Gastrointestinal Tract Changes in the Malnourished Child

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Malnutrition may be considered as an effect and a cause of underdevelopment (1). The environment in which children become malnourished includes adverse factors that compromise their health, such as heavy microbiological contamination of the environment, unfavorable social and economic conditions, etc., all of which result in a more effective operation of the fecal–oral cycle (2). It is important to keep this concept in mind, because it is likely that the studies of the morphologic and functional changes of the small intestine of malnourished children may have been performed in subjects in whom current or recent enteral or systemic infections of variable severity and duration have been present. Repeated enteral infection and the continuous passage of microorganisms along the gastrointestinal tract lead to changes of gut structure and function, "chronic environmental enteropathy," that persist as long as the individual lives in the unfavorable environment and take months to improve after moving to a clean environment (3,4). Chronic environmental enteropathy is a well-known condition among adults living in the less developed countries, where it probably starts very early in life. In fact, passage of enteropathogens begins shortly after delivery, even if the infant lives under what may be considered as the best socioeconomic conditions for that country. When feces of 225 Chilean newborns were repeatedly cultured during the first week of life, 21% of the children excreted an enteropathogen, and this was independent of their socioeconomic status (5).

The gastrointestinal tract has many characteristics that make it particularly susceptible to the effect of nutrient deprivation: it is lined by highly differentiated epithelial cells, which have a high turnover rate (6), it handles large volumes of fluids and nutrients, and it must act as a barrier against foreign molecules (7). It also maintains a very complex equilibrium with the resident flora (8). Malnutrition affects all these characteristics at the local and systemic levels, and this explains the derangements of gastrointestinal function that have been described for many years.
ESOPHAGEAL FUNCTION

There are no systemic studies of esophageal function in human malnutrition. However, it can be assumed that the mass of the esophageal musculature is reduced, as is that of the rest of the gastrointestinal tract (9). Little is known about the function of the lower esophageal sphincter in malnutrition. It is possible that this is altered for a variety of reasons, ranging from alterations in nerve conduction (10) to disturbances in the concentration and metabolism of neurotransmitters (11).

GASTRIC FUNCTION

Gastric function has been evaluated in malnourished Indonesian children by Gracey and co-workers (12). Fundal mucosa obtained by peroral biopsy from nine of Gracey's patients revealed mild to moderate inflammatory changes. Basal, maximal, and peak acid outputs were reduced compared with controls. Mean serum gastrin levels were also reduced. It may be postulated that in addition to altered hormone levels, there could be a reduction in the number of receptors to hormones, a phenomenon that has been demonstrated in other tissues in malnourished animals (13). Acid secretion is an important factor in the control of the bacteria that gain access to the gastric lumen with foodstuffs (14,15). The hypochlorhydria of malnutrition may be one of the reasons for the increased bacterial counts detected in the upper segments of the small intestine (16) and for the greater susceptibility of these patients to acute diarrhea (17). Furthermore, gastric secretions play an important role in the denaturation and hydrolysis of food antigens (18,19). Increased levels of circulating bovine albumin have been reported (18) in individuals suffering from achlorhydria. Knowledge about gastric emptying in malnourished infants is scant, limited mostly to clinical observations showing that severe cases tend to present gastric dilatation, slow emptying, and a tendency to vomit.

SMALL INTESTINAL FUNCTION

It was recognized many years ago that the wall of the small intestine of malnourished children is very thin (20). This is probably due to the thinning of the muscular layers and to depletion of the other wall tissues. Observations in animals show that the small intestine loses more weight than any other organ during restriction of protein and energy intake (21,22).

With the advent of devices enabling peroral biopsies to be obtained, studies of intestinal mucosal histology were started. Stanfield and co-workers (23) investigated East African infants with kwashiorkor. In the majority of these children, the mucosa was severely altered, either flat or with thick, short villi, reminiscent of the changes observed in celiac disease. Follow-up studies for up to 1 year did not reveal significant improvement of mucosal architecture. They postulated that these findings were a consequence of the long periods during which the patients had been on low-protein diets. By contrast, histologic changes in the patients studied by Burman (24) were
relatively minor and not sufficient to account for the steatorrhea that was frequently found. The controversy about the magnitude of the histologic damage in malnutrition has not been solved, some authors stating that the mucosa is severely altered and others that it is only mildly affected (23–29). A probable explanation for this discrepancy may be the different quality of the diets. Other factors may be the magnitude of the microbiological contamination of the environment and the ease with which microorganisms may gain access to the intestinal lumen in the areas from which the patients originated.

