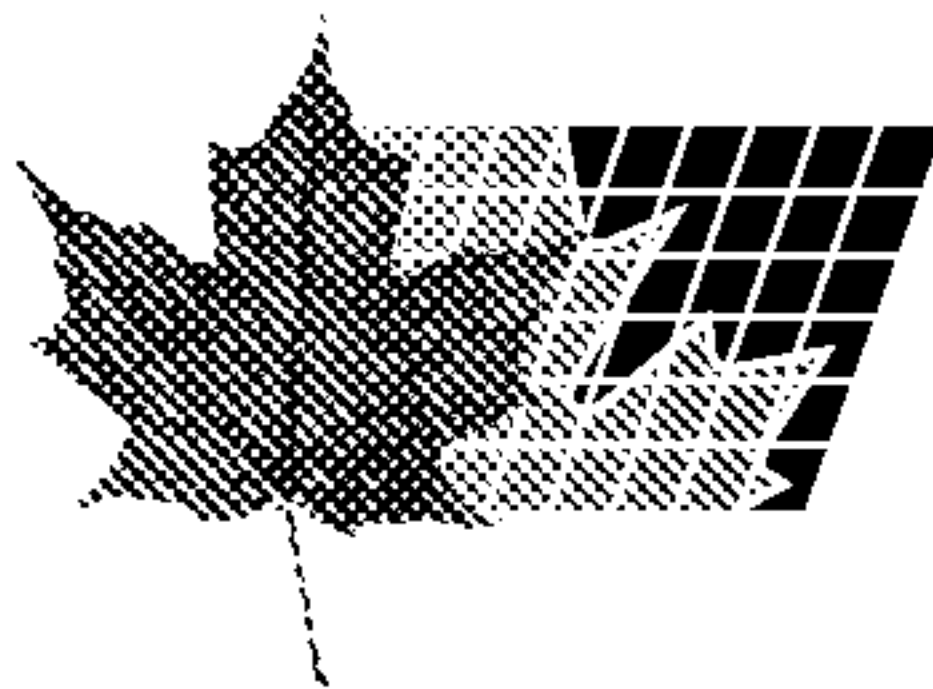




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(54) **UTILISATION OPTIMISEE D'UN MEDICAMENT CONTENANT
DE LA 6-MERCAPTOPURINE POUR LE TRAITEMENT DE
MALADIES GASTRO-INTESTINALES A MEDIATION
IMMUNE**

(54) **OPTIMIZED USE OF 6-MERCAPTOPURINE DRUG IN THE
TREATMENT OF IMMUNE-MEDIATED GASTROINTESTINAL
DISORDERS**

(57) The present invention provides a method of optimizing therapeutic efficacy and reducing toxicity associated with 6-mercaptopurine drug treatment of an immune-mediated gastrointestinal disorder such as inflammatory bowel disease. The method of the invention includes the step of determining the level of one or more 6-mercaptopurine metabolites in the patient having an immune-mediated gastrointestinal disorder.

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(54) Title: OPTIMIZED USE OF 6-MERCAPTOPURINE DRUG IN THE TREATMENT OF IMMUNE-MEDIATED GASTROIN- TESTINAL DISORDERS (57) Abstract The present invention provides a method of optimizing therapeutic efficacy and reducing toxicity associated with 6-mercaptopurine drug treatment of an immune-mediated gastrointestinal disorder such as inflammatory bowel disease. The method of the invention includes the step of determining the level of one or more 6-mercaptopurine metabolites in the patient having an immune-mediated gastrointestinal disorder.		

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OPTIMIZED USE OF 6-MERCAPTOPURINE DRUG IN THE TREATMENT OF IMMUNE-MEDIATED GASTROINTESTINAL DISORDERS

BACKGROUND OF THE INVENTION

The present invention relates generally to
5 autoimmunity and immune-mediated gastrointestinal disorders such as inflammatory bowel disease and more specifically to methods for optimizing treatment of immune-mediated gastrointestinal disorders.

BACKGROUND INFORMATION

10 Immune-mediated gastrointestinal disorders encompass a wide range of debilitating gastrointestinal diseases of various etiologies. One such immune-mediated gastrointestinal disorder, inflammatory bowel disease (IBD), is the collective term used to describe two
15 gastrointestinal disorders of unknown etiology: Crohn's disease (CD) and ulcerative colitis (UC). The course and prognosis of IBD, which occurs world-wide and is reported to afflict as many as two million people, varies widely. Onset of IBD is predominantly in young adulthood with
20 diarrhea, abdominal pain, and fever the three most common presenting symptoms. The diarrhea may range from mild to severe and in ulcerative colitis often is accompanied by bleeding. Anemia and weight loss are additional common signs of IBD. Ten percent to fifteen percent of all
25 patients with IBD will require surgery over a ten year period. In addition, patients with IBD are at increased risk for the development of intestinal cancer. Reports of an increasing occurrence of psychological problems, including anxiety and depression, are perhaps not
30 surprising symptoms of what is often a debilitating disease that strikes people in the prime of life.

6-Mercaptopurine (6-MP) and azathioprine (AZA), a pro-drug that is non-enzymatically converted to 6-mercaptopurine (6-MP), are 6-MP drugs that can be used as an effective treatment for inflammatory bowel diseases such as Crohn's disease and ulcerative colitis (Kirschner Gastroenterology 115:813-821 (1998)). 6-MP can be enzymatically converted to various 6-MP metabolites, including 6-methyl-mercaptopurine (6-MMP) and 6-thioguanine (6-TG) and their nucleotides. 6-TG nucleotides are thought to be the active metabolite in mediating many of the effects of 6-MP drug treatment.

Thiopurine methyltransferase (TPMT) is a cytoplasmic enzyme that preferentially catalyzes the S-methylation of 6-MP and 6-TG to form S-methylated metabolites such as 6-MMP and 6-methylthioguanine (6-MTG), respectively. TPMT exhibits genetic polymorphism, with 89% of Caucasians and African Americans having high activity, 11% intermediate activity and 1 in 300 TPMT deficient. Clinical studies with AZA and 6-MP have shown an inverse relationship between TPMT activity and 6-TGN accumulation. Patients who less efficiently methylate these thiopurines have more extensive conversion to 6-TGN, which can lead to potentially fatal hematopoietic toxicity. Therefore, patients who have less active TPMT can be more susceptible to toxic side effects of 6-MP therapy.

Although drugs such as 6-MP and AZA have been used for treating IBD, non-responsiveness and drug toxicity unfortunately complicate treatment in some patients. Complications associated with 6-MP drug treatment include allergic reactions, neoplasia, opportunistic infections, hepatitis, bone marrow suppression, and pancreatitis. Therefore, many

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physicians are reluctant to treat patients with AZA because of its potential side effects, especially infection and neoplasia.

Thus, there exists a need to develop methods to optimize the dose of 6-mercaptopurine drugs and assess biotransformation in individual patients to optimize the therapeutic efficacy of 6-mercaptopurine drugs while minimizing toxic side effects. The present invention satisfies this need and provides related advantages as well.

SUMMARY OF THE INVENTION

The present invention provides a method of optimizing therapeutic efficacy of 6-mercaptopurine drug treatment of an immune-mediated gastrointestinal disorder. The method includes the steps of administering a 6-mercaptopurine drug to a subject having an immune-mediated gastrointestinal disorder; and determining a level of 6-thioguanine in the subject having the immune-mediated gastrointestinal disorder, where a level of 6-thioguanine less than a level corresponding to about 230 pmol per 8×10^8 red blood cells indicates a need to increase the amount of 6-mercaptopurine drug subsequently administered to the subject and where a level of 6-thioguanine greater than a level corresponding to about 400 pmol per 8×10^8 red blood cells indicates a need to decrease the amount of 6-mercaptopurine drug subsequently administered to the subject. The methods are directed to treating immune-mediated gastrointestinal disorders, including inflammatory bowel diseases (IBD) such as Crohn's disease and ulcerative colitis, lymphocytic colitis, microscopic colitis, collagenous colitis, autoimmune enteropathy, allergic gastrointestinal disease

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and eosinophilic gastrointestinal disease. In a method of optimizing therapeutic efficacy of 6-mercaptopurine treatment of IBD, the subject having IBD can be, for example, a pediatric subject. The level of 6-thioguanine
5 can be determined, for example, in red blood cells using high pressure liquid chromatography.

The present invention also provides a method of reducing toxicity associated with 6-mercaptopurine drug treatment of an immune-mediated gastrointestinal
10 disorder. The method of reducing toxicity associated with an immune-mediated gastrointestinal disorder includes the steps of administering a 6-mercaptopurine drug to a subject having the immune-mediated gastrointestinal disorder; and determining a level of a
15 6-mercaptopurine metabolite in the subject having the immune-mediated gastrointestinal disorder, where a level of the 6-mercaptopurine metabolite greater than a predetermined toxic level of the 6-mercaptopurine metabolite indicates a need to decrease the amount of
20 6-mercaptopurine drug subsequently administered to the subject, thereby reducing toxicity associated with 6-mercaptopurine drug treatment of the immune-mediated gastrointestinal disorder. In a method of the invention, the 6-mercaptopurine metabolite can be, for example,
25 6-thioguanine and the predetermined toxic level of 6-thioguanine can correspond, for example, to a level of about 400 pmol per 8×10^8 red blood cells. Where the elevated 6-mercaptopurine metabolite is 6-thioguanine, the toxicity associated with 6-mercaptopurine treatment
30 can be, for example, hematologic toxicity. The 6-mercaptopurine metabolite also can be a metabolite such as 6-methyl-mercaptopurine and the predetermined toxic level of 6-methyl-mercaptopurine can correspond, for example, to a level of about 7000 pmol per 8×10^8 red blood

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cells. Where the elevated 6-mercaptopurine metabolite is 6-methyl-mercaptopurine, the toxicity associated with 6-mercaptopurine treatment can be, for example, hepatic toxicity.

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Further provided by the invention is a method of optimizing therapeutic efficacy and reducing toxicity associated with 6-mercaptopurine drug treatment of an immune-mediated gastrointestinal disorder. The method includes the steps of administering a 6-mercaptopurine drug to a subject having an immune-mediated gastrointestinal disorder; determining a level of 6-thioguanine in the subject having the immune-mediated gastrointestinal disorder; and determining a level of 6-methyl-mercaptopurine in the subject having the immune-mediated gastrointestinal disorder, where a level of 6-thioguanine less than a predetermined minimal therapeutic level indicates a need to increase the amount of 6-mercaptopurine drug subsequently administered to the subject, thereby increasing therapeutic efficacy; where a level of 6-thioguanine greater than a predetermined toxic level of 6-thioguanine indicates a need to decrease the amount of 6-mercaptopurine drug subsequently administered to the subject, thereby reducing toxicity associated with 6-mercaptopurine treatment of the immune-mediated gastrointestinal disorder; and where a level of 6-methyl-mercaptopurine greater than a predetermined toxic level of 6-methyl-mercaptopurine indicates a need to decrease the amount of 6-mercaptopurine drug subsequently administered to the subject, thereby reducing toxicity associated with 6-mercaptopurine treatment of the immune-mediated gastrointestinal disorder.

In such a method of optimizing therapeutic efficacy and reducing toxicity associated with 6-mercaptopurine drug treatment of an immune-mediated gastrointestinal disorder, the predetermined minimal
5 therapeutic level of 6-thioguanine can be, for example, a level corresponding to about 230 pmol per 8×10^8 red blood cells; the predetermined toxic level of 6-thioguanine can be, for example, a level corresponding to about 400 pmol per 8×10^8 red blood cells; and the predetermined toxic
10 level of 6-methyl-mercaptopurine can be, for example, a level corresponding to about 7000 pmol per 8×10^8 red blood cells. The level of 6-thioguanine and 6-methyl-mercaptopurine each can be conveniently determined, for example, in red blood cells using high
15 pressure liquid chromatography. The invention further provides methods to optimize the therapeutic efficacy of 6-mercaptopurine drug treatment of a non-IBD autoimmune disease.

BRIEF DESCRIPTION OF THE DRAWINGS

20 Figure 1 shows mercaptopurine metabolism and the structures of 6-mercaptopurine (6-MP) metabolites. The initial metabolism of 6-MP is catalyzed by thiopurine methyltransferase (TPMT), xanthine oxidase (XO), and hypoxanthine phosphoribosyltransferase (HPRT). Further
25 metabolism of the thionucleotide is catalyzed by inosine monophosphate dehydrogenase (IMPD) and guanosine monophosphate synthetase (GMPS). The breakdown of azathioprine to 6-mercaptopurine is nonenzymatic.

Figure 2 shows 6-mercaptopurine (6-MP)
30 metabolism and the 6-MP metabolites that are measured as 6-MP, 6-thioguanine (6-TG) and 6-methyl-mercaptopurine (6-MMP) (indicated as "MP," "TG" and "MMP" inside the

base). 6-TG mono-phosphate is converted to the di- and tri-phosphate by monophosphate kinase (MPK) and diphosphate kinase (DPK), respectively. The ribonucleoside diphosphate is converted to
5 deoxyribonucleoside diphosphate by ribonucleotide reductase (RR).

Figure 3 shows ranges of 6-thioguanine in IBD patients treated with a 6-MP drug.

Figure 4 shows the correlation of quartile 6-MP
10 metabolite levels with clinical response in IBD.

Panel A shows the frequency of clinical response was significantly higher within the upper 6-TG level quartiles ($>235 \text{ pmol}/8 \times 10^8 \text{ RBC}$) ($*p < 0.001$). Panel B shows an association between 6-MMP quartile levels and clinical
15 response. No significant differences were observed ($p = 0.48$). n = number of clinical evaluation points per quartile.

Figure 5 shows the frequency of 6-TG levels $>235 \text{ pmol}/8 \times 10^8 \text{ RBC}$ at clinical evaluation points
20 corresponding to therapeutic response, compared to points of therapeutic failure ($*p < 0.001$).

Figure 6 shows the relationship between 6-MP dose and clinical response in IBD. No significant differences were observed in the frequency of clinical
25 response within 6-MP dose quartiles. AZA dose was converted to 6-MP dose by a factor of 2.07.
 n = number of clinical evaluation points per quartile.

Figure 7 shows correlation of erythrocyte 6-MP metabolite levels with drug-related side effects in IBD.
30 n = number of observations. Panel A shows the correlation

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of 6-MMP levels with hepatotoxicity. Hepatotoxic events were associated with higher median 6-MMP levels (*p<0.05). Panel B shows the correlation of 6-TG levels with leukopenia at times of therapeutic response and failure. The solid line for each group represents the median 6-TG level (*p=0.035, leukopenia vs. no leukopenia).

Figure 8 shows the relationship between TPMT genotype and 6-TG level in IBD. Median 6-TG levels were higher among heterozygotes (TPMT^H/TPMT^L) (n=8) than homozygous normals (TPMT^H/TPMT^H) (n=85) with high activity (H) alleles. *p<0.0001

DETAILED DESCRIPTION OF THE INVENTION

The present invention provides a method of optimizing therapeutic efficacy of 6-mercaptopurine (6-MP) drug treatment of an immune-mediated gastrointestinal disorder. The method includes the steps of administering a 6-MP drug to a subject having an immune-mediated gastrointestinal disorder; and determining a level of 6-thioguanine (6-TG) in the subject having the immune-mediated gastrointestinal disorder, where a level of 6-TG less than a level corresponding to about 230 pmol per 8x10⁸ red blood cells indicates a need to increase the amount of 6-MP drug subsequently administered to the subject and where a level of 6-TG greater than a level corresponding to about 400 pmol per 8x10⁸ red blood cells indicates a need to decrease the amount of 6-MP drug subsequently administered to the subject. The methods are directed to treating immune-mediated gastrointestinal disorders, including inflammatory bowel diseases (IBD) such as Crohn's disease and ulcerative colitis, lymphocytic

colitis, microscopic colitis, collagenous colitis, autoimmune enteropathy, allergic gastrointestinal disease and eosinophilic gastrointestinal disease. In a method of optimizing therapeutic efficacy of 6-MP treatment of IBD, the subject having IBD can be, for example, a pediatric subject. The level of 6-TG can be determined, for example, in red blood cells using high pressure liquid chromatography (HPLC).

