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# A prospective evaluation of the predictive value of faecal calprotectin in quiescent Crohn's disease

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**KEYWORDS**
Crohn's disease;
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**Abstract**

*Background:* Faecal calprotectin (FC) is a non-invasive marker of gastrointestinal inflammation.
*Aim:* To determine whether higher FC levels in individuals with quiescent Crohn's disease are associated with clinical relapse over the ensuing 12 months.
*Methods:* A single centre prospective study was undertaken in Crohn's disease patients in clinical remission. The receiver operating characteristic (ROC) curve for the primary endpoint of clinical relapse by 12 months, based on FC at baseline, was calculated. Kaplan–Meier curves of time to relapse were based on the resulting optimal FC cutoff for predicting relapse.
*Results:* Of 97 patients recruited, 92 were either followed up for 12 months without relapsing, or reached the primary endpoint within that period. Of these, 10 (11%) relapsed by 12 months. Median FC was lower for non-relapsers, 96 μg/g (IQR 39–237), than for relapsers, 414 μg/g (IQR 259–590), (p = 0.005). The area under the ROC curve to predict relapse using FC was 77.4%. An optimal cutoff FC value of 240 μg/g to predict relapse had sensitivity of 80.0% and specificity of 74.4%. Negative predictive value was 96.8% and positive predictive value was 27.6%, FC ≥ 240 μg/g was associated with likelihood of relapse by 12-months 12.18 (95%CI 2.55–58.2) times higher than lower values (p = 0.002).

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*Conclusions:* In this prospective dataset, FC is a useful tool to help identify quiescent Crohn's disease patients at a low risk of relapse over the ensuing 12 months. FC of 240 μg/g was the optimal cutoff in this cohort.


## 1. Introduction

Calprotectin is a calcium and zinc binding protein found in the cytosol of neutrophils. It is released at times of cell damage in the gastrointestinal (GI) tract and is resistant to enzymatic degradation allowing for measurement in faecal samples. The faecal calprotectin (FC) test has been shown to correlate well with faecal excretion of indium$^{111}$ labelled leucocytes[1] and with both microscopic and endoscopic evidence of GI inflammation.[2,3] In addition to its use in differentiating irritable bowel syndrome (IBS) from inflammatory bowel disease (IBD),[4–8] it has been assessed as a marker of mucosal healing.[9–12] There are seven published studies in adult IBD patients that address the issue of FC as a predictor of clinical relapse with ongoing medical therapy in quiescent Crohn's disease (CD).[13–19] Higher FC levels were associated with a greater risk of relapse for those with Ulcerative colitis (UC),[13–17] but discrepant results have been seen in CD.[14,15,19] Furthermore meta-analysis has shown that there is insufficient evidence to determine whether FC levels in those with ileal CD can serve to predict relapse.[20] The aim of this study was to prospectively assess the role of FC as a predictive marker of relapse within 12 months in those with asymptomatic CD of all phenotypes.

## 2. Methods

### 2.1. Patients

In this single centre prospective study, 97 consecutive CD patients in clinical remission, attending for routine outpatient review between August 2010 and November 2011, were identified and enrolled. Written informed consent was obtained. Remission at the time of enrolment was defined as a Crohn's disease Activity Index (CDAI)[21] of <150 points.

We excluded patients with an unclear diagnosis (ie. 'indeterminate colitis'), clinical relapse within the preceding 3 months, concomitant serious illness, pregnancy, age <18 years, alcohol abuse, non-steroidal anti-inflammatory use, and stool culture positivity.

Full ethical approval was awarded on 15 April 2010 by the West of Scotland Research Ethics Service (WeSRES) (REC reference 10/S0704/1).

The first FC sample provided by each participant from our recently published study[22] on the intra-individual variability of FC was used as a baseline value for this prospective follow-up study. The samples were collected by the patients at home and processed at the biochemistry laboratory at Glasgow Royal Infirmary. Patients were reviewed at regular 3–6 monthly intervals or at relapse. The primary endpoint was relapse within 12 months, while the secondary endpoint was relapse at any time during follow-up. Relapse was defined as an unplanned escalation in therapy, progression of disease phenotype by the Montreal classification, or hospitalisation and/or emergency surgery for active CD.