We compared the mucosal histology in patients with marasmus and kwashiorkor and showed that it was more severely altered in the latter, in whom the majority of changes resembled those of celiac disease (Figs. 1 and 2). This is in agreement with

FIG. 1. Low magnification of jejunal biopsy in child with kwashiorkor. The surface is flat, and crypts reach up to the surface. There is increased cellularity of the lamina propria. There are some goblet cells in the surface epithelium. Hematoxylin-eosin stain. ×160.

FIG. 2. Abnormal surface epithelium in patient with kwashiorkor. There is a slightly irregular disposition of the nuclei of epithelial cells, with many lymphocytes interspersed. The basement membrane appears normal. Increased cellularity of the lamina propria is evident. Hematoxylin-eosin stain, ×400.
the description by Stanfield. These patients improved considerably after about a month on a diet containing gluten: They gained weight and grew, and the signs of vitamin deficiencies disappeared rapidly. The jejunal mucosa of marasmic infants looked nearly normal under light microscopy but was thinner and had lower mitotic counts (Figs. 3 and 4). Marasmic children who had already begun to gain weight at a satisfactory rate had mitotic counts that were intermediate between the controls and those cases in whom weight gain had not yet started. This decreased renewal

FIG. 3. Low magnification of jejunal mucosa in marasmus. Mucosal architecture is well-preserved. Hematoxylin-eosin stain, ×160.

FIG. 4. Surface epithelium in upper third of a villus of a marasmic patient. The brush border is quite evident, with some sparseness of the microvilli. Nuclei have a regular disposition, and the basement membrane is normal. There are a few intraepithelial lymphocytes. Hematoxylin-eosin stain, ×1400.
rate probably explains some of the functional derangements described in this type of patient, such as decreased absorption of fat and D-xylose and low disaccharidase levels (30). It is worth emphasizing that at the time of the biopsy, our patients were free of evidence of enteral infection or other intercurrent disease and that their marasmus was considered to be due to low food intake resulting from adverse socioeconomic and cultural conditions.

Fine structural changes in the enterocytes affect three main parts of the cell: (a) the brush-border area, (b) the rest of the cytoplasm, and (c) the junction area where the epithelium and the lamina propria meet. Morphologic changes, consisting of shortening, branching, and sparsity of the microvilli, were present in many but not all of the mature cells. These alterations may represent the effect of nutrient restriction on the morphogenesis of the brush border in the cells of the crypts of Lieberkühn (31), which, because they are undergoing repeated mitosis and differentiation, are vulnerable to nutrient deprivation. Similar changes have been shown to appear under the effect of a variety of physical and chemical agents, including inhibitors of protein synthesis (32), and in various pathologic conditions (33–38). For this reason, they cannot be considered as specific to malnutrition. The most outstanding finding in the cytoplasm of the mature absorptive cells in human marasmus is the presence of large bodies of up to 1 to 2 μm in diameter, which are visible under the light microscope. It is possible to follow their transition from autophagosomes that contain recognizable organelles to somewhat smaller, more compact, dense residual bodies (29). The appearance of autophagocytosis is associated with starvation in other organs and tissues, as well as with involution and cell injury from various causes (39–41). It is remarkable that other organelles in the absorptive cell appear morphologically normal. Thus the Golgi apparatus contains very low density lipoprotein (VLDL) particles, and the mitochondria and the endoplasmic reticulum are normal. Mitochondria became enlarged and packed with cristae during nutritional rehabilitation. Perhaps this is a sign of subclinical nutrient deficiency, which becomes more evident as growth resumes (42). Beneath the basal lamella there may be deposits of collagen fibers, of dense, finely fibrillar material, and some fat droplets (29). Comparable changes have been described in other forms of the malabsorption syndrome and in other organs in conditions in which immune reactions occur close to epithelia (33,35,36,43). According to Martins-Campos et al. (27), the decreased numbers of plasma cells in the lamina propria of marasmic infants are a morphologic demonstration of a lack of stimulation or response to stimuli. This may be considered as further evidence of the impaired immune function observed in these patients.

