Clinical Gastroenterology and Hepatology

Diet and Inflammatory Bowel Disease

Review of Patient-Targeted Recommendations

Jason K. Hou, Dale Lee, James Lewisk

Clin Gastroenterol Hepatol. 2014;12(10):1592-1600.

Abstract and Introduction

Abstract

Patients have strong beliefs about the role of diet in the cause of inflammatory bowel disease (IBD) and in exacerbating or alleviating ongoing symptoms from IBD. The rapid increase in the incidence and prevalence of IBD in recent decades strongly suggests an environmental trigger for IBD, one of which may be dietary patterns. There are several pathways where diet may influence intestinal inflammation, such as direct dietary antigens, altering the gut microbiome, and affecting gastrointestinal permeability. However, data that altering diet can change the natural history of IBD are scarce, and evidence-based dietary guidelines for patients with IBD are lacking. Patients, therefore, seek nonmedical resources for dietary guidance, such as patient support groups and unverified sources on the Internet. The aim of this review is to identify patient-targeted dietary recommendations for IBD and to critically appraise the nutritional value of these recommendations. We review patient-targeted dietary information for IBD from structured Internet searches and popular defined diets. Patient-targeted dietary recommendations focus on food restrictions and are highly conflicting. High-quality dietary intervention studies are needed to facilitate creation of evidence-based dietary guidelines for patients with IBD.

Introduction

Inflammatory bowel disease (IBD) is hypothesized to result from an environmental trigger in a genetically susceptible person. The incidence of Crohn's disease (CD) and ulcerative colitis (UC) are rising in Europe and North America, and in countries where IBD was previously thought to be uncommon (eg, China, South Korea, Puerto Rico).[1–3] Rapid shifts in the epidemiology of IBD point to an environmental trigger to IBD. The spread of the "Western" diet, high in fat and protein but low in fruits and vegetables, has been proposed as a possible explanation of the increase in IBD incidence.[4] The bowel lumen is continually exposed to numerous antigens, including the food that we consume and the enormous population of organisms that compose the gut microbiome. There are numerous proposed mechanisms through which diet could influence the incidence of IBD, including direct dietary antigens, altering the gut microbiome, and affecting gastrointestinal permeability.[5]

Patients frequently ask physicians for recommendations about food and diet, seeking ways to improve, or even cure their IBD. However, there are very limited data regarding the impact of diet on IBD. The combination of the paucity of quality data with strong patient interest may drive patients to seek nonmedical sources of diet recommendations, such as the Internet and the lay literature. In this review, we discuss patient-targeted dietary recommendations from the Internet and defined diets for IBD and evaluate the scientific evidence behind them.

Potential Mechanism of Action: Diet and Gut Inflammation

Various dietary components have been proposed to increase the risk of developing or exacerbating symptoms of IBD. One of the first dietary components associated with developing IBD was intake of sugar and refined carbohydrates.[6–9] However, an ecologic study in North America, Europe, and Japan failed to show an association between refined sugar intake and CD incidence rates.[10] There are consistent associations between both fatty acid and protein composition in the diet with the development of IBD in ecologic and prospective cohort studies.[11–14] Furthermore, dietary fiber intake has been associated with a lower risk of developing CD, but not UC (hazard ratio, 0.59; 95% confidence interval, 0.39–0.90).[15]

Two studies of patients who underwent ileocolonic resection provide the strongest evidence for the role of intestinal contents on the course of CD. Both studies demonstrated that recurrence of inflammation after ileal resection is dependent on exposure of the neoterminal ileum to the fecal contents. Inflammation recurred within 8 days of exposure to the luminal contents.[16,17] However, the fecal stream is a complex mixture of bacteria, other microorganisms, digested food content, and the metabolic products of digestion of food components by the host and microbiota. This makes it very challenging to

identify the components of the luminal content that drive the underlying inflammation. Furthermore, these components are not independent of each other.

There is a potential link between diet and the composition of the gut microbiome. Long-term agrarian dietary patterns are associated with an enterotype characterized by *Prevotella*,[18] a genera more commonly observed in people from rural Africa where IBD and particularly CD is uncommon.[19] *Prevotella* and related bacteria are efficient at fermenting dietary fiber, thereby leading to higher concentrations of short-chain fatty acids,[20] which may protect against bowel inflammation.[21] In contrast, high-fat diets, through dietary-induced changes in the gut microbiota, may increase bowel permeability, a hallmark of CD.[22] High-fat diets also worsen dextran sodium sulfate–induced colitis in mice, possibly by increasing colonic epithelial nonclassical natural killer T cells and reducing Treg cells.[23] In animal models, consumption of milk-derived saturated fat alters bile acid composition, allowing for a bloom of sulfate-reducing bacteria, which in turn can produce greater amounts of the potentially mucosal toxic hydrogen sulfide.[24,25] A major source of hydrogen sulfide in the bowel is bacterial fermentation of sulfur amino acids, which are found in high-protein foods, such as meats.[26] Hydrogen sulfide has been proposed as contributing to bowel inflammation through a variety of mechanisms, including impaired use of short-chain fatty acids and direct toxic effects.[27,28] However, other research suggests that hydrogen sulfide has anti-inflammatory properties and contributes to mucosal healing.[29,30] These are but a few of the proposed mechanisms by which diet can affect the course of IBD. Unfortunately, it is currently unknown whether these findings in animal models translate to humans with IBD.