The invention provides methods of optimizing therapeutic efficacy of 6-MP drug treatment of an immune-mediated gastrointestinal disorder. The methods of the invention are particularly useful for treating an immune-mediated gastrointestinal disorder such as IBD, including Crohn's disease and ulcerative colitis and subtypes thereof. The methods of the invention allow the clinician to provide an individually optimized dosage of a 6-MP drug so as to achieve a target level of a 6-MP metabolite in a particular patient having an immune-mediated gastrointestinal disorder, thereby optimizing the effectiveness of 6-MP drug therapy in the patient. The methods of the invention for optimizing therapeutic efficacy of 6-MP drug treatment involve determining the level of 6-TG in a patient having an immune-mediated gastrointestinal disorder. As disclosed herein, the level of 6-TG measured in a patient treated with a 6-MP drug was an indicator of the effectiveness of drug treatment. A level of at least 230 pmol 6-TG/ 8×10^8 red blood cells (RBC) was found in responders to drug therapy (see Examples I and II). These results indicate that determining the level of 6-TG can be used to assess whether a patient has a level of 6-TG that is sufficient to alleviate symptoms of an immune-mediated gastrointestinal disorder such as IBD, thus optimizing therapeutic efficacy.

As used herein, the term "6-mercaptopurine drug" or "6-MP drug" refers to any drug that can be metabolized to an active 6-mercaptopurine metabolite that has therapeutic efficacy such as 6-TG. Exemplary
5 6-mercaptopurine drugs as defined herein include 6-mercaptopurine (6-MP) and azathioprine (AZA). As illustrated in Figure 1, both of 6-MP and AZA can be metabolized to 6-mercaptopurine metabolites such as the exemplary 6-mercaptopurine metabolites shown in Figure 1,
10 including 6-thioguanine (6-TG), 6-methyl-mercaptopurine (6-MMP) and 6-thiouric acid. (Lennard, Eur. J. Clin. Pharmacol. 43:329-339 (1992)).

Other 6-MP drugs include, for example, 6-methylmercaptopurine riboside and 6-TG (Loo et al.,
15 Clin. Pharmacol. Ther. 9:180-194 (1968); O'Dwyer et al., J. Natl. Cancer Inst. 83:1235-1240 (1991); Erb et al., Cancer Chemother. Pharmacol. 42:266-272 (1998); Lancaster et al., Br. J. Haematol. 102:439-443 (1998); Ingle et al., Am. J. Clin. Oncol. 20:69-72 (1997); Evans and
20 Relling, Leuk. Res. 18:811-814 (1994)). 6-TG is a particularly useful 6-MP drug in patients having high TPMT activity. Patients exhibiting high TPMT activity are expected to more easily convert 6-MP drugs such as 6-MP and AZA to 6-MMP (see Figures 1 and 2). As disclosed
25 herein, high levels of 6-MMP are associated with hepatotoxicity (see Examples I and II). Therefore, patients with high TPMT activity can be more susceptible to toxic effects of 6-MP drug therapy. By administering 6-TG, which is an active 6-MP metabolite associated with
30 therapeutic efficacy (see Examples I and II), the toxicity that can be associated with conversion of 6-MP to 6-MMP is bypassed.

It is understood that the 6-MP metabolites can be the metabolites shown in Figure 1 or analogues thereof. As used herein, the term "6-thioguanine" or "6-TG" refers to 6-thioguanine or analogues thereof, including molecules having the same base structure, for example, 6-thioguanine ribonucleoside, 6-thioguanine ribonucleotide mono-, di- and tri-phosphate, 6-thioguanine deoxyribonucleoside and 6-thioguanine deoxyribonucleotide mono-, di, and triphosphate. The term "6-TG" also includes derivatives of 6-thioguanine, including chemical modifications of 6-TG, so long as the structure of the 6-TG base is preserved.

As used herein, the term "6-methyl-mercaptopurine" or "6-MMP" refers to 6-methyl-mercaptopurine or analogues thereof, including analogues having the same base structure, for example, 6-methyl-mercaptopurine ribonucleoside, 6-methyl-mercaptopurine ribonucleotide mono-, di-, and tri-phosphate, 6-methyl-mercaptopurine deoxyribonucleoside, and 6-methyl-mercaptopurine deoxyribonucleotide mono-, di- and tri-phosphate. The term "6-MMP" also includes derivatives of 6-methyl-mercaptopurine, including chemical modifications of 6-MMP, so long as the structure of the 6-MMP base is preserved.

The methods of the invention relate to treatment of an immune-mediated gastrointestinal disorder. As used herein, the term "immune-mediated gastrointestinal disorder" or "immune-mediated GI disorder" refers to a non-infectious disease of the gastrointestinal tract or bowel that is mediated by the immune system or cells of the immune system. Immune-mediated gastrointestinal disorders include, for example,

inflammatory bowel diseases (IBD) such as Crohn's disease and ulcerative colitis, lymphocytic colitis, microscopic colitis, collagenous colitis, autoimmune enteropathy, allergic gastrointestinal disease and eosinophilic
5 gastrointestinal disease.

The methods of the invention are particularly useful for treating IBD, or subtypes thereof, which has been classified into the broad categories of Crohn's disease and ulcerative colitis. As used herein, "a
10 subject having inflammatory bowel disease" is synonymous with the term "a subject diagnosed with having an inflammatory bowel disease," and means a patient having Crohn's disease or ulcerative colitis. Crohn's disease (regional enteritis) is a disease of chronic inflammation
15 that can involve any part of the gastrointestinal tract. Commonly, the distal portion of the small intestine (ileum) and cecum are affected. In other cases, the disease is confined to the small intestine, colon or anorectal region. Crohn's disease occasionally involves
20 the duodenum and stomach, and more rarely the esophagus and oral cavity.

The variable clinical manifestations of Crohn's disease are, in part, a result of the varying anatomic localization of the disease. The most frequent symptoms
25 of CD are abdominal pain, diarrhea and recurrent fever. CD is commonly associated with intestinal obstruction or fistula, which is an abnormal passage between diseased loops of bowel, for example. Crohn's disease also includes complications such as inflammation of the eye,
30 joints and skin; liver disease; kidney stones or amyloidosis. In addition, CD is associated with an increased risk of intestinal cancer.

Several features are characteristic of the pathology of Crohn's disease. The inflammation associated with CD, known as transmural inflammation, involves all layers of the bowel wall. Thickening and edema, for example, typically also appear throughout the bowel wall, with fibrosis also present in long-standing disease. The inflammation characteristic of CD also is discontinuous in that segments of inflamed tissue, known as "skip lesions," are separated by apparently normal intestine. Furthermore, linear ulcerations, edema, and inflammation of the intervening tissue lead to a "cobblestone" appearance of the intestinal mucosa, which is distinctive of CD.

A hallmark of Crohn's disease is the presence of discrete aggregations of inflammatory cells, known as granulomas, which are generally found in the submucosa. Some Crohn's disease cases display the typical discrete granulomas, while others show nonspecific transmural inflammation. As a result, the presence of discrete granulomas is indicative of CD, although the absence of granulomas also is consistent with the disease. Thus, transmural or discontinuous inflammation, rather than the presence of granulomas, is a preferred diagnostic indicator of Crohn's disease (Rubin and Farber, Pathology (Second Edition) Philadelphia: J.B. Lippincott Company (1994)).

Ulcerative colitis (UC) is a disease of the large intestine characterized by chronic diarrhea with cramping abdominal pain, rectal bleeding, and loose discharges of blood, pus and mucus. The manifestations of ulcerative colitis vary widely. A pattern of exacerbations and remissions typifies the clinical course of most UC patients (70%), although continuous symptoms

without remission are present in some patients with UC. Local and systemic complications of UC include arthritis, eye inflammation such as uveitis, skin ulcers and liver disease. In addition, ulcerative colitis and especially
5 long-standing, extensive disease is associated with an increased risk of colon carcinoma.

Several pathologic features characterize UC in distinction to other inflammatory bowel diseases. Ulcerative colitis is a diffuse disease that usually
10 extends from the most distal part of the rectum for a variable distance proximally. The term left-sided colitis describes an inflammation that involves the distal portion of the colon, extending as far as the splenic flexure. Sparing of the rectum or involvement of
15 the right side (proximal portion) of the colon alone is unusual in ulcerative colitis. The inflammatory process of ulcerative colitis is limited to the colon and does not involve, for example, the small intestine, stomach or esophagus. In addition, ulcerative colitis is
20 distinguished by a superficial inflammation of the mucosa that generally spares the deeper layers of the bowel wall. Crypt abscesses, in which degenerated intestinal crypts are filled with neutrophils, also are typical of ulcerative colitis (Rubin and Farber, *supra*, 1994).

25 In comparison with Crohn's disease, which is a patchy disease with frequent sparing of the rectum, ulcerative colitis is characterized by a continuous inflammation of the colon that usually is more severe distally than proximally. The inflammation in ulcerative
30 colitis is superficial in that it is usually limited to the mucosal layer and is characterized by an acute inflammatory infiltrate with neutrophils and crypt abscesses. In contrast, Crohn's disease affects the

entire thickness of the bowel wall with granulomas often, although not always, present. Disease that terminates at the ileocecal valve, or in the colon distal to it, is indicative of ulcerative colitis, while involvement of the terminal ileum, a cobblestone-like appearance, discrete ulcers or fistulas suggest Crohn's disease.

In addition to IBD, immune-mediated GI disorders also include other gastrointestinal diseases such as lymphocytic colitis; microscopic colitis; collagenous colitis; autoimmune enteropathy, including autoimmune enteritis and autoimmune enterocolitis; allergic gastrointestinal disease; and eosinophilic gastrointestinal disease, including eosinophilic gastroenteritis and eosinophilic enteropathy.

Over the past two decades, the histological evaluation of colorectal biopsies obtained by colonoscopy has expanded the spectrum of chronic IBD. A new group of immune-mediated bowel disorders has emerged, characterized by chronic watery diarrhea, minimal or absent endoscopic findings, and inflammatory changes in mucosal biopsies. Lymphocytic colitis, also commonly referred to as microscopic colitis, is a clinicopathological syndrome characterized primarily by lymphocytic infiltration of the epithelium. Collagenous colitis is defined by the presence of a collagenous band below the surface epithelium, accompanied by an increase in inflammatory cell infiltrate (Lazenby et al. Hum. Pathol. 20:18-28 (1989)). These disorders are often associated with other autoimmune diseases such as rheumatoid arthritis, pernicious anemia, thyroiditis, uveitis and type I diabetes mellitus. Clinicians have used immunosuppressive drugs, including 6-MP, to treat

these disorders (Deslandres et al. J. Pediatr. Gastroenterol. Nutr. 25:341-346 (1997)).

Autoimmune enteropathy, including autoimmune enteritis and autoimmune enterocolitis, is a syndrome of severe secretory diarrhea and marked enterocolitis, in association with diagnostic circulating antibodies to enterocytes (Seidman et al., J. Pediatr. 117:929-932 (1990)). This syndrome, most often seen in infancy, can be seen in association with other autoimmune diseases. Complete villous atrophy is associated with a severe inflammatory reaction on small bowel biopsies. Although some cases remit after an extended period of time, most patients die without immunosuppressive therapy, which can include 6-MP drug therapy.

Eosinophilic gastrointestinal disease, including eosinophilic gastroenteritis and eosinophilic enteropathy, is characterized by a dense infiltration of eosinophils in one or more areas of the gastrointestinal tract, variable intestinal symptoms, and usually a peripheral eosinophilia (80% of cases). Food allergic, including allergic gastrointestinal disease, and eosinophilic disorders of the gastrointestinal tract are commonly treated by dietary elimination of the offending nutrients. However, both food induced and eosinophilic enteropathies may, in certain circumstances, require corticosteroid and immunosuppressive therapy, including 6-MP (Russo et al., Pediatric Dev. Path. 2:65-71 (1999)).

The methods of the invention relate to optimizing therapeutic efficacy of 6-MP drug treatment of an immune-mediated GI disorder, including IBD such as Crohn's disease and ulcerative colitis and subtypes

thereof. The methods of the invention are particularly useful for treating patients dependent on steroid therapy for maintenance of remission of disease in Crohn's disease and ulcerative colitis patients. As used herein, the phrase "optimizing therapeutic efficacy of 6-MP drug treatment" refers to adjusting the therapeutic dosage of a 6-MP drug such as 6-MP or azathioprine so that the concentration of a 6-MP metabolite that is correlated with effective treatment is maintained. As set forth above, the methods of the invention allow the clinician to provide an individually optimized dosage of a 6-MP drug so as to achieve a target level of a 6-MP metabolite in a particular patient, thereby optimizing the effectiveness of 6-MP drug therapy in the patient. Therapeutic efficacy generally is indicated by alleviation of one or more signs or symptoms associated with the disease. In the case of immune-mediated GI disorders, in particular IBD, therapeutic efficacy is indicated by alleviation of one or more signs or symptoms associated with the disease, including, for example, joint pain, arthritis, arthralgia, anorexia, growth failure, fistula closure, abdominal pain, diarrhea, recurrent fever, anemia, weight loss, rectal bleeding, inflammation of the intestine, and loose discharges of blood, pus and mucus. Methods for determining therapeutic efficacy, in particular for treating IBD, are disclosed herein in Examples I and II.

Therapeutic efficacy can be readily determined by one skilled in the art as the alleviation of one or more signs or symptoms of the disease being treated. In the case of IBD, patients can be analyzed using a Crohn's disease activity index (Best et al., Gastroenterology 70:439-444 (1976)). IBD patients can also be analyzed using a Harvey-Bradshaw index (HBI) (Harvey and Bradshaw,

Lancet 1:514 (1980)). The Harvey-Bradshaw index provides an analytical method for measuring signs or symptoms of Crohn's disease, including the signs or symptoms of general well-being, abdominal pain, number of liquid stools per day, abdominal mass, and complications such as arthralgia, uveitis, erythema nodosum, aphthous ulcers, pyoderma gangrenosum, anal fissure, new fistula and abscess. The Harvey-Bradshaw index is particularly useful when evaluating pediatric patients.

10 Previous studies suggested that measurement of 6-MP metabolite levels can be used to predict clinical efficacy and tolerance to azathioprine or 6-MP (Cuffari et al., Gut 39:401-406 (1996a)). However, it was unknown what concentrations of 6-MP metabolites correlated with
15 optimized therapeutic efficacy or with toxicity (Cuffari et al., *supra*, 1996a). As disclosed herein, levels of 6-MP metabolites such as 6-TG and 6-MMP were determined and correlated with therapeutic efficacy and toxicity associated with 6-MP drug therapy (see Examples I and
20 II).

The invention is directed to methods of optimizing therapeutic efficacy of 6-MP drug treatment of an immune-mediated GI disorder by monitoring predetermined levels associated with therapeutic efficacy
25 or toxicity and adjusting the 6-MP drug dosage so as to maintain an optimized dose that is efficacious and has reduced toxicity. The methods involve administering a 6-MP drug such as 6-MP or azathioprine to a subject having an immune-mediated GI disorder and determining a
30 level of a 6-MP metabolite in the subject having the immune-mediated GI disorder. The methods of the invention are advantageous in that the dosage of a 6-MP drug can be adjusted to maximize the efficacy of treating

an immune-mediated GI disorder such as IBD while minimizing toxicity associated with 6-MP drug treatment.