In children with kwashiorkor, the fine structural changes as described by Theron and co-workers (44) consist mainly of the accumulation of fat in the endoplasmic reticulum, the Golgi apparatus, the intercellular spaces of the epithelium, and the lamina propria. In some patients, fat was observed in the cytoplasm, with very little present in the Golgi apparatus or farther down the morphologic absorption pathway for triglycerides. Theron et al. (44) postulated that these findings may be the result of derangement of VLDL metabolism, which is considered to be one of the main
causes of the disturbances of fat transport, including the appearance of fatty liver, in kwashiorkor (45). In the cases studied by Shiner et al. (46), damage to the epithelial cells was shown by shortening of the microvilli, round mitochondria, increase in polyribosomes, presence of lysosome-like bodies, and sparseness of the basal lamella. These changes were reversed by adequate refeeding. Some of these changes were also seen in Colombian patients studied by Duque et al. (47). This sparseness of the basal lamella was one of the few obvious changes detected by us in protein-malnourished piglets (Fig. 5) (48). It is possible to speculate that the lesions observed in kwashiorkor may be explained by protein depletion, leading to severe derangements of cell metabolism, while in marasmus many of the disturbances may be ascribed to altered cell renewal, resulting in slower and incomplete repair of mucosal injury and in a decrease of the activity of some enzymes. A reduced mitotic rate may also represent a way of reducing energy expenditure when the supply is limited. This would allow infants to adapt to these lower energy intakes and increase their chances of survival.

It has been known for a long time that children with kwashiorkor excrete increased amounts of fat and nitrogen in the feces (49–51). This has been shown in many parts of the world. It is important to keep in mind, however, that in the genesis of these abnormal nutrient losses, there may be many intervening factors such as altered pancreatic secretion (52,53), bile salt deconjugation (54), the presence of diarrhea, and an abnormal resident flora (55–58). In severe nutrient deprivation, intestinal cell desquamation is reduced, and this may modulate fecal nitrogen losses to some extent (21,59,60). During refeeding, the excessive losses of both fat and protein decrease toward normal values (50–54). Malabsorption associated with malnutrition does not impede the recovery of the patients when adequate amounts of protein and energy are provided in the diet.

FIG. 5. Base of jejunal epithelial cell of piglet with severe kwashiorkor. Basal lamella and its underlying area lack density, and some breaches are present. Uranyl magnesium acetate-lead citrate stain. ×16,000.
The activity of brush-border enzymes has been described as generally depressed in malnourished children. As shown by Römer et al. (61), there was a direct correlation between the severity of the malnutrition and the magnitude of the decrease in the activity of lactase, sucrase, and maltase. This did not correlate with the severity of the histologic changes. Part of this decrease in enzymatic activity may be explained by the presence of episodes of diarrhea, either at the time the tests were done or shortly prior to them. Indeed, a few authors acknowledge that some of their patients were suffering from diarrhea, sometimes mild, when the measurements were carried out (62). Since in addition to the disaccharidase deficiency there is a decrease in the transport capacity for glucose, unabsorbed sugars will reach lower segments of the intestine where they are fermented by the flora (62). This may be another cause of acute diarrhea. Further evidence for disturbance of nutrient transport is provided by the decrease of D-xylose absorption described in these patients (30,63). While this evidence suggests that the membrane of the microvilli is altered, other physicochemical variables such as membrane fluidity point in the opposite direction (64). Dipeptidases have been shown to be decreased in malnourished infants and adults (65,66). However, it is important to keep in mind that part of this decrease may not be strictly due to malnutrition itself but to nonspecific damage to the mucosa or to lower levels of amino acid intake, as shown by Gjessing et al. (66). These authors found that the apparently healthy Colombian adults who served as controls had dipeptide hydrolase activity levels in their intestinal mucosa that were roughly half those reported in healthy Swedish controls. Essential amino acid transport has been shown to be decreased in adults suffering from nutrient deprivation (67). This is not supported by evidence obtained after biopsies from malnourished children were incubated with labeled lysine and alanine (68). For obvious reasons, results from cultured biopsies cannot be extrapolated to the whole body. However, when labeled leucine was introduced into the lumen of the jejunum of malnourished rats, a high proportion was retained by the intestinal mucosa and incorporated in the intracellular protein of absorptive cells (69,70). It has been shown that the presence of nutrients in the intestinal lumen stimulates epithelial cell turnover (71,72). These mechanisms may be of importance in the restoration of mucosal integrity during recovery from malnutrition.