### 2.2. Biochemistry procedures

The Roche faecal extraction device was used to prepare and analyse stool samples adhering to the manufacturer's instructions (Bühlmann calprotectin ELISA kit). Stool was collected in screw-capped plastic containers and received by laboratory within 48 h of the final stool collection. The samples were processed by qualified biochemical scientists with Health and Care Professions Council registration on site at Glasgow Royal Infirmary. Samples weighing between 98 and 102 mg were placed into the extraction tube cap. 4.9 ml of extraction buffer was subsequently added to all tubes which were recapped and homogenised for 15 min on the Alpha multi tube vortexer at maximum speed. The homogenate was centrifuged at 3000 rpm for 10 min and the supernatants were transferred to plastic tubes and stored at −20 °C. The time from sampling to preparation and freezing was approximately 1 to 3 days. The supernatants were thawed then mixed and centrifuged before analysis with the Bühlmann quantitative calprotectin ELISA kit on the Triturus automated ELISA analyser for determination of calprotectin concentration in stools. Calprotectin was expressed as micrograms per gramme (μg/g) of faeces. The faecal samples were stable between 2 and 8 °C for up to 10 days and faecal extracts for 4 months at −20 °C.

### 2.3. Statistical considerations

The Mann–Whitney or *t*-test was used, as appropriate, to test for significant differences in continuous variables (including FC) between patients who relapsed by 12 months and those who did not, while Fisher's exact test was used for categorical variables.

The sensitivity and specificity of different FC values to predict relapse by 12 months were calculated for all those who either reached the primary endpoint within 12 months or were followed up for at least 12 months without reaching the primary endpoint, and the resulting receiver operating characteristic (ROC) curve was plotted. The corresponding area under the curve (AUC) was calculated to represent the overall predictive power of FC in predicting relapse up to 12 months later. The sensitivity, specificity, and negative and positive predictive values are presented for the FC cutoff value with the optimal balance of sensitivity and specificity. Patients who died or were otherwise lost to follow-up before relapsing or being followed up for 12 months were excluded from analysis.

The optimal FC cutoff value was subsequently used to calculate Kaplan–Meier (K–M) cumulative event curves of time to relapse for all patients throughout the entire study.

Patients who did not relapse were censored at the end of follow-up. A Cox proportional hazards model was fitted to assess the impact of an FC value above or below the chosen cutoff on time to relapse at any point in the study, adjusted for age (in years), gender, any previous surgery (yes/no), and stoma (yes/no).

### 2.4. Sample size calculation

The sample size was calculated for the reliability phase of this study, which is reported in detail elsewhere.[22] Briefly, we estimated that 95 patients would have 80% power to show a 95% confidence interval of total width 0.13 around an intraclass correlation coefficient of 0.9 between the FC values from 3 samples.

## 3. Results

The mean age of all 97 recruited patients at baseline was 47 years (SD 16), 38% were male and 20% were smokers. The Montreal Classification of CD was as follows: age at diagnosis (A1 8%, A2 71%, A3 21%), location (L1 16%, L2 36%, L3 47%) and behaviour (B1 59%, B2 30%, B3 11%, p 15%).

Of the 97 patients recruited, the care of three individuals was transferred to another centre, one died of non-IBD related pathology, and one was lost to follow-up prior to reaching either the primary endpoint or a follow up of 12 months. The sensitivity/specificity part of the analysis therefore included 92 patients.

