Circulating immunoglobulin G1 antibody in patients with ulcerative colitis against the colonic epithelial protein detected by a novel monoclonal antibody

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Abstract
Autoimmunity has been implicated in the pathogenesis of ulcerative colitis (UC). Several studies have shown amplified immunoglobulin G1 (IgG1) antibody response in UC; however the immunoreactive antigen(s) is unknown. To study this antigen(s), mucosal colonic extract was prepared by sonication, ultracentrifugation followed by ion exchange chromatography in fast protein liquid chromatography. The fraction (enriched colonic peptide), that was most reactive to a novel monoclonal antibody, 7E12H2 (IgM isotype), was isolated and used to examine the immunoreactivity against the patients’ serum samples. Two hundred and thirteen coded samples from 111 patients with UC (symptomatic and untreated), symptomatic and treated (26), remission (22)); 47 with Crohn’s disease (CD) (40 were symptomatic and untreated, and 30 had colonic disease); 29 with acute diarrhoea caused by specific pathogen(s): 10 with systemic lupus erythematosus, and 16 normal subjects were examined against the enriched colonic peptide by IgG subtype specific enzyme linked immunosorbent assays (ELISAs). Total IgG antibody reactivity was significantly (p<0.01) higher only in symptomatic and untreated UC patients compared with each of the non-UC group, but the sensitivity was only 50%. IgG2 and IgG3 reactivities were not different among various groups. The IgG1 antibody reactivity against the enriched colonic peptide, however, differentiated UC patients from CD and each of the other non-UC groups. Seventy nine per cent of the patients with UC, treated or untreated, symptomatic or in remission, had significantly (p<0.0001) higher IgG1 antibody against the enriched colonic peptide when compared with each of the other non-UC groups. Only 12% of CD serum samples and none of the other control serum samples reacted. Using purified serum IgG1 and 7E12H2-IgM, by sandwich ELISA, we confirmed that 7E12H2 reactive peptide indeed reacts with UC-IgG1 antibody but not with control IgG1.

Although the cause of ulcerative colitis (UC) is unknown, autoimmunity plays an important part in its pathogenesis. Serum autoantibodies to colonic epithelial cells have been identified in up to 60% of patients with UC and occur at a lower frequency in their relatives. The autoantibodies have been described both against colonic goblet cells as well as absorptive epithelial cells. In UC, an amplified immunoglobulin G1 (IgG1) antibody response in the circulation and in situ have been reported. In the second group there was also deposition of IgG1 together with activated early (Clq, C4c, C3b) and late (terminal complement complex) components of the complement cascade, on the apical face of the colonic epithelium in patients with active UC but not in patients with Crohn’s colitis. The immunoreactive antigen(s) recognised by the IgG1 antibody is, however, unknown. Tissue bound IgG, eluted from colonic mucosa, has been shown to react with an Mr 40K colonic protein (P40) only when the IgG was obtained from UC lesions. The UC colon eluted IgG (CCA-IgG) also reacted with P40 from the autologous colon further supporting its autoantigenicity. The subclass of CCA-IgG is unknown.

A monoclonal antibody (7E12H2, IgM isotype) against highly enriched P40 was developed and the reactivity of the monoclonal antibody was specifically localised to colonic epithelium and not in 13 other epithelial organs including other parts of the gastrointestinal tract and small intestinal enterocytes. Using a three colour immunofluorescence technique, recently epithelial deposits of IgG1 autoantibody and activated complement were colocalised along with the 7E12H2 reactive peptide on the colonic epithelium from patients with active UC and not from patients with Crohn’s disease (CD) affecting the colon.

In this study, we have examined the presence of circulating autoantibodies and their subclasses in patients with UC against the colonic epithelial protein highly enriched for the 7E12H2 reactivity. The disease specificity and sensitivity were examined using serum samples from a large number of patients with UC, CD, colitides resulting from specific pathogens and another autoimmune disease, systemic lupus erythematosus. The influence
of the activity of the disease and effect of treatment against the immunoreactivity was also examined.

