpoint was mucosal healing (CDEIS <4) with absence of deep ulcers 48 weeks after randomisation. Primary and safety analyses were done in the intention-to-treat population. Between Feb 11, 2011, and Nov 3, 2016, 244 patients (mean disease duration: clinical management group, 0·9 years [SD 1·7]; tight control group, 1·0 year [2·3]) were randomly assigned to monitoring groups (n=122 per group). 29 (24%) patients in the clinical management group and 32 (26%) patients in the tight control group discontinued the study, mostly because of adverse events. A significantly higher proportion of patients in the tight control group achieved the primary endpoint at week 48 (56 [46%] of 122 patients) than in the clinical management group (37 [30%] of 122 patients), with a Cochran–Mantel–Haenszel test-adjusted risk difference of 16·1% (95% CI 3·9–28·3; p=0·010). 105 (86%) of 122 patients in the tight control group and 100 (82%) of 122 patients in the clinical management group reported treatment-emergent adverse events; no treatment-related deaths occurred. The most common adverse events were nausea (21 [17%] of 122 patients), nasopharyngitis (18 [15%]), and headache (18 [15%]) in the tight control group, and worsening Crohn’s disease (35 [29%])
of 122 patients), arthralgia (19 [16%]), and nasopharyngitis (18 [15%]) in the clinical management group. The authors concluded that CALM is the first study to show that timely escalation with an anti-tumour necrosis factor therapy on the basis of clinical symptoms combined with biomarkers in patients with early Crohn's disease results in better clinical and endoscopic outcomes than symptom-driven decisions alone. Future studies should assess the effects of such a strategy on long-term outcomes such as bowel damage, surgeries, hospital admissions, and disability.

Pharmacogenomic and Metabolic Assessment of Thiopurine Therapy

The PRO-Predict series of tests were developed by Prometheus, Inc. with the intent of providing guidance in determining therapeutic direction and predicting therapeutic response in individual patients. PRO-Predict 6MP is for 6-MP/Azathioprine remission and toxicity monitoring, PRO-Predict TPMT is for 6-MP/azathioprine response stratification, and PRO-Predict TNF is for anti-TNF response stratification. However, there is insufficient scientific evidence in the current medical literature to support the routine use of these tests in clinical practice.

Although there is a potential to regulate azathioprine and mercaptopurine according to measurement of metabolites, the optimal mode of therapeutic monitoring remains to be established through prospective clinical trials demonstrating that clinical outcomes are improved through metabolite monitoring. Current evidence is largely limited to studies exploring correlations between metabolite levels and azathioprine and mercaptopurine toxicity and response. These studies have shown conflicting results in the strength of the relationship between metabolite levels, toxicity, and response. There are no well-designed prospective clinical studies demonstrating that azathioprine or mercaptopurine therapy based upon results of metabolite testing leads to improved
clinical outcomes compared to therapy based upon clinical assessment and standard testing including routine blood counts and liver enzymes.

A significant association has been found between erythrocyte 6-thioguanine levels and the likelihood of clinical remission with azathioprine and 6-mercaptopurine (Osterman et al., 2006); however, studies of the relationship between 6-thioguanine levels and the likelihood of clinical remission have not shown consistent results (Cuffari et al. 1996; Gupta et al, 2001; Lowry et al, 2001; Belaiche et al, 2001; Gilissen et al, 2004). A similar association with clinical remission has not been found with levels of 6-methylmercaptopurine (Cuffari et al, 1996; Dubinsky et al, 2000; Gilissen et al, 2004). Despite an overall correlation with clinical response rates, clinical studies have shown a wide range of rates of response and toxicity across a range of 6-TG levels (e.g., Cuffari et al, 1996; Dubinsky et al, 2000). In addition, studies have shown that the predictive value of metabolite levels in individual patients is low (e.g., Cuffari et al, 2006; Goldenberg et al, 2004). Another limitation to using metabolites levels to guide drug dosing is that there may be substantial variation in levels between measurements in individual patients (e.g., Wright et al, 2004).

Bone marrow toxicity due to azathioprine or 6-mercaptopurine has been found to correlate with elevated levels of 6-thioguanine, and liver toxicity has been found to correlate with levels of 6-methylmercaptopurine (Ciffari et al, 1996; Dubinsky et al, 2000; Ooi et al, 2007). However, clinical studies have shown that 6-methylmercaptopurine levels are not an accurate predictor of liver toxicity in individual patients (e.g., Goldenberg et al, 2004; Shaye et al, 2007; Heneghan et al, 2006; Reinshagen et al, 2007). In addition, other adverse reactions, such as pancreatitis or leukopenia, can occur unrelated to serum metabolite levels (Cuffari et al, 1996; Ooi et al, 2007). Thus, measurement of serum metabolite levels can not replace regular monitoring for toxicity with blood counts and liver enzymes.
In addition, measurement of serum metabolite levels must be compared with commonly available standard laboratory methods. Waljee et al (2010) reported that algorithms that use age and laboratory values (CBC and chemistries) can differentiate clinical response, nonadherence, and shunting of thiopurine metabolism among patients who take thiopurines, and that this approach was more accurate than 6-TGN metabolite measurements in predicting clinical response.

A Cochrane Collaboration meta-analysis of literature on azathioprine and 6-mercaptopurine in Crohn’s disease (Sandborn et al, 2002) concluded: “Another potential area of investigation is individualization of therapy. 6-Mercaptopurine is inactivated by methylation catalyzed by thiopurine methyltransferase (TPMT) whereas the active metabolites are the 6-thioguanine nucleotides (6-TGN). The toxicity and effectiveness of 6-mercaptopurine therapy in childhood lymphocytic leukemia is inversely correlated with the activity of TPMT and directly correlated with the erythrocyte concentrations of 6TGN. Measurement of both TPMT enzyme activity and erythrocyte 6TGN (therapeutic drug monitoring) in patients with Crohn’s disease may allow individualized dosing to produce an optimal therapeutic effect while minimizing the potential for leukopenia. Colanna and Korelitz (1994) have advocated using the presence of mild leukopenia as an indicator of the appropriate dose of 6-mercaptopurine. In their recent retrospective analysis of 6-mercaptopurine therapy in 98 patients with refractory CD, they demonstrated a correlation between leukopenia and the achievement and maintenance of remission. However, another retrospective study reported that leukopenia did not predict response in patients with UC treated with 6-mercaptopurine. Prospective studies are needed to determine whether any of these attempts to optimize therapy with azathioprine or 6-mercaptopurine will be of use in routine clinical practice.”
Guidelines from the American College of Gastroenterology (2001) on management of CD state that, although there is a potential to regulate azathioprine and mercaptopurine according to measurement of metabolites, the optimal mode of therapeutic monitoring remains to be established through clinical trials. “It remains to be determined how to optimize dose and whether induction of leukopenia or therapeutic monitoring of 6-thioguanine metabolites offer improved means of assuring a long-term response.” American College of Gastroenterology guidelines on UC (2004) reached similar conclusions about the utility of metabolite monitoring. “The utility of thiopurine metabolite testing requires prospective controlled evaluation before routine use can be recommended.”

A position statement from the American Gastroenterological Association (Lichtenstein et al, 2006) provides a Grade C recommendation for the use of thiopurine metabolite monitoring in the treatment of patients with 6-MP or AZA when attempting to determine medical noncompliance. The guidelines note that thiopurine metabolite monitoring “may be helpful” for optimizing dose and monitoring for toxicity. The guidelines, however, do not provide specific recommendations for use of thiopurine monitoring for these indications. “Given the conflicting data, the retrospective nature of these studies, and the limited positive and negative predictive values for these particular uses, the utility of these tests needs prospective controlled evaluation before their routine use can be recommended.”

More recently, an American College of Gastroenterology (ACG) (Lichtenstein et al, 2009) guideline on CD in adults stated that, although retrospective analyses indicate that determination of 6-TGN and 6 MMP levels can be helpful to assess lack of response, patient adherence, leukopenia, or elevations in liver enzymes, "at the present time, there are inadequate data to recommend routine measurement of these metabolites...” The discussion of metabolite monitoring in the
supporting ACG technical review cites a European evidence based consensus on the diagnosis and management of Crohn's disease (2006), where none of the consensus used 6-thioguanine concentrations to adjust the dose. The discussion in the AGA technical review also cites an American Gastroenterological Association Technical Review (Lichtenstein, et al., 2006), which stated that “[t]hio purine metabolite monitoring in the treatment of patients with 6-MP or AZA is useful when attempting to determine medical noncompliance …”. It should be noted that this is a grade C recommendation based upon low quality evidence (defined as “evidence based on clinical experience, descriptive studies, or reports of expert committees”). Although thiopurine metabolite monitoring has been advocated for assessing compliance, there are no rigorous study data on this use. The guidelines also state that thiopurine metabolite monitoring “may be helpful” (grade C recommendation) for optimizing dose and monitoring for toxicity. The guidelines, however, do not provide specific recommendations for use of thiopurine monitoring for these indications. The technical review reports that “[s]ome, but not all, recent retrospective studies have suggested that measurement of AZA and 6-MP metabolites may be useful in dose adjustments…. Given the conflicting data, the retrospective nature of these studies, and the limited positive and negative predictive values for these particular uses, the utility of these tests needs prospective controlled evaluation before their routine use can be recommended. The utility of these metabolite markers, however, can assist an individual in determining whether a patient is noncompliant with their immunomodulator therapy.” The technical review also states that “Future prospective studies with measurement of dose optimization based on clinical efficacy and remission compared with measurements of TPMT, 6-TGN, and 6-MMP levels are still needed to better define appropriate treatment algorithms and doses in patients with UC. These particular studies can also assess the level (if any is present) of incremental benefit to the traditional routine of monitoring complete blood count, liver-associated laboratory chemistries,
and clinical response.” It also should be noted that the FDA-approved labeling for Imuran (azathioprine) and mercaptopurine include recommendations for TPMT genotyping and phenotyping, but include no recommendation for use of thiopurine metabolites in dosing and administration.