As used herein, the term "6-mercaptopurine metabolite" refers to a product derived from 6-mercaptopurine in a biological system. Exemplary 6-mercaptopurine metabolites are shown in Figure 1 and include 6-thioguanine (6-TG), 6-methyl-mercaptopurine (6-MMP) and 6-thiouric acid and analogues thereof. For example, 6-MP metabolites include 6-TG bases such as 6-TG, 6-thioguanosine mono-, di- and tri-phosphate; 6-MMP bases such as 6-methyl-mercaptopurine and 6-methyl-thioinosine monophosphate; 6-thioxanthosine (6-TX) bases such as 6-thioxanthosine mono-phosphate; 6-thioruric acid (6-TUA); and 6-MP bases such as 6-mercaptopurine and 6-thioinosine monophosphate (see Figure 2). The immunosuppressive properties of 6-MP are believed to be mediated via the intracellular transformation of 6-MP to its active metabolites such as 6-TG and 6-MMP nucleotides. Furthermore, 6-MP metabolites such as 6-TG and 6-MMP were found to correlate with therapeutic efficacy and toxicity associated with 6-MP drug treatment of IBD patients (see Examples I and II).

The level of a 6-MP metabolite can be determined by methods well known in the art including, for example, those described in Lilleyman and Lennard, Lancet 343:1188-1190 (1994); Lennard and Singleton, J. Chromatography Biomed. Applicat. 583:83-90 (1992); Lennard and Singleton, J. Chromatography 661:25-33 (1994); and Cuffari et al., Can. J. Physiol. Pharmacol. 74:580-585 (1996b)). 6-MP metabolites such as 6-TG and 6-MMP can be measured, for example, by collecting red blood cells and extracting thiobases, for example, 6-MP,

6-TG, 6-TX and 6-MMP, which are released by acid hydrolysis. 6-MMP is converted to a form extractable by phenyl mercury salts (Dervieux and Boulieu, Clin. Chem. 44:2511-2525 (1998); Duchesne et al., Proc. Amer. Soc. Clin. Oncol. 13:137 (1994a); Duchesne et al., Can. J. Physiol. Pharmacol. 72:197 (1994b)). Such an analysis measures the thiobase and its analogues, including ribonucloside, ribonucleotide, deoxyribonucleoside, deoxyribonucleotide thiobases as well as mono-, di- and tri-phosphate analogues, which have been converted to thiobases.

Acid hydrolyzed extracts can be analyzed by resolving 6-MP metabolites and measuring their levels. For example, HPLC such as reverse phase HPLC is a useful method for resolving and measuring the levels of 6-MP metabolites, including 6-MP, 6-TG and 6-MMP (Lennard and Singleton, *supra*, 1992). Ultraviolet light (UV) detection can be used to measure the 6-MP metabolites. A particularly useful method of measuring 6-MP metabolites is isocratic reverse phase HPLC with UV detection (Cuffari et al., *supra*, 1996b).

Other methods for measuring 6-MP metabolites can also be used. For example, ion-pairing HPLC with dual UV-wavelength detection can be used to measure 6-MP metabolites (Zimm and Strong, Anal. Biochem. 160:1-6 (1987)). Additional methods for measuring 6-MP metabolites include, for example, capillary electrophoresis with laser-induced fluorescence detection (Rabel et al., Anal. Biochem. 224:315-322 (1995)); anion exchange chromatography and fluorescent detection (Tidd and Dedhar J. Chromatography 145:237-246 (1978)); lanthanum precipitation, acid hydrolysis, back extraction and fluorometric assay (Fletcher and Maddocks, Brit. J.

Clin. Pharmacol. 10:287-292 (1980)); thin layer chromatography (Bennet and Allen, Cancer Res. 31:152-158 (1971)); precolumn derivatization with the thiol-reactive fluorophore monobromobimane, treatment with alkaline phosphatase, HPLC resolution and quantification by fluorometry (Warren and Slordal, Anal. Biochem. 215:278-283 (1993)); and enzymatic hydrolysis followed by HPLC separation and UV detection (Giverhaug et al., Ther. Drug Monit. 19:663-668 (1997)). 6-MP metabolites such as 6-TG can also be measured in DNA by degrading DNA to deoxyribonucleosides, derivatizing deoxy-6-TG with a fluorophore and resolving on reverse phase HPLC (Warren et al., Cancer Res. 55:1670-1674 (1995)).

As used herein, the level of a 6-MP metabolite can include the 6-MP metabolite itself, or the level of the 6-MP metabolite and analogues thereof. For example, as described above, acid hydrolysis can be used to release thionucleotides from a sample, resulting in conversion of mono-, di- and tri-phosphates to thiobases. In such an analysis, the level of several analogues of a thionucleotide are measured (see Figure 2). For example, measuring 6-TG can include 6-thioguanosine 5'-mono-, di-, and tri-phosphate, and 6-thiodeoxyguanosine 5'-di-, and tri-phosphate. Measuring 6-MP can include 6-mercaptopurine and 6-thioinosine 5'-monophosphate. Measuring 6-MMP can include 6-methylmercaptopurine and 6-methylthioinosine 5'-monophosphate, and can also include 6-methylthioinosine di- and tri-phosphate, as well as 6-methyl thioguanosine.

A particularly useful determination of the level of a 6-MP metabolite is the median level of the 6-MP metabolite since the distribution of 6-MP metabolite values is trimodal. Unless otherwise designated, the

levels referred to herein are median levels. A 6-MP metabolite level can also be a mean level, if so desired. Unless otherwise designated, the levels of 6-MP metabolites referred to herein are values per 8×10^8 RBC, whether reported as mean or median values.

6-MP metabolite levels can be conveniently assayed using red blood cells because such cells are readily available from the patient, lack a nucleus and are easy to manipulate. However, it should be understood that any measurement that allows determination of 6-MP metabolite levels can be used. For example, leukocytes can be used to measure 6-MP metabolite levels, which can be correlated with 6-MP metabolite levels in erythrocytes (Cuffari et al., *supra*, 1996b). Regardless of the method employed to measure 6-MP metabolites, one skilled in the art can readily measure 6-MP metabolite levels in a sample, for example, in leukocytes or DNA obtained from a patient, and correlate the level of 6-MP metabolites to the values disclosed herein, which were determined using RBC.

For convenience, levels of 6-MP metabolites disclosed herein are given in terms of an assay with RBC and, therefore, are given as an amount of a 6-MP metabolite in a given number of RBCs. 6-MP metabolites assayed in RBCs can also be determined relative to the amount of hemoglobin. However, it should be understood that one skilled in the art can measure 6-MP metabolite levels in samples other than RBCs and readily correlate such levels with 6-MP metabolite levels in RBCs. For example, one skilled in the art can readily determine levels of a 6-MP metabolite in cells such as leukocytes, or cells from the oral mucosa, and in RBCs by measuring the level of 6-MP metabolites in both types of cells and

determining the correspondence between levels of 6-MP metabolites in RBCs and the levels in the other cells. Once a correspondence between 6-MP metabolites in RBCs and in a sample has been determined, one skilled in the art can use that correspondence to measure levels in the other sample and correlate those levels with the levels in RBCs disclosed herein.

As disclosed herein, the level of 6-TG in an IBD patient treated with a 6-MP drug was found to correlate with therapeutic efficacy (see Examples I and II). In particular, a median level of 230 pmol 6-TG/ 8×10^8 RBC or more was found in IBD patients who responded to 6-MP drug therapy. Thus, as disclosed herein, a level of at least about 230 pmol 6-TG per 8×10^8 RBC can be a minimal therapeutic level of 6-TG for efficaciously treating a patient (Examples I and II). For example, a minimal therapeutic level of 6-TG can be about 235 pmol 6-TG per 8×10^8 RBC (see Example II). Accordingly, a level of 6-TG below about 230 pmol/ 8×10^8 RBC indicates a need to increase the amount of a 6-MP drug administered to the patient. A minimal therapeutic level of 6-TG for efficaciously treating a patient also can be, for example, at least about 240 pmol per 8×10^8 RBC; at least about 250 pmol per 8×10^8 RBC; at least about 260 pmol per 8×10^8 RBC; at least about 280 mol per 8×10^8 RBC or at least about 300 pmol per 8×10^8 RBC. It is understood that the minimal therapeutic levels of 6-TG disclosed herein are useful for treating immune-mediated gastrointestinal disorders, including IBD, as well as non-IBD autoimmune diseases.

As disclosed herein, erythrocyte 6-TG concentration, not drug dose, is significantly and independently associated with therapeutic response (see

Example II). The results indicate that response to 6-MP drug therapy is optimized at 6-TG levels greater than about 230 pmol per 8×10^8 RBC, for example, greater than about 230 pmol per 8×10^8 RBC (see Example II).

5 As further disclosed herein, 6-MP metabolites are associated with toxicity (Example II). For example, hepatotoxicity correlated with the presence of significantly higher concentrations of 6-MMP (Example II). Monitoring 6-MMP levels is useful in
10 identifying patients at risk for hepatotoxicity. Monitoring 6-MMP levels can also be used to determine the level at which a hepatic event has occurred in order to individualize appropriate dose adjustments to optimize the therapeutic dose. Moreover, 6-MMP monitoring can be
15 performed in conjunction with liver function tests.

 Furthermore, as disclosed herein, leukopenia was associated with higher 6-TG levels (see Example II). The median 6-TG level was 342 pmol per 8×10^8 RBC (mean 490) in leukopenic individuals, well above the threshold
20 level of 235 pmol per 8×10^8 RBC. However, leukopenia is not a reliable marker for therapeutic response and is not required to control IBD (Example II).

 As exemplified herein, 6-MP metabolite measurements can provide clinicians with useful methods
25 to optimize 6-MP drug therapy for individuals having immune-mediated gastrointestinal disorders and IBD. 6-MP metabolite monitoring is advantageous for identifying causes of failure to respond to 6-MP therapy. For example, 6-MP metabolite levels can be used to indicate
30 an inadequate dose or an excessive dose that could lead to toxicity. Additionally, monitoring of 6-MP

metabolites can also be used to indicate non-compliance with a therapeutic regimen.

The methods of the invention directed to determining whether a patient has a minimal therapeutic level of a 6-MP metabolite are useful for indicating to the clinician a need to monitor a patient for therapeutic efficacy and to adjust the 6-MP drug dose, as desired. For example, in a patient having less than a minimal therapeutic level of a 6-MP metabolite such as 6-TG and who also presents as unresponsive to 6-MP drug therapy or having poor responsiveness to 6-MP drug therapy as measured by minimal or no effect on a sign or symptom of the disease being treated, one skilled in the art can determine that the dosage of a 6-MP drug should be increased. However, if it is determined that a patient has less than a predetermined minimal therapeutic level of a 6-MP metabolite but is responsive to 6-MP therapy, the current dose of 6-MP drug can be maintained. Based on measuring 6-MP metabolite levels and assessing the responsiveness of the patient to 6-MP therapy, one skilled in the art can determine whether a 6-MP drug dose should be maintained, increased, or decreased.

Although 6-MP drugs such as 6-MP and azathioprine can be used for effective treatment of an immune-mediated GI disorder, including IBDs such as Crohn's disease or ulcerative colitis, administration of such drugs can be associated with toxic side effects. Toxicities associated with 6-MP drug administration include pancreatitis, bone marrow depression, allergic reactions and drug hepatitis as well as neoplasms and infectious complications (Present et al., Annals Int. Med. 111:641-649 (1989); Cuffari et al., *supra*, 1996a). As disclosed herein, various toxicities associated with

6-MP drug treatment, including hepatic toxicity, pancreatic toxicity and hematologic toxicity, correlate with the level of 6-MP metabolites in a subject administered a 6-MP drug (see Examples I and II).

5 Thus, the present invention also provides a method of reducing toxicity associated with 6-MP drug treatment of an immune-mediated GI disorder. The method of the invention for reducing toxicity associated with 6-MP drug treatment includes the steps of administering a
10 6-MP drug to a subject having an immune-mediated GI disorder; and determining a level of a 6-MP metabolite in the subject having the immune-mediated GI disorder, where a level of the 6-MP metabolite greater than a predetermined toxic level of the 6-MP metabolite
15 indicates a need to decrease the amount of 6-MP drug subsequently administered to the subject, thereby reducing toxicity associated with 6-MP drug treatment of the immune-mediated GI disorder. In a method of the invention, the 6-MP metabolite can be, for example, 6-TG
20 and the predetermined toxic level of 6-TG can correspond, for example, to a level of about 400 pmol per 8×10^8 red blood cells. Where the elevated 6-MP metabolite is 6-TG, the toxicity associated with 6-MP treatment can be, for example, hematologic toxicity, including leukopenia or
25 bone marrow suppression. The 6-MP metabolite also can be a metabolite such as 6-MMP, and the predetermined toxic level of 6-MMP can correspond, for example, to a level of about 7000 pmol per 8×10^8 red blood cells. Where the elevated 6-MP metabolite is 6-MMP, the toxicity
30 associated with 6-MP drug treatment can be, for example, hepatic toxicity.

As disclosed herein, the level of a 6-MP metabolite can be determined in a subject treated with a

6-MP drug and compared to a predetermined toxic level of a 6-MP metabolite such as 6-TG or 6-MMP to adjust future 6-MP drug administration, thereby reducing toxicity in the subject. For example, as disclosed herein, levels of 6-TG above about 400 pmol/ 8×10^8 RBC indicated that a patient was likely to experience toxicity, in particular hematologic toxicity such as leukopenia (see Examples I and II). Accordingly, a level of 6-TG above about 400 pmol/ 8×10^8 RBC can be a predetermined toxic level of 6-TG, which indicates that the amount of 6-MP drug subsequently administered should be decreased.

It is understood that, when a patient is determined to have a level of a 6-MP metabolite such as 6-TG or 6-MMP higher than a predetermined toxic level, one skilled in the art can make a determination as to whether a 6-MP drug dose should be decreased. For example, if the level of a 6-MP metabolite such as 6-TG or 6-MMP is higher than a predetermined toxic level, one skilled in the art can monitor for toxic side effects by measuring one or more of the toxicities associated with 6-MP drug treatment, as disclosed herein. As disclosed herein, a level of 6-TG greater than about 400 pmol per 8×10^8 RBCs was associated with increased risk of leukopenia or bone marrow suppression. Therefore, one skilled in the art can measure white blood cells (WBC) in a patient having levels of 6-TG higher than a predetermined toxic level to determine if the patient is exhibiting signs of reduced WBC counts. If such a patient exhibits signs of leukopenia or bone marrow suppression, the 6-MP drug dose can be reduced. However, if it is determined that a patient has levels of a 6-MP metabolite higher than a predetermined toxic level but does not exhibit signs of leukopenia or other 6-MP drug toxicities, one skilled in the art can determine that the

current 6-MP drug dose can be maintained. Based on measuring 6-MP metabolite levels and determining signs or symptoms of toxicities associated with 6-MP drug treatment, one skilled in the art can determine whether a 6-MP drug dose should be maintained or decreased. As such, a level of a 6-MP metabolite higher than a predetermined toxic level can indicate a need to measure a toxicity associated with 6-MP drug treatment such as measuring WBCs or any of the other signs or symptoms of toxicities associated with 6-MP drug treatment to determine if the 6-MP drug dose should be adjusted.

Furthermore, it is understood that, when decreasing the 6-MP drug dose, one skilled in the art will know or can readily determine whether the 6-MP drug dose should be decreased to a lower dose or whether 6-MP drug administration should be stopped for some period of time, or terminated. For example, if the clinician determines that 6-MP drug therapy should be stopped for some period of time due to levels of a 6-MP metabolite exceeding a level predetermined to be toxic, the levels of 6-MP metabolites can be monitored after stopping 6-MP drug therapy until the level of the toxic 6-MP metabolite returns to a safe, non-toxic level. At that time, the clinician can resume 6-MP drug therapy, if desired.