Methods

PREPARATION OF COLON EXTRACT HIGHLY ENRICHED IN 7E12H12 REACTIVE PEPTIDE (ENRICHED COLON EPITHELIAL PEPTIDE)

Twelve specimens of colon (normal segments) were obtained from patients undergoing colectomy for colon cancer. The mucosa was carefully stripped off the muscle layer and the mucosal tissue was minced in 50 ml of buffer A, containing 50 mM TRIS HCl, pH 8.0; 0.15 M NaCl, 2 mM EDTA, 2 mM phenylmethylsulphonylfluoride, 0.3 μM aprotinin, 1 μM peptatin, and 1 μM leupeptin (Boehringer Manheim, Indianapolis, Indiana). The tissue was washed in the same buffer at least seven times until the supernatant was clear. The final pellet was homogenised in buffer A with 10 mM EDTA. The homogenate was centrifuged at 10,000×g for 30 minutes. The resulting supernatant was ultracentrifuged at 100,000×g for 90 minutes. The supernatant was frozen and thawed three times, then centrifuged for 10 minutes at 10,000×g to remove precipitates. The supernatant was dialysed against 20 mM bis-TRIS propane, pH 6.5 (buffer B) at 4°C. To remove lipids, the supernatant was mixed vigorously with an equal volume of 1,1,2-trichlorotetrifluoroethane (Sigma, St Louis, MO), and centrifuged. The aqueous phase was filtered through 0.20 micron cellulose acetate membrane filter. The filtrate was then subjected to anion exchange chromatography using a Mono Q HR 5/5 column (Pharmacia Fine Chemicals, Piscataway, NJ) in fast protein liquid chromatography (FPLC). Five mg of the colon extract were loaded in the column, which was then washed with buffer B. Proteins were eluted with a step gradient of 0.2, 0.35, and 0.48 M NaCl in buffer B. The immunoreactivity of the various eluates was examined in an ELISA using 7E12H12 monoclonal antibody. The 0.48 M NaCl colon extract was highly enriched for the 7E12H12 reactive peptide and used for the ELISA as described below.

IMMUNOREACTIVITY OF THE ENRICHED COLONIC PEPTIDE AGAINST PATIENTS SERUM SAMPLES

In preparation for the ELISA analysis, blood serum was obtained from a total of 203 subjects. These included 111 patients with UC, 47 with CD, 29 colitides, 10 patients with systemic lupus erythematosus, and 16 normal subjects. UC and CD were diagnosed on the basis of the patient’s clinical history, sigmoidoscopic, or colonoscopic examinations, or all three, and radiographic and histological studies of intestinal specimens. The activity of the disease was assessed by the physicians and noted in a specific protocol while collecting the blood samples. The colitides patients were diagnosed on the basis of their stool examination for specific pathogens. All serum samples were decomplexed by heating at 56°C for 30 minutes, then delipidated by treating with equal volume of 1,1,2-trichlorotetrafluoroethane, and ultracentrifuged at 100,000×g for 30 minutes to remove aggregates.