The role of 6-TGN for assessing compliance, and in combination with 6-MMP to assess drug-failure attributable to high methylator status has been advocated but has not been substantiated by rigorous study data.

Prospective clinical studies are needed to determine whether outcomes are improved by tailoring individual drug regimens using azathioprine metabolite testing. A prospective, randomized controlled clinical trial found that 6-TGN-adapted azathioprine therapy did not lead to higher remission rates than standard therapy in patients with chronic active CD. Reinshagen et al (2007) reported on a prospective randomized trial that examined whether 6-TGN concentration-adapted azathioprine therapy is clinically superior to a standard dose of 2.5 mg/kg/day azathioprine in patients with CD. After 2 weeks of standard therapy, patients (n = 71) were randomized into standard (n = 32) or adapted-dose (n = 25) groups; 14 patients dropped out before randomization. In the adapted group, the azathioprine dose was adjusted to maintain 6-TGN concentrations between 250 and 400 pmol/8 x 10(8) erythrocytes (Ery). Response criteria were the number of patients in remission after 16 weeks without steroids (primary) and remission after 24 weeks, frequency of side effects, and quality of life (secondary). After 16 weeks, 14 of 32 (43.8 %) patients in the standard group versus 11 of 25 (44 %) in the adapted group were in remission without steroids (intent-to-treat analysis). After 24 weeks, 43.8 % versus 40 % were in remission. The researchers found no significant differences concerning quality of life, disease activity, 6-TGN concentrations, azathioprine dose, or dropouts due to side effects. Sixty-six patients had a wild-type TPMT genotype, with TPMT activities of 8 to 20 nmol/(mL Ery x h). Five
patients (dropouts after randomization) were heterozygous, with TPMT activities less than 8 nmol/(mL Ery x h). 6-MMP concentrations greater than 5,700 pmol/8 x 10(8) Ery were not associated with hepatotoxicity. The investigators concluded that standard and adapted dosing with the provided dosing scheme led to identical 6-TGN concentrations and remission rates. The investigators reported that adapted dosing had no apparent clinical benefit for patients with TPMT activity between 8 and 20 nmol/(mL Ery x h). The investigators also found that 6-MMP monitoring had no predictive value for hepatotoxicity. Additional prospective controlled clinical studies of thiopurine metabolite monitoring have been sponsored by the National Institutes of Health (NIDDK, 2010).

Thiopurine methyltransferase (TPMT) catalyzes the S-methylation of azathioprine, 6-mercaptopurine and thioguanine. Several studies have reported correlations between mutations in the TPMT gene with susceptibility to leukopenia from azathioprine and mercaptopurine therapy, and investigators have proposed using the results of TPMT gene mutation testing to select candidates for azathioprine therapy. However, almost all studies that have been published to date have only tested patients exhibiting toxicity for TPMT gene mutations and not a broader group of patients; thus, the sensitivity and specificity of TPMT gene mutation testing to toxicity susceptibility is unknown (Evans et al, 2001; Colombel et al, 2000). In those studies where all patients were tested for TPMT gene mutations prior to therapy, TPMT mutations were detected in only a minority of patients exhibiting drug-induced leukopenia (Naughton et al, 1999; Dubinsky et al, 2000; Relling et al., 1999). This has led investigators to conclude that myelosuppression may be due to other factors in addition to variable TPMT therapy, and that monitoring of blood counts throughout azathioprine or mercaptopurine therapy is essential in all patients, regardless of the presence or absence of TPMT gene mutations. In addition, there are no prospective studies
demonstrating improvement in outcomes by guiding azathioprine therapy or mercaptopurine therapy based on the results of TPMT gene mutation testing.

Prometheus Laboratories, manufacturer of the ProPredict Series of Tests, had obtained United States distribution rights for Imuran (azathioprine). The FDA had agreed to include information about TPMT genotyping and phenotyping in the Imuran product labeling. It should be noted that the product labeling emphasized that TPMT testing cannot substitute for complete blood count monitoring in patients receiving Imuran. As of December 2018, Imuran was the registered trademark of Sebela International Ltd (Roswell, GA).

A position statement from the American Gastroenterological Association (Lichtenstein et al, 2006) notes that information about TPMT testing is included in azathioprine product labeling. The position statement explains that “[c]urrent Food and Drug Administration (FDA) recommendations suggest that individuals should have thiopurine methyltransferase (TPMT) genotype or phenotype assessed before initiation of therapy with AZA [azathioprine] or 6-MP [6-mercaptopurine] in an effort to detect individuals who have low enzyme activity (or who are homozygous deficient in TPMT) in an effort to avert AZA or 6-MP therapy and thus avoid potential adverse events.” The position statement notes, however, that individuals who have intermediate or normal TPMT activity (wild type or heterozygotes) need measurement of frequent complete blood counts (as above) in addition to TPMT assessment because these individuals may still develop myelosuppression subsequent to use of azathioprine or 6-mercaptopurine.

Guidelines from the British Society of Gastroenterology (2004) stated that TPMT testing is not necessary. The guidelines state that research has shown that the majority (77 %) of inflammatory bowel disease patients with azathioprine (AZA) -induced bone marrow suppression did not carry a TPMT mutation. The guidelines noted that evidence that TPMT
activity predicts other side effects or outcome is limited. The
guidelines noted that TPMT testing “cannot yet be
recommended as a prerequisite to therapy, because decades
of experience has shown clinical AZA to be safe in UC
[ulcerative colitis] or CD [Crohn’s Disease].”

Guidelines from the American College of Gastroenterology
(Kornbluth and Sachar, 2004) are in agreement. “6-MP and its
prodrug azathioprine are both metabolized by thiopurine
methyltransferase (TPMT), and enzyme that exhibits variation
as a result of a genetic polymorphism of its alleles and this
enzyme can now be measured by commercial laboratories.
Approximately 0.3% of the general population have low to
absent enzyme activity, 11% have intermediate, and 89%
have normal to high levels of activity. However, only about a
quarter of cases of leukopenia in practice are associated with
one of these genetic polymorphisms. Therefore, prospective
studies of dose-optimization based on measurements of
TPMT, 6-TG, or 6-MP levels to monitor clinical response are
still needed before the routine use of these assays can be
recommended as providing much incremental benefit to the
traditional routine of monitoring the CBC, liver associated
laboratory chemistry abnormalities, and clinical response.”

Teml et al (2007) summarized clinical pharmacological aspects
of thiopurines in the treatment of chronic IBD. These
investigators noted that on the basis of an excellent
phenotype-genotype correlation for TPMT, genotyping has
become a safe and reliable tool for determination of a patient's
individual phenotype. Based on several cost-benefit analyses,
assessment of TPMT activity is recommended prior to
thiopurine therapy in patients with IBD. They also stated that
although the therapeutic response appears to be related to
6-TGN concentrations above a threshold of 230 to 260 pmol/8
x 10^8 red blood cells, currently therapeutic drug monitoring of
6-TGN can be recommended only to estimate patients’
compliance.
In a cross-sectional study, Firooz et al (2008) examined the role of TPMT activity in the safety and effectiveness of azathioprine in the treatment of pemphigus vulgaris. A total of 139 patients were included in this study. The TPMT activity in red blood cells was measured using high-performance liquid chromatography. Severe adverse effects were defined as those judged serious enough that azathioprine therapy be discontinued. These investigators also evaluated the relationship of clinical response and TPMT concentration in 52 patients who had been treated with a combination of prednisolone and azathioprine for at least 1 year, and the clinical response was considered favorable if there was no recurrence of pemphigus vulgaris in the first year of treatment. The median activity of TPMT was 44.7 ng/ml/h (interquartile range of 28.7 ng/ml/h). Eleven patients (7.9 %) had low TPMT activity (TPMT-HL), 127 patients (91.4 %) had normal TPMT activity (TPMT-HH), and 1 patient (0.7 %) had supra-normal enzyme activity; TPMT activity was noted in all patients. Serious adverse effects occurred in 14 patients (10.1 %). There was no relationship between development of adverse effects and TPMT activity (p = 0.29). Eleven patients with low TPMT activity had been treated with azathioprine for a mean (SD) of 10.2 (4.1) months. Only 1 patient exhibited serious adverse effects. The TPMT enzyme activity was not different in 28 patients with unfavorable clinical response compared with 24 patients with favorable clinical response (p = 0.09). The authors concluded that larger prospective studies are needed to determine the clinical relevance of TPMT activity and to determine accurate azathioprine dosing guidelines based on TPMT activity.

A study by Heneghan et al (2006) of patients with autoimmune hepatitis receiving azathioprine found that advanced fibrosis, rather than TPMT genotype or phenotype, predicted drug toxicity. In addition, the investigators found that measurement of 6-TG and 6-MMP levels was not useful. The investigators retrospectively evaluated data on 6-TG and 6-MMP levels and on TPMT genotyping and enzyme activity.
in patients with autoimmune hepatitis who received azathioprine therapy with or without prednisone. From 1995 through 2001, 86 patients began courses of azathioprine; to maintain remission, 26 received azathioprine alone, 19 received prednisone alone, 26 received azathioprine plus prednisone, 9 received alternative therapies (mycophenolate mofetil, sirolimus, or cyclosporine), and the rest received no therapy. TPMT genotyping was performed and 6-TG and 6-MMP levels were measured in all patients. Twenty-two patients had at least 1 episode of azathioprine-related toxicity. Neither TPMT genotype nor enzyme activity predicted such episodes, although cirrhosis was more common among patients who developed azathioprine toxicity than among those who did not (p = 0.043). No threshold levels of 6-TG or 6-MMP predicted remission.