Infants with kwashiorkor have a decrease in conjugated bile acids, which mainly affects the taurine conjugates (54). Increased free bile acids in the intestinal lumen exert a negative effect on the formation of the micellar solution during fat absorption and may well be one of the main causes for the steatorrhea observed in these patients (49–51). They also stimulate water secretion in the colon and thus increase the severity of diarrhea (73). In turn, the presence of diarrhea and of an abnormal resident flora considerably increases the amount of free bile acids. Patients with kwashiorkor have malabsorption of vitamins A and B\textsubscript{12} (51). The first is associated with the malabsorption of fat, while the latter has not been studied in depth.

Macromolecular transport was studied by Heyman and co-workers (74) in jejunal biopsies of malnourished children, most of whom were considered to have marasmus and only one to have kwashiorkor. Most cases had diarrhea when first studied, and celiac disease or other disorders that may lead to malnutrition were not ruled
out. The mean flux of horseradish peroxidase was much higher in the malnourished children and fell by two-thirds after nutritional rehabilitation. Degradation of the tracer within the mucosa was no different in malnourished and rehabilitated patients. Paracellular protein transport did not seem to be increased. These results are in agreement with observations in both children and experimental animals, which show that when histologic damage is present, or during experimental malnutrition, there is increased transport of peroxidase across the intestinal mucosa (75). Worthington and co-workers (76,77) showed that injection of peroxidase into the intestinal lumen of malnourished rats stimulated pinocytosis, but it remains to be clarified whether this was a nonspecific effect. We observed increased pinocytotic activity in young asymptomatic adults whose intestinal mucosa exhibited the morphologic and functional characteristics of chronic environmental enteropathy. It is possible that the patients reported by Heyman (74) may already have developed this condition (3). It is interesting to speculate whether, at least in humans, it is the presence of enteral infection or the decreased availability of nutrients that facilitates macromolecular passage across the epithelium. Chandra (78) has shown that malnourished infants have increased levels of circulating antibodies against food proteins. Similar findings have been reported in malnourished animals (79). On the other hand, it is well-known that the capacity to mount an appropriate immune response is impaired by malnutrition (80). This may be one of the reasons why malnourished children do not develop serious allergic reactions to dietary components at the time when their nutritional status is most deteriorated. Malnutrition affects not only the transport of macromolecules but also that of some smaller molecules such as lactulose and mannitol (81), which are used as tracers or indicators of transepithelial or paracellular permeability. Studies in Gambian children (81) indicate that the ratio of excretion of lactulose to that of mannitol in the urine is increased in malnutrition (1.3 in malnourished patients compared with 0.42 in controls). Despite these changes, which suggest that paracellular transport is increased, the junctional complexes between mature jejunal absorptive cells appear normal on electron microscopy (Fig. 6). Behrens et al. (81) reported that the lactulose/mannitol ratio increased in Gambian children after weaning; this finding could be interpreted as another consequence of the microbiological contamination of the milieu in which these children lived.

In summary, many factors interact in malnourished infants to explain the presence of lesions, their disturbances of absorption, and their special susceptibility to acute diarrhea. Hypochlorhydria, malabsorption, deconjugation of bile salts, disturbances of intestinal motility, and enzymatic and transport deficiencies in the absorptive epithelial cells contribute directly or indirectly to this damage. Despite all these disturbances, the intestine of malnourished children retains sufficient absorptive capacity for the repair of the mucosa and for recovery of the patient to begin soon after adequate amounts of nutrients are provided. The intestinal mucosa receives a significant proportion of its nutrition from the intestinal lumen; therefore, it is in an advantageous position to initiate the process of organ repair (82).

Knowledge about colonic histology and function in malnutrition is very limited. Redmond and co-workers (83) described prominent vascularization of the mucosa at
endoscopy, which may be interpreted as indicating that the superficial layers are thin. According to these authors, the surface epithelium is atrophic, and the mucosa is congested, with increased numbers of plasma cells and edema of the lamina propria.

In view of the availability of new techniques for the study of the morphology and physiology of the gastrointestinal tract, and the better understanding gained over the years of the relationship between nutrition and the environment, further studies on the structure and function of these organs, especially the intestinal mucosa, should be carried out in infantile malnutrition. This will help clarify the nature of the damage caused by nutrient restriction and its long-term repercussions.

REFERENCES


DISCUSSION

Dr. Jackson: You made the observation that luminal leucine is incorporated into protein within the mucosal cell. In such an experiment, is it possible to differentiate a change in leucine uptake occurring as a result of a decrease in protein synthesis from one that occurs due to a defect in the carrier mechanism for the uptake of leucine by the cell?