The methods of the invention for reducing toxicity associated with 6-MP drug treatment of a disease involve comparing a level of a 6-MP metabolite to a predetermined toxic level of a 6-MP metabolite. In general, a "predetermined toxic level" of a 6-MP metabolite means a level of a 6-MP metabolite that has been correlated with one or more toxicities associated with 6-MP drug treatment. As disclosed herein, a predetermined toxic level of 6-TG can be about 400 pmol

per 8×10^8 RBC. A predetermined toxic level of 6-TG also can be about 350 pmol per 8×10^8 RBC; 370 pmol per 8×10^8 RBC; 390 pmol per 8×10^8 RBC; 425 pmol per 8×10^8 RBC; or 450 pmol per 8×10^8 RBC. It is understood that the
5 predetermined toxic levels of 6-TG disclosed herein are useful for treating immune-mediated GI disorders, including IBD, as well as non-IBD autoimmune diseases.

Another 6-MP metabolite useful for predicting the likelihood of toxicity is 6-methyl-mercaptopurine
10 (6-MMP). As disclosed herein, a level of greater than about 7000 pmol 6-MMP/ 8×10^8 in patients administered a 6-MP drug was associated with toxicity, in particular hepatotoxicity (see Examples I and II). These results indicate that the level of 6-MMP can be used to predict
15 toxicity in a patient treated with a 6-MP drug. As disclosed herein, a predetermined toxic level of 6-MMP can be about 7000 pmol per 8×10^8 RBC. A predetermined toxic level of 6-MMP also can be about 6000 pmol per 8×10^8 RBC; 6500 pmol per 8×10^8 RBC; 7500 pmol per 8×10^8 RBC; or
20 8000 pmol per 8×10^8 RBC. Furthermore, a predetermined toxic level of 6-MMP can also be about 5500 pmol per 8×10^8 RBC or about 5700 pmol per 8×10^8 RBC (see Example II). It is understood that the predetermined toxic levels of 6-MMP disclosed herein are useful for treating
25 immune-mediated GI disorders, including IBD, as well as non-IBD autoimmune diseases. According to a method of the invention, if the level of 6-MMP is above a predetermined toxic level, the subsequent administration of a 6-MP drug can be decreased to minimize toxicity.

30 Further provided by the invention is a method of optimizing therapeutic efficacy and reducing toxicity associated with 6-MP drug treatment of an immune-mediated GI disorder such as IBD. The method includes the steps

of administering a 6-MP drug to a subject having an immune-mediated GI disorder; determining a level of 6-TG in the subject having the immune-mediated GI disorder; and determining a level of 6-MMP in the subject having
5 the immune-mediated GI disorder, where a level of 6-TG less than a predetermined minimal therapeutic level indicates a need to increase the amount of 6-MP drug subsequently administered to the subject, thereby increasing therapeutic efficacy; where a level of 6-TG
10 greater than a predetermined toxic level of 6-TG indicates a need to decrease the amount of 6-MP drug subsequently administered to the subject, thereby reducing toxicity associated with 6-MP treatment of the immune-mediated GI disorder; and where a level of 6-MMP
15 greater than a predetermined toxic level of 6-MMP indicates a need to decrease the amount of 6-MP drug subsequently administered to the subject, thereby reducing toxicity associated with 6-MP drug treatment of the immune-mediated GI disorder.

20 In such a method of optimizing therapeutic efficacy and reducing toxicity associated with 6-MP drug treatment of an immune-mediated GI disorder such as IBD, the predetermined minimal therapeutic level of 6-TG can be, for example, a level corresponding to about 230 pmol
25 per 8×10^8 red blood cells; the predetermined toxic level of 6-TG can be, for example, a level corresponding to about 400 pmol per 8×10^8 red blood cells; and the predetermined toxic level of 6-MMP can be, for example, a level corresponding to about 7000 pmol per 8×10^8 red blood
30 cells. In a method of the invention, the subject having an immune-mediated GI disorder such as IBD can be, for example, a pediatric subject. The level of 6-TG and 6-MMP each can be conveniently determined, for example, in red blood cells using HPLC.

The methods of the invention are useful for optimizing the amount of a 6-MP drug to be administered to a patient with an immune-mediated GI disorder such as IBD. By measuring the levels of 6-MP metabolites such as 5 6-MMP and 6-TG, one skilled in the art can determine the 6-MP drug dosage that will result in optimized therapeutic efficacy and reduced toxicity when administered to a patient.

As disclosed herein, gender and age differences 10 were observed in pediatric patients treated with 6-MP drug therapy (see Example III). Very little change in 6-MP metabolite levels of 6-TG and 6-MMP was seen for girls who had gone through puberty (older than age 12). However, boys who had gone through puberty (older than 15 age 14) had a marked decrease in the level of 6-MMP, suggesting that hormonal changes occurring during puberty can affect the metabolism of a 6-MP drug. Therefore, the methods of the invention can additionally be used to monitor 6-MP metabolite levels in adolescents, 20 particularly those going through puberty, in order to optimize therapeutic efficacy or minimize toxic side effects associated with 6-MP therapy.

As disclosed herein, TPMT genotyping is useful for predicting the effectiveness of 6-MP therapy in an 25 IBD patient (see Example IV). Heterozygote patients are expected to have lower TPMT activity and should therefore be monitored for high levels of 6-TG for possible toxic levels associated with leukopenia or bone marrow suppression. 6-MP drug doses can be reduced accordingly. 30 Wild type homozygous patients are expected to have higher TPMT activity and should therefore be monitored to maintain an effective therapeutic level of 6-TG and to determine if patients develop toxic levels of 6-MMP.

Homozygous patients deficient in TPMT activity can be treated with lower doses of a 6-MP drug provided that patients are closely monitored for toxicity such as leukopenia. Therefore, TPMT genotyping can be used to
5 predict patient responsiveness to and potential toxicities associated with 6-MP drug therapy. Furthermore, TPMT genotyping can be combined with other methods of the invention to both determine TPMT genotype and to monitor 6-MP metabolites. TPMT genotyping can be
10 particularly valuable when determining a starting dose of 6-MP drug therapy but can also be useful when adjusting 6-MP drug doses after therapy has begun.

The invention additionally provides a method of optimizing therapeutic efficacy of 6-MP drug treatment of
15 a non-IBD autoimmune disease. The method includes the steps of administering a 6-MP drug to a subject having a non-IBD autoimmune disease; and determining a level of 6-thioguanine (6-TG) in the subject having the non-IBD autoimmune disease, where a level of 6-TG less than a
20 minimal therapeutic level indicates a need to increase the amount of 6-MP drug subsequently administered to the subject and where a level of 6-TG greater than a predetermined toxic level indicates a need to decrease the amount of 6-MP drug subsequently administered to the
25 subject. The level of 6-MMP can also be monitored in a patient having a non-IBD autoimmune disease to determine if the level is higher than a predetermined toxic level of 6-MMP.

The methods of the invention can be used to
30 optimize therapeutic efficacy of 6-MP drug treatment of a non-IBD autoimmune disease. Such a non-IBD autoimmune disease can be any non-IBD autoimmune disease treatable by a 6-MP drug such as 6-MP or azathioprine and, in

particular, can be a disease such as rheumatoid arthritis, systemic lupus erythematosus, autoimmune hepatitis (chronic active hepatitis) or pemphigus vulgaris.

5 As used herein, the term "non-IBD autoimmune disease" means a disease resulting from an immune response against a self tissue or tissue component, including both self antibody responses and cell-mediated responses. The term non-IBD autoimmune disease
10 encompasses organ-specific non-IBD autoimmune diseases, in which an autoimmune response is directed against a single tissue, including myasthenia gravis, vitiligo, Graves' disease, Hashimoto's disease, Addison's disease, autoimmune gastritis, and Type I diabetes mellitus. The
15 term non-IBD autoimmune disease also encompasses non-organ specific autoimmune diseases, in which an autoimmune response is directed against a component present in several or many organs throughout the body. Non-organ specific autoimmune diseases include, for
20 example, systemic lupus erythematosus, progressive systemic sclerosis and variants, polymyositis and dermatomyositis, and rheumatoid disease. Additional non-IBD autoimmune diseases include pernicious anemia, primary biliary cirrhosis, autoimmune thrombocytopenia,
25 and Sjögren's syndrome. One skilled in the art understands that the methods of the invention can be applied to these or other non-IBD autoimmune diseases treatable by a 6-MP drug such as 6-MP or azathioprine, or other 6-MP drugs, as desired. Specifically excluded from
30 the term "non-IBD autoimmune disease" are diseases resulting from a graft versus host response and inflammatory bowel diseases such as Crohn's disease or ulcerative colitis.

The methods of the invention are also useful for treating a non-immune-mediated GI disorder autoimmune disease. As used herein, the term "non-immune-mediated GI disorder autoimmune disease" is a non-IBD autoimmune disease and specifically excludes immune-mediated GI disorders.

The methods of the invention can be particularly useful for optimizing therapeutic efficacy of 6-MP drug treatment of rheumatoid arthritis.

10 Rheumatoid arthritis is a chronic systemic disease primarily of the joints, usually polyarticular, marked by inflammatory changes in the synovial membranes and articular structures and by muscle atrophy and rarefaction of the bones.

15 The methods of the invention also can be particularly valuable for optimizing therapeutic efficacy of 6-MP drug treatment of lupus erythematosus and, in particular, systemic lupus erythematosus (SLE). Systemic lupus erythematosus is a chronic, remitting, relapsing inflammatory, and sometimes febrile multisystemic

20 disorder of connective tissue. SLE can be acute or insidious at onset and is characterized principally by involvement of the skin, joints, kidneys and serosal membranes.

25 Autoimmune hepatitis, also called chronic active hepatitis, also can be treated with a 6-MP drug and the dose optimized using the methods of the invention. Autoimmune hepatitis is a chronic inflammation of the liver occurring as a sequel to

30 hepatitis B or non-A, non-B hepatitis and is characterized by infiltration of portal areas by plasma cells and macrophages, piecemeal necrosis, and fibrosis.

The methods of the invention also can be useful for treating pemphigus vulgaris, the most common and severe form of pemphigus, which is a chronic, relapsing and sometimes fatal skin disease characterized clinically
5 by the development of successive crops of vesicles and bullae and treated by azathioprine. This disorder is characterized histologically by acantholysis, and immunologically by serum autoantibodies against antigens in the intracellular zones of the epidermis.

10 The methods of the invention can also be used to optimize the therapeutic efficacy of 6-MP drug treatment of graft versus host disease, which can occur in transplant patients. Graft versus host disease occurs when a transplant patient has an immune reaction to the
15 non-self transplant organ or tissue. The methods of the invention for optimizing the therapeutic efficacy of 6-MP drug treatment is particularly useful for treating heart, kidney and liver transplant recipients. The methods of the invention can be used to optimize therapeutic
20 efficacy and/or minimize toxicity associated with 6-MP drug treatment of a transplant patient.

The following examples are intended to illustrate but not limit the present invention.

EXAMPLE I

25 6-MERCAPTOPURINE METABOLITE LEVELS PREDICT CLINICAL
EFFICACY AND DRUG TOXICITY IN PEDIATRIC IBD

This example describes measuring 6-MP metabolite levels and correlation with the response of IBD patients treated with a 6-MP drug.

The levels of the 6-MP metabolites 6-TG and 6-MMP were measured in IBD patients to whom 6-MP pro-drug was administered, and the relationship of 6-MP metabolites to clinical disease activity and drug toxicity was determined. Briefly, blood was sampled (n=89) prior to daily administration of 6-MP in 55 IBD patients (CD n=51, UC n=4) receiving 1-1.5 mg/kg/day over at least a 4 month period (≥ 4 mo.). When AZA was administered, a conversion factor of 2.07 was used to convert to the equivalent 6-MP dose. Twice as much AZA is administered relative to 6-MP to have an equivalent dose of 6-MP.

Erythrocyte 6-TG, 6-MMP and 6-MP thiobases were measured (pmol/ 8×10^8 RBC) using reverse phase HPLC. Briefly, blood samples were collected in EDTA (ethylene diamine tetraacetic acid) as anticoagulant. Cells were centrifuged and washed three times with an equal volume of 0.9% saline. Washed packed cells were stored at -70°C until analysis was performed.

For acid hydrolysis, 500 μl deionized H_2O , 50 μl thawed red blood cells, 40 μl of the appropriate standard or control, 500 μl 3.0 N H_2SO_4 , and 300 μl 10 mM dithiothreitol (DTT) was added to an 8 ml glass screw cap tube. The capped tubes were placed in a heating block preheated to 100°C and hydrolyzed. For 6-MMP, hydrolysis was carried out for 5 hours. For 6-MP and 6-TG, hydrolysis was carried out for 1 hour. After the incubation, tubes were cooled in a room temperature water bath. To tubes hydrolyzed for 5 hours (6-MMP), 400 μl 3.4 N NaOH and 1.0 ml 2 M Tris buffer, pH 9.0 was added. To tubes hydrolyzed for 1 hour (6-MP/6-TG), 450 μl 3.4 N NaOH and 500 μl 2M Tris base was added. A volume of 4 ml 0.03% phenylmercuric chloride in methylene chloride was

added to each tube. The tubes were capped and lightly agitated on a bi-directional rotator (15 min for 6-MMP and 30 min for 6-MP/6-TG). The contents were transferred to a 15 ml polypropylene centrifuge tube and centrifuged
5 at 3500 rpm for 3 min at 10°C. The aqueous phase (top layer) was discarded, and 3.0 ml of the organic phase (bottom layer) was transferred to a clean 15 ml polypropylene centrifuge tube. The analytes in the organic phase were back extracted by adding 225 µl 0.1 N
10 HCl and lightly mixing on an orbital rotator for 5 min. Following vortexing for 30 seconds, the tubes were centrifuged at 3500 rpm for 3 min at 10°C.

For 6-MMP analysis, 50 µl analyte was analyzed on a C18 reverse phase column with the mobile phase
15 containing 1 mM DTT, 2.078% triethylamine and 4% methanol, adjusted to pH 3.2 with concentrated H₃PO₄. For 6-MP and 6-TG analysis, 100 µl analyte was analyzed on a C18 reverse phase column using 0.1 M H₃PO₄ and 1 mM DTT in H₂O as the mobile phase.

20 Hepatic, pancreatic and hematological tests were obtained every 3 months. Clinical remission was defined as a Harvey Bradshaw Index < 5 in those patients off corticosteroids or weaned to a level of prednisone ≤ 0.4 mg/kg/od (administered every other day). Treatment
25 failures were defined as non-responders (HBI > 5 or steroid dependence) or cessation of 6-MP due to side effects.

As shown in Table 1, a 6-TG level of >225 pmol per 8x10⁸ RBC was associated with remission. The median
30 values shown in the tables represent pmol of the indicated 6-MP metabolite per 8x10⁸ RBC. Excessive 6-TG and 6-MMP levels were associated with leukopenia and

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hepatotoxicity, respectively. Negligible metabolite levels detected non-compliance as a cause of treatment failure in 2/31 cases. These results indicate that 6-MP metabolite levels predict both clinical responsiveness and drug-related toxicity.

Table 1:

Group	n	median 6-TG	6-TG >225	median 6-MMP
Responders	58	295	45/58 (78%)	3094
Non-responders	31	184*	8/31 (26%)	2048
Hepatic toxicity	7	258	5/7	9211**
Pancreatic toxicity	6	211	2/6	2342
Hematologic toxicity	6	414+	5/5	7042
p Values		*<0.001	†0<0.001	**<0.001
		+<0.03		

These results demonstrate that determining levels of 6-MP metabolites is useful for predicting efficacy and toxicity of 6-MP drug therapy administered to IBD patients.

EXAMPLE II

6-MERCAPTOPURINE METABOLITE LEVELS CORRELATE WITH OPTIMAL
6-MP THERAPY IN IBD PATIENTS

This example describes prospective examination of the correlation of 6-MP metabolite levels with therapeutic response to 6-MP drug therapy and 6-MP drug related toxicity in IBD patients treated with 6-MP.