Cao et al (2009) identified the TPMT gene polymorphisms in Chinese IBD patients and studied the relationship between TPMT status and thiopurine-related toxicity in these patients. A total of 189 IBD patients, 87 with CD and 102 with UC, and 273 healthy controls were enrolled. All subjects were from the Han Chinese ethnic group. Polymorphisms in TPMT*2, *3A, *3B and *3C were analyzed using allele-specific polymerase chain reaction (PCR) and PCR-restriction fragment length polymorphism. Direct sequencing was used to confirm the mutation results. Exons of the TPMT gene from patients who suffered from azathioprine-induced toxicity were amplified and sequenced to detect TPMT mutations. No TPMT*2, *3A or *3B mutant alleles were detected. The allele frequency of TPMT*3C in the IBD group was 1.59 %, which was similar to that of the healthy control group (1.59 % versus 1.47 %, p = 1.000). Forty-three patients were treated with azathioprine therapy, 4 experienced myelotoxicity, and 1 experienced hepatotoxicity, so the incidence of drug toxicity was 11.7 % (5/43). No TPMT*2, *3A, *3B or *3C polymorphisms were detected in these 5 patients. After directly sequencing the exons of the TPMT gene in these 5 patients, a synonymous single-nucleotide polymorphism (TPMT*1S), which does not
alter the encoded amino acid, was found in 3 patients. The authors concluded that TPMT*3C seemed to be a unique variant allele in this Han Chinese population. The overall frequencies of variant TPMT alleles in this population were lower than those in Caucasians, but thiopurine toxicity in Han Chinese IBD patients is not low. The authors reported that factors other than TPMT polymorphisms may be responsible for the development of toxicity. Similarly, Takatsu et al (2009) found that adverse reactions to azathioprine cannot be predicted by thiopurine S-methyltransferase genotype in Japanese patients with inflammatory bowel disease.

There is no indication for repeat pharmacogenomic testing for TPMT, as a person’s TPMT genotypic or phenotypic status remains unchanged over one’s lifetime.

NOD2/CARD15 Genotyping for Crohn’s Disease

Nucleotide-binding oligomerization domain (NOD) proteins are cytosolic proteins that include principal regulators of apoptosis such as the apoptotic protease activating factor 1. NOD proteins have also been described as intra-cellular activators of the caspase and nuclear factor-kappaB (NF-kappaB) signaling pathways. In particular, NOD1, NOD2, cryopyrin, and ICE protease-activating factor (ICE refers to interleukin-1b converting enzyme that is also known as caspase-1) have been implicated in protective immune responses against pathogens. Moreover, a large number of NOD proteins contain leucine-rich repeats (LRR), hence referred to as NOD-LRR proteins, which include human NOD2, cryopyrin, and MHC class II trans-activator (CIITA), as well as mouse neuronal apoptosis inhibitory protein 5. NOD2 participates in the signaling events triggered by host recognition of specific motifs in bacterial peptidoglycan and, upon activation, induces the production of pro-inflammatory mediators. Neuronal apoptosis inhibitory protein 5 is needed in macrophages to restrict intra-cellular growth of Legionella pneumophila, whereas CIITA plays a critical role in antigen presentation and
development of antigen-specific T lymphocytes. Thus, NOD-LRR proteins appear to be involved in a diverse array of processes needed for host immune reactions against pathogens (Inohara and Nunez, 2003; Inohara et al, 2005; Eckmann and Karin, 2005).

Epidemiological data, notably concordance rates in twin pairs as well as sibling pairs, have provided support for the importance of the genetic contribution to inflammatory bowel diseases, especially in CD. Studies have found that genetic variations in several NOD-LRR proteins resulting in the abolishment of NF-kappaB signal transduction of pattern recognition receptors such as NOD/caspase recruitment domain (NOD/CARD) receptors is associated with inflammatory disease or increased susceptibility to microbial infections. The identification of the IBD1 gene on chromosome 16 as NOD2 (also known as CARD15) is an important finding. Specifically, mutations in the gene encoding NOD2 have been reported to be associated with the predisposition to CD and Blau syndrome. It is estimated that at least 5 additional genes are also involved in susceptibility to CD. These findings provided the impetus for laboratory-based studies of the molecular genetics of IBD, CD and UC. Although many issues regarding gene function and expression remain to be resolved, there is much enthusiasm that useful clinical applications may follow (Satsangi et al, 2003; Girardin et al, 2003; Carneiro et al, 2004; Philpott and Viala, 2004).

Mutations in the gene that encodes NOD2 occur in a small portion of patients with CD. Hampe, et al. (2001) noted that background genetic predisposition to IBD has been shown by epidemiological and linkage studies. These researchers sequenced the coding region of the NOD2 gene and genotyped an insertion polymorphism affecting the leucine-rich region of the protein product in 512 individuals with IBD from 309 German or British families, 369 German trios (namely, German patients with sporadic IBD and their unaffected parents), and 272 normal controls. They then tested for
association with CD and UC. Family-based association analyses were consistently positive in 95 British and 99 German affected sibling pairs with CD (combined \( p < 0.0001 \)); the association was confirmed in the 304 German trios with CD. No association was seen in the 115 sibling pairs and 65 trios with UC. The genotype-specific disease risks conferred by heterozygous and homozygous mutant genotypes were 2.6 (95% CI: 1.5 to 4.5) and 42.1 (4.3 to infinity), respectively. These investigators stated that the insertion mutation in the NOD2 gene confers a substantially increased susceptibility to CD, but not to UC. The lack of effect of the described mutation on UC might be due to the use of different pathways in this disorder. Also, the NF-kappaB activation is stronger in CD than UC. Moreover, the authors noted that this NOD2 frameshift mutation is rather rare -- approximately 6.5% of CD patients are homozygous for it. They estimated that about 18% of the genetic risk in the population can be attributed to this mutation; and did not find any homozygote in the control group.

Ahmad and co-workers (2002) stated that mutations in the NOD2 gene have been associated with CD, but are found in only 25% of patients. No data regarding their contribution to specific disease subtypes exist. The authors reported a detailed genotype-phenotype analysis of accurately characterized patients. A total of 244 white patients with CD recruited from a single center in the United Kingdom were studied. All patients were phenotyped and followed-up for a median time of 16 years. By using linkage disequilibrium mapping, these researchers studied 340 polymorphisms in 24 HLA genes and 3 NOD2 polymorphisms. They demonstrated that NOD2 mutations determine ileal disease only, and confirmed that alleles on specific long-range HLA haplotypes determine overall susceptibility to CD. These investigators concluded that clinical pattern of CD may be defined by specific genotypes.
There is also ethnic variation in the relationship of NOD2 genotype and clinical phenotype. Guo et al (2004) noted that an insertion mutation at nucleotide 3020 (3020insC) in NOD2 is associated with CD. The C-insertion mutation at nucleotide 3020 (3020insC) in the LRR region results in a frame-shift in the 10th LRR followed by a premature stop codon, which is responsible for the inability to activate NF-kappaB in response to bacterial lipopolysaccharide. These researchers aimed to genotype NOD2 gene 3020insC frame-shift mutation in Chinese patients with IBD. They genotyped an insertion polymorphism affecting the leucine-rich region of the protein product by the allele specific PCR in 74 unrelated patients with ulcerative colitis of Han nationality in Hubei Province of China, 15 patients with CD and 172 healthy individuals. No significant differences were found in the genotype and allele frequencies of the C-insertion mutation of NOD2 gene among patients with CD and UC and healthy controls. These investigators concluded that NOD2 gene 3020insC frame-shift mutation is not a major contributor to the susceptibility to both CD and UC in Chinese Han patients. Moreover, Tosa et al (2006) noted that Japanese patients with CD do not have any of the common NOD2/CARD15 variants that are associated with CD in Caucasians.

Economou et al (2004) stated that 3 variants of the NOD2 gene -- SNP8, SNP12, and SNP13 -- have been associated with CD. These investigators assessed the impact of NOD2 variants on the CD risk across diverse populations and examined possible associations with disease phenotype. In a meta-analysis, a total of 42 eligible studies contributed data on 206 comparisons. No variants were detected in Asians. In non-Jewish descent Caucasians, carriage of SNP8, SNP12, or SNP13 had an odds ratio (OR) for CD of 2.20 (95 % CI: 1.84 to 2.62), 2.99 (95 % CI: 2.38 to 3.74), and 4.09 (95 % CI: 3.23 to 5.18), respectively. For Jewish descent patients, the corresponding ORs were 1.74, 1.93, and 2.45, respectively. The OR in carriers of at least 2 alleles was 17.1 (95 % CI: 10.7 to 27.2). Large studies tended to yield more conservative
estimates than smaller studies, so publication or other bias can not be excluded. Among patients with CD, carrying at least 1 high-risk variant increased slightly the risk for familial disease (OR = 1.49, (95 % CI: 1.18 to 1.87)), modestly the risk of stenosing CD (OR = 1.94, (95 % CI: 1.61 to 2.34)), and more prominently the risk of small bowel involvement (OR = 2.53, (95 % CI: 2.01 to 3.16)). The authors concluded that SNP8, SNP12, and SNP13 have differential effects on CD risk, with SNP13 having the strongest genetic effect. The authors found that these NOD2 variants may also be significant risk factors for CD phenotype, especially ileal location.

Uyar and co-workers (2006) stated that 3 common genetic variations -- R702W, G908R, and 1007fs -- on CARD15 have been shown to increase the risk for CD in Caucasian populations. The authors ascertained the frequencies of these CARD15 variants by genotyping in 56 patients with CD and 100 healthy ethnically matched controls from Turkey. Overall frequency of all 3 variants was 10.7 % in patients with CD, compared with 1.5 % in controls (OR: 7.9). Among them, the frequency of the G908R variant allele was 8 % in CD cases, compared with 0 % in controls (OR: 36.8). The allele frequencies of 3 CD-related CARD15 variants were considerably lower in the control group compared to the reported Caucasian populations. Among the described CARD15 variants, G908R confers an increased susceptibility to CD, whereas the more frequently reported associations in Europeans with R702W and 1007fs are not confirmed in this Turkish population.