Of these 92 patients, 10 (11%) relapsed within 12 months. Table 1 shows that patients who experienced a relapse within 12 months exhibited higher median FC levels at baseline (414 μg/g; IQR 259–590) than those who did not (96 μg/g; IQR 39–237; p = 0.005). There were no significant differences in age, gender, surgery, stoma, smoking, age at diagnosis, location, disease behaviour, medication use at baseline or C reactive protein (CRP) between those who did and did not relapse by 12 months. All patients meeting the criteria for clinical relapse had a treatment escalation during the study period. Colonoscopy confirmed active mucosal disease in 5 of the relapsers while magnetic resonance imaging or computed tomography was used in 2 patients. 3 patients were defined on solely clinical grounds and their requirement for escalation of Crohn's disease therapy.

Fig. 1 shows the ROC curve for predicting relapse by 12 months, with sensitivity and specificity of various cutoff values of FC. The optimal balance of sensitivity and specificity corresponded to an FC cutoff value of 240 μg/g. This cutoff gave a sensitivity of 80.0%, specificity of 74.4%, negative predictive value of 96.8% and positive predictive value of 27.6%. The area under the curve (AUC) to predict CD relapse at 12 months using FC determination was 77.4%.

Fig. 2 explains the discrepancy between the negative and positive predictive values. Only two patients who relapsed by 12 months had FC of less than 240 μg/g. Therefore if a patient had FC < 240 μg/g they would have a low risk of relapse over the ensuing 12 months. However, while many more patients with FC ≥ 240 μg/g did relapse, two-thirds of all patients with FC of or above 240 μg/g did not and this is reflected in the low positive predictive value for relapse prediction in our cohort.

The selected cutoff of 240 μg/g was used to produce Kaplan–Meier (K–M) cumulative event curves of time to relapse for the 92 patients included, and these are presented in Fig. 3. The shortest time to relapse was 87 days and the longest was 298 days. There is a clear separation between the curves, with patients with FC ≥ 240 μg/g having a substantially shorter time to relapse than those with FC below the cutoff.

Table 2 shows the results of the Cox proportional hazards model of FC on time to relapse adjusted for demographics. The model confirmed the difference in time to relapse between those with high or low FC exhibited in the K–M curves, with a hazard ratio (HR) for FC ≥ 240 μg/g vs FC < 240 μg/g of 12.18 (95% CI 2.55–58.2; p = 0.002). Thus, based on our sample, a patient with FC ≥ 240 μg/g is 12.18 times more likely to relapse within 12 months than one with FC below 240 μg/g. Table 2 also shows that there was no impact of demographics on time to relapse.

As exploratory analyses, the 16 patients with ileal only disease and the 35 patients with colonic only disease were considered separately. Three of the 16 ileal patients relapsed during the study, at 142, 394 and 560 days, with only one having relapsed by 12 months. The three ileal patients who relapsed at any time during the study had higher median baseline FC levels (371 μg/g; IQR 284–741) than the 13 who did not (57 μg/g; IQR 20–101). A Mann Whitney test showed marginal statistical non-significance for this difference (p = 0.057). Two of the 35 colonic patients relapsed by 12 months, at 94 and 298 days, with a further two relapsing later at 470 and 524 days. The four colonic patients who relapsed at any time during the study had higher median baseline FC levels (424 μg/g; IQR 209–695) than the 31 who did not (187 μg/g; IQR 48–386), though the difference was not statistically significant (p = 0.16).

## 4. Discussion

Our prospective dataset, which is the largest yet studied, demonstrates that an FC concentration below 240 μg/g is predictive of a low risk of clinical relapse within 12 months for adults with quiescent CD. The ROC curve analysis revealed that the 240 μg/g concentration gave an optimal balance of sensitivity (80.0%) and specificity (74.4%). Despite a reassuringly high negative predictive value of 96.8% at this cutoff, the low positive predictive value (27.6%) suggested that FC is most useful as a tool to predict low risk of clinical relapse.