Dr. Brunser: I know of no detailed study that has defined the mechanism for the decreased incorporation of leucine. If $^{14}$C-leucine is injected parenterally into rats on a protein-free diet, the highest uptake occurs in the epithelium of the jejunal mucosa, followed by the colon,
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liver, striated muscle, and blood cells (1). If tritiated leucine is administered perorally, its incorporation into protein is also increased (2). Quantitatively, it does not seem to make any difference whether this amino acid is administered orally or parenterally. There is some indication that although amino acid transport across the plasma membrane of the enterocytes and their release from peptide bonds may be decreased in malnutrition, their incorporation into proteins may be normal or even increased (3,4). Evidence suggests that when amino acids are provided to protein-malnourished individuals, they are readily incorporated into cellular proteins. Enough capacity for transport and synthesis is retained in the mucosa so that when adequate amounts of amino acids are provided in the diet, recovery is initiated.

Dr. Jackson: Is there any change in either the rate of production or the quality of the mucus produced?

Dr. Brunser: Sherman et al. (5) recently studied this aspect of mucosal function in rats that had been fed decreased amounts of a balanced diet to reproduce what happens in marasmic malnutrition. The amount of immunoreactive mucin expressed per milligram mucosal protein was decreased. The same was observed when the amount of mucin was expressed in relation to mucosal DNA. The chemical composition of this glycoprotein was considered to be similar in malnourished and control animals.

Some morphologic observations suggest that a moderate decrease in the number of goblet cells may occur in protein-deprived swine (6). Our findings in pigs with kwashiorkor, however, do not support this (7). I do not know of any good studies of goblet cells in human malnutrition. In our studies on marasmic infants, the goblet cells looked normal (8). However, we need to study them using new immunocytochemical methods in order to explain changes that result in the increased susceptibility of malnourished infants to acute diarrhea.

Dr. Aggett: What about studies on the actual composition of the glycocalyx?

Dr. Brunser: The glycocalyx has a variety of appearances in normal epithelial cells. However, when the mucosa is severely damaged, the glycocalyx appears “shredded,” and of decreased density.

We have done some studies on malnourished patients, some with chronic environmental enteropathy. In marasmic infants, the glycocalyx had little density and was filamentous and sparse. There were no consistent changes in the young adults with environmental enteropathy (9).

Dr. Durie: We have shown an increased uptake of lactulose in patients with primary pancreatic insufficiency, which is reflected by its increased urinary excretion (10). I am concerned, however, about making too much of this molecule as a marker of permeability. Are you aware of any human data regarding the issue of acute viral infection in malnourished patients?

Dr. Brunser: In biopsies of small intestinal mucosa obtained from patients with viral diarrhea, viral particles are frequently seen in either the endoplasmic reticulum or enterocytes (11). However, nothing of this sort was observed in our patients.

Viral particles in different stages of assembly are also seen in experimental models (12,13). In Hamilton’s rotavirus infection in piglets, one can see the viral particles beginning to appear in the mature epithelial cells. These cells are considerably damaged (14). The same happens in other animal species (12).

We never saw this in our patients. In fact, our patients had to be free of gastrointestinal or upper-respiratory symptomatology for at least a week before the biopsy so nothing would interfere with the interpretation of the alterations we found.

Dr. Tanner: I’d like to comment on the secretory IgA response. Altorfer et al. (15) studied IgA production in rats following cholera toxin and showed that some of the secretory IgA in
the gut is of hepatic origin. Furthermore, the earliest IgA class antibodies to cholera toxin were those derived from the bile, as opposed to the small bowel. However, I do not know of any similar work in humans.

*Dr. Truswell:* PEM often produces bacterial colonization of the small intestine. Is it possible that in the tests in which D-xylose, vitamin B₁₂, or even amino acids are given, the bacteria utilize some of the nutrients, making absorption by the intestinal epithelium look worse than it actually is?

*Dr. Brunser:* This is certainly a possibility. When we studied biopsies, we never observed bacteria attached to, or in the vicinity of, the mucosa. When fixing biopsies, we have been careful to avoid disturbing the surface coat, which is probably formed by mucin, bacteria, and desquamated cells. As a result, if there are bacteria, we frequently see them. Filamentous material seems to connect the outer coat of the bacterial body to the glycocalyx. The filaments that span the distance between the microorganism and the epithelium may represent an early stage of attachment. Therefore, pictures from such electron-microscopy studies may yield valuable information about the earliest interactions between the bacterial flora and the GI epithelium.