DIRECT ELISA

Ninety-six wells microtitre plates (Immulon IV, Dynatech Lab, Chantilly, VA) were coated with the enriched colonic peptide at a concentration of 0.5 μg/well in 100 microlitre of carbonate buffer, pH 9.6, overnight at 4°C. Thereafter, wells were washed with phosphate buffered saline (PBS), pH 7.4, containing 0.1% TWEEN-20 (PBS-TWEEN 20). Plates were blocked with 3% bovine serum albumin diluted in PBS for two hours at room temperature. Each serum was diluted 200-fold in the blocking buffer. One hundred microlitre of the diluted serum was added per well in triplicate, incubated for two hours at 37°C, and washed. Then the plates were treated as follows: (a) for the detection of total IgG, the plates were incubated with 100 μl/well of 1:5000 diluted alkaline phosphatase conjugated donkey anti-HuIgG (H+L) (Jackson Laboratories, West Grove, PA); (b) for detection of IgG subclasses, the plates were incubated for one hour at 37°C with 100 μl/well of murine monoclonal anti-HuIgG1 (1:2000), anti-HuIgG2 (1:200), and anti-HuIgG3 (1:100) antibodies (Miles Scientific, Naperville, IL). Bound monoclonal antibodies were detected by alkaline phosphatase conjugated goat antimouse IgG (1:1000) (Zymed Lab, South San Francisco, CA). Finally, the chromogen p-nitrophenyl phosphate (Sigma Chemicals, St Louis, MO) was added in 1 mM magnesium chloride and 50 mM sodium carbonate, pH 9.8. Blanks consisted of protein coated wells that received similar treatment except human serum. Additional control experiments were performed using Escherichia coli extract. E coli, strain Y1090, was grown in standard Luria-Bertani medium, washed with PBS three times, and lysed by sonication. Debris was removed by centrifugation and soluble proteins were precipitated by cold acetone and dried. Dried powder was reconstituted in carbonate buffer, pH 9.6, protein estimated by Biorad protein assay, and the ELISA plate was coated at a concentration of 0.5 μg per well. Subsequent steps were the same as described above using human serum. The plates were read at 405 nm using a V max kinetic microplate reader (Molecular Devices, Menlo Park, CA). The mean blank values were deducted from the experimental values.

SANDWICH ELISA USING PURIFIED SERUM IgG1 AND 7E12H12 IgM

Purification of IgG1 from serum using anti-human IgG1 affinity column
Monoclonal antibody to human IgG1 (Calbiochem, San Diego, CA) was mixed with Affinia (S&S, Keene, NH), tresyl activated
TABLE 1 Serum samples from patients with IBD and controls

<table>
<thead>
<tr>
<th>Serum samples</th>
<th>Disease activity and treatment</th>
<th>No of subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>UC (111)</td>
<td>Symptomatic, untreated</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td>Symptomatic, treated with corticosteroids*</td>
<td>26</td>
</tr>
<tr>
<td>CD (47)</td>
<td>1 Symptomatic, untreated</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>2 Remission</td>
<td>7</td>
</tr>
<tr>
<td>Colitis (29)</td>
<td>Symptomatic, untreated</td>
<td>29</td>
</tr>
<tr>
<td>Systemic lupus erythematosus (10)</td>
<td>Symptomatic, treated with corticosteroids (5)</td>
<td>10</td>
</tr>
<tr>
<td>Normal subjects (16)</td>
<td>Healthy</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>213</td>
</tr>
</tbody>
</table>

* = > 15 mg prednisone. † = 30 of 47 CD patients had colonic involvement. ‡ = Shigella (7), salmonella (6), giardia (6), amoebiasis (5), cryptosporidia (5), CI difficile (2).

Sandwich ELISA

Two sets of sandwich ELISAs were performed to capture the antigen(s) and examine the cross-reactivity of the antigen by purified IgG1 and 7E12 H12 IgM.

(1) The microtitre plate was coated with purified serum IgG1 from each of the 10 subjects in a concentration of 1 μg/well in triplicate/100 μl of coating buffer (pH 9-6) and left at 4°C for overnight. The next day, after washing three times in PBS/TWEEN 20 (0-1%), the plate is blocked with 0-25% bovine serum albumin in PBS. After this, sequential steps included incubation with FPLC purified 0-48 M NaCl mucosal extract (enriched colonic peptide) (2 μg/well), for one hour at 37°C, washed with PBS/TWEEN 20, and then incubated with 7E12 H12 IgM (1 μg/well) for one hour at 37°C, followed by alkaline-phosphatase conjugated antimonie IgM (Zymed, 1:15 000, one hour at room temperature). Substrate buffer was added as described above and optical density was measured at 405 nm in the ELISA reader. The binding of IgG1 to the plate was confirmed with alkaline-phosphatase labelled antihuman IgG run in parallel. Antigen control included similarly extracted small intestinal protein(s) in place of 0-48 M NaCl colon extract and an unrelated murine IgM monoclonal antibody (MOPC-104E) was used as control in place of 7E12 H12 IgM.