FC is a relatively cheap and non-invasive test making its use attractive in the increasingly financially conscious and risk-averse realm of modern health care. Its use is now established in differentiating irritable bowel syndrome (IBS) from inflammatory bowel disease (IBD).[4–8] There are also data supporting its use in evaluating abdominal discomfort,[23] reducing the need for endoscopy in suspected IBD,[24] assessing treatment response in IBD,[25,26] predicting mucosal healing in IBD,[9,11,12,26] detecting post-operative relapse in CD[27–29]and predicting response to anti-Tumour necrosis factor (anti-TNF) therapy.[30–32]

We have recently shown that FC levels do not vary considerably within individuals with quiescent CD on a day to day basis.[22] This is reassuring if a one off FC is to be used as a tool to predict future relapse. It would be

**Table 1** Subject demographics, by whether or not they relapsed by 12 months (N = 92). CRP measurements taken within 1 month of the FC sample only were included.

| | | Non-relapsers | Relapsers | p-Value |
|---|---|---|---|---|
| Faecal calprotectin (μg/g) | $N_{obs}$ ($N_{miss}$) | 82 (0) | 10 (0) | 0.005 |
| | Mean (SD) | 215.0 (279.4) | 529.6 (448.8) | |
| | Median (IQR) | 95.5 (39.2,237.2) | 414.0 (258.8,590.2) | |
| | [Range] | [9.0,1550.0] | [38.0,1480.0] | |
| Age (years) | $N_{obs}$ ($N_{miss}$) | 82 (0) | 10 (0) | 0.207 |
| | Mean (SD) | 47.9 (16.0) | 41.0 (15.4) | |
| | Median (IQR) | 46.0 (35.2,60.8) | 44.5 (28.2,47.8) | |
| | [Range] | [18.0,83.0] | [18.0,66.0] | |
| Gender | Female | 53 (89.8%) | 6 (10.2%) | 0.742 |
| | Male | 29 (87.9%) | 4 (12.1%) | |
| Surgery | No | 38 (92.7%) | 3 (7.3%) | 0.503 |
| | Yes | 44 (86.3%) | 7 (13.7%) | |
| Stoma [a] | No | 69 (88.5%) | 9 (11.5%) | 1.000 |
| | Yes | 13 (92.9%) | 1 (7.1%) | |
| Smoker | No | 68 (89.5%) | 8 (10.5%) | 0.684 |
| | Yes | 14 (87.5%) | 2 (12.5%) | |
| Age at diagnosis (years) | <16 | 6 (75.0%) | 2 (25.0%) | 0.092 |
| | 17–40 | 58 (87.9%) | 8 (12.1%) | |
| | > 40 | 18 (100.0%) | 0 (0.0%) | |
| Duration of disease (years) | $N_{obs}$ ($N_{miss}$) | 82 (0) | 10 (0) | 0.367 |
| | Mean (SD) | 10.7 (9.7) | 14.1 (10.8) | |
| | Median (IQR) | 7.5 (3.0,15.8) | 13.0 (4.0,23.2) | |
| | [Range] | [1.0,38.0] | [1.0,30.0] | |
| Location | Ileal | 15 (93.8%) | 1 (6.2%) | 0.493 |
| | Colonic | 29 (93.5%) | 2 (6.5%) | |
| | Ileal colonic | 38 (84.4%) | 7 (15.6%) | |
| | Isolated upper disease | 0 (NaN%) | 0 (NaN%) | |
| Behaviour | Non stricturing non penetrating | 53 (94.6%) | 3 (5.4%) | 0.077 |
| | Stricturing | 23 (79.3%) | 6 (20.7%) | |
| | Penetrating | 6 (85.7%) | 1 (14.3%) | |
| Peri-anal | No | 71 (88.8%) | 9 (11.2%) | 1.000 |
| | Yes | 11 (91.7%) | 1 (8.3%) | |
| C-reactive protein | $N_{obs}$ ($N_{miss}$) | 40 (42) | 5 (5) | 0.539 |
| | Mean (SD) | 8.62 (15.78) | 2.14 (1.57) | |
| | Median (IQR) | 2.10 (0.98,7.78) | 2.00 (1.10,3.00) | |
| | [Range] | [0.20,77.00] | [0.30,4.30] | |
| *Medications at baseline* | | | | |
| 5-Amino-salicylic acid | No | 45 (88.2%) | 6 (11.8%) | 1.000 |
| | Yes | 37 (90.2%) | 4 (9.8%) | |
| Thiopurine | No | 54 (93.1%) | 4 (6.9%) | 0.164 |
| | Yes | 28 (82.4%) | 6 (17.6%) | |
| Anti-tumour necrosis factor | No | 71 (88.8%) | 9 (11.2%) | 1.000 |
| | Yes | 11 (91.7%) | 1 (8.3%) | |
| Steroid [b] | No | 81 (90.0%) | 9 (10.0%) | 0.207 |
| | Yes | 1 (50.0%) | 1 (50.0%) | |
| Methotrexate | No | 79 (88.8%) | 10 (11.2%) | 1.000 |
| | Yes | 3 (100.0%) | 0 (0.0%) | |
| No medications [c] | No | 57 (86.4%) | 9 (13.6%) | 0.272 |
| | Yes | 25 (96.2%) | 1 (3.8%) | |