In addition to studies on the role of NOD2 genetic variations in the development of intestinal strictures, questions also arise regarding whether the response to treatment or need for surgery can be predicted by genotype. Preliminary reports analyzing the association between these variants and the need for surgeries have produced inconsistent results. Alvarez-Lobos and associates (2005) examined the predictive value of NOD2 gene variants along with disease phenotypic
characteristics for requirement of initial surgery and for surgical recurrence in CD. A total of 170 CD patients were included prospectively in the study and followed-up regularly for a mean of 7.4 ± 6.1 years. Clinical characteristics of CD, time and indication for surgery, and recurrence were noted. NOD2 gene variants were determined by DNA sequencing analysis. It was reported that surgery for stricturing disease was significantly more frequent in patients with NOD2 variants in the uni-variate analysis (OR, 3.63; 95% CI: 1.42 to 9.27), and it was required at an earlier time (p = 0.004). Only NOD2 variants (OR, 3.58; 95% CI: 1.21 to 10.5) and stricturing phenotype at diagnosis of CD (OR, 9.34; 95% CI: 2.56 to 33.3) were independent predictive factors of initial surgery for stricturing lesions in the multivariate analysis. Among 70 patients that required surgery, post-operative recurrence was also more frequent in patients with NOD2 variants in the uni-variate and multi-variate analysis (OR, 3.29; 95% CI: 1.13 to 9.56), and re-operation was needed at an earlier time (p = 0.03). The authors concluded that NOD2 genotyping may have a useful clinical application as a major marker of evolution of CD, especially an early need of initial surgery due to stricturing disease and need of re-operation. They noted that although determination of the NOD2 genotype presently cannot be used to guide indications for surgery, it might define a subgroup of patients with a severe course of the disease, who may require a more aggressive therapeutic approach to prevent the appearance of complications. Moreover, these investigators stated that confirmation of these results in future studies is needed before interventional studies based on NOD2 genotyping are designed.

Fries and associates (2005) noted that a defect of gastrointestinal barrier function is considered to represent an important step in the pathogenesis of CD; but the mechanisms leading to an increased intestinal permeability (IP) are poorly understood. Since IP is influenced by pro-inflammatory mediators, it seems likely that a genetically determined abnormal immune response may lead to a loss of barrier
function. In a geographic area in Southern Italy with high incidence of CD, these researchers examined IP (by means of lactulose/mannitol testing) together with the 3 main mutations of the NOD2/CARD15 and the D299G polymorphism of the toll-like receptor (TLR)-4 gene in 23 families of CD patients (patients and 1st-degree relatives). A total of 48% of CD patients and 40% of their healthy relatives were found to have an abnormal IP compared to 5% of an appropriate control population (p < 0.0001). However, IP was not associated with the L1007finsC mutation of the NOD2/CARD15 or the D299G variant of the TLR-4 gene. Allele frequency of the only L1007finsC mutation of CARD15 was significantly increased in patients (8.7%, p < 0.003) and in relatives (8.3%, p < 0.024) compared with controls (2.4%), whereas the D299G variant of the TLR-4 gene was found to be increased only in relatives (8.3%, p < 0.022), but not in patients (4.3%) compared with the control population (1.7%). These investigators concluded that there was no association between IP and genetic markers. These findings showed a very high proportion of healthy 1st-degree relatives to bare alterations suggested to constitute determinants of CD. Mutations of NOD2/CARD15 or TLR-4, however, do not lead to permeability defects emphasizing the importance of additional environmental and/or genetic factors for pathogenesis.

While research has been focused on trying to explain the biological role of NOD2 and how mutations can contribute to the development of CD, it is important to note that the association between NOD2 gene variants and CD is not absolute (i.e., not everyone who has one of the variants will get the disease, and not everyone with CD has an alteration in NOD2). Mascheretti and Schreiber (2005) noted that genetic testing for the NOD2/CARD15 variants has only a modest relevance in clinical practice. This is in agreement with the observations of Vermeire (2004) who stated that the relevance of NOD2/CARD15 genotyping for clinical practice is modest. The current data show that NOD2/CARD15 mutations in CD are associated with small-bowel involvement. More studies
are needed to ascertain if NOD2/CARD15 mutations are also associated with a fibrostenotic behavior of the disease. If CARD15 variants would predict a more aggressive disease course, then a more aggressive treatment may be justified in these patients after NOD2/CARD15 genetic testing. It is not clear whether NOD2/CARD15 genotyping is helpful in differentiating indeterminate colitis patients. Although CARD15 variants do not predict response to the tumor necrosis factor-alpha monoclonal antibodies, the role of the gene in response to other drugs is not known. Finally, screening unaffected relatives of CD patients is not recommended until preventive strategies are available. It is also interesting to note that although there is evidence to suggest that NOD2/CARD15 may influence individuals' susceptibility to colorectal cancer, there is no evidence to indicate that mutations of this gene predict the clinicopathological characteristics of this disease (Roberts et al, 2006). Chamaillard and colleagues (2006) stated that the current etiologic model for IBD emphasizes an interaction between susceptibility and modifier genes along with environmental factors. Together, these lead to disease progression. However, further work should clarify the pathophysiological mechanisms leading to IBD and how innate immune signaling confers susceptibility to intestinal inflammation.

There is currently insufficient scientific evidence to support the clinical use of NOD2/CARD15 genotyping of CD. More research is needed to define more precisely the relationship between NOD2/CARD15 genotype, clinical phenotype, and the effect of ethnic variation on this relationship. Further investigation is also needed to better understand the mechanisms involved in gene-environment interactions in the gastrointestinal tract, and to examine the role of genetic variations in the NOD2/CARD15 gene on the natural cause of the disease, response to therapies and need for surgery.
Fecal lactoferrin

Fecal lactoferrin is an iron binding protein found in secondary granules of neutrophils. It has been investigated for use as a noninvasive marker of intestinal inflammation. They have also been utilized to differentiate CD from UC. When there is inflammation in the GI tract, fecal lactoferrin levels are increased in the stool, thereby indicating intestinal inflammation.

Silberer et al (2005) compared 5 different leukocyte proteins in feces of patients with chronic IBD, irritable bowel syndrome (IBS) and healthy persons who underwent prophylactic colonoscopy. The leukocyte proteins calprotectin, lactoferrin, lysozyme, myeloperoxidase (MPO), and PMN-elastase were determined with immunoassays in fecal samples of 3 consecutive feces (e.g., 3 days) in 40 healthy persons, 39 patients with chronic IBD (of these 21 with Crohn's disease and 18 with ulcerative colitis), and 40 patients with IBS. Receiver operating characteristics (ROC) curves calculated for healthy persons and patients with IBD yielded the following areas under the curves (AUCs): PMN-elastase 0.916, calprotectin 0.872, MPO 0.750, lysozyme 0.726, and lactoferrin 0.693. The AUCs of PMN-elastase and calprotectin were not significantly different (p = 0.327), whereas PMN-elastase or calprotectin versus the other proteins were significantly different (p < 0.001). PMN-elastase and calprotectin correlated with the endoscopically classified severity of inflammation. All fecal leukocyte markers in IBS were found in the range of the healthy persons. Data on storage stability of leukocyte proteins in fecal supernatants are given. The authors concluded that fecal PMN-elastase and calprotectin support the differentiation of chronic IBD from IBS and correlate with the severity of inflammation.

Boon et al (2015) reviewed the published literature concerning the accuracy of fecal inflammatory markers for identifying mucosal healing. Bibliographical searches were performed in
Medline electronic database up to February 2015, using the following terms: "inflammatory bowel disease", "Crohn's disease", "ulcerative colitis", "faecal markers", "calprotectin", "lactoferrin", "S100A12", "endoscop*", "mucosal healing", "remission". In addition, relevant references from these studies were also included. Data were extracted from the published papers including ORs with 95 % CI, p values and correlation coefficients. Data were grouped together according to each fecal marker, Crohn's disease or ulcerative colitis, and pediatric compared with adult study populations. Studies included in this review assessed mucosal inflammation by endoscopic and/or histological means and compared these findings to fecal marker concentrations in IBD patient cohorts. Articles had to be published between 1990 and February 2015 and written in English. Papers excluded from the review were those where the fecal biomarker concentration was compared between patients with IBD and controls or other disease groups, those where serum biomarkers were used, those with a heterogeneous study population and those only assessing post-operative disease. The available studies showed that fecal markers, such as calprotectin and lactoferrin, are promising non-invasive indicators of mucosal healing. However, due to wide variability in study design, especially with regard to the definition of mucosal healing and evaluation of marker cut-offs, the available data do not yet indicate the optimal roles of these markers. A total of 36 studies published between 1990 and 2014 were included. Studies comprised variable numbers of study participants, considered CD (15 to 164 participants) or UC (12 to 152 participants) separately or as a combined group (11 to 252 participants); 8 reports included pediatric patients. Several indices were used to document mucosal inflammation, encompassing 11 endoscopic and 8 histologic grading systems. The majority of the available reports focused on fecal calprotectin (33 studies), whilst others assessed fecal lactoferrin (13 studies) and 1 study assessed S100A12. Across all of the biomarkers, there was a wide range of correlation describing the association between fecal markers and endoscopic disease activity (r
values ranging from 0.32 to 0.87, p values ranging from < 0.0001 to 0.7815). Correlation coefficients were described in almost all studies and were used more commonly than outcome measures such as sensitivity, specificity, positive predictive value (PPV) and/or negative predictive value (NPV). Overall, the studies that have evaluated fecal calprotectin and/or fecal lactoferrin and their relationship with endoscopic disease activity showed inconsistent results. The authors concluded that future studies should report the results of fecal inflammatory markers in the context of mucosal healing with clear validated cut-offs.