To obtain additional statistical data on IBD patients treated with a 6-MP drug, additional patients and samples were analyzed and combined with the data obtained in Example I. Blood was sampled at least once
5 in 92 IBD patients followed by the clinical investigators at Sainte-Justine Hospital IBD Center, Montreal, Canada, who were administered 6-MP drug therapy for at least 4 months. Patients were less than 19 years of age and were eligible for inclusion if receiving 6-MP or AZA for at
10 least 4 months. Diagnoses of Crohn's disease (CD), ulcerative colitis (UC) or indeterminate colitis (IC) were established by standard clinical, radiological, histological and endoscopic criteria (Lennard-Jones, Scand. J. Gastroenterol Suppl. 170:2-6 (discussion 16-
15 19) (1989)). Patients with leukopenia or with elevated serum hepatic or pancreatic enzyme activities prior to initiation of therapy were excluded from this study.

The dose of AZA/6-MP, determined by the treating physician, was stable for at least one month.
20 Clinical information collected included: (a) Patient related data - gender, age at diagnosis, site of disease. (b) Disease activity - assessed at each visit corresponding to a 6-MP metabolite blood drawing, by calculating a validated index based on direct
25 questioning, clinical examination and laboratory data. A modified Harvey Bradshaw Index (HBI) (Myren et al. Scand. J. Gastroenterol Suppl. 95:1-27 (1984)) was used for CD, Truelove & Witts' Index for UC (Truelove and Witts, Br. Med. J. 2:1041-1044 (1955)), or a detailed assessment of
30 perianal disease and fistulae was used as previously described (Korelitz and Present, Dig. Dis. Sci. 30:58-64 (1985) (Hughes, Dis. Colon Rectum 35:928-932 (1992)). (c) 6-MP related data - age at initiation, indication, dose (mg/kg/day). (d) Toxicity related data - complete blood

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count and differential, ALT, AST, billirubin, amylase and lipase, dose of 6-MP, timing of event relative to initiation of therapy, course of action taken and concurrent medications. Blood samples from 92 consenting
5 patients, for analyzing 6-MP, 6-TG and 6-MMP moieties, were obtained prospectively during the study period (1995-1998). When possible, multiple samples were obtained from the same patient separated by an interval exceeding 3 months of the first specimen. The clinical
10 investigators remained blinded to the 6-MP metabolite levels and the results of TPMT genotyping.

The 92 patients were pediatric patients, with 79 diagnosed as having CD, 8 diagnosed as having UC, and 5 diagnosed as having indeterminate colitis (CD or UC)
15 (see Table 2). Seven patients were given AZA. The dosages of AZA were converted to 6-MP equivalents using a factor of 2.07 (Sandborne, Am. J. Gastroenterol. 91:423-433 (1996)).

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**Table 2. Characteristics of Pediatric IBD Patients
Treated With 6-MP/AZA**

	Gender (male-female)	41:51
5	Mean age at diagnosis (yr/range)	11.5 (1-18)
	Disease classification and location	
	Crohn's Disease (n)	79
	Small Bowel (n)	2
	Small Bowel + perianal +/-or duodenal	1
10	involvement (n)	
	Ileocolitis (n)	33
	Ileocolitis + perianal +/-or duodenal	21
	involvement (n)	
	Colitis alone (n)	13
15	Colitis + perianal +/-or duodenal	8
	involvement (n)	
	Perianal disease alone (n)	1
	Ulcerative Colitis (n)	8
	Pancolitis (n)	6
20	Left sided (n)	2
	Indeterminate Colitis (n)	5
	Mean age at initiation of 6-MP/AZA	13 (4-18.5)
	(yr(range))	
	Delay from diagnosis to start of 6-MP/AZA	1.5 (0-7)
25	(yr(range))	
	Primary indication for 6-MP/AZA use	
	Steroid dependent (n)	68
	Steroid refractory (n)	17
	Fistulizing disease (n)	7
30	Mean 6-MP/AZA dose (mg/kg/day, (range))	1.25 (0.4-2.4)

The study population was divided into patients with a satisfactory clinical response and those who failed therapy. A clinical evaluation point was

designated as a clinic visit or outpatient visit corresponding to each 6-MP metabolite measurement. Primary outcomes were based on each individual patient's initial indication for 6-MP. For those patients with
5 chronic active or steroid dependent disease, response was defined by clinical remission based on a modified HBI score <4 for CD (Myren et al., *supra*, 1984) or according to the criteria for remission defined by Truelove and Witts criteria (Truelove and Witts, *supra*, 1955), in the
10 absence of oral or parenteral corticosteroids. Complete fistula closure was considered a response for patients in whom fistulizing disease was the primary indication. Treatment failure applied to cases where the above stated therapeutic goals were not achieved. Response to 6-MP
15 was defined by clinical remission (HBI <5, closed fistula) without corticosteroids. Disease activity and physical exam were ascertained at each clinic visit at which 6-MP metabolite levels were determined (clinical evaluation point). Hematological, pancreatic and hepatic
20 laboratory parameters were evaluated simultaneously.

Among the single sampled patient group, 27 of 46 (59%) responded and 19 of 46 (41%) failed. In the multi-sampled patients, 20 of 46 (43%) had a response sustained at each clinical evaluation point, 11 (24%)
25 never achieved a clinical response and 15 (33%) responded inconsistently over time. Among all 173 metabolite measurements, 103 (60%) corresponded to patients with a clinical response to therapy and 70 (40%) were in patients not responding at the designated clinical
30 evaluation points (see Table 3).

Erythrocyte 6-TG and 6-MMP concentrations (pmol/8x10⁸ RBC) were measured by HPLC (Cuffari et al., *supra*, 1996a). Briefly, heparinized blood (5 ml) was

obtained along with other routine blood work at the time of a scheduled clinic visit or hospitalization. RBC free thiobases, 6-MP, 6-TG and 6-MMP (pmol/ 8×10^8 RBC) levels were determined by a reversed phase high performance liquid chromatography assay (Cuffari et al., *supra*, 1996a).

In an initial analysis, the induction and maintenance of remission was found to be optimal at 6-TG levels >230 pmol/ 8×10^8 RBC. 78% of patients above a median 6-TG of 230 pmol/ 8×10^8 RBC were responders (see Figure 3). These results indicate that a 6-TG value of 230 pmol/ 8×10^8 RBC can be used to predict efficacy of drug treatment with a 6-MP drug such as 6-MP or azathioprine.

The results of the analysis of 6-MP metabolites in IBD patients are shown in Table 3. The number of samples corresponds to the number of different samples obtained from the 92 patients. Overall, higher median 6-TG levels were observed at points of clinical response vs non-response (312 vs 199; $p < 0.0001$) (Table 3). Secondary analysis of all 92 patients tested at their initial clinical evaluation point revealed similar results (313 vs 209 at 53 points of response vs 39 non-response, $p < 0.004$). 6-TG quartile analysis on all samples, in which values are determined at 25, 50 and 75% of the data set, revealed that the best probability of treatment response was not significantly increased until RBC 6-TG levels were greater than 235 pmol/ 8×10^8 RBC (Figure 4A). Patients' 6-TG levels were evenly distributed within the third quartile, suggesting 235 pmol/ 8×10^8 RBC as the true threshold point. Among patients in relapse, only 27% (20 of 70) of patients had 6-TG levels >235 pmol/ 8×10^8 RBC (Figure 5). In contrast, 67% (69 of 103) of patients in remission, at times of response, had 6-TG levels > 235

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pmol/ 8×10^8 RBC ($p < 0.001$). Presenting the data in an alternate manner useful clinically, the odds ratio of a therapeutic response for a 6-TG level higher than the cutoff of 235 pmol/ 8×10^8 RBC was calculated to be 5.0 (95% CI, 2.6-9.7; $p < 0.001$). Therefore, erythrocyte 6-TG concentrations were significantly and independently associated with therapeutic response to 6-MP drug therapy.

Table 3. 6-Mercaptopurine Metabolite Levels At Designated Clinical Evaluation Points In Relation To Therapeutic Efficacy In IBD.

THERAPEUTIC EFFICACY	6-TG LEVEL [†] pmol/ 8×10^8 RBC	6-MMP LEVEL [†] (pmol/ 8×10^8 RBC)
RESPONSE (n=103)	312 (49-1203)	2683 (0-23 129)
FAILURE (n=70)	199 (0-705)	1739 (0-25 982)
p value	<0.0001	0.37

[†] Median (range).

6-MMP levels did not correlate with disease activity, nor did quartile analysis demonstrate a specific level that corresponded with outcome in the primary (Figure 4B) or secondary analyses (2683 vs 1420 for response and non-response). The theoretically competitive enzymatic pathways determining concentrations of 6-TG and 6-MMP suggest a negative correlation between these two metabolites. Nevertheless, a positive correlation between 6-TG and 6-MMP was observed ($r=0.21$, $p < 0.007$). 6-MP moieties were undetected in most

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samples, indicating that 6-MP and 6-thioinosine 5' monophosphate had been entirely biotransformed.

Statistical analysis was performed using SAS computer software (Version 6.10; SAS Institute, Inc., Cary, NC, 1994). Quantitative variables are described as medians, with the range indicated in parentheses. Normality was tested for all quantitative variables. Both parametric and nonparametric statistic tests were used, accordingly based on the distribution of variables in order to evaluate correlation between two variables and to test mean/median differences of quantitative variables between two groups. Statistical differences in proportions were evaluated by using the χ^2 method or Fisher's Exact tests, when appropriate.

To evaluate the relationship between therapeutic response and metabolite levels, linear logistic regression was performed by the maximum likelihood method. The dependent variable was therapeutic response or failure for an individual, either at one evaluation point or consistently over time. Independent variables were the patient characteristics detailed in Table 2, the 6-MP dose and metabolite levels, as well as TMPT genotype. In this analysis, for individuals with blood drawn for metabolite levels at more than one evaluation point, mean values were used and cases with mixed clinical responses (n=16) were excluded. However, they were used to identify therapeutic response-associated factors within each individual with paired tests (response vs failure).

Logistic regression analysis revealed that 6-TG levels were significantly associated with therapeutic response, independent of other confounding factors

potentially affecting prognosis ($p=0.002$). For each of the 15 patients inconsistently responsive over time, the values of 6-TG, 6-MMP, dose and duration of therapy were compared between points of clinical response and of non-response. Again, the 6-TG level was the only statistically significant variable determining therapeutic response ($p<0.02$). Unsuspected non-compliance was confirmed in 3 patients by documenting metabolite levels below the limits of detection.

10 A meta-analysis reported a beneficial effect of increasing 6-MP dose in treating quiescent CD, although not for active CD (Pearson et al., Ann. Intern. Med. 123:132-142 (1995)). In the present study, the median dose of 6-MP was not statistically different in relation to therapeutic response (1.25 and 1.25 mg/kg/day, for response and treatment failures, respectively). Similarly, there was no difference in dose when analyzed at the time of the first clinical assessment alone (1.2 vs 1.1 mg/kg/day). Quartile analysis demonstrated that 20 the frequency of remission was not significantly different across the dose range (Figure 6). Since 6-TG levels correlated with response, the relationship between 6-MP dose and metabolite level was examined. A non-linear, very weakly positive correlation was observed 25 between dose and 6-TG ($r=0.0009$), and 6-MMP ($r=0.32$) levels.

In addition to the lack of, or delay in, the therapeutic response to 6-MP, drug related toxicity has led to the underutilization of this class of immunosuppressive therapy in IBD. Toxicity in the IBD patients treated with a 6-MP drug was therefore evaluated. Toxicity was measured essentially as described previously (Cuffari et al., *supra*, 1996a).

Toxicity was defined as: (a) hematological - leukocytes <4000/mm³; (b) hepatic - aspartate aminotransferase (AST) or alanine aminotransferase (ALT) >2x upper limit of normal; (c) pancreatic - amylase or lipase >2x upper
5 limit of normal (Goldstein et al., Gastroenterology 114:A4042 (1998); Kirschner, Gastroenterology 115:813-821 (1998)). Thirty six patients (36 of 92) (39%) experienced an adverse event attributable to 6-MP drug therapy. As a measure of hepatotoxicity, elevated transaminases,
10 measured as the serum level of ALT or AST (ALT, AST; exceeding or greater than 2x upper limit of normal) occurred in 16 (17%) patients. Pancreatic toxicity, measured as increased amylase and lipase levels (lipase/amylase >2x N), was observed in 7 cases (8%).
15 However, only one patient developed clinically overt pancreatitis. Another experienced hepatic and pancreatic toxicity simultaneously. In all but 1 of 16 events, reduction of the dose of 6-MP was associated with normalization of transaminases within weeks. In the
20 latter case, extensive investigations revealed steatohepatitis.

High 6-MMP levels correlated significantly with hepatotoxicity (5463 with hepatotoxicity versus 2177 without hepatotoxicity; p=0.04). As shown in Figure 7A,
25 median 6-MMP levels were significantly higher at the time of a hepatotoxic event (n=16). Although hepatotoxicity was observed at low 6-MMP levels, the risk increased three-fold (18 vs 6%) at 6-MMP levels above the third quartile (>5,700). 6-TG levels did not affect
30 hepatotoxicity, nor did the 6-MP dose.

In regard to hematological effects, leukopenia occurred in 13 individuals (14%). The median 6-TG level during leukopenic events in 12 individuals was 286, as

compared to 232 without leukopenia ($p=0.06$). Two-thirds of leukopenic events occurred during remission, representing only 8% of all therapeutic responses. Significantly higher 6-TG levels were observed in these patients in remission (mean value of 490 in patients with leukopenia versus mean value of 323 without leukopenia; $p < 0.04$; median values were 342 versus 307, respectively). The majority (92%) of clinical responses thus occurred in the absence of leukopenia. 6-TG levels correlated significantly with the presence of leukopenia at points of therapeutic response (Figure 7B). Although 4 of 70 (6%) leukopenic events occurred during points of treatment failure, the 6-TG levels were lower (198 (range 101-215)). Neither the 6-MP dose nor 6-MMP levels influenced leukopenia.

On average, hematological toxicity occurred later in the course of 6-MP therapy compared to hepatic or pancreatic complications (means of 1.5, vs 0.4, and 0.6 years, respectively). Permanent discontinuation of 6-MP as a result of myelosuppression was deemed necessary in 1 of these patients (6-TG=793). Leukopenia did not correlate with therapeutic efficacy. However, those patients who do develop leukopenia have a higher 6-TG level than the rest of the responder group. These results indicate that 6-TG levels should be monitored to avoid potential clinical bone marrow suppression in responder patients who have high levels of 6-TG. No correlation between 6-MP dose or metabolite levels and pancreatic toxicity was observed.

Kinetic studies have demonstrated that derivatives of benzoic acid such as sulfasalazine and 5-aminosalicylic acid (5-ASA) (ASACOL™), its active metabolite, inhibit TPMT activity *in vitro* (Szumlanski et

al., Br. J. Clin. Pharmacol. 39:456-459 (1995). In this study, 48 of 92 (52%) of patients were treated with 5-ASA concomitantly (mean 45 mg/kg/day). Of 173 metabolite levels measured, 77 coincided with 5-ASA use. No effect
5 of concurrent 5-ASA use was observed on either therapeutic response, 6-TG and 6-MMP determination and levels, or drug related toxicity.

These results demonstrate a significant correlation between erythrocyte 6-TG levels and the
10 therapeutic response to 6-MP drug treatment in IBD patients. The induction and maintenance of remission was found to be optimal at 6-TG levels greater than about 230 pmol/8x10⁸ RBC, for example about 235 pmol/8x10⁸ RBC. Therefore, monitoring 6-MP metabolite levels, in
15 particular 6-TG, is useful for determining that a therapeutically effective concentration of 6-MP metabolites is maintained while treating IBD patients with a 6-MP drug. Monitoring 6-MP metabolite levels, in particular 6-TG and 6-MMP, is also useful for minimizing
20 6-MP drug related toxicity.