[a] One patient underwent elective stoma closure during study period.
[b] Long term low dose maintenance steroid only.
[c] One quiescent patient later commenced adalimumab for arthritis only.

beneficial for clinicians to target early effective therapies if they could better predict risk. It has been noted that FC may correlate more closely with endoscopic scores than clinical severity scores in CD,[33] hinting at the potential to predict preclinical disease. There are published data on the use of FC levels to predict relapse in UC, which consistently show it to be both sensitive and specific.[13–17,20]

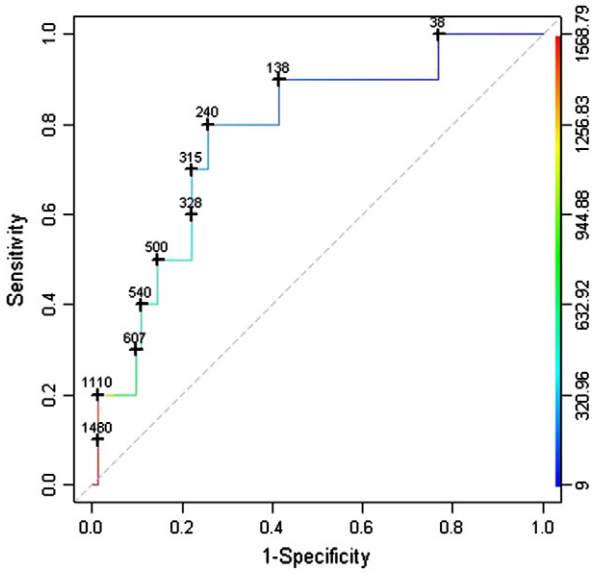


**Figure 1** Receiver operating characteristic (ROC) curve of the sensitivity and specificity of FC predicting relapse at 12 months for the 92 patients followed up for at least that length of time, based on various cutoffs of FC.

There are seven previously published prospective studies that have explored the issue of utilising FC concentrations to predict relapse within a 12 month time period in quiescent adult CD, showing conflicting results.[13–19] Three studies showed no statistically significant difference between the baseline median FC for relapsers and non-relapsers.[14,15,19] Costa et al.[14] compared FC levels in both UC patients and 38 CD patients.[14] Although the results were higher for those relapsing in UC, the levels in CD were comparable for both

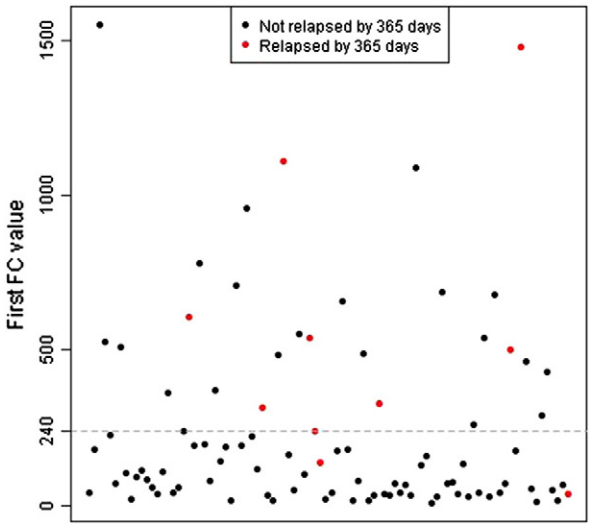


**Figure 2** Scatterplot of the FC values of the 92 patients, with those who relapsed by 12 months marked in red, and those who did not marked in black. The optimal cutoff of 240 μg/g marked as a dashed line.