Observational Studies of Diet and the Natural History of Inflammatory Bowel Disease

There are surprisingly few observational studies examining the association of diet with the natural history of IBD. Jowett and coworkers[31] conducted a prospective study of patients with UC. They observed that patients who reported higher levels of meat, eggs, protein, and alcohol consumption were more likely to have a relapse of UC. Importantly, the association was much stronger for red and processed meats than for other meats and there was no association with fish consumption. Jowett and coworkers hypothesized that these dietary patterns resulted in higher intestinal concentration of sulfate, which in turn led to disease relapse. Another study found a correlation between sulfite consumption and endoscopic activity in UC.[32]

Dietary Intervention Studies to Alter the Course of Inflammatory Bowel Disease

In CD, exclusive enteral nutrition with elemental, semielemental, and defined formula diets has been widely studied for induction of remission and is considered first-line therapy in Europe.[33,34] Exclusive enteral nutritional therapy does not act by immunosuppression, but it has been shown to induce mucosal healing and prolong clinical remission of CD.[35] However, the practicality of maintaining exclusive enteral nutritional therapy over long periods of time is doubtful. In head-to-head randomized clinical trials, the degree of hydrolysis of proteins does not seem to impact the response rate with exclusive enteral nutrition therapy.[36] In general, response rates to enteral therapy exceed 80% among children with CD. For maintenance of remission, a diet in which half of the daily calories were from an elemental supplement resulted in a nearly 50% reduction in CD relapse rates compared with a regular diet.[37] Some evidence suggests that response rates are higher among those with small bowel disease. Furthermore, exclusive enteral nutrition has not been effective for UC.[38] The reason for this is uncertain but raises interesting hypotheses about the potential mechanism of action of exclusive enteral therapy.

Several small trials of diet restriction using regular food have also demonstrated improved disease activity and prolonged time to relapse.[39–41] In a recent uncontrolled trial, food-specific IgG4 levels were used to select which foods to exclude rather than excluding nearly all foods and gradually adding back selected foods.[42] Eggs and beef were the most common foods with high IgG4 antibody levels and were therefore excluded by the greatest number of patients. The 29 patients on the exclusion diet experienced a significant reduction in symptoms based on a modified Crohn's Disease Activity Index and reduction in the erythrocyte sedimentation rate compared with pretreatment levels. The major limitation of this study was the absence of a control group. In another small study (n = 22), Chiba and coworkers[43] demonstrated superiority of the semivegetarian versus an omnivorous diet to maintain clinical remission over 2 years (94% vs 33%). This study included patients with medically or surgically induced remission who received a lacto-ova-vegetarian diet in hospital. After discharge, the semivegetarian diet allowed for fish once weekly and meat once every 2 weeks. Eggs were allowed without limitation. It should be noted that this was not a randomized trial but rather allowed patients to choose whether or not to continue on the diet after discharge.

Other dietary intervention studies have not suggested a benefit. Omega-3 fatty acid supplements have been tested and were not effective in preventing CD relapse in 2 large placebo-controlled trials.[44] One of the largest dietary trials (n = 352) compared recommendations for a diet high in refined carbohydrates with one high in unrefined carbohydrates and low in

sugar among patients with CD. Although there were differences in sugar and fiber intake between the study groups, rates of clinical deterioration were not statistically different.[45]

Patient-Targeted Diet Recommendations

Internet Search

We performed an Internet query of dietary recommendations for IBD using 2 separate search engines, Google and Bing, for the following searches: "Crohn's disease diet" and "ulcerative colitis diet." The top 30 hits on each engine were reviewed (Supplementary Appendices 1–4 http://www.cghjournal.org/cms/attachment/2018566941/2038726214/mmc1.docx). Each site was assessed for recommendations to include or exclude specific food categories. The food categories evaluated included macronutrients, food groups, cooked versus raw foods, taste classifications, fiber content, specific foods, and beverages. General food recommendations, foods thought to be possible triggers of disease, and dietary recommendations specific to periods of disease flare were aggregated ( ). Recommendations for physician and/or dietician consultation were also assessed on each site. Search results leading to sites containing the same Web address stem and dietary recommendations were considered duplicates and were only included once. For CD, the Web search resulted in 47 unique sites and the UC query identified 55 unique sites. Each Web site's recommendations to include or exclude the food categories were noted. If a Web site gave recommendations supporting both inclusion and exclusion of a food category, this was noted as a "conflicting" recommendation. We included food categories with recommendations from 10 or more Web sites included in our search.

Table 1. Combined Results of Web Search for "Crohn's disease diet" and "ulcerative colitis diet"

Grouping	Food category	No. of sites w/rec	Include (%)	Avoid (%)	Conflicting[a] (%)
Fruits/Vegetables	Any fruit	41	24	44	32
	Any vegetables	28	57	22	21
	Raw vegetables	22	8	92	—
	Cruciferous vegetables	21	—	100	—
	Cooked vegetables	12	100	—	—
	Citrus fruit	10	20	80	—
Proteins	Bean/legume/lentils	32	16	78	6
	Fish	25	96	4	—
	Nuts	24	4	79	17
	Poultry	17	100	—	—
	Eggs	16	69	31	—
	High protein	13	92	8	—
	Soy/tofu	12	83	17	—
	Lean protein	11	100	—	—
	Red meat	10	20	80	—
Fiber	Whole grain	34	26	56	18
	High fiber	32	19	72	9
	Seeds/popcorn	30	—	93	7
	Low fiber	15	87	13	—
	Refined grain	10	40	60	—
Beverages/dairy	Any dairy	42	17	69	14
	Alcohol	35	—	100	—
	Coffee/tea	34	3	91	6
	Carbonated beverages	21	—	100	—

Other	Fatty/fried food	41	5	88	7
	Spicy food	29	3	97	—
	Sugars	25	—	100	—
	Healthy oil	18	89	11	—

rec, recommendation.