Wang, et al., (2015) conducted a systematic review using meta-analysis to assess the diagnostic accuracy of fecal lactoferrin (FL) in patients with inflammatory bowel disease (IBD). The investigators performed a literature review and systematically searched the Medline and EMBASE databases for eligible studies. The quality of the included studies was assessed using the QUADAS tool. The sensitivity, specificity, and other diagnostic indexes of FL were pooled using a random-effects model. Seven studies, involving 1816 patients, met the inclusion criteria. In all studies, the pooled FL sensitivity and specificity were 0.82 (95% confidence interval [CI]: 0.72, 0.89) and 0.95 (95% CI: 0.88, 0.98), respectively. The positive and negative likelihood ratios were 16.63 and 0.18, respectively. The area under the summary receiver-operating characteristic curve (SROC) was 0.95 (95% CI: 0.93, 0.97), and the diagnostic odds ratio was 90.04 (95% CI: 37.01, 219.02). The pooled FL sensitivity and specificity for Crohn's disease (CD) diagnosis (sensitivity =75%, specificity =100%) was not as good as it was for ulcerative colitis (UC) diagnosis (sensitivity =82%, specificity =100%).

Bar-Gil Shitrit et al (2017) prospectively evaluated the value of FC and lactoferrin to predict capsule endoscopy (CE) findings. A total of 68 consecutive patients who were referred for CE were included. Stool samples for calprotectin and lactoferrin and blood samples were collected for relevant parameters.
Correlation between fecal markers and CE findings was assessed and ROC curves were built to determine the predictive values of fecal markers for the diagnosis of CD; FC data was available for all the patients and lactoferrin data for 38. Capsule endoscopy findings compatible with CD were found in 23 (33 %) patients and 45 (67 %) were negative for CD. The average age of the CD group was 34 compared to 46 in the non-CD group (p = 0.048). Median calprotectin and lactoferrin in the CD group and in the control group were 13 mg/kg versus 40 (p = 0.004) and 6.6 mg/kg versus 1 (p = 0.051), respectively. The area under the ROC curve was 0.767 for calprotectin and 0.70 for lactoferrin. A FC concentration of 95 mg/kg and fecal lactoferrin of 1.05 mg/kg had a sensitivity, specificity, PPV and NPV of 77 and 73%, 60 and 65%, 50 and 50%, and 84 and 84% in predicting CE findings compatible with CD. The authors concluded that fecal markers are simple and non-invasive surrogates for predicting CE findings compatible with CD; they stated that fecal markers can help determine which patients should be referred for CE. The authors noted, however, that the relatively low sample size limits the power of their conclusions.

Caccaro and associates (2016) noted that the role of FC and fecal lactoferrin has been extensively studied in many areas of IBD patients' management. The post-operative setting in both CD and UC patients has been less investigated although few promising results come from small, cross-sectional studies. Therefore, the current post-operative management still requires endoscopy 6 to 12 months after intestinal resection for CD in order to exclude endoscopic recurrence and plan the therapeutic strategy. In patients who underwent restorative proctocolectomy, endoscopy is required whenever symptoms include the possibility of pouchitis. There is emerging evidence that FC and fecal lactoferrin are useful surrogate markers of inflammation in the post-operative setting, they correlate with the presence and severity of endoscopic recurrence according to Rutgeerts' score and possibly predict the subsequent clinical recurrence and response to therapy in
CD patients. Similarly, fecal markers show a good correlation with the presence of pouchitis, as confirmed by endoscopy in operated UC patients. Fecal calprotectin appears to be able to predict the short-term development of pouchitis in asymptomatic patients and to vary according to response to medical treatment. The authors concluded that the possibility of both fecal markers to be used in the routine clinical practice for monitoring IBD patients in the post-operative setting should be confirmed in multi-centric clinical trial with large sample set. The authors stated that an algorithm that can predict the optimal use and timing of fecal markers testing, the effective need and timing of endoscopy and the cost-effectiveness of these as a strategy of care would be of great interest.

Wright (2016) stated that the diagnosis and monitoring of IBD has traditionally relied on clinical assessment, serum markers of inflammation and endoscopic examination. Fecal biomarkers such as calprotectin and lactoferrin are predominantly derived from neutrophils, are easily detectable in the feces and are now established as valuable markers of intestinal inflammation. In recent years, a “treat to target” concept has emerged for the management of IBD. Adequate control of inflammation in IBD at a biochemical level is quickly becoming an important target in IBD management. Fecal biomarkers have been shown to be significantly and consistently increased in both adult and pediatric patients with IBD versus those without IBD. Fecal biomarkers are therefore useful in determining those patients with gastrointestinal symptoms who are likely to benefit from colonoscopy versus those in whom colonoscopy is likely to be normal. Fecal biomarkers correlate significantly with endoscopic disease in both CD and UC. Suggested cut-offs for FC for endoscopically active disease in IBD range from 50 to 280 μg/g. Fecal biomarkers reflect the success of treatment intensification and can help predict clinical relapse. Both FC and FL lactoferrin are accurate in the detection of post-operative endoscopic recurrence of CD, and FC may be clinically useful in predicting those patients with acute severe UC who may progress to
Colectomy. There are limitations to these fecal tests including a false positive rate and intra-individual variability. The authors noted that this review focused on the role of fecal biomarkers in the diagnosis, monitoring and management of IBD and how best to interpret results. They discussed the emerging role of these biomarkers in the IBD management landscape including FC-guided drug dosing and the development of home-based testing and e-health applications. They stated that fecal biomarker results must always be interpreted in a clinical context; endoscopic assessment remains the gold standard for diagnosis and monitoring of IBD.

Guidelines from the Infectious Diseases Society of America (Shane, et al., 2017) state that "fecal leukocyte examination and stool lactoferrin detection should not be used to establish the cause of acute infectious diarrhea (strong, moderate)." ISDA guidelines on Clostridium difficile infection (McDonald, et al., 2018) state that "their usefulness [of fecal lactoferrin] in the diagnosis of CDI has not been established."

Similarly, guidelines from the American College of Gastroenterology (Riddle, et al., 2016) state: "Historically, a decision to obtain a stool culture in an individual with diarrhea has often been guided by the finding of fecal leukocytes or the presence of stool lactoferrin. Although the latter is a more sensitive predictor of a positive stool culture, using these markers to guide further diagnostic studies has been proven to be imprecise and probably unnecessary."

Guidelines on Crohn's disease from the American College of Gastroenterology (Lichtenstein, et al., 2018) state that fecal lactoferrin is "useful in differentiating patients with IBD from those with irritable bowel syndrome."

An UpToDate review on "Approach to the adult with chronic diarrhea in resource-rich settings" (Bonis and Lamont, 2017) states that "Fecal lactoferrin (another marker of neutrophils)
has also been proposed as an indicator of intestinal inflammation but its role in the evaluation of patients with chronic diarrhea remains uncertain.

Furthermore, an UpToDate review on “Clinical manifestations, diagnosis and prognosis of Crohn disease in adults” (Peppercorn and Kane, 2017) states that “Tests for fecal calprotectin or lactoferrin may help identify patients with intestinal inflammation, though they are not routinely performed in clinical practice”.

**Firmicutes and Bacteroidetes** (F/B) Ratio Stool Test

Gram-positive *Firmicutes* and gram-negative *Bacteroidetes* phyla are the most common types of bacteria that live in the human gut. It has been suggested that an imbalance in the *Firmicutes/Bacteroidetes* ratio, a type of intestinal dysbiosis, may lead to inflammatory bowel disease (IBD), irritable bowel syndrome, gastric ulcers, and other chronic diseases (Koliada et al, 2017). Salveo Diagnostics offers the “Intestinal Dysbiosis” stool test which evaluates the *Firmicutes/Bacteroidetes* ratio by providing an estimate of the predominance of major phyla of gut bacteria; associated with dysbiosis and a number of metabolic disorders. It has also been suggested that a shift in the F/B ratio may be influenced by various factors and/or conditions such as nutritional changes, weight fluctuations (obesity), and metabolic comorbidities. Antibiotic-associated diarrhea, Crohn’s disease, and ulcerative colitis have been correlated with decreases in *Firmicutes* strains, a concomitant increase in *Bacteroidetes* (low F/B ratio), and a reduced gut biodiversity (Salveo Diagnostics, 2019).

Bamola et al. (2017) state that intestinal microbiota, such as *Firmicutes* and *Bacteroidetes*, play a key role in the pathogenesis of inflammatory bowel disease (IBD) and colon carcinoma. The authors prospectively evaluated gut microbial profile of healthy subjects and patients with IBD and colon
cancer who are of Indian descent. Stool samples were collected from healthy Indian vegetarians/lactovegetarians and non-vegetarians, and colon cancer and IBD patients. Healthy adults included in the study were classified into two groups: subjects on an Indian vegetarian diet (who consume plant produce, milk and milk products) and those on a non-vegetarian diet (who eat eggs at least three or four times and meat/fish twice a week). Patients included in the study were also classified into two groups: patients with IBD and those with colon carcinoma. Clonal libraries of 16S ribosomal DNA (rDNA) of bacteria were created from each sample. Clones were sequenced from one representative sample of each group. Approximately 500 white colonies were picked at random from each sample and 100 colonies were sequenced after amplified rDNA restriction analysis. The authors found that the dominant phylum from the healthy vegetarian was Firmicutes (34%), followed by Bacteroidetes (15%). The balance was reversed in the healthy non-vegetarian (Bacteroidetes 84%, Firmicutes 4%; ratio 21:1). The colon cancer and IBD patients had higher percentages of Bacteroidetes (55% in both) than Firmicutes (26% and 12%, respectively) but lower Bacteroidetes/Firmicutes ratios than the healthy non-vegetarian. Bacterial phyla of Verrucomicrobiota and Actinobacteria were detected in 23% and 5% of IBD and colon patients, respectively. Study limitations included the authors picked up 96 clones from the genomic library of one randomly selected participant from each group for sequencing. Selecting a larger number of clones for sequencing would have been a better method of demonstrating microbial diversity in [their] group of patients. Nonetheless, the authors state that in their IBD patient, they observed a reduction in the proportion of Bacteroidetes with respect to Firmicutes who was on a non-vegetarian diet, compared to the healthy non-vegetarian control; however, they did not find an increase in Proteobacteria and Actinobacteria compared to the healthy non-vegetarian adults. The authors overall conclusion to their study is that Indian patients with colon carcinoma and IBD showed unique patterns of microbial diversity compared to
data from Western countries. Even healthy controls had different signature gut microbiota. The authors believe the reason is likely to be the Indian dietary practices, which are very different from Western diets. Studies involving metagenomic and metaproteomic approaches that include larger subsets of participants are required to look into the colonic microbial diversity.