EXAMPLE III

GENDER AND AGE DIFFERENCES IN METABOLISM OF A 6-MP DRUG

This example describes gender and age differences observed in pediatric patients treated with
25 6-MP drug therapy.

Pediatric IBD patients undergoing 6-MP drug therapy were assessed for levels of 6-MP metabolites. These patients were wild type for TPMT. Patients were assessed based on gender and age as it relates to

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puberty. Puberty is established at 12 years of age in girls and 14 years of age in boys.

- As shown in Table 4, the 6-MMP values are much lower in boys after puberty (greater than 14 years).
- 5 Since the total amount of thiometabolites is lower, this indicates that either lower doses of 6-MP are used or that there is a difference in the bioavailability of 6-MP after puberty in males.

Table 4: 6-MP Metabolite Levels in Pediatric IBD Patients

	Number Observed	6-TG level (pmol per 8x10 ⁸ RBC)	6-MMP level (pmol per 8x10 ⁸ RBC)	Ratio 6-MMP/6-TG	
10	Girls (0-12y)	39	182.2	3447.0	18.52
	Girls (>12y)	116	217.2	3304.5	12.55
15	Boys (0-14y)	51	235.0	3681.6	17.24
	Boys (>14y)	104	222.5	1662.3*	6.78*
	*p<0.001				

- These results demonstrate that gender and age
- 20 can affect the metabolism of 6-MP in pediatric IBD patients undergoing 6-MP drug therapy.

EXAMPLE IVTHIOPURINE METHYLTRANSFERASE (TPMT) GENOTYPING AND
RESPONSIVENESS TO 6-MP DRUG THERAPY

This example describes TPMT genotyping of IBD
5 patients treated with 6-MP drug therapy.

The genotype of TPMT was determined in IBD
patients that were responders and non responders.
Genotyping of TPMT was measured essentially as described
previously (Baccichet et al., Leuk. Res. 21:817-823
10 (1997); Zietkiewicz et al., Gene 205:161-171 (1997)).
All individuals were genotyped for two polymorphisms in
TPMT transitions at position 460 (G460A, Ala-to-Thr) and
at position 719 (A719G, Tyr-to-Cys) using a PCR-allele
specific oligonucleotide (ASO) hybridization assay
15 (Szumlanski et al., DNA Cell Biol. 15:17-30 (1996); Tai
et al., Am. J. Hum. Genet. 58:694-702 (1996); Zietkiewicz
et al., Gene 205:161-171 (1997)). These mutations were
used to define three distinct alleles: TMPT 3*A (both
G460A and A719G), TMPT 3*B (only G460A) and TMPT 3*C
20 (only A719G). The data shown in Table 5 indicate that
patients heterozygous for the TPMT mutation had
significantly higher 6-TG levels compared to those
patients without the mutation. All heterozygote patients
were responders to 6-MP.

25 Table 5: TPMT Genotyping of IBD Patients

	Heterozygote	Normal
Responder	100%	55%
Non responder	0%	45%
mean 6-TG	589*	247

p value *less than 0.0001

Among the patients examined, TPMT genotyping revealed that 8 (9%) of patients were heterozygous for the TPMT allele (TPMT^H/TPMT^L). No homozygous TPMT deficient patients were detected. All heterozygotes, compared to 39 of 84 (46%) of patients homozygous for normal alleles, achieved a clinical response (single and multisampled) on 6-MP and had 6-TG levels >230 pmol/8x10⁸ RBC. Thirty of the remaining 45 never responded and 15 were mixed responders. Higher 6-TG levels were found among heterozygotes (Figure 8). However, 6-MMP levels were comparable among heterozygotes and normals (1115 vs 2231 pmol/8x10⁸ RBC). The median dose of 6-MP was not significantly different in relation to genotype (1.2 and 1.1 mg/kg/day, for normals and heterozygotes, respectively). Only 1 of 13 patients with leukopenia was heterozygous for the TPMT allele. Overall, 35 of 36 patients with drug related toxicity had a normal TPMT genotype.

These results demonstrate that TPMT genotyping is useful for predicting the effectiveness of 6-MP therapy in an IBD patient. Heterozygote patients are expected to have lower TPMT activity and should therefore be monitored for high levels of 6-TG for possible toxic levels associated with leukopenia or bone marrow suppression. 6-MP drug doses can be reduced accordingly. Wild type homozygous patients are expected to have higher TPMT activity and should therefore be monitored to maintain an effective therapeutic level of 6-TG and to determine if patients develop toxic levels of 6-MMP. Homozygous patients deficient in TPMT activity can be treated with lower doses of a 6-MP drug provided that patients are closely monitored for toxicity such as leukopenia.

All journal articles and references provided herein, in parenthesis or otherwise, are incorporated herein by reference.

Although the invention has been described with
5 reference to the examples provided above, it should be understood that various modifications can be made without departing from the spirit of the invention. Accordingly, the invention is limited only by the claims.

We claim:

1. A method of optimizing therapeutic efficacy of 6-mercaptopurine drug treatment of an immune-mediated gastrointestinal disorder, comprising:

5 (a) administering a 6-mercaptopurine drug to a subject having said immune-mediated gastrointestinal disorder; and

(b) determining a level of 6-thioguanine in said subject having said immune-mediated gastrointestinal
10 disorder,

wherein a level of 6-thioguanine less than a level corresponding to about 230 pmol per 8×10^8 red blood cells indicates a need to increase the amount of 6-mercaptopurine drug subsequently administered to said
15 subject and

wherein a level of 6-thioguanine greater than a level corresponding to about 400 pmol per 8×10^8 red blood cells indicates a need to decrease the amount of 6-mercaptopurine drug subsequently administered to said
20 subject.

2. The method of claim 1, wherein said immune-mediated gastrointestinal disorder is inflammatory bowel disease (IBD).

3. The method of claim 2, wherein said
25 subject having IBD is a pediatric subject.

4. The method of claim 1, wherein said immune-mediated gastrointestinal disorder is selected from the group consisting of lymphocytic colitis, microscopic colitis, collagenous colitis, autoimmune enteropathy, allergic gastrointestinal disease and eosinophilic gastrointestinal disease.

5. The method of claim 1, wherein said level of 6-thioguanine is determined in red blood cells.

6. The method of claim 5, wherein said level is determined using high pressure liquid chromatography.

7. A method of reducing toxicity associated with 6-mercaptopurine drug treatment of an immune-mediated gastrointestinal disorder, comprising:

(a) administering a 6-mercaptopurine drug to a subject having said immune-mediated gastrointestinal disorder; and

(b) determining a level of a 6-mercaptopurine metabolite in said subject having said immune-mediated gastrointestinal disorder,

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wherein a level of said 6-mercaptopurine metabolite greater than a predetermined toxic level of said 6-mercaptopurine metabolite indicates a need to decrease the amount of 6-mercaptopurine drug subsequently administered to said subject, thereby reducing toxicity associated with 6-mercaptopurine drug treatment of said immune-mediated gastrointestinal disorder.

8. The method of claim 7, wherein said immune-mediated gastrointestinal disorder is IBD.

9. The method of claim 8, wherein said subject having IBD is a pediatric subject.

10. The method of claim 7, wherein said immune-mediated gastrointestinal disorder is selected from the group consisting of lymphocytic colitis, microscopic colitis, collagenous colitis, autoimmune enteropathy, allergic gastrointestinal disease and eosinophilic gastrointestinal disease.

11. The method of claim 7, wherein said 6-mercaptopurine metabolite is 6-thioguanine.

12. The method of claim 11, wherein said predetermined toxic level of 6-thioguanine corresponds to a level of about 400 pmol per 8×10^8 red blood cells.

13. The method of claim 11, wherein said toxicity associated with 6-mercaptopurine drug treatment is hematologic toxicity.

14. The method of claim 7, wherein said 6-mercaptopurine metabolite is 6-methyl-mercaptopurine.

15. The method of claim 14, wherein said predetermined toxic level of 6-methyl-mercaptopurine corresponds to a level of about 7000 pmol per 8×10^8 red blood cells.

16. The method of claim 14, wherein said toxicity associated with 6-mercaptopurine treatment is hepatic toxicity.

17. The method of claim 7, wherein said level of 6-mercaptopurine metabolite is determined in red blood cells.

18. The method of claim 17, wherein said level
5 is determined using high pressure liquid chromatography.

19. A method of optimizing therapeutic efficacy and reducing toxicity associated with 6-mercaptopurine drug treatment of an immune-mediated gastrointestinal disorder, comprising:

10 (a) administering a 6-mercaptopurine drug to a subject having said immune-mediated gastrointestinal disorder;

(b) determining a level of 6-thioguanine in said subject having said immune-mediated gastrointestinal
15 disorder; and

(c) determining a level of 6-methyl-mercaptopurine in said subject having said immune-mediated gastrointestinal disorder,

wherein a level of 6-thioguanine less than a
20 predetermined minimal therapeutic level indicates a need to increase the amount of 6-mercaptopurine drug subsequently administered to said subject, thereby increasing therapeutic efficacy,

wherein a level of 6-thioguanine greater than a
25 predetermined toxic level of 6-thioguanine indicates a need to decrease the amount of 6-mercaptopurine drug subsequently administered to said subject, thereby reducing toxicity associated with 6-mercaptopurine drug

treatment of said immune-mediated gastrointestinal disorder, and

wherein a level of 6-methyl-mercaptopurine greater than a predetermined toxic level of 6-methyl-mercaptopurine indicates a need to decrease the amount of 6-mercaptopurine drug subsequently administered to said subject, thereby reducing toxicity associated with 6-mercaptopurine drug treatment of said immune-mediated gastrointestinal disorder.

20. The method of claim 19, wherein said immune-mediated gastrointestinal disorder is IBD.

21. The method of claim 20, wherein said subject having IBD is a pediatric subject.

22. The method of claim 19, wherein said immune-mediated gastrointestinal disorder is selected from the group consisting of lymphocytic colitis, microscopic colitis, collagenous colitis, autoimmune enteropathy, allergic gastrointestinal disease and eosinophilic gastrointestinal disease.

23. The method of claim 19, wherein said predetermined minimal therapeutic level of 6-thioguanine is a level corresponding to about 230 pmol per 8×10^8 red blood cells.

24. The method of claim 19, wherein said predetermined toxic level of 6-thioguanine is a level corresponding to about 400 pmol per 8×10^8 red blood cells.

25. The method of claim 19, wherein said predetermined toxic level of 6-methyl-mercaptopurine is a level corresponding to about 7000 pmol per 8×10^8 red blood cells.

5 26. The method of claim 19, wherein said predetermined minimal therapeutic level of 6-thioguanine is a level corresponding to about 230 pmol per 8×10^8 red blood cells, said predetermined toxic level of
10 6-thioguanine is a level corresponding to about 400 pmol per 8×10^8 red blood cells, and said predetermined toxic level of 6-methyl-mercaptopurine is a level corresponding to about 7000 pmol per 8×10^8 red blood cells.

27. The method of claim 19, wherein said level of 6-thioguanine and said level of
15 6-methyl-mercaptopurine each is determined in red blood cells.

28. The method of claim 27, wherein said level is determined using high pressure liquid chromatography.

29. The method of claim 19, wherein said
20 toxicity associated with 6-mercaptopurine drug treatment is selected from the group consisting of hepatic toxicity and hematologic toxicity.

30. A method of optimizing therapeutic efficacy of 6-mercaptopurine drug treatment of a non-IBD
25 autoimmune disease, comprising:

(a) administering a 6-mercaptopurine drug to a subject having said non-IBD autoimmune disease; and

(b) determining a level of 6-thioguanine in said subject having said non-IBD autoimmune disease,

wherein a level of 6-thioguanine less than a minimal therapeutic level indicates a need to increase
5 the amount of 6-mercaptopurine drug subsequently administered to said subject and

wherein a level of 6-thioguanine greater than a level corresponding to a predetermined toxic level indicates a need to decrease the amount of
10 6-mercaptopurine drug subsequently administered to said subject.

31. The method of claim 30, wherein said minimal therapeutic level is about 230 pmol per 8×10^8 red blood cells.

15 32. The method of claim 30, wherein said predetermined toxic level is about 400 pmol per 8×10^8 red blood cells.

33. The method of claim 30, wherein said level of 6-mercaptopurine metabolite is determined in red blood
20 cells.

34. The method of claim 33, wherein said level is determined using high pressure liquid chromatography.

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35. The method of any one of claims 1-6, further comprising administering a 6-mercaptopurine drug to the subject subsequent to and in accordance with said determining, whereby the amount of drug subsequently administered to the subject is increased or decreased relative to the drug administered before said determining.

36. The method of any one of claims 7-18, further comprising administering a 6-mercaptopurine drug to the subject subsequent to and in accordance with said determining, whereby the amount of drug subsequently administered is decreased relative to the drug administered before said determining.

37. The method of any one of claims 19-29, further comprising administering a 6-mercaptopurine drug subsequent to and in accordance with said determining, whereby the amount of drug subsequently administered is increased or decreased relative to the drug administered before said determining.

38. The method of any one of claims 30-34, further comprising administering a 6-mercaptopurine drug to the subject subsequent to and in accordance with said determining, whereby the amount of drug subsequently administered is increased or decreased relative to the drug administered before said determining.



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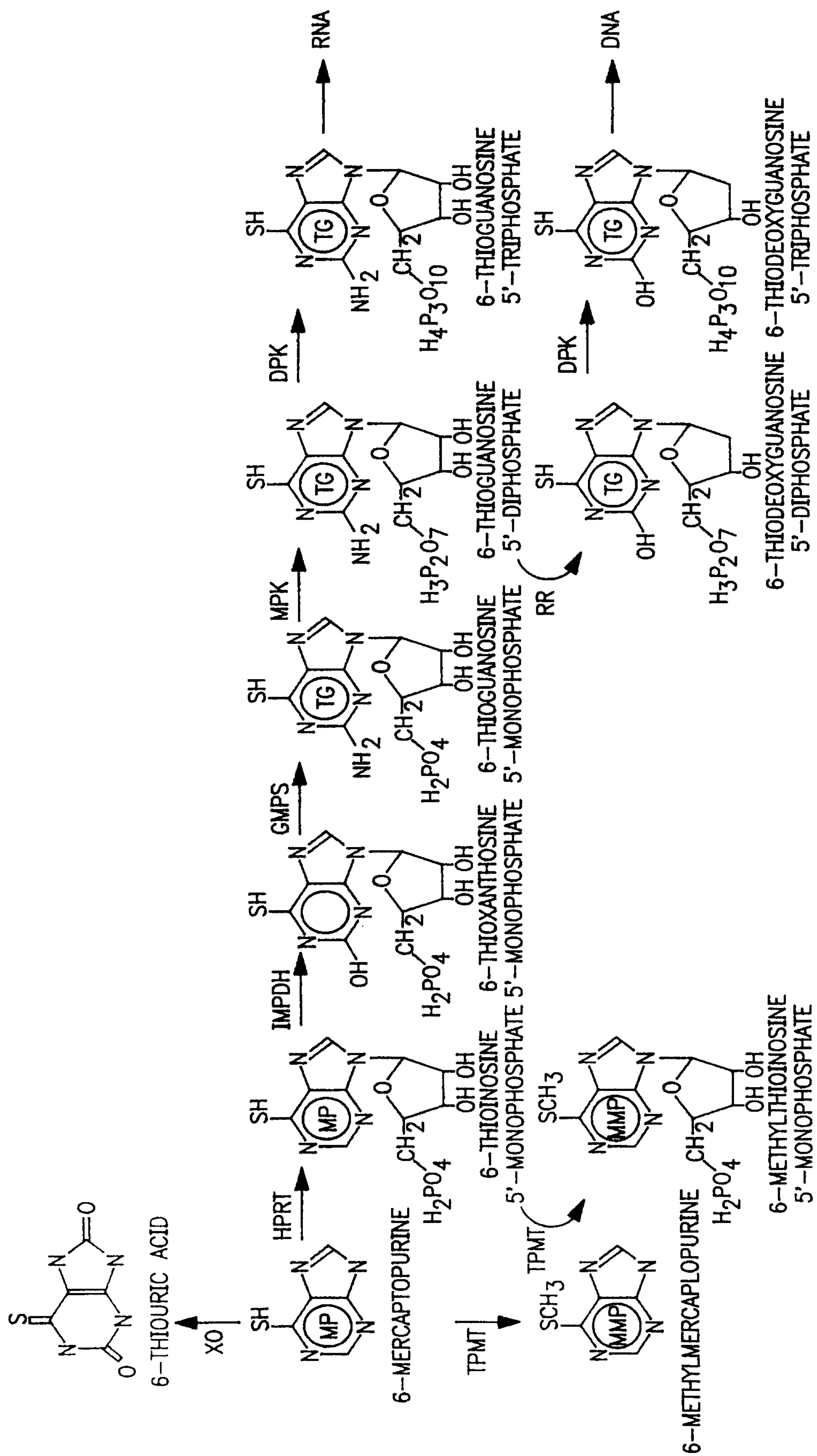