[a]Conflicting: Web site mentioned food category but gave recommendation to both include and exclude.

Recommendations on vegetables, fruits, and fiber were particularly common. The vegetable food categories included were raw vegetables, cruciferous vegetables, cooked vegetables, and any vegetables. If a recommendation on a particular vegetable was made, but did not specify raw, cooked, or cruciferous, it was included as a recommendation for "any vegetable." Comparisons of dietary recommendations between CD and UC using chi-square testing showed similar rates of recommendations except for fatty and fried foods. Fatty and fried foods were recommended to be excluded in 100% of CD sites compared with 71% of UC sites (P = .02). Given the general similarity, the food recommendations for CD and UC are presented together.

Of the 28 food categories included, avoidance (by ≥80% sites mentioning the food) was recommended for 11 categories: raw vegetables, cruciferous vegetables, citrus fruit, red meat, carbonated beverages, coffee and tea, alcohol, fatty and fried foods, spicy foods, sugars, and seeds and popcorn. Of these categories, cruciferous vegetables, alcohol, carbonated beverages, and sugars were recommended to be avoided by 100% of sites mentioning the food category. Inclusion (by ≥80% sites mentioning the food) was recommended for 5 categories: cooked vegetables, fish, poultry, lean protein, and high-protein diet. Of these categories, cooked vegetables, poultry, and lean protein were recommended to be included by 100% of sites mentioning the food. The food categories having a higher percentage of "conflicting" recommendations for both inclusion and exclusion were any vegetables (21%), any fruit (32%), nuts (17%), and whole grains (18%).

Our Web search analysis demonstrated that patient-targeted dietary recommendations are highly restrictive and frequently conflicting. These recommendations may result in patient confusion and unnecessarily restrictive diets in patients who are already at risk for nutritional deficiencies.

Defined Diets

Defined diets are dietary regimens prescribed based on an underlying "theory" of how food interacts with the body. There are several defined diets that have been touted to affect intestinal inflammation and other medical conditions.[46–50] Defined diets are promoted in the lay literature through anecdotal success stories but to date lack rigorous scientific assessment. In this review we detail 3 defined diets that are commonly advocated for patients with IBD in the lay literature: the specific carbohydrate diet (SCD); the fermentable oligosaccharides, disaccharides, and monosaccharides (FODMAP) diet; and the Paleolithic diet (Paleo). This review is not advocating the use of these diets to treat patients with IBD, but rather highlights the underlying philosophy and potential nutritional impact of these diets on patients with IBD.

Specific Carbohydrate Diet

The SCD was first described by Dr. Sidney Haas in 1924 as a means to treat celiac disease.[48] The SCD was popularized for the treatment of IBD by biochemist Elaine Gottschall through her lay book *Breaking the Vicious Cycle* after her daughter was reportedly cured of UC using the SCD.[46] The SCD is also promoted in the lay literature to manage other diseases, including celiac disease, constipation, hyperactivity, night terrors, and autism.[46]

The underlying theory of the SCD is that disaccharide and polysaccharide carbohydrates are poorly absorbed in the human intestinal tract, resulting in bacterial and yeast overgrowth and subsequent overproduction of mucus. These effects are hypothesized to result in small bowel injury thus perpetuating the cycle of carbohydrate malabsorption and intestinal injury.[46] Strict adherence to the diet is recommended, because any exposure to restricted carbohydrates is hypothesized to worsen bacterial overgrowth and exacerbate mucosal damage. There are significant variations in diet recommendations within the community of SCD and related diets. Although not as restrictive as the SCD, the gluten-free diet has also been advocated by some patients to treat IBD. For the purposes of this review, we focus on the specific recommendations as described in *Breaking the Vicious Cycle*.[46]

Dietary Restrictions and Allowances on the Specific Carbohydrate diet. The SCD restricts all but simple carbohydrates ( ). The only carbohydrates permitted are monosaccharides: glucose, fructose, and galactose. Fresh fruits and vegetables are universally acceptable with the exception of potatoes and yams. Certain legumes (ie, lentils, split pea) are permitted; however, others (ie, chickpeas, soybeans) are not. No grains are permitted in the SCD. Saccharin and honey are permitted in addition to moderate use of sorbitol and xylitol. Canned fruits and vegetables are not permitted because of possible added sugars and starches.