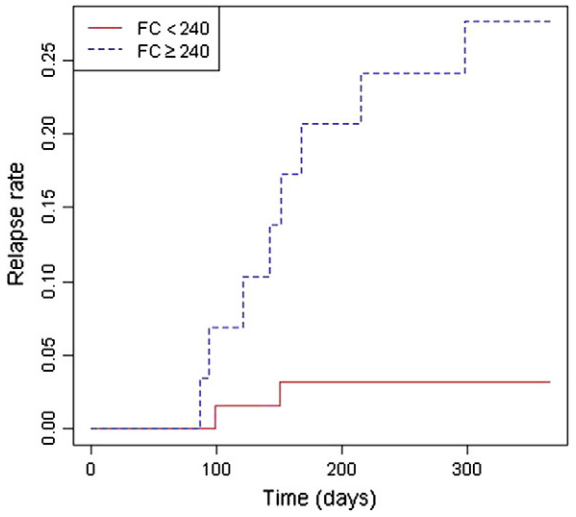


**Figure 3** Kaplan–Meier (K–M) cumulative event curves of time to relapse in days for the 92 patients, stratified by whether their FC was below or above 240 μg/g.

relapsers and non-relapsers (220.1 vs 220.5 μg/g p = 0.395). Similarly, in the 65 CD patients studied by D'Inca et al.[15] there was also no statistically significant difference between relapse and non-relapse median FC levels (207 vs 88 mg/kg p = 0.55). They found that the subgroup of colonic CD was the only group where FC level was predictive, but the numbers of relapsers in this cohort were small (4 of 6 colonic patients relapsed). The study by Laharie et al.[19] differed from the others described, as their 50 CD patients were all in remission 14 weeks post-infliximab induction. They found no significant difference between week 14 FC levels in relapsers vs non-relapsers (200 vs 150 μg/g p = NS). This cohort had a high 12-month relapse rate (46% vs 11% in our study).

Conversely, four other studies[13,16–18] showed a positive association between FC baseline level and risk of relapse. Tibble and colleagues[13] use a different and older assay but the FC results are equivalent to those of later studies (calprest) when the result is multiplied by a factor of five. They showed in 43 CD patients that relapsing patients had higher median baseline FC compared with that of non-relapsers (122 mg/l – which converts to 610 μg/g vs 42 mg/l – which converts to 220 μg/g). They combined the results with UC patients to produce a receiver operating characteristic (ROC) curve showing that an equivalent FC concentration of over 250 μg/g predicted relapse with a sensitivity of 90%

**Table 2** Cox proportional hazards model showing the relationship between time to relapse and high FC, adjusted for demographics (n = 92).

| | Estimate (95% CI) | p-Value |
|---|---|---|
| Age (years) | 0.98 (0.94,1.02) | 0.250 |
| Gender (male vs female) | 1.25 (0.34,4.51) | 0.737 |
| Surgery | 3.18 (0.77,13.25) | 0.111 |
| Stoma | 0.52 (0.06,4.42) | 0.551 |
| Faecal calprotectin ≥ 240 | 12.18 (2.55,58.2) | 0.002 |