Fig. 2

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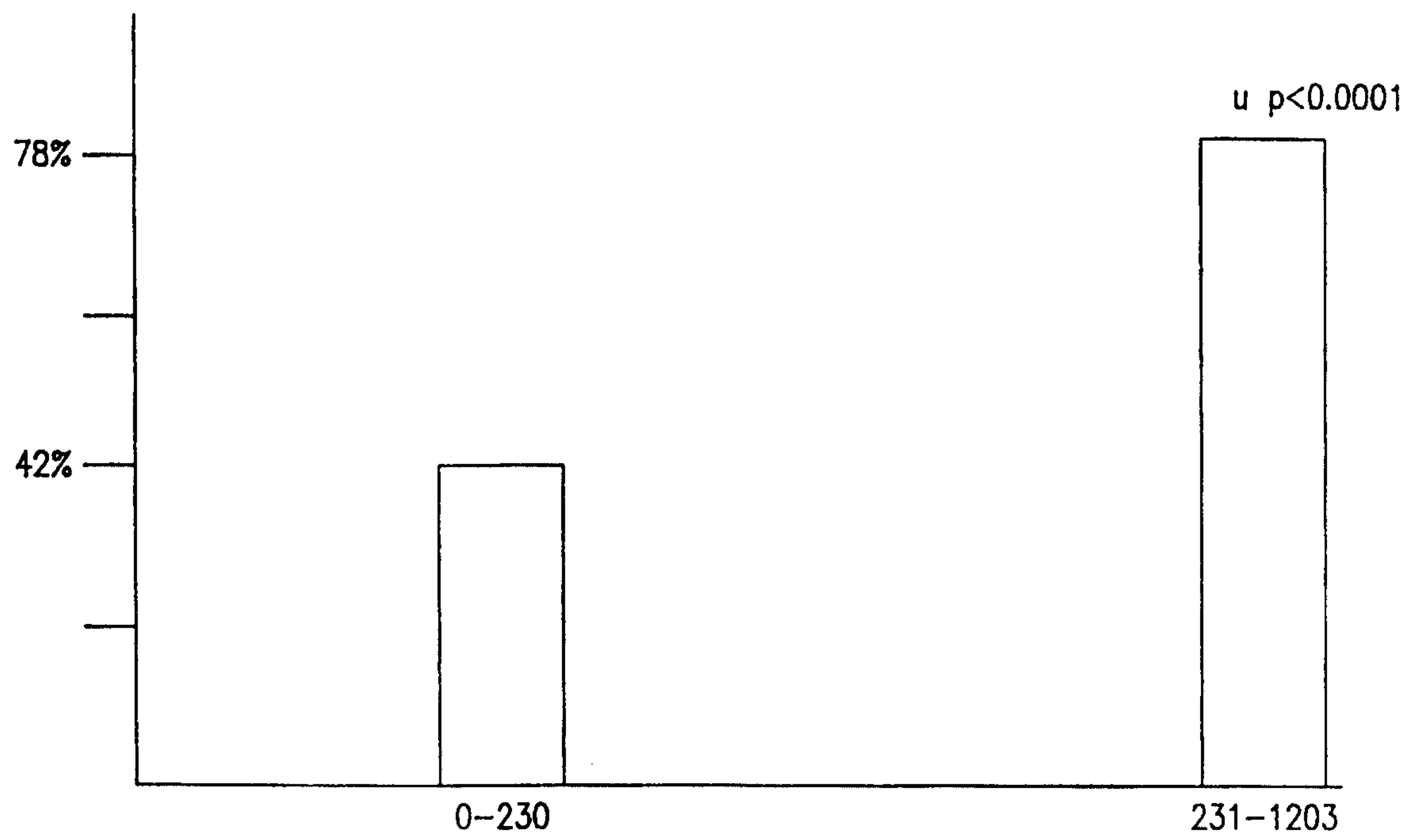


FIG. 3

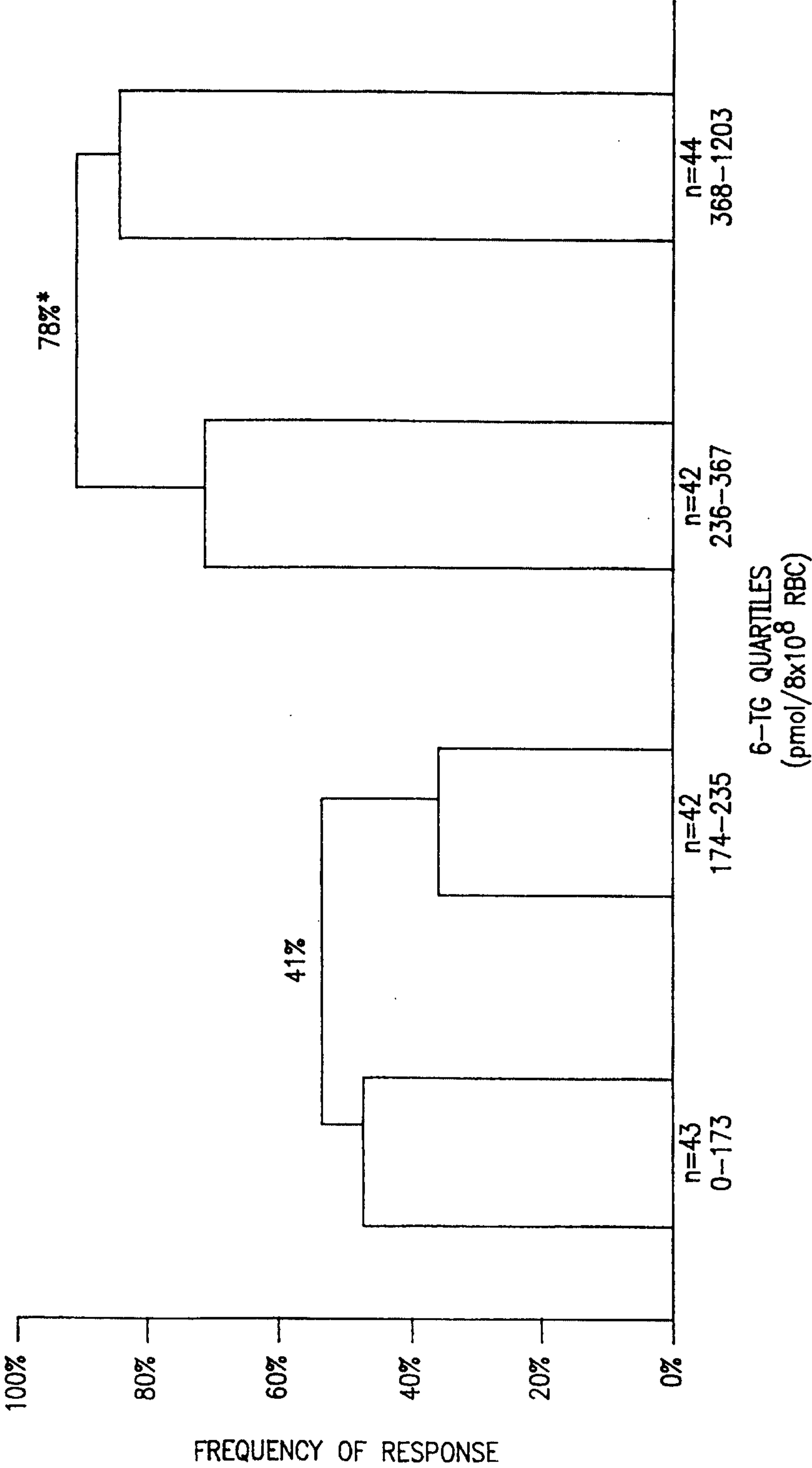


FIG. 4A

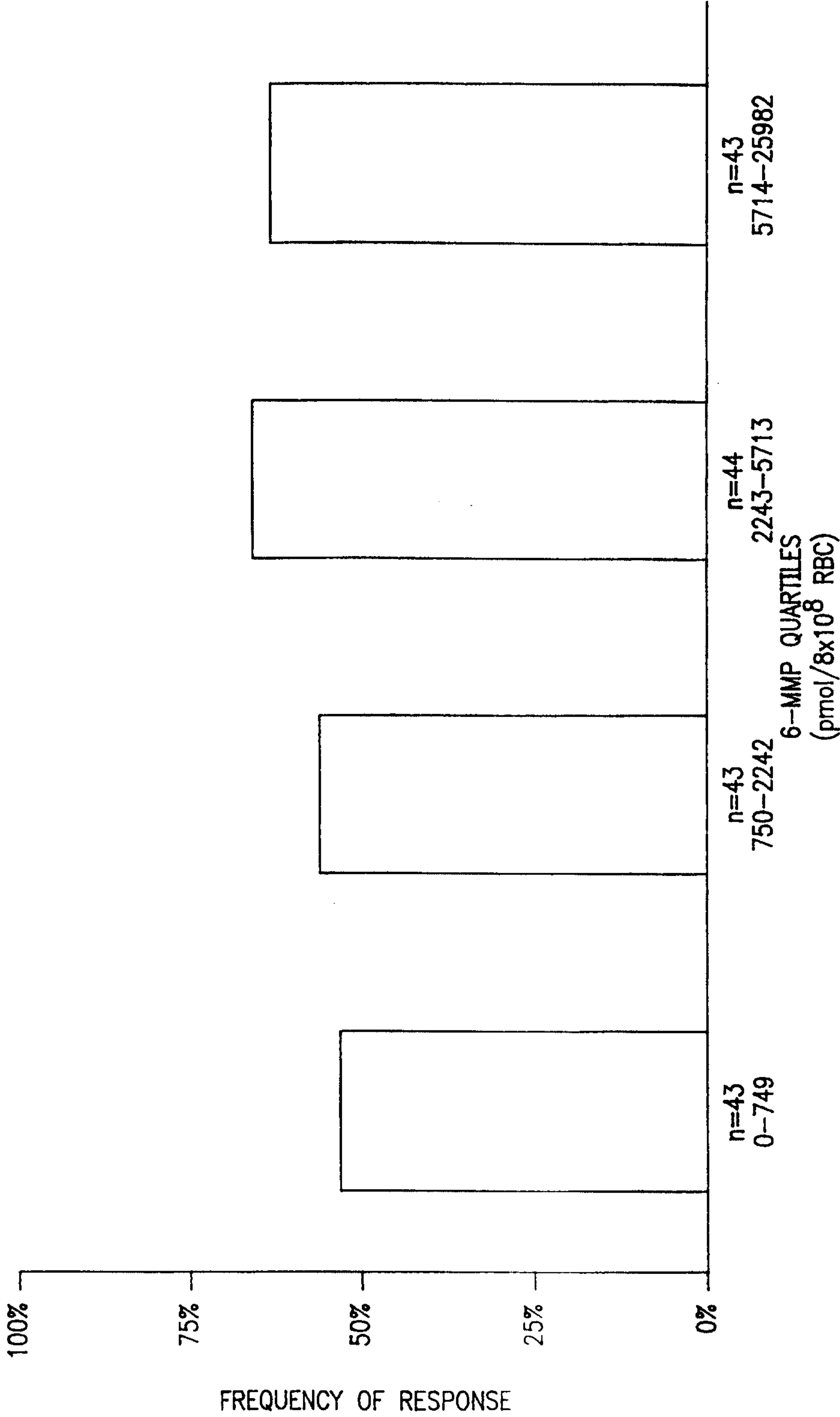


FIG. 4B

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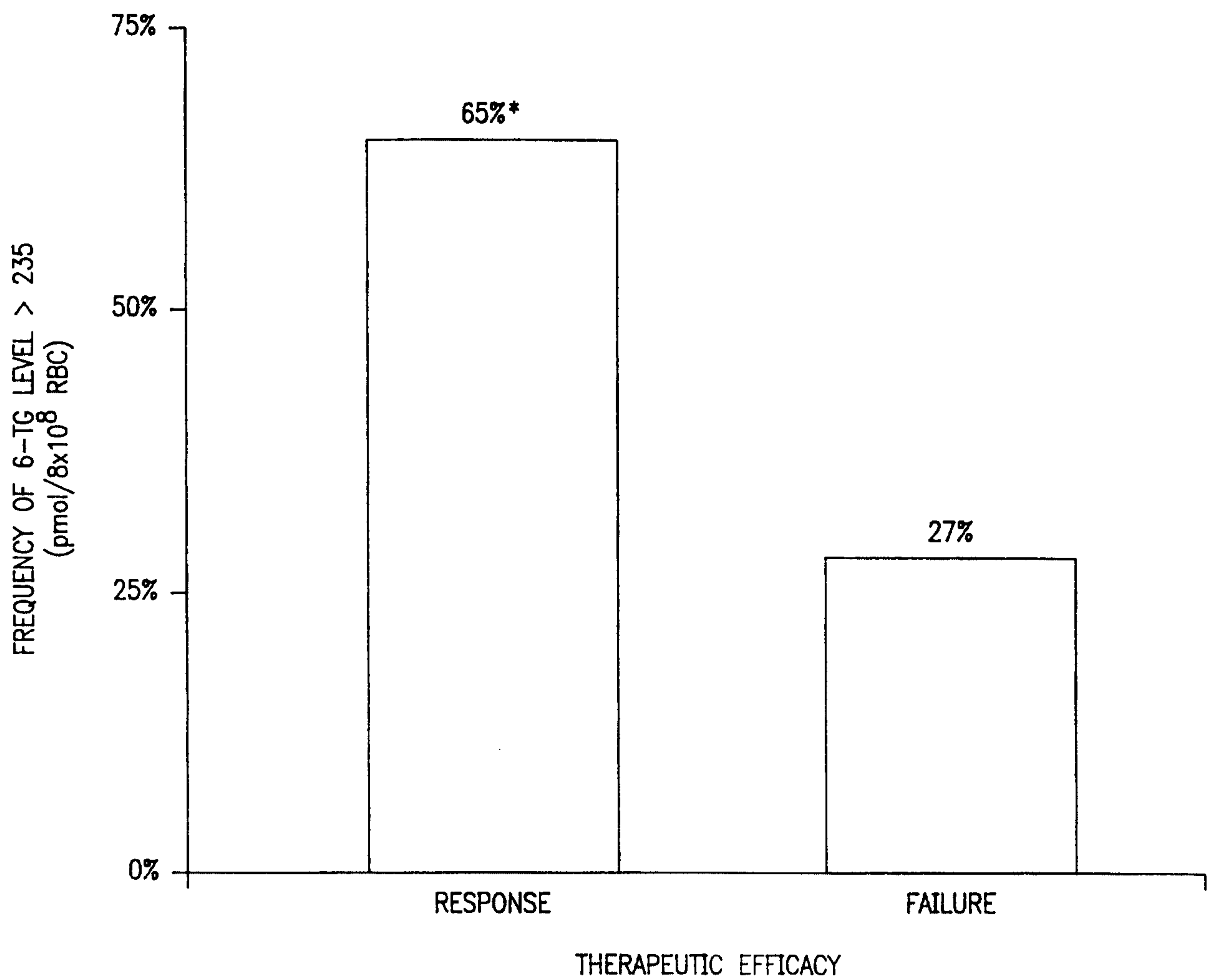