Table 2. Examples of Included and Restricted Foods in Diet Therapies for IBD

	SCD		Paleolithic diet		FODMAP		Chiba et al[43]	
Food group	**Include**	**Avoid**	**Include**	**Avoid**	**Include**	**Avoid**	**Include**	**Avoid**
Fruits	All	None	All	None	Bananas	Apples	All	None
					Blueberries	Apricots		
					Grapefruit	Cherries		
					Honeydew	Pears		
						Watermelon		
Vegetables	Most	Potatoes	All	Potatoes[a]	Carrots	Brussel sprouts	All	None
		Yams		Legumes[a]	Celery	Cabbage	Legumes	
		Legumes			Corn	Legumes	Potatoes	
		Canned vegetables			Eggplant	Onions	Miso	
		Seaweed			Lettuce	Artichokes		
Protein	Nuts	Processed meats	Game meats	Domesticated meats	All	None	Eggs	Meat (a)
	Fresh meats		Fish					Fish (b)
			Nuts					
Fiber		Cereal grains		Cereal grains	Rice	Wheat	White rice	
		Quinoa			Oats	Rye	Brown rice	
Beverages/dairy	Wine	Milk		All dairy	Hard cheese	Milk	Milk	
		Instant tea		Yogurt		Yogurt	Yogurt	
		Instant coffee		Soft drinks		Ice cream	Green tea	
		Soybean milk		Beer		Soft cheese		
		Beer		Fruit juices				
Other	Honey	Chocolate	Honey[a]	Refined sugar	Maple syrup	Sweeteners		
	Butter	Corn syrup				Honey		
		Margarine				HFCS		

a, allowed once every 2 weeks; b, allowed once a week; HFCS, high fructose corn syrup.

[a]Disputed.

Unprocessed meats are permitted in the SCD without limitation. However, processed, canned, and most smoked meats are restricted because of possible sugars and starches used in additives. Milk is not permitted in the SCD because of lactose content. However, certain lactose-free cheeses are permitted as is homemade lactose-free yogurt.

FODMAP Diet

The underlying mechanistic theory of the FODMAP diet overlaps with the SCD; poorly absorbed carbohydrates result in bacterial overgrowth.[50] The FODMAP diet has been studied primarily for irritable bowel syndrome and functional gastrointestinal disorders. However, despite the similar mechanistic theories, the SCD and FODMAP diets are diametrically opposed when it comes to honey and many fruits and vegetables ( ).[50] Although they are similar in the restrictions of cereal grains and unrestricted meat, the FODMAP diet is highly restrictive on certain fruit and vegetable intake, whereas the SCD has unrestricted fruit and vegetable intake except for potatoes and yams.

Table 2. Examples of Included and Restricted Foods in Diet Therapies for IBD

	SCD		Paleolithic diet		FODMAP		Chiba et al[43]	
Food group	**Include**	**Avoid**	**Include**	**Avoid**	**Include**	**Avoid**	**Include**	**Avoid**
Fruits	All	None	All	None	Bananas	Apples	All	None
					Blueberries	Apricots		
					Grapefruit	Cherries		
					Honeydew	Pears		
						Watermelon		
Vegetables	Most	Potatoes	All	Potatoes[a]	Carrots	Brussel sprouts	All	None
		Yams		Legumes[a]	Celery	Cabbage	Legumes	
		Legumes			Corn	Legumes	Potatoes	
		Canned vegetables			Eggplant	Onions	Miso	
		Seaweed			Lettuce	Artichokes		
Protein	Nuts	Processed meats	Game meats	Domesticated meats	All	None	Eggs	Meat (a)
	Fresh meats		Fish					Fish (b)
			Nuts					
Fiber		Cereal grains		Cereal grains	Rice	Wheat	White rice	
		Quinoa			Oats	Rye	Brown rice	
Beverages/dairy	Wine	Milk		All dairy	Hard cheese	Milk	Milk	
		Instant tea		Yogurt		Yogurt	Yogurt	
		Instant coffee		Soft drinks		Ice cream	Green tea	
		Soybean milk		Beer		Soft cheese		
		Beer		Fruit juices				
Other	Honey	Chocolate	Honey[a]	Refined sugar	Maple syrup	Sweeteners		
	Butter	Corn syrup				Honey		
		Margarine				HFCS		

a, allowed once every 2 weeks; b, allowed once a week; HFCS, high fructose corn syrup.

[a]Disputed.

Paleolithic Diet

The Paleo diet was introduced by Dr. Walter L. Voegtlin, a gastroenterologist, who published a lay book titled *Stone Age Diet: Based on In-Depth Studies on Human Ecology and the Diet of Man*.[49] A scientific review of the Paleo diet was published in the *New England Journal of Medicine* in 1995 further describing the evolutionary rationale for the Paleo diet and contrasting it with the modern diet.[47] The underlying hypothesis behind the Paleo diet is that the human digestive tract is poorly evolved to handle the modern diet that resulted from development of modern agricultural methods. It is hypothesized that exposure of the human digestive tract to foods that were not present at the time of human evolution may result in modern diseases. Because the primary principle behind the Paleo diet is based on assumptions of evolutionary biology, there is no mechanistic theory as to the effect of diet on intestinal inflammation specifically. The lack of mechanistic theory has also led to great variations in the recommended foods and restrictions. There are multiple variations of the Paleo diet published in the lay literature, including the Caveman, Stone-Age, and Hunter-gatherer diets.