and a specificity of 83%. Garcia-Sanchez et al.[17] studied 66 CD patients and identified a best cutoff value of 200 μg/g (sensitivity 80%, specificity 65%, PPV 46%, and NPV 88%) to predict relapse. They did, however stress that relapse predictability was more accurate for colonic CD. Their PPV and NPV values were similar to our own which suggest greater accuracy for prediction of remission than relapse. In the study by Gisbert et al.,[16] a total of 89 CD patients were included, 13 of whom relapsed. FC levels were found to be higher in relapsers (266 vs 145 μg/g; P = 0.002). Both Gisbert[16] and Garcia-Sanchez[17] drew attention to the fact that a high FC level appeared to be more predictive of relapse in colonic disease. Published commentaries[34–36] suggested that two of the earlier studies[13,14] had conflicting results which could be accounted for by differing proportions of small bowel CD patients. Given that greater levels of excreted indium$^{111}$-labelled leucocytes have been found in colonic vs small bowel CD,[37] Kallel et al.[18] were prompted to exclude small bowel CD from their analysis of 53 CD patients. Higher median FC values were measured at baseline in the relapse group (380.5 μg/g cf 155 μg/g $p < 0.001$). The ROC curve analysis revealed that a level of >340 μg/g provided the maximal sum of sensitivity (80%) and specificity (90.7%) to predict relapse.

More recently, Primas and colleagues[38] have published an abstract describing 57 CD patients post-ileocolonic resection. They found that an FC cutoff of over 100 μg/g 6 months post-surgery could predict relapse at a median of 11 months post-surgery with a sensitivity of 93% and specificity of 47%. Additionally, a large retrospective analysis of 650 patients (32% relapsers) by Kennedy et al.[39] has been published in abstract form; the primary endpoint was a composite of Montreal behaviour progression, hospitalisation for a flare of disease or surgery. A total of 211 reached the endpoint within 12 months of whom 57 had a progression in Montreal behaviour. They discovered a significant difference between median FC levels in relapsers vs non-relapsers (595 vs 320 μg/g). It should be noted that neither Primas nor Kennedy appears to have identified clinically quiescent patients at baseline as was done in the seven published studies described.[13–19] The patient populations may therefore not be directly comparable.

Louis et al.[40] studied a very different CD population who had undergone at least 12 months of infliximab therapy in combination with an antimetabolite. Anti-TNF therapy was withdrawn and calprotectin was measured at 2 monthly intervals. Of the 115 patients studied, 85 had FC measurements. An FC level >300 μg/g at baseline was associated with relapse (hazard ratio estimate 2.5 p = 0.04). De Suray et al.[41] looked at this data in greater detail in 113 patients, finding a sharp rise in FC within 4 months of relapse with a FC cutoff of 305 μg/g giving a sensitivity of 70% and specificity of 74% for relapse prediction.

Our own study shows a positive association between FC level and risk of relapse. Our relapse rate is relatively low at 11% compared with 18.9% in the group studied by Kallel et al.[18] and 58% in the study by Tibble et al.[13] Our study, and that by Gisbert et al.,[16] included patients on continuing biological therapy which may contribute to their similarly low relapse rate (14.6%). We chose to study all CD phenotypes in an attempt to establish, in a larger cohort, whether an effective cutoff could be determined. Our most effective FC cutoff level to predict relapse was shown to be 240 μg/g, which is similar to that of Tibble et al.[13] but lower than the 340 μg/g of Kallel et al.[18] Given that the latter study[19] excluded those without colonic disease and indium$^{111}$ leucocytes are excreted in higher levels in colonic disease,[38] this could explain the higher cutoff level.

In the meta-analysis by Mao et al.,[20] it was commented that there were insufficient available data to determine the use of FC to predict relapse in ileal CD. It is more challenging to assess proximal gastrointestinal inflammation by endoscopy and patients with inflammatory ileal disease may be less likely to have symptoms than those with colonic CD, leading to a greater chance of progressing to fistulising or stricturing disease.[42] Thus, although FC levels tend to be lower in ileal as opposed to colonic disease,[37] the FC test may well have a greater discriminant ability in ileal CD due to the disconnect between clinical symptoms and ileal disease activity in this cohort. Interestingly, we found that the difference in median baseline FC between relapsers and non-relapsers with ileal CD was large and close to statistical significance (371 vs 57 μg/g; p = 0.057) despite the small number of patients in this subgroup. It should be noted that these figures were obtained over an extended period of about two years, during which time 3 of the 16 ileal patients had relapsed, since only 1 patient relapsed within 12 months. This result suggests that a larger study, ideally over a longer time period, of those with ileal CD would be worthwhile to clarify this potential association. In our subgroup of colonic CD, only two of 31 patients relapsed within 12 months and four in the whole study period. Although the mean FC values were higher for the four relapsers (424 vs 187 μg/g), statistical significance was not reached (p = 0.16).