FIG. 5

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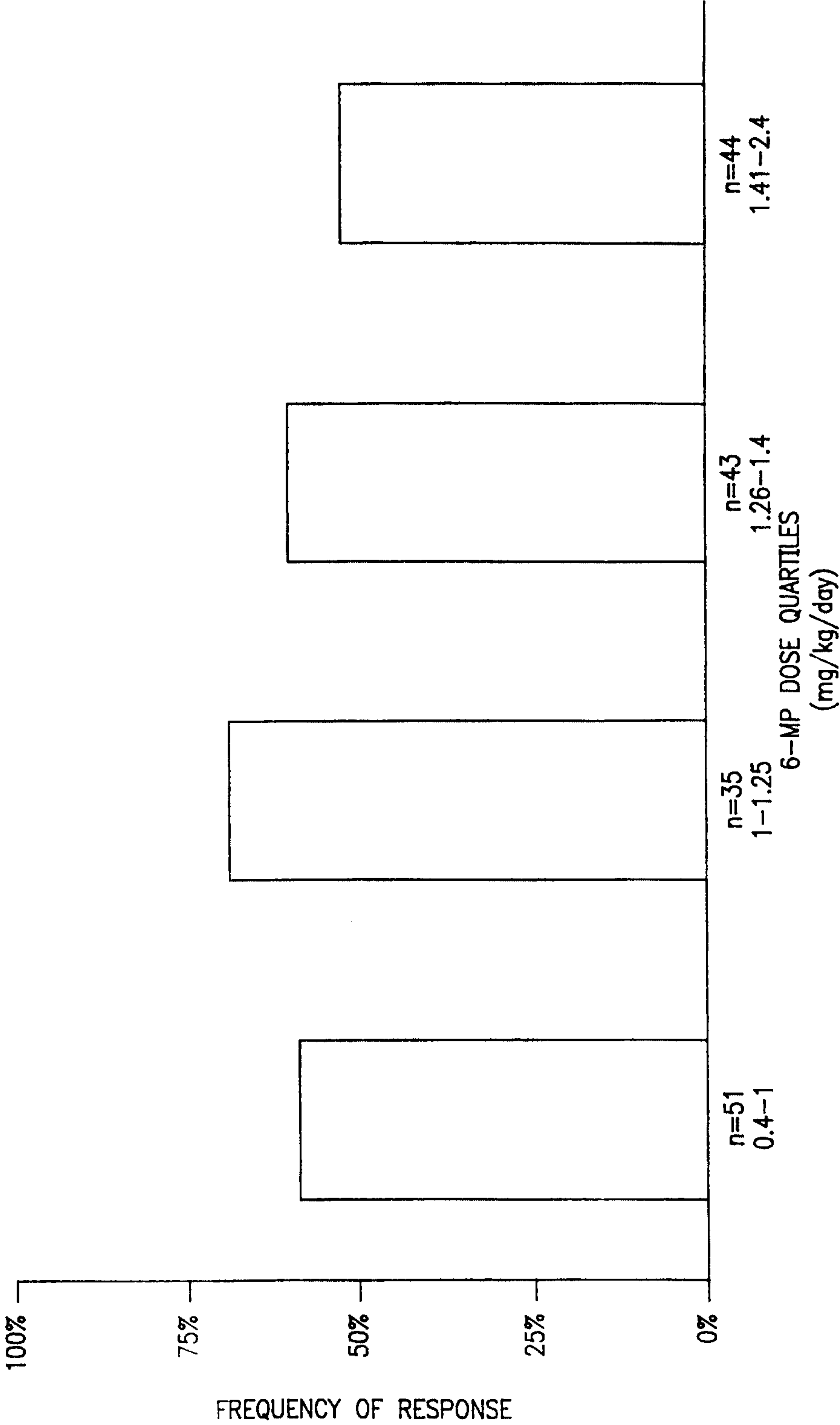


FIG. 6

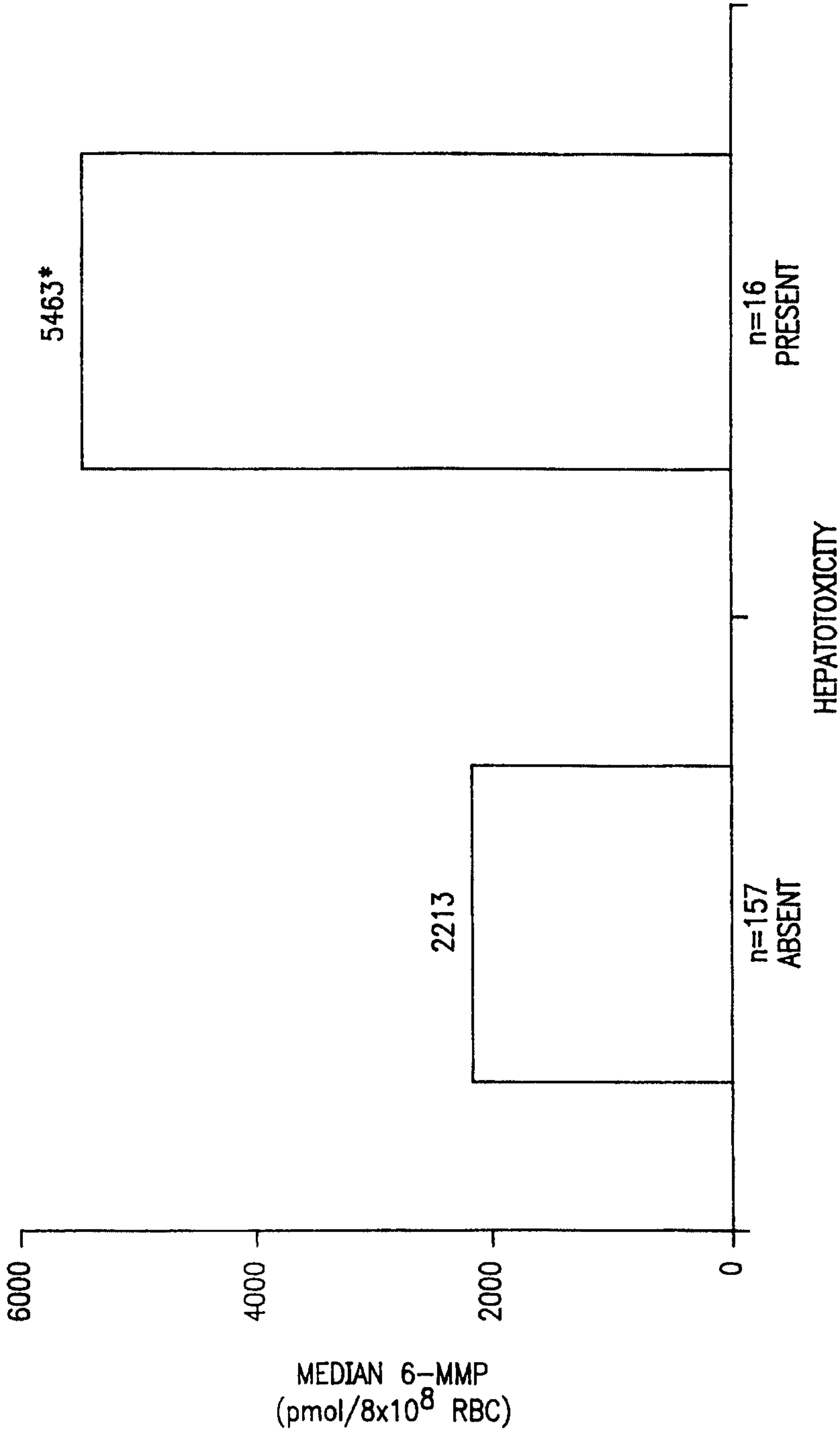


FIG. 7A

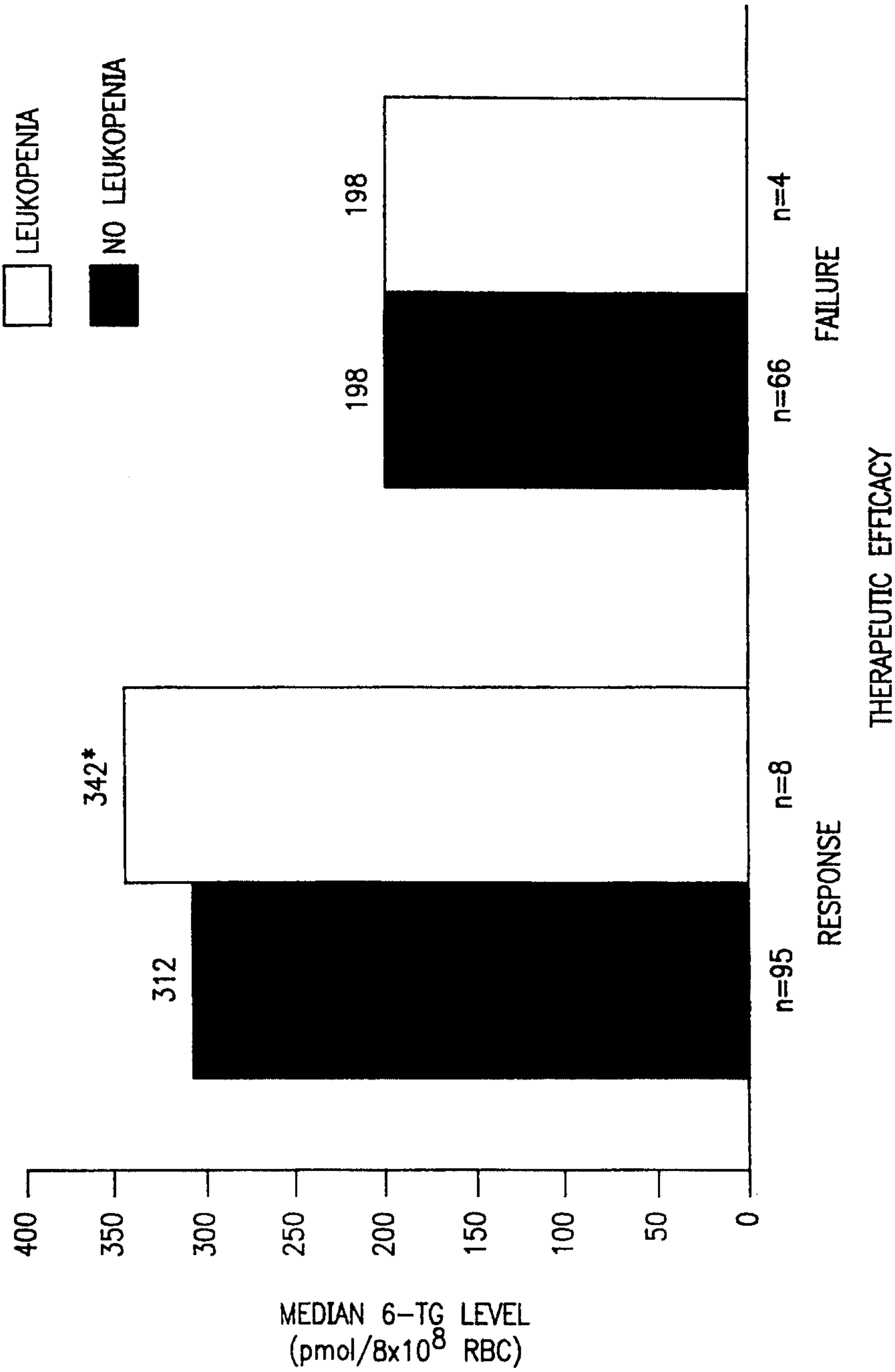


FIG. 7B

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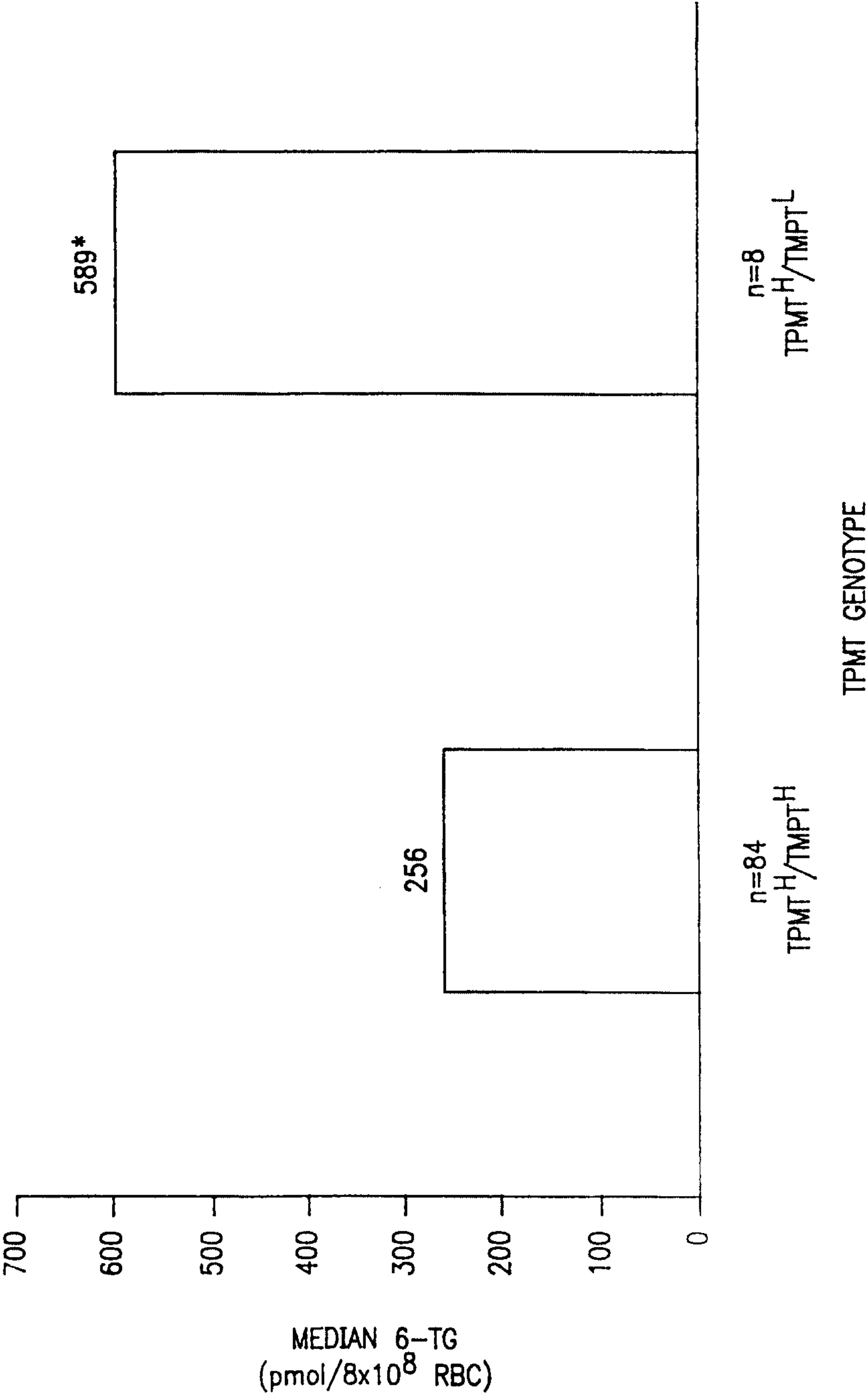


FIG. 8