Kabeerdoss et al. (2015) state that microbial communities are closely associated with the intestinal mucosa, and are important in the pathogenesis of inflammatory bowel disease (IBD), and note that the ratio of Firmicutes to Bacteroidetes has been used to express the degree of dysbiosis in IBD. The authors prospectively analyzed colonic mucosal biopsies of patients with UC (n=32), CD (n=28) and patients undergoing screening colonoscopy (controls) via RT-qPCR using primers targeted at 16S rRNA sequences specific to selected microbial populations. The authors found that the Firmicutes to Bacteroidetes ratio was significantly decreased in both UC and CD compared with controls, indicative of a dysbiosis in both conditions. The authors concluded that dysbiosis appears to be a primary feature in both CD and UC. Microbiome-directed interventions are likely to be appropriate in therapy of IBD. The authors further state that the microbial populations did not significantly differ between normal and inflamed mucosa or between untreated and treated patients. These findings suggested that dysbiosis was a primary feature of both forms of IBD and that microbiome-directed interventions could be appropriate targets for therapy of IBD.

IBSDetex Test (an ELISA Test for Cytolethal Distending Toxin B Antibody and Vinculin Antibody) / ibs-smart

Pimentel and associates (2015) noted that diarrhea-predominant IBS (D-IBS) is diagnosed through clinical criteria after excluding "organic" conditions, and can be precipitated by acute gastroenteritis. Cytolethal distending toxin B (CdtB) is produced by bacteria that cause acute gastroenteritis, and a
post-infectious animal model demonstrates that host antibodies to CdtB cross-react with vinculin in the host gut, producing an IBS-like phenotype. These researchers evaluated circulating anti-CdtB and anti-vinculin antibodies as biomarkers for D-IBS in human subjects. Subjects with D-IBS based on Rome criteria (n = 2,375) were recruited from a large-scale multi-center clinical trial for D-IBS (TARGET 3). Subjects with IBD (n = 142), subjects with celiac disease (n = 121), and healthy controls (n = 43) were obtained for comparison. Subjects with IBD and celiac disease were recruited based on the presence of intestinal complaints and histologic confirmation of chronic inflammatory changes in the colon or small intestine. Subjects with celiac disease were also required to have an elevated tTG and biopsy. All subjects were aged between 18 and 65 years. Plasma levels of anti-CdtB and anti-vinculin antibodies were determined by ELISA, and compared between groups. Anti-CdtB titers were significantly higher in D-IBS subjects compared to IBD, healthy controls and celiac disease (p < 0.001). Anti-vinculin titers were also significantly higher in IBS (p < 0.001) compared to the other groups. The AUCs were 0.81 and 0.62 for diagnosis of D-IBS against IBD for anti-CdtB and anti-vinculin, respectively. Both tests were less specific in differentiating IBS from celiac disease. Optimization demonstrated that for anti-CdtB (optical density [OD] of greater than or equal to 2.80) the specificity, sensitivity and likelihood ratio were 91.6 %, 43.7 and 5.2, respectively, and for anti-vinculin (OD of greater than or equal to 1.68) were 83.8 %, 32.6 and 2.0, respectively. The authors concluded that these findings confirmed that anti-CdtB and anti-vinculin antibodies were elevated in D-IBS compared to non-IBS subjects. They stated that these biomarkers may be especially helpful in distinguishing D-IBS from IBD in the work-up of chronic diarrhea.

The authors stated that this study had several drawbacks. First, this test had been validated for the 18 to 65 years age group only, and additional studies would be needed to validate it in other age groups. Second, the test had a lower specificity
for identifying D-IBS compared to celiac disease, although concomitant testing with anti-tTG should compensate for this. In addition, it is possible that immune responses to CdtB and vinculin could vary with differing ethnic backgrounds -- Asians have been shown to have differing prevalence of certain antibodies for celiac disease. Further studies are needed to address this, although the comparisons are difficult given the rarity of celiac disease in Asian populations. Lastly, it might be anticipated that 10 to 15% of subjects with IBD also have co-existing IBS. This was not controlled for as it is difficult to identify these subjects. Previous studies have commented that symptoms compatible with IBS co-exist in patients with IBD, and are significantly more common in Crohn's disease than in UC patients, making it impossible to find a biomarker with perfect specificity or sensitivity. In the future, careful examination of IBD subjects might show that anti-vinculin and anti-CdtB antibodies identify IBS in IBD subjects also. This would be another important finding. In IBD, for example, these biomarkers might be important to suggest IBS as a cause of ongoing symptoms when there is complete mucosal healing on therapy but the patient continues to have functional symptoms.

Rezaie and colleagues (2017) noted that antibodies to cytolethal distending toxin B (CdtB) and vinculin are novel biomarkers that rule-in and differentiate IBS with diarrhea (IBS-D) from other causes of diarrhea and healthy controls. These researchers examined if these antibodies can also diagnose and differentiate other IBS subtypes. Subjects with IBS-D based on Rome III criteria (n = 2,375) were recruited from a large-scale multi-center clinical trial (TARGET 3). Healthy subjects without GI diseases or symptoms (n = 43) and subjects with mixed IBS (IBS-M) (n = 25) or IBS with constipation (IBS-C) (n = 30) were recruited from 2 major medical centers. Plasma levels of anti-CdtB and anti-vinculin antibodies in all subjects were determined by ELISA. Optical densities of greater than or equal to 1.68 and greater than or equal to 2.80 were considered positive for anti-vinculin and
anti-CdtB, respectively. Plasma levels of anti-CdtB and anti-vinculin antibodies were highest in IBS-D and lowest in IBS-C and healthy controls ($p < 0.001$). Levels in IBS-C subjects were not statistically different from controls ($p > 0.1$). Positivity for anti-CdtB or anti-vinculin resulted in a statistically significant negative gradient from IBS-D (58.1%) to IBS-M (44.0%), IBS-C (26.7%), and controls (16.3%) ($p < 0.001$).

The authors concluded that anti-CdtB and anti-vinculin titers and positivity rates differed in IBS subtypes, with higher antibody levels and positivity rates in IBS-D and IBS-M, and lower levels in IBS-C subjects that were similar to those in healthy controls. They stated that these antibodies appeared useful in the diagnosis of IBS-M and IBS-D, but not IBS-C. Furthermore, these findings suggested that IBS-C was pathophysiologically distinct from subtypes with diarrheal components (i.e., IBS-M and IBS-D).

Furthermore, an UpToDate review on “Clinical manifestations and diagnosis of irritable bowel syndrome in adults” (Ward, 2018) states that “The diagnostic role of antibodies to cytolethal distending toxin B (CdtB) and vinculin requires confirmation before they can be used in the evaluation of patients with suspected IBS. One study that evaluated anti-CdtB and anti-vinculin titers in 2,375 patients with IBS diarrhea, found that patients anti-CdtB were significantly higher in IBS diarrhea as compared to patients with IBD, healthy controls, celiac disease, and IBS constipation. The specificity of anti-CdtB for IBS diarrhea was 92% but the sensitivity was only 44%. Anti-vinculin had a sensitivity and specificity of 33 and 84%, respectively”.

ibs-smart is a blood test that detects biomarkers (anti-cytolethal distending toxin B [CdtB] antibody and anti-vinculin antibody) for the diagnosis of irritable bowel syndrome.

An UpToDate review on “Clinical manifestations and diagnosis of irritable bowel syndrome in adults” (Ward, 2020) states that “The diagnostic role of antibodies to cytolethal distending toxin
B (CdtB) and vinculin requires confirmation before they can be used in the evaluation of patients with suspected IBS. One study that evaluated anti-CdtB and anti-vinculin titers in 2375 patients with IBS diarrhea, found that patients anti-CdtB were significantly higher in IBS diarrhea as compared to patients with IBD, healthy controls, celiac disease, and IBS constipation. The specificity of anti-CdtB for IBS diarrhea was 92% but the sensitivity was only 44%. Anti-vinculin had a sensitivity and specificity of 33% and 84%, respectively.

Measurements of Biomarkers for Predicting Therapeutic Response in Inflammatory Bowel Disease

Stevens and colleagues (2018) noted that IBD is characterized by substantial heterogeneity in treatment response. With an expanding number of therapeutic agents, identifying optimal treatment at the patient level remains a major challenge. These investigators systematically reviewed available literature on predictive biomarkers of therapeutic response in IBD. An electronic literature search was carried out on 30 January 30, 2018 using Medline, Embase and the Cochrane Library.

Retrospective, prospective, uncontrolled and controlled studies reporting on biomarkers predicting therapeutic response in pediatric and adult IBD populations were eligible for inclusion. The methodological quality of the included studies was assessed using the QUIPS tool. Due to anticipated heterogeneity and limited data, a qualitative, rather than quantitative, assessment was planned. Of the 10,638 citations identified, 92 articles met the inclusion criteria. Several potential DNA, mRNA and protein markers were evaluated as predictive biomarkers. Most studies focused on predicting response to anti-TNF agents. Substantial between-study heterogeneity was identified with respect to both the biomarkers studied and the definition of response. None of the included studies received a low risk of bias rating for all 6 domains. Currently, none of the biomarkers was sufficiently predictive for clinical use. The authors concluded that the search for predictive biomarkers is still in its infancy and
current evidence is limited. They stated that future research efforts should consider the high patient heterogeneity within prospective trials with objective response assessment; and predictive models will most likely comprise a combination of several molecular markers from integrated omics-levels and clinical characteristics.