Dietary Allowances and Restrictions on the Paleo Diet. The Paleo diet emphasizes intake of lean, nondomesticated (game) meats and noncereal plant-based foods (ie, fruits, roots, legumes, and nuts).[47] The Paleo diet is not as prescriptive as the SCD regarding food types but rather focuses on the source and balance of caloric intake. Lean protein is recommended to be the source of 30%–35% of daily caloric intake. The balance of subtypes of polyunsaturated fatty acids (PUFAs), n-6 and n-3, are recommended to be as low as 2:1, in contrast to estimates of the modern diet ratio of upward of 11:1. Consumption of lean protein from nondomesticated meat is recommended to reach recommended PUFA ratios. The Paleo diet hypothesizes that domesticated livestock raised on grain-based feed has unfavorable fat composition and should be avoided. In addition to lean nondomesticated meats, the Paleo diet advocates a very-high-fiber diet from noncereal-based plant sources, up to 45–100 g/day.[47] There is debate in the Paleo diet community regarding the acceptability of potatoes and legumes in the Paleo diet.

Scientific Evidence Regarding Defined Diets for Inflammatory Bowel Disease

There are no formal published studies on the benefits of either the SCD or Paleo diets in the management or prevention of IBD. Only a few small pilot studies have evaluated the FODMAP diet in patients with IBD. Both the SCD and FODMAP diets purport that carbohydrates lead to bacterial overgrowth. Detecting bacterial overgrowth (ie, an increase in the abundance of bacteria) is difficult and standard tests are fraught with misclassification. Furthermore, dietary composition is correlated with the composition of the gut microbiome as measured in terms of relative abundance. For example, Wu and coworkers[18] demonstrated that consumption of carbohydrates was positively correlated with the relative abundance of most but not all firmicutes within human feces. Similarly, Hoffmann and coworkers[51] found that consumption of carbohydrates is positively correlated with the proportional abundance of *Candida* and the methanogen Archaea *Methanobrevibacter*. The link between diet and abundance of certain bacteria, yeast, and Archaea is complex but may represent a syntrophic relationship.[51] For example, *Candida* may use starch, liberating simple carbohydrates that are used by bacteria, such as *Prevotella* and *Ruminococcus*, which in turn produce substrates for fermentation that can be used by *Methanobrevibacter* to produce CH_4 and or CO_2.

How bacterial overgrowth may result in intestinal inflammation is unclear. The SCD postulates that bacterial overgrowth results in fermentation and subsequent production of short-chain organic acids that are injurious to the small intestinal mucosa. However, *Breaking the Viscous Cycle* references only case studies on systemic D-lactic acidosis, not mucosal concentrations of organic acids or mucosal injury.[52–54] The FODMAP authors hypothesize bacterial overgrowth may result in increased intestinal permeability, which has been associated with the pathogenesis of CD.[55,56]

There have been two small pilot studies evaluating the FODMAP diet in IBD.[57,58] The first was performed in 8 patients with UC who had undergone colectomy. Median stool frequency per day dropped from 8 to 4 ($P = .02$) after initiation of the low-FODMAP diet in the retrospective analyses; however, no benefit was observed in 5 patients who were studied prospectively.[58] In the second study, 72 patients with IBD were retrospectively evaluated after education regarding a low-FODMAP diet. Based on self-report, 70% of patients remained adherent on the diet after 3 months, and symptoms of pain, bloating, and diarrhea improved among those adherent to the diet ($P < .02$).[57] These limited retrospective studies are supportive of dietary interventions to improve IBD symptoms but may be biased because of their retrospective nature and lack of objective data regarding inflammatory changes associated with dietary intervention. Symptomatic response in patients with IBD to these dietary interventions may also suggest a component of functional gastrointestinal symptoms or nonceliac gluten intolerance.

The existing data on dietary risk factors are not clear regarding the role of carbohydrates in the development of IBD. A systematic review of dietary risk factors for IBD included 5 studies reporting the association of carbohydrate intake and risk of developing IBD showing conflicting results.[59] The two most recent and largest cohort studies showed no association

between carbohydrate intake and UC risk.[12,60] None of the included studies specifically differentiated monosaccharides from other carbohydrates, which could limit its applicability to SCD recommendations. However, the existing data do not strongly support the role of carbohydrates in the development of IBD or in perpetuating intestinal inflammation.

The carbohydrate malabsorption/bacterial overgrowth theory does not incorporate observations of increased risks of IBD associated with high protein or high fats. As discussed previously, Chiba and coworkers[43] demonstrated a reduction in disease relapse for patients with CD on a semivegetarian diet compared with a control omnivorous diet. The semivegetarian diet included brown rice, soybeans, seaweed, yam, potato, onion, and corn, foods restricted by both the SCD and FODMAP diets. In a prospective cohort study, Jantchou and coworkers[60] observed a positive association of high animal protein intake with the development of IBD (hazard ratio, 3.01; 95% confidence interval, 1.45–6.34). Similarly, high-fat diets have been associated with an increased risk of development of both CD and UC.[4,13,14,61] Although therapeutic trials of omega-3 PUFA to treat IBD have not proved successful, there are signals that the balance of omega-6:omega-3 PUFA may affect IBD risk.[13,44] The concept of balance between PUFA does correspond conceptually with the Paleo diet; however, means to assess ratios of PUFA in a practical manner in the modern diet are challenging.