(2) The microtitre plate was coated with purified 7E12 H12 IgM to capture the antigen. The plate was coated with 7E12 H12 IgM (0-5 μg/well) followed by 0-48 M NaCl colon extract and then with purified human serum IgG1. Detection system in this case was alkaline phosphatase labelled goat antihuman IgG.

Results

Table I shows the demographic data of the 203 subjects. These included 63 patients with symtomatic UC who were treated with immunosuppressive drugs, or both and 22 patients with UC in remission. Additional samples were obtained from 40 patients with symptomatic CD who did not receive any drugs other than sulphasalazine, and seven patients with CD in remission; 29 symptomatic patients with diarrhoea resulting from various pathogens, 16 healthy subjects, and 10 patients with systemic lupus erythematosus. The patients with UC ranged in age from 9 to 83 years (mean age 40) and 52 patients were men. The duration of their disease varied from two months to 22 years (mean 6-1 years). The patients with CD ranged in age from 12 to 67 years (mean 36). The duration of CD ranged from two months to 40 years (mean 7-38 years). Patients with both UC and CD with active disease and who were not receiving drugs were not treated with corticosteroids or other immunosuppressive drugs at the time of collection of serum samples. However, several patients were taking sulphasalazine or other 5-ASA preparations. Serum samples were also obtained from 29 patients with acute diarrhoea caused by...
Figure 1: Scatterogram showing the IgG1 antibody response against the colonic extract highly enriched in the colonic peptide reactive to 7E12H12 monoclonal antibody. Patients with UC belonged to three groups: UC-1, symptomatic and untreated; UC-2, symptomatic and treated with corticosteroids or immunosuppressive drugs; UC-3, patients in remission. Patients with CD included CD-1, symptomatic and untreated and CD-2, the patients in remission. Thirty CD patients had colonic involvement with or without ileal involvement. Patients with colitides caused by specific pathogens are identified as patients with diarrhea. NL-normal subjects and SLE-systemic lupus erythematosus. The highest background value of this ELISA with a normal serum was an optical density of 0.125. Eighty eight of 111 UC serum samples (79%) and only six of 47 CD serum samples had optical density values above this baseline. Each of the UC group had significantly (p<0.0001) higher optical density when compared with any of the non-UC groups.

specific pathogenes, which, as identified by stool examinations, were: shigella (6); salmonella (6); giardia (5); amoebiasis (4); cryptosporidia (4); Cl difficile (1); blastocystis (2), and intestinal tuberculosis (1).

The immunoreactivity of 7E12H12 monoclonal antibody increased in various colonic mucosal extracts during the purification in FPLC. A 21-fold enrichment of the immunoreactivity of 7E12H12 monoclonal antibody was seen in the 0.48 M NaCl eluate. This eluate containing the enriched colonic peptide was used for both direct and sandwich ELISAs.

The enriched colonic peptide was further characterised as follows: the 7E12H12 reactive peptide is heat stable and the reactivity does not change after boiling and it reacts with concanavalin A, suggesting that it is a glycoprotein. The reactivity of 7E12H12 is, however, against the peptide rather than sugar. This is evidenced by the fact that periodate treatment and N- and O-glycanase treatments do not change the 7E12H12 monoclonal antibody reactivity; whereas trypsin digestion destroys the activity.

Figure 1 shows the ELISA data of IgG1 antibody responses with all 213 subjects. The highest background value of this ELISA with a non-inflammatory bowel disease subject was an optical density of 0.125 with a normal serum. The mean (SEM) value for all normal subjects was 0.040 (0.008). Eighty eight serum samples from the total 111 (79%) UC patients produced an optical density higher than 0.125. Only six of 47 CD serum samples (12%) had an optical density value higher than 0.125.

Table II summarises the results in all patients with different clinical activities and their statistical analysis. The mean (SEM) value for UC group with symptomatic disease without any treatment was 0.199 (0.009), symptomatic UC treated with corticosteroids was 0.204 (0.024); UC in remission was 0.160 (0.018). The mean value for CD group with active disease was 0.077 (0.012) and for CD patients in remission it was 0.067 (0.014). The mean value for symptomatic diarrhoeal patients was 0.028 (0.006) and for systemic lupus erythematosus patients the mean optical density value was 0.009 (0.005). The difference between the mean value for each of the UC subgroups (treated or untreated, symptomatic or in remission) is highly significant (p<0.001 to 0.0001) against each non-UC group (Table II). There was no difference in IgG2 and the IgG3 responses. IgG4 response was not examined.