NUDT15 Gene Analysis

NUDT15 is a member of a large phosphatase protein family that shares a common NUDIX catalytic domain and metabolizes a wide range of nucleotide substrates. Originally characterized as a pyrophosphatase, NUDT15 converts oxidized GTP to its monophosphate form, preventing the integration of the damaged purine nucleotides into DNA and subsequent mismatch repair. However, 8-oxo-GTP is a weak substrate for NUDT15 compared with its main metabolizer NUDT1; thus, the physiological functions of NUDT15 remain unclear. NUDT15 has been linked to xenobiotic drug metabolism in genome-wide association studies of drug toxicity, and subsequent mechanistic studies have demonstrated that it plays a key role in the conversion of the active thiopurine metabolite thioguanosine triphosphate to thioguanosine monophosphate. NUDT15 variants encoding no or severely decreased function predispose patients to excessive thiopurine activation and hematopoietic toxicities when receiving this class of drugs for either benign (e.g., inflammatory bowel diseases) or malignant (e.g., acute lymphoblastic leukemia) conditions. Given the compelling underlying biology and clinical relevance of this pharmacogenetic association, there is a growing interest in preemptive NUDT15-guided thiopurine dosing to avoid severe adverse events.

The importance of including NUDT15 genetic information in dosing recommendations for preventing thiopurine toxicity is further evidenced by the updated 2018 Clinical Pharmacogenetics Implementation Consortium (CPIC)
guideline on TPMT-guided thiopurine dosing recommendation that includes NUDT15 in addition to TPMT. Inherited TPMT deficiency is the primary genetic cause of thiopurine intolerance in Europeans and Africans, whereas risk alleles in NUDT15 explain the majority of thiopurine-related myelosuppression in Asians and are also common in Hispanics. The degree of thiopurine intolerance is largely comparable between carriers of TPMT and carriers of NUDT15 decreased function alleles; although there is a lack of multiethnic studies examining both TPMT and NUDT15 variants. Therefore, the CPIC recommendations for NUDT15 parallel those for TPMT.

Pre-emptive dose adjustments based on TPMT genotype have reduced thiopurine-induced adverse effects without compromising desired antitumor and immunosuppressive therapeutic effects in several clinical settings. Similarly, retrospective studies strongly indicate that patients with loss-of-function NUDT15 alleles are at excessive risk of thiopurine toxicity if the standard dose is administered. This body of evidence, rather than randomized clinical trials, provides the basis for most of the dosing recommendations.

Fucosyltransferase 2 Gene Variant Testing

Zhou and colleagues (2019a) noted that several studies have examined the association of fucosyltransferase 2 gene (rs601338) variant with UC and CD, but the results were inconsistent. These researchers performed a meta-analysis to clarify this issue based on a relatively larger sample size. They conducted a systematic literature search in PubMed, Embase, CNKI, and Chinese Wangfang databases up to May 31, 2018. Meta results were synthesized by using crude OR with 95% CI. Heterogeneity, sensitivity analysis, subgroup analysis, and publication bias were assessed using STATA 11.0 software. A total of 8 relevant studies including 3,874 IBDs patients (1,872 UC cases, 2,002 CD cases) and 5,445 controls were included for meta-analysis. These investigators
found a significant association between rs601338 A allele and risk of IBDs in the Chinese population (OR = 2.35, 95% CI: 1.66 to 3.34, p = 0.001), but not in whites. Stratified by disease type, they found a significant association between rs601338 polymorphism with CD and UC in the Chinese population, but not in the white population. In addition, funnel plot and Egger's linear regression test suggested no publication bias in all genetic models. The authors concluded that fucosyltransferase 2 gene (rs601338) polymorphism was associated with susceptibility to IBD, UC, and CD in the Chinese population, but these results might not be generalizable to other ethnic populations. Moreover, these researchers stated that further well-designed studies are needed to clarify the mechanism and increase comprehensive understanding of the role of the FUT2 gene (rs601338) polymorphism in IBDs.

The authors stated that this meta-analysis had several drawbacks. First, these researchers included relevant articles published only in English and Chinese, so language bias may exist in this study. Second, most of the studies were conducted in Chinese populations, and there were few studies in the white subgroup analyses, which could have led to insufficient statistic power to detect weak relationships. Third, the onset of IBD is affected by risk factors such as age, sex, genetic variants, and exposure to environmental factors and their interactions. However, only gene polymorphisms were considered in this study. The effects of gene-gene and gene-environment interactions on the initiation and development of the disease need to be further studied.

Glutathione S-Transferase M1 Null Genotyping

Zhou and colleagues (2019b) noted that UC and CD are the 2 main types of IBDs. Several studies have examined the association of glutathione S-transferase M1 (GSTM1) null genotype with UC and CD, but the results are inconsistent. These researchers performed a meta-analysis to clarify this
controversy based on relative large sample size. They conducted a systematic article searching in the PubMed, EmbaseE, SCOPUS, WOS, ProQuest, Chinese National Knowledge Infrastructure (CNKI), and Chinese Wanfang databases up to August 31, 2019. Meta-analysis results were synthesized by using crude OR with its 95% CI. Heterogeneity, sensitivity analysis, subgroup analysis, and publication bias were assessed by using STATA 11.0 software. A total of 15 relevant studies including 4,353 IBDs patients (1,848 CD cases, 2,505 UC cases) and 5,413 controls were included in this meta-analysis. These investigators found a significant association between GSTM1 null genotype and risk to IBDs in the overall populations (OR = 1.37, 95% CI: 1.13 to 1.65, p = 0.001). Stratified by ethnicity, these researchers found a significant association between GSTM1 null genotype and risk to IBDs in the Asian population (OR = 2.54, 95% CI: 2.15 to 3.00, p = 0.001), but not in the Caucasian population. Stratified by disease type, they found a significant association between GSTM1 null genotype with CD in the Asian population (OR = 2.37, 95% CI: 1.11 to 5.06, p = 0.026) and with UC in the Asian (OR = 2.48, 95% CI: 1.93 to 3.20, p = 0.001) population. In addition, funnel plot and Egger linear regression test suggested no publication bias in all genetic models. The authors concluded that GSTM1 null genotype was associated with susceptibility to IBD, UC, and CD in the Asian population. Moreover, these researchers stated that further well-designed studies with more sample size and including other confounding factors are needed to confirm these findings.

The authors stated that this meta-analysis had several drawbacks. First, these researchers included relevant articles published only in English and Chinese so that potential language bias may exist in this study. Second, most of the studies were conducted in Chinese population, the number of studies was small in Caucasians subgroup analyses, which could have led to insufficient statistic power to detect slight relationships. Third, the onset of IBD is affected by risk factors.
such as age, sex, genetic variants, and exposure to environmental factors and their interactions. However, only gene polymorphisms were considered in this study. The effects of gene-gene and gene-environment interactions on the initiation and development of the disease need to be further studied in the future.

**CPT Codes / HCPCS Codes / ICD-10 Codes**

Information in the [brackets] below has been added for clarification purposes. Codes requiring a 7th character are represented by "+":

<table>
<thead>
<tr>
<th>Code</th>
<th>Code Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0034U</td>
<td>TPMT gene mutation assays or TPMT phenotypic assays (eg, Prometheus TPMT Genetics, Prometheus TPMT Enzyme):</td>
</tr>
<tr>
<td>81335</td>
<td>TPMT (thiopurine S-methyltransferase), NUDT15 (nudix hydrolase 15) and TPMT (thiopurine S-methyltransferase) (eg, drug metabolism) gene analysis, common variants</td>
</tr>
<tr>
<td>81401</td>
<td>Molecular pathology procedure, Level 5 (eg, analysis of 2-5 exons by DNA sequence analysis, mutation scanning or duplication/deletion variants of 6-10 exons, or characterization of a dynamic mutation disorder/triplet repeat by Southern blot analysis)</td>
</tr>
<tr>
<td>Code</td>
<td>Code Description</td>
</tr>
<tr>
<td>--------</td>
<td>----------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>82657</td>
<td>Enzyme activity in blood cells, cultured cells, or tissue, not elsewhere specified; nonradioactive substrate, each specimen</td>
</tr>
<tr>
<td>83789</td>
<td>Mass spectrometry and tandem mass spectrometry (eg, MS, MS/MS, MALDI, MS-TOF, QTOF), non-drug analyte(s) not elsewhere specified, qualitative or quantitative, each specimen</td>
</tr>
<tr>
<td>86256</td>
<td>Fluorescent noninfectious agent antibody; titer, each antibody</td>
</tr>
</tbody>
</table>

Anti-chitobioside carbohydrate antibodies (ACCA), Anti-laminaribioside carbohydrate antibodies (ALCA), Anti-mannobioside carbohydrate antibodies (AMCA) anti-chitin IgA (Anti-C), anti-laminarin IgA (Anti-L):

Anti-neutrophil cytoplasmic antibodies (ANCA), anti-Saccharomyces cerevisiae antibodies (ASCA), anti-outer membrane porin C (OmpC) antibodies, anti-CBir1 flagellin (anti-CBir1) antibodies, 12 antibodies, and Anti-smooth muscle antibodies (ASMA):

**CPT codes not covered for indications listed in the CPB:**

<table>
<thead>
<tr>
<th>Code</th>
<th>Code Description</th>
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<tbody>
<tr>
<td>82397</td>
<td>Chemiluminescent assay</td>
</tr>
<tr>
<td>83516</td>
<td>Immunoassay for analyte other than infectious agent antibody or infectious agent antigen, qualitative or semi-quantitative; multiple step method</td>
</tr>
<tr>
<td>83518</td>
<td>Immunoassay for analyte other than infectious agent antibody or infectious agent antigen; qualitative or semi quantitative, single step method (eg, reagent strip)</td>
</tr>
<tr>
<td>83519</td>
<td>quantitative, by radioimmunoassay (eg, RIA)</td>
</tr>
<tr>
<td>83520</td>
<td>Immunoassay, analyte, quantitative; not otherwise specified</td>
</tr>
<tr>
<td>Code</td>
<td>Code Description</td>
</tr>
<tr>
<td>--------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>86021</td>
<td>Antibody identification; leukocyte antibodies [ANCA antibodies]</td>
</tr>
<tr>
<td>86255</td>
<td>Fluorescent noninfectious agent antibody; screen, each antibody</td>
</tr>
<tr>
<td>86671</td>
<td>Antibody; fungus, not elsewhere specified</td>
</tr>
<tr>
<td>88350</td>
<td>Immunofluorescence, per specimen; each additional single antibody stain procedure (List separately in addition to code for primary procedure)</td>
</tr>
</tbody>
</table>