Both the SCD and Paleo diets advocate a high-fiber diet but restrict cereal grain–based fiber. Fermentation of dietary fiber in the colon produces short-chain fatty acids, which act as an energy source for colonocytes, modulate the local immune response (attenuate interleukin-6, interleukin-8, and tumor necrosis factor-α), and modify the intestinal microbial flora.[62] Interventions using grain-based fiber have demonstrated potential therapeutic benefits in UC. Hallert and coworkers[63] performed a pilot study of 22 patients with UC in remission, demonstrating that an increase of dietary fiber intake of 60 g of oat bran daily can increase fecal butyrate levels by 36% without an exacerbation in symptoms. Kanauchi and coworkers[64] performed an open-label control trial of 18 patients with mild-to-moderate UC, treated with 20–30 g/day of germinated barley foodstuff. An improvement of bowel-related symptoms benefit was observed ($P < .05$) in the germinated barley foodstuff-treated group as were increased fecal concentrations of *Bifidobacterium* and *Eubaterium limosum*. In contrast to the SCD and Paleo diets, these data suggest that inclusion of cereal-based grains may be beneficial to patients with UC in particular. Further study of the role of cereal grain and noncereal grain based fiber in IBD is required.

Both the SCD and Paleo diets have the potential to contribute to vitamin D deficiency. This is a particular concern given the association of vitamin D deficiency and increased risk of surgery and hospitalization.[65] In patients expressing interest in either of these diets, assessment of vitamin D status may be important.

Putting It All Together: What to Tell Patients?

Patients with IBD have a strong interest in dietary modifications as part of a holistic approach to manage their disease. There is scientific evidence that dietary factors may influence both the risk of developing IBD and intestinal mucosal inflammation. However, there is a lack of large prospective controlled trials to provide the dietary recommendations patients desire. Taken together, studies of exclusive enteral nutrition, exclusion diets, and semivegetarian diets suggest that minimizing exposure of the intestinal lumen to selected food items may prolong the remission state of patients with IBD.[35] Even less evidence exists for the efficacy of the SCD, FODMAP, or Paleo diets. Furthermore, the practicality of maintaining these interventions over long periods of time is doubtful. At a practical level, adherence to defined diets may result in an unnecessary financial burden or reduction in overall caloric intake in patients who are already at risk for protein–calorie malnutrition.

Many patient-targeted dietary recommendations from the Internet and defined diets parallel those of irritable bowel syndrome and functional gastrointestinal disorders. Although the existing data do not support these recommendations as a means of reduction of intestinal mucosal inflammation, the anecdotal response reported by patients to these dietary restrictions may highlight a functional component of gastrointestinal symptoms among patients with IBD. There is a growing body of evidence of nonceliac gluten intolerance, which may also be addressed with these dietary restrictions. Avoidance of these foods is likely of little danger and could potentially improve gastrointestinal symptoms. Patients with IBD describe the ability to identify foods that can exacerbate their symptoms.[66] However, essentially all food groups (fruits, vegetables, meats, and grains) have been noted by patient self-report to exacerbate symptoms and do not provide generalizable information for other patients with IBD. Rather, patients may be instructed to be aware of their diet through food diaries and their symptoms and make modifications specific to the individual patient. This personalized approach may identify specific triggers to their symptoms and also empower patients with a sense of control over their symptoms. Further controlled studies are necessary to make stronger recommendations on the role of diet and IBD course.