Although some published articles have shown an association between higher baseline CRP and risk of relapse,[18,41,42] others have failed to show this.[13,14,16] This study also shows no association between baseline CRP and the risk of subsequent clinical relapse. It should, however, be noted that this study was not designed to detect such an association and approximately half of the patients did not have a baseline CRP measurement. We did not show an association with relapse and smoking, but the numbers of those smoking at baseline were low[16] and we did not specifically collect data on starting or stopping smoking during the study.

There are additional limitations in our study which merit consideration. Like the previous studies described, we used CDAI rather than endoscopy as an objective assessment of disease activity to define remission at enrolment. This measure has been shown to correlate poorly with more objective assesments.[12] We would argue however that the risk of invasive endoscopy is not justified for asymptomatic CD patients in clinical remission as it does not reflect current standard clinical practice. Although our power calculation is based on our earlier intra-individual reliability study,[22] the subjects recruited do represent the largest prospective cohort yet studied in this field. As discussed above, the relapse rate and proportion with ileal disease were relatively low and an appropriately powered cohort of this CD phenotype is needed to elucidate the important issue of the clinical utility of FC in ileal CD. Furthermore, we conducted the study in a tertiary referral institute that may make the findings less applicable to the general population, although no patients on investigational therapies were recruited to this study. Lastly, despite not being blinded to the FC results, all investigators

agreed at the start of the recruitment that treatment decisions would be based solely on clinical assessment during the study period.

This study, utilising the largest prospective dataset in the current literature, provides evidence that adults with quiescent CD with a faecal calprotectin level below 240 μg/g are unlikely to relapse within 12 months, while those with a level of 240 μg/g or above are substantially more likely to relapse within 12 months. Our large dataset clarifies the previously conflicting data on this subject.[13–19] The FC result, obtained by non-invasive means, can provide prognostic information for both the patient and clinician alike. We believe that an FC below 240 μg/g should become a therapeutic target for physicians treating Crohn's patients who are in clinical remission when attending the outpatient clinic.

## Conflict of interest

The biochemistry processing and statistical analysis required financial support which was secured by an educational grant from 'Cure Crohn's colitis' ($C^3$) www.curecrohnscolitis.org – charity number SC036559. Dr Gaya is funded by an IBD Research Fellowship from the Chief Scientist Office (CSO) of the Scottish Government. There are no financial conflicts of interest to declare.

## Acknowledgements

Dr Naismith and Dr Gaya designed the study. Dr Rankin coordinated the processing of samples. Ms Munro, Ms Laird, Dr Morris, Dr Winter, Dr Gaya and Dr Smith collected the data. Dr Smith collated the data. Dr Barry performed statistical analysis and wrote the results and statistical methods sections of the paper. Dr Naismith wrote the paper with contributions from Dr Smith, Dr Gaya and Dr Rankin.

**Study highlights**

What is current knowledge?

Faecal calprotectin is a useful non-invasive marker of inflammatory burden in inflammatory bowel disease.

Faecal calprotectin has shown conflicting results when utilised as a predictive marker in quiescent Crohn's disease.

Faecal calprotectin is thought to be less useful to predict relapse in ileal Crohn's disease.

What is new here?

Confirmation of the predictive value of faecal calprotectin in Crohn's disease in the largest prospective study

Faecal calprotectin shows potential to predict disease recurrence in quiescent ileal Crohn's disease.

Faecal calprotectin concentrations <240 μg/g help predict sustained remission in Crohn's disease.

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