Table II also shows the total IgG antibody response in the UC group, particularly patients with symptomatic colitis without being treated, the mean (SEM) optical density was the highest at 0.190 (0.014) followed by symptomatic patients who were treated. The background optical density for total IgG with normal subjects and diarrhoeal patients was 0.073 and 0.079 respectively; patients with active CD and UC in remission had mean optical density values 0.096 and 0.108 respectively. Statistical analysis of total IgG responses showed that only symptomatic patients with UC treated or untreated had significantly higher (p<0.05 to <0.001) optical density than each of the non-UC group. The optical density value in patients with UC in remission, however, was not significantly different than any of the non-IBD group.

The IgG1 responses against the E coli extract was measured with 20 UC, 10 CD, and 10 normal serum samples. The mean (SEM) optical density values for UC, CD, and normal subjects were 0.161 (0.018), 0.212 (0.055), and 0.238 (0.039) respectively. The differences among these values were not statistically significant. The total IgG response in UC (0.487 (0.064)) was also similar to normal subjects (0.479 (0.083)).

Figure 2 and Table III shows the results of the capture ELISA using the enriched colonic peptide and purified IgG1 or 7E12H12 IgM. The peptide bound to UC IgG1 also bound to 7E12H12 monoclonal antibody and vice versa, showing the cross reactivity of the two
IgG against the same peptide. Such reactivity was not seen with CD-IgG1 MOPC-104E, and when small intestinal mucosal extract was used in place of enriched colonic peptide (Fig 2 and Table III).

Discussion

In this study, we show that almost 80% of the patients with UC, symptomatic or in remission, treated or untreated had specific IgG1 autoantibody (p=0.0001) directed against the colon extract highly enriched for 7E12H12 reactive peptide. Only six of 47 (12%) patients with CD reacted. Serum samples from 29 patients with colitides caused by specific pathogens, serum from patients with systemic lupus erythematosus, and normal subjects did not react, however, with the peptide in the direct ELISA. The sandwich ELISAs using purified serum IgG1 and 7E12H12 IgM further confirmed that the IgG1 autoantibody in UC indeed reacts with the colonic protein also recognised by the 7E12H12 monoclonal antibody. That the IgG1 response in UC is specific to the colonic peptide rather than a general antibody response, is supported by the fact that the IgG antibody response in UC against the E.coli extract was not subclass specific.

The total IgG reactivity using the UC serum samples showed only 50% sensitivity with 25% false positive for CD. Similar results were reported by us earlier using 0.35 M NaCl eluate of colon extract. We did not perform IgG subtype specific ELISAs in this earlier study. Thus, the IgG antibody response in the absence of subclass specific ELISA would not have detected the UC specific response against the colonic peptide as shown here. The high background activity with total IgG can be explained because of the presence of non-specific proteins still present in the colon extracts.

Hibi et al.15 described in vitro synthesis of anti-colon epithelial antibody by mucosal and peripheral blood lymphocytes from UC. We earlier described colon tissue bound IgG antibodies, termed CCA-IgG7 in UC patients and not in patients with CD, diverticulitis and normal subjects. CCA-IgG recognises an Mr 40K protein present in the colon extracts. To study this antigen further, we developed a monoclonal antibody of the IgM isotype designated 7E12H12, which exclusively binds with the colonic epithelium mainly along the plasma membrane at the basolateral and apical or luminal aspects of the epithelial cells.10 Using immunofluorescent assay, the organ specificity of 7E12H12 monoclonal antibody to the colonic epithelium with more intense expression in the rectum has been reported recently by Halstensen et al.11 Although the subtype of CCA-IgG was not analysed, it inhibited the binding of 7E12H12 monoclonal antibody to the colonic peptide, suggesting that both antibodies probably react with the same peptide.10 The reactive peptide recognised by the 7E12H12 monoclonal antibody has since been localised also in epithelial cells of the skin and biliary tract,16 the extra colonic organs often involved in UC. In animal models of spontaneous colitis such as that seen in Saginus oedipus (cotton top tamarins) a similar distribution of 7E12H12 monoclonal antibody was seen in the colon epithelium.17 The small intestine of the cotton top tamarins did not react. Furthermore, serum from cotton top tamarins with spontaneous colitis had circulating antibodies against the 7E12H12 reactive peptide, whereas normal cotton top tamarins did not.17 These data suggest an autoantigenic role of 7E12H12 reactive peptide. Using a triple colour immunofluorescence technique, recently IgG1 autoantibody was shown to