References

1. Appleyard CB, Hernández G, Rios-Bedoya CF. Basic epidemiology of inflammatory bowel disease in Puerto Rico. Inflamm Bowel Dis 2004;10:106–111.
2. Yang SK, Yun S, Kim JH, et al. Epidemiology of inflammatory bowel disease in the Songpa-Kangdong district, Seoul, Korea, 1986–2005: a KASID study. Inflamm Bowel Dis 2008;14:542–549.
3. Hou J, El-Serag H, Thirumurthi S. Distribution and manifestations of inflammatory bowel disease in Asians, Hispanics, and African Americans: a systematic review. Am J Gastroenterol 2009;104:2100–2109.
4. Amre DK, D'Souza S, Morgan K, et al. Imbalances in dietary consumption of fatty acids, vegetables, and fruits are associated with risk for Crohn's disease in children. Am J Gastroenterol 2007;102:2016–2025.
5. Chapman-Kiddell CA, Davies PS, Gillen L, et al. Role of diet in the development of inflammatory bowel disease. Inflamm Bowel Dis 2010;16:137–151.
6. Miller B, Fervers F, Rohbeck R, et al. [Sugar consumption in patients with Crohn's disease]. Verh Dtsch Ges Inn Med 1976;82(Pt 1):922–924.
7. James AH. Breakfast and Crohn's disease. Br Med J 1978;2:1715–1716.
8. James AH. Breakfast and Crohn's disease. Br Med J 1977;1:943–945.
9. Mayberry JF, Rhodes J, Newcombe RG. Increased sugar consumption in Crohn's disease. Digestion 1980;20:323–326.
10. Sonnenberg A. Geographic and temporal variations of sugar and margarine consumption in relation to Crohn's disease. Digestion 1988;41:161–171.
11. Shoda R, Matsueda K, Yamato S, et al. Epidemiologic analysis of Crohn disease in Japan: increased dietary intake of n-6 polyunsaturated fatty acids and animal protein relates to the increased incidence of Crohn disease in Japan. Am J Clin Nutr 1996;63:741–745.
12. Hart AR, Luben R, Olsen A, et al. Diet in the aetiology of ulcerative colitis: a European prospective cohort study. Digestion 2008;77:57–64.
13. John S, Luben R, Shrestha SS, et al. Dietary n-3 polyunsaturated fatty acids and the aetiology of ulcerative colitis: a UK prospective cohort study. Eur J Gastroenterol Hepatol 2010;22:602–606.
14. Ananthakrishnan AN, Khalili H, Konijeti GG, et al. Long-term intake of dietary fat and risk of ulcerative colitis and Crohn's disease. Gut 2014;63:776–778.
15. Ananthakrishnan AN, Khalili H, Konijeti GG, et al. A prospective study of long-term intake of dietary fiber and risk of Crohn's disease and ulcerative colitis. Gastroenterology 2013;145:970–977.
16. Rutgeerts P, Goboes K, Peeters M, et al. Effect of faecal stream diversion on recurrence of Crohn's disease in the neoterminal ileum. Lancet 1991;338:771–774.
17. D'Haens GR, Geboes K, Peeters M, et al. Early lesions of recurrent Crohn's disease caused by infusion of intestinal contents in excluded ileum. Gastroenterology 1998;114:262–267.
18. Wu GD, Chen J, Hoffmann C, et al. Linking long-term dietary patterns with gut microbial enterotypes. Science 2011;334:105–108.
19. De Filippo C, Cavalieri D, Di Paola M, et al. Impact of diet in shaping gut microbiota revealed by a comparative study in children from Europe and rural Africa. Proc Natl Acad Sci U S A 2010;107:14691–14696.
20. Flint HJ, Bayer EA, Rincon MT, et al. Polysaccharide utilization by gut bacteria: potential for new insights from genomic analysis. Nat Rev Microbiol 2008;6:121–131.
21. Scheppach W, Weiler F. The butyrate story: old wine in new bottles? Curr Opin Clin Nutr Metab Care 2004;7:563–567.
22. Cani PD, Possemiers S, Van de Wiele T, et al. Changes in gu microbiota control inflammation in obese mice through a mechanism involving GLP-2-driven improvement of gut permeability. Gut 2009;58:1091–1103.
23. Ma X, Torbenson M, Hamad AR, et al. High-fat diet modulates non-CD1d-restricted natural killer T cells and regulatory T cells in mouse colon and exacerbates experimental colitis. Clin Exp Immunol 2008;151:130–138.
24. Devkota S, Wang Y, Musch MW, et al. Dietary-fat-induced taurocholic acid promotes pathobiont expansion and colitis in Il10-/- mice. Nature 2012;487:104–108.
25. Sartor RB. Gut microbiota: diet promotes dysbiosis and colitis in susceptible hosts. Nat Rev Gastroenterol Hepatol 2012;9:561–562.
26. Magee EA, Richardson CJ, Hughes R, et al. Contribution of dietary protein to sulfide production in the large intestine: an in vitro and a controlled feeding study in humans. Am J Clin Nutr 2000;72:1488–1494.
27. Pitcher MC, Cummings JH. Hydrogen sulphide: a bacterial toxin in ulcerative colitis? Gut 1996;39:1–4.
28. Coffey JC, Docherty NG, O'Connell PR. Hydrogen sulphide: an increasing need for scientific equipoise. Gastroenterology 2009;137:2181–2182; author reply 2.
29. Wallace JL, Vong L, McKnight W, et al. Endogenous and exogenous hydrogen sulfide promotes resolution of colitis in rats. Gastroenterology 2009;137:569–578.
30. Fiorucci S, Orlandi S, Mencarelli A, et al. Enhanced activity of a hydrogen sulphide-releasing derivative of mesalamine (ATB-429) in a mouse model of colitis. Br J Pharmacol 2007;150:996–1002.
31. Jowett SL, Seal CJ, Pearce MS, et al. Influence of dietary factors on the clinical course of ulcerative colitis: a prospective cohort study [see comment]. Gut 2004;53:1479–1484.
32. Magee EA, Edmond LM, Tasker SM, et al. Associations between diet and disease activity in ulcerative colitis patients using a novel method of data analysis. Nutr J 2005;4:7.
33. Sandhu BK, Fell JM, Beattie RM, et al. Guidelines for the management of inflammatory bowel disease in children in the United Kingdom. J Pediatr Gastroenterol Nutr 2010;50 Suppl 1:S1–13.
34. Caprilli R, Gassull MA, Escher JC, et al. European evidence based consensus on the diagnosis and management of Crohn's disease: special situations. Gut 2006;55(Suppl. 1):36–58.
35. Borrelli O, Cordischi L, Cirulli M, et al. Polymeric diet alone versus corticosteroids in the treatment of active pediatric Crohn's disease: a randomized controlled open-label trial. Clin Gastroenterol Hepatol 2006;4:744–753.