6-thioguanine nucleotide (6-TGN) and 6-methylmercaptopurine nucleotide (6-MMPN) (Prometheus Thiopurine Metabolites):

CPT codes covered if selection criteria are met:

<table>
<thead>
<tr>
<th>Code</th>
<th>Code Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>82491</td>
<td>Chromatography, quantitative, column (e.g., gas liquid or HPLC); single analyte not elsewhere specified, single stationary and mobile phase</td>
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</tbody>
</table>

Other HCPCS codes related to the CPB:

<table>
<thead>
<tr>
<th>Code</th>
<th>Code Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>J7500</td>
<td>Azathioprine, oral, 50 mg</td>
</tr>
<tr>
<td>J7501</td>
<td>Azathioprine, parenteral, 100 mg</td>
</tr>
</tbody>
</table>

Calprotectin:

CPT codes covered if selection criteria are met:

<table>
<thead>
<tr>
<th>Code</th>
<th>Code Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>83993</td>
<td>Calprotectin, fecal</td>
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</tbody>
</table>

CPT codes not covered for indications listed in the CPB:

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<thead>
<tr>
<th>Code</th>
<th>Code Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>83520</td>
<td>Immunoassay, analyte, quantitative; not otherwise specified</td>
</tr>
</tbody>
</table>

Other HCPCS codes related to the CPB:

<table>
<thead>
<tr>
<th>Code</th>
<th>Code Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>J7500</td>
<td>Azathioprine, oral, 50 mg</td>
</tr>
<tr>
<td>J7501</td>
<td>Azathioprine, parenteral, 100 mg</td>
</tr>
<tr>
<td>Code</td>
<td>Code Description</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------------------------------------</td>
</tr>
<tr>
<td>S0108</td>
<td>Mercaptopurine, oral 50 mg</td>
</tr>
</tbody>
</table>

ICD-10 codes covered if selection criteria are met:

- K50.0 - K51.919: Regional enteritis and ulcerative colitis
- K58.0 - K58.9: Irritable bowel syndrome

Fecal lactoferrin:

CPT codes covered if selection criteria are met:

- Fir micutes and Bacteroidetes (F/B) ratio stool test, measurements of DNA, mRNA and protein biomarkers - no specific code

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>83630</td>
<td>Lactoferrin, fecal; qualitative</td>
</tr>
<tr>
<td>83631</td>
<td>Lactoferrin, fecal; quantitative</td>
</tr>
</tbody>
</table>

ICD-10 codes covered if selection criteria are met:

- K50.00 - K50.919: Crohn’s disease
- K51.00 - K51.919: Ulcerative colitis
- K52.9: Noninfective gastroenteritis and colitis, unspecified
- K58.0 - K58.9: Irritable bowel syndrome
- K59.0 - K59.09: Constipation
- K59.1: Toxic gastroenteritis and colitis
- R10.0 - R10.13: Abdominal and pelvic pain
- R10.30 - R10.34: Pain localized to other parts of lower abdomen
<table>
<thead>
<tr>
<th>Code</th>
<th>Code Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>R14.0</td>
<td>Abdominal distension (gaseous) [bloating]</td>
</tr>
<tr>
<td>R19.7</td>
<td>Diarrhea, unspecified</td>
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</tbody>
</table>

ICD-10 codes not covered if selection criteria are met (not all-inclusive):  

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<tr>
<th>Code</th>
<th>Code Description</th>
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<tr>
<td>A02.0</td>
<td>Salmonella enteritis</td>
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<tr>
<td>A03.0 - A03.9</td>
<td>Shigellosis</td>
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<tr>
<td>A04.0 - A04.9</td>
<td>Other bacterial intestinal infection</td>
</tr>
<tr>
<td>A06.0 - A06.4</td>
<td>Acute amebic dysentery, chronic intestinal amebiasis, amebic nondysenteric colitis, ameboma of intestine, and amebic liver abscess</td>
</tr>
<tr>
<td>A07.0 - A07.9</td>
<td>Other protozoal intestinal diseases</td>
</tr>
<tr>
<td>A08.0 - A08.8</td>
<td>Viral and other specified intestinal infections</td>
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<tr>
<td>A09</td>
<td>Infectious gastroenteritis and colitis, unspecified</td>
</tr>
<tr>
<td>B37.82</td>
<td>Candidal enteritis</td>
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<tr>
<td>B55.0</td>
<td>Visceral leishmaniasis</td>
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<tr>
<td>B65.1</td>
<td>Schistosomiasis due to Schistosoma mansoni [intestinal schistosomiasis]</td>
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<tr>
<td>B78.0</td>
<td>Intestinal strongyloidiasis</td>
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<tr>
<td>B82.0</td>
<td>Intestinal helminthias, unspecified</td>
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</table>

**NOD2/CARD15 genotyping:**

<table>
<thead>
<tr>
<th>No specific code</th>
<th>Code Description</th>
</tr>
</thead>
</table>
The Prometheus IBD sgi diagnostic panel and Prometheus IBS diagnostic panel (see next entry):

(i including BDNF [brain-derived neurotrophic factor],
GRO-a [growth-regulated oncogene-alpha], IL1B
[interleukin-1beta], NGAL [neutrophil gelatinase-
associated lipocalin], CD14 gene C-260T polymorphism
testing, fucosyltransferase 2 gene (rs601338) variant
testing, glutathione S-transferase M1 (GSTM1) null
genotyping, interleukin-10-1082A/G polymorphism
testing, Prometheus Crohn's Prognostic

<table>
<thead>
<tr>
<th>Code</th>
<th>Code Description</th>
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<tbody>
<tr>
<td></td>
<td>No specific code</td>
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<tr>
<td>TIMP-1</td>
<td>[tissue inhibitor of metalloproteinase-1], tTG [anti-human tissue transglutaminase IgA] and TWEAK [TNF-related weak inducer of apoptosis]:</td>
</tr>
<tr>
<td></td>
<td>No specific code</td>
</tr>
<tr>
<td>CPT codes not covered for indications listed in the CPB:</td>
<td></td>
</tr>
<tr>
<td>82397</td>
<td>Chemiluminescent assay</td>
</tr>
<tr>
<td>83520</td>
<td>Immunoassay, analyte, quantitative; not otherwise specified</td>
</tr>
<tr>
<td>86140</td>
<td>C-reactive protein</td>
</tr>
<tr>
<td>88347</td>
<td>Immunofluorescent study, each antibody; indirect method</td>
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<tr>
<td></td>
<td>Crohn's disease peptide antibody testing, eXalBD test (a quantitative PCR test for 6 genes [BLCAP, UBE2G1, RAP1A, CALM3 AND NONO]), Measurement of serum mannose-binding lectin, Macrophage inflammatory protein-1β (MIP-1β) :</td>
</tr>
<tr>
<td></td>
<td>Interleukin-6, IL-8:</td>
</tr>
</tbody>
</table>
No specific code

CPT codes not covered for indications listing in the CPB:

- **83520**: Immunoassay, analyte, quantitative; not otherwise specified

ICD-10 codes not covered if selection criteria are met:

- **K50.00** - **K51.919**: Regional enteritis and ulcerative colitis

IBS Detex test/IBS-smart:

CPT codes not covered for indications listed in the CPB:

- **0164U**: Gastroenterology (irritable bowel syndrome [IBS]), immunoassay for antiCdtB and anti-vinculin antibodies, utilizing plasma, algorithm for elevated or not elevated qualitative results

Myeloperoxidase antibody testing:

CPT codes not covered for indications listing in the CPB:

- **83876**: Myeloperoxidase (MPO)

Proteinase-3 antibody testing:

CPT codes not covered for indications listed in the CPB:

- **83516**: Immunoassay for analyte other than infectious agent antibody or infectious agent antigen, qualitative or semi-quantitative; multiple step method

- **83520**: Immunoassay, analyte, quantitative; not otherwise specified

- **86021**: Antibody identification; leukocyte antibodies

Raman spectroscopy:

- No specific code

ICD-10 codes covered if selection criteria are met:
The above policy is based on the following references:

Fecal Markers of Inflammatory Bowel Disease

6. Bonis PAL, Lamont JT. Approach to the adult with chronic diarrhea in resource-rich settings. UpToDate


40. Peppercorn MA, Kane SV. Clinical manifestations, diagnosis and prognosis of Crohn disease in adults. UpToDate [online serial]. Waltham, MA: UpToDate; reviewed February 2017.


55. van Rheenen PF, Van de Vijver E, Fidler V. Faecal calprotectin for screening of patients with suspected inflammatory bowel disease: Diagnostic meta-analysis. BMJ. 2010;341:c3369.
Firmicutes and Bacteroidetes (F/B) Ratio Stool Test


Fucoaryltransferase 2 Gene Variant Testing


Glutathione S-Transferase M1 Null Genotype

1. Zhou YJ, Zhao BL, Qian Z, et al. Association of glutathione S-transferase M1 null genotype with

IBSDetex Test / ibs-smart


Measurements of Biomarkers for Predicting Therapeutic Response in Inflammatory Bowel Disease


NOD2/CARD15 Genotyping


NUDT15 Gene Analysis


Pharmacogenomic and Metabolic Assessment of Thiopurine Therapy


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Amendment to
Aetna Clinical Policy Bulletin Number: 0249 Inflammatory Bowel Disease: Serologic Markers and Pharmacogenomic and Metabolic Assessment of Thiopurine Therapy

There are no amendments for Medicaid.