Table III  The immunoreactivity of serum IgG1 and 7E12H12-IgM monoclonal antibody against FPLC enriched colonic peptide by the sandwich ELISA, where the plate was coated with purified IgG1 followed by enriched colonic peptide and then 7E12H12 IgM

<table>
<thead>
<tr>
<th>Optical density (SEM)*</th>
<th>Enriched colonic peptide</th>
<th>Enriched colonic peptide + MOPC</th>
<th>E SI extract + 7E12H12 IgM</th>
</tr>
</thead>
<tbody>
<tr>
<td>UC</td>
<td>0.177 (0.010)</td>
<td>0.015 (0.005)</td>
<td>0.016 (0.009)</td>
</tr>
<tr>
<td>CD</td>
<td>0.021 (0.004)</td>
<td>0.010 (0.002)</td>
<td>0.014 (0.006)</td>
</tr>
</tbody>
</table>

*When the plate was first coated with 7E12H12 IgM followed by enriched colonic peptide and then with serum IgG1 the mean optical density value for UC was 0.344 and for CD it was 0.076. This difference was statistically highly significant, p<0.0001.

†The background value for normal serum IgG1 is deducted from all samples.

IgG1, IgM, or †=p<0.0001, E SI extract= enriched small intestinal mucosal extract.
IgGI antibody in ulcerative colitis

and activated complement products in the colonic mucosa of patients with UC. 11 but not CD. 8 Further supporting the notion that the IgGlH12 reactive peptide acts as an auto-antigen capable of inducing IgGl autoantibody in UC and can activate complement mediated colonic cell injury. The postulated IgGl mediated epithelial attack by the 7E12H12 reactive peptide is also supported by the finding that peripheral blood lymphocytes from patients with UC (but not controls) and lamina propria lymphocytes from UC mucosa spontaneously release IgGl antibodies to the colonic peptide. Several studies reported that UC serum samples and not CD serum samples can induce antibody dependent cell mediated cytolysis against specific colon cancer cell targets. 19-21 Antibody dependent cell mediated cytolysis induced by UC serum samples on DLD-1 colon cancer cells that express 7E12H12 reactive peptide could be blocked by the 7E12H12 monoclonal antibody, suggesting that the 7E12H12 reactive peptide participates in antibody dependent cell mediated cytolysis in UC. 22 The absence of antibody dependent cell mediated cytolysis with UC serum sample, against another colon cancer cell line, HT-29 as reported by Snook et al. 22 may result from the absence of the 7E12H12 reactive peptide in these cells. The predominating mucosal IgGl response in UC may be genetically determined, as suggested by the identical twins study. 25

To summarise, our data provide evidence that circulating antibody of IgGl subclass against the colonic peptide reactive to the 7E12H12 monoclonal antibody exists in most (at least three quarters) of the patients with UC. Thus, these findings strongly support previous in situ data 11 and provide further evidence that an autoimmune response to the 7E12H12 reactive peptide is an important immunopathological mechanism in UC. Further characterisation of the peptide, reactive to 7E12H12 monoclonal antibody, may elucidate the mechanism of autoimmune response in UC.

This work is supported in part by research grants RO1 DK44314 and DK47673 from the National Institute of Health, Bethesda, MD, USA.

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Gut 1994 35: 1712-1717
doi: 10.1136/gut.35.12.1712