*Dr. Truswell:* I think there is a difference between bacteria in the mucosal epithelium and bacteria free in the lumen. I should have thought there would be bacteria at least in the terminal ileum when the vitamin B₁₂ test is done.

*Dr. Brunser:* There are always bacteria in the intestinal lumen, even in healthy individuals. This count is higher in samples obtained from more distal segments. The counts are higher in the ileum than in the jejunum and duodenum (16). The presence of bacteria in the lumen decreases nutrient absorption under both normal and pathologic conditions. The difficult part is quantitating this effect and establishing correlations with normal, or abnormal, intestinal function. It had been shown years ago that some strains of *Escherichia coli* have the capacity to split the vitamin B₁₂-intrinsic factor complex and utilize the vitamin for their metabolic needs (17). It is probable that other strains can also utilize some micronutrients in competition with the organism.

*Dr. Warrier:* In the gastrointestinal mucosa, you showed changes that might predispose to easy entry of an antigen. Is there any proof that this predisposition might lead to an antigenic overload that contributes to immune dysfunction (18,19)?

*Dr. Brunser:* Some of the changes that we observed in marasmic patients provide indirect evidence of the possible passage of macromolecules from the lumen of the intestine to the epithelium. It is indirect, because it consists of an increase in the number of pinocytotic pits and vesicles between the bases of the microvilli and their rootlets (8,9). There is evidence as well from animal models that absorption of macromolecules may be increased in malnutrition and that this is enhanced by unconjugated bile acids in the lumen (20,21). It is also possible that luminal factors may act as inducers of pinocytosis. It would be interesting to know whether the pinocytosed material will eventually be transported, more or less intact, to the intercellular space of the epithelium and will, therefore, enter the bloodstream to be distributed to the rest of the organism, or if, in fact, it will be fused with virgin or secondary lyso- somes and degraded by their acid hydrolases. That appreciable amounts of antigens may get through is supported by the dense deposits underneath the basal lamella. This is similar to what is observed when antigen-antibody reactions occur in the vicinity of epithelia (22,23). Furthermore, antigens can be detected in the blood when immunity fails (24).

*Dr. Guesry:* Is there an accelerated migration of intestinal epithelial cells from the crypt to the tip of the villi in malnourished children that could lead to an increase in lactose intolerance?
Dr. Brunser: The epithelial cells lining the villi in these patients are mature, even though they are damaged. The mitotic index is decreased but may be adequate for replacement of the reduced cell population of the small intestinal mucosa, the thickness of which is reduced (25). Migration rate of the crypt cells is decreased in experimental models (26). Information could be gained from studies in cultured biopsies, but the question remains as to what extent a piece of tissue separated from its links with the rest of the organ and the body behaves normally.

Dr. Suskind: In looking at the effect of malnutrition on the gastrointestinal tract, we often focus on the small intestine. Is there much information concerning the effect of PEM on gastrointestinal reflux or gastric acid production?

Dr. Brunser: It has been shown that hydrochloric acid production is reduced in PEM (27-29). Low levels of gastrin, as well as a decreased response of the gastric mucosa to this hormone, have been demonstrated. I do not know of any morphologic studies. Newer techniques may help us gain greater insight into gastrointestinal function in malnutrition and help predict the potential residual damage.

Studies of the large intestine in malnutrition are essentially unknown. I know of only one paper in which overall normal histology is described in children with PEM (30).

Dr. Fuchs: In PEM, gastric emptying is probably delayed. I should include that as a cautionary note when we try to interpret some of these indirect markers, such as xylose, for intestinal permeability. One can, perhaps, exaggerate the abnormality by virtue of delayed gastric emptying.

Apart from delayed gastric emptying, is there much known about intestinal motility in PEM?

Dr. Brunser: WP James (31,32) demonstrated that fluid movement in the intestine is altered because water transport across the epithelium is decreased. The jejunum functions as if its diameter were reduced and fluid moves at a greater speed.

Dr. Truswell: Studies done in Cape Town on gastric function in PEM demonstrated a tendency to reduced acid response that responded to iron supplementation (33). The same group studying the colon in kwashiorkor reported atrophic changes under the dissecting microscope, with the histology of rectal biopsies showing submucosal infiltration of plasma cells (34).

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