36. Zachos M, Tondeur M, Griffiths AM. Enteral nutritional therapy for induction of remission in Crohn's disease. Cochrane Database Syst Rev 2007;24(1):CD000542.
37. Takagi S, Utsunomiya K, Kuriyama S, et al. Effectiveness of an 'half elemental diet' as maintenance therapy for Crohn's disease: a randomized-controlled trial. Aliment Pharmacol Ther 2006;24:1333–1340.
38. Lochs H, Dejong C, Hammarqvist F, et al. ESPEN Guidelines on Enteral Nutrition: Gastroenterology. Clin Nutr 2006;25:260–274.
39. Riordan AM, Hunter JO, Cowan RE, et al. Treatment of active Crohn's disease by exclusion diet: East Anglian multicentre controlled trial. Lancet 1993;342:1131–1134.
40. Bartel G, Weiss I, Turetschek K, et al. Ingested matter affects intestinal lesions in Crohn's disease. Inflamm Bowel Dis 2008;14:374–382.
41. Jones VA, Dickinson RJ, Workman E, et al. Crohn's disease: maintenance of remission by diet. Lancet 1985;2:177–180.
42. Rajendran N, Kumar D. Food-specific IgG4-guided exclusion diets improve symptoms in Crohn's disease: a pilot study. Colorectal Dis 2011;13:1009–1013.
43. Chiba M, Abe T, Tsuda H, et al. Lifestyle-related disease in Crohn's disease: relapse prevention by a semi-vegetarian diet. World J Gastroenterol 2010;16:2484–2495.
44. Feagan BG, Sandborn WJ, Mittmann U, et al. Omega-3 free fatty acids for the maintenance of remission in Crohn disease: the EPIC Randomized Controlled Trials. JAMA 2008;299:1690–1697.
45. Ritchie JK, Wadsworth J, Lennard-Jones JE, et al. Controlled multicentre therapeutic trial of an unrefined carbohydrate, fibre rich diet in Crohn's disease. Br Med J (Clin Res Ed) 1987;295:517–520.
46. Gottschall E. Breaking the vicious cycle: intestinal health through diet. Baltimore: Kirkton, 2012.
47. Eaton SB, Konner M. Paleolithic nutrition. A consideration of its nature and current implications. N Engl J Med 1985;31:283–289.
48. Haas SV, Haas MP. The treatment of celiac disease with the specific carbohydrate diet; report on 191 additional cases. Am J Gastroenterol 1955;23:344–360.
49. Voegtlin W. Stone Age diet: based on in-depth studies on human ecology and the diet of man. New York: Vantage Press, 1975.
50. Gibson PR, Shepherd SJ. Personal view: food for thought– western lifestyle and susceptibility to Crohn's disease. The FODMAP hypothesis. Aliment Pharmacol Ther 2005;21:1399–1409.
51. Hoffmann C, Dollive S, Grunberg S, et al. Archaea and fungi of the human gut microbiome: correlations with diet and bacterial residents. PLoS One 2013;8:e66019.
52. Stolberg L, Rolfe R, Gitlin N, et al. S. d-Lactic acidosis due to abnormal gut flora: diagnosis and treatment of two cases. N Engl J Med 1982;306:1344–1348.
53. Traube M, Bock JL, Boyer JL. D-Lactic acidosis after jejunoileal bypass: identification of organic anions by nuclear magnetic resonance spectroscopy. Ann Intern Med 1983;98:171–173.
54. Oh MS, Phelps KR, Traube M, et al. D-lactic acidosis in a man with the short-bowel syndrome. N Engl J Med 1979;301:249–252.
55. Teshima CW, Dieleman LA, Meddings JB. Abnormal intestinal permeability in Crohn's disease pathogenesis. Ann N Y Acad Sci 2012;1258:159–165.
56. Hollander D, Vadheim CM, Brettholz E, et al. Increased intestinal permeability in patients with Crohn's disease and their relatives. A possible etiologic factor. Ann Intern Med 1986;105:883–885.
57. Gearry RB, Irving PM, Barrett JS, et al. Reduction of dietary poorly absorbed short-chain carbohydrates (FODMAPs) improves abdominal symptoms in patients with inflammatory bowel disease-a pilot study. J Crohns Colitis 2009;3:8–14.
58. Croagh C, Shepherd SJ, Berryman M, et al. Pilot study on the effect of reducing dietary FODMAP intake on bowel function in patients without a colon. Inflamm Bowel Dis 2007;13:1522–1528.
59. Hou JK, Abraham B, El-Serag H. Dietary intake and risk of developing inflammatory bowel disease: a systematic review of the literature. Am J Gastroenterol 2011;106:563–573.
60. Jantchou P, Morois S, Clavel-Chapelon F, et al. Animal protein intake and risk of inflammatory bowel disease: The E3N prospective study. Am J Gastroenterol 2010;105:2195–2201.
61. Sakamoto N, Kono S, Wakai K, et al. Dietary risk factors for inflammatory bowel disease: a multicenter case-control study in Japan. Inflamm Bowel Dis 2005;11:154–163.
62. Galvez J, Rodríguez-Cabezas ME, Zarzuelo A. Effects of dietary fiber on inflammatory bowel disease. Mol Nutr Food Res 2005;49:601–608.
63. Hallert C, Björck I, Nyman M, et al. Increasing fecal butyrate in ulcerative colitis patients by diet: controlled pilot study. Inflamm Bowel Dis 2003;9:116–121.
64. Kanauchi O, Suga T, Tochihara M, et al. Treatment of ulcerative colitis by feeding with germinated barley foodstuff: first report of a multicenter open control trial. J Gastroenterol 2002;37(Suppl. 14):67–72.
65. Ananthakrishnan AN, Cagan A, Gainer VS, et al. Normalization of plasma 25-hydroxy vitamin D is associated with reduced risk of surgery in Crohn's disease. Inflamm Bowel Dis 2013;19:1921–1927.
66. Cohen AB, Lee D, Long MD, et al. Dietary patterns and self-reported associations of diet with symptoms of inflammatory bowel disease. Dig Dis Sci 2013;58:1322–1328.

Clin Gastroenterol Hepatol. 2014;12(10):1592-1600.