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HYPOCHLORHYDRIA: A Factor in Nutrition

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INTRODUCTION

Gastric acid hyposecretion results from atrophy of the gastric glands of the fundic mucosa of the stomach. The reduction in acid secretion parallels the decrease in the parietal cell mass. In atrophic gastritis, hypochlorhydria is caused by variable gland loss that ranges from mild to severe. In total gastric atrophy, a total gland loss with achlorhydria occurs even under chemical stimulation.

The terms *type A* and *type B gastritis* refer to nonerosive fundic and antral

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gland gastritis, respectively. While type A gastritis may be related to autoimmune factors and pernicious anemia, type B gastritis is apparently due primarily to environmental factors (78).

Type A Gastritis

Evidence indicates that the frequency of type A atrophic gastritis increases with age. The association of type A atrophic gastritis with pernicious anemia is well established. Although type A atrophic gastritis is not uncommon in the elderly population, only a small subset of these individuals develops classic pernicious anemia with antibodies against parietal cells and intrinsic factor. Type A atrophic gastritis has a higher frequency in the relatives of patients with pernicious anemia and autoimmune diseases, especially those diseases affecting the thyroid and adrenal glands (19).

Type B Gastritis

Although it has been suggested that agents commonly associated with atrophic gastritis such as aspirin and alcohol may cause atrophic gastritis with repeated exposure, no evidence currently substantiates this idea. Gastric cancers of the antrum and body are usually associated with extensive type B gastritis (41). Moreover, patients with chronic gastric ulcer disease often exhibit chronic diffuse type B gastritis of the antrum (66). Gastric resection with gastrojejunostomy is often followed by progressive atrophy of the gastric mucosal remnant (81). Growing evidence suggests that long-term exposure of the stomach to bile salts in the setting of reflux of bile through the pylorus, as in gastric ulcer, or in cases of complicating gastric resection with gastrojejunal anastomosis, may lead to degeneration of the deeper glandular layers of the stomach, which, in turn, results in type B atrophic gastritis (41, 66).

Chronic infections, particularly syphilis, have been implicated as a rare cause of chronic type B gastritis. Present evidence indicates that the gastric spiral bacteria *Campylobacter pylori* is associated with peptic ulcer disease and gastritis (9, 35, 58, 62), and the literature suggests that serologic evidence of *C. pylori* is common in the elderly US population. However, no evidence supports the role of *C. pylori* infection in the development of chronic atrophic gastritis in the elderly (27), nor in patients with pernicious anemia (46a).

THE PREVALENCE OF ATROPHIC GASTRITIS

Prevalence

The prevalence of atrophic gastritis and gastric atrophy increases with advancing age; 30% of those over the age of 60 have one condition or the other (53, 76, 82, 84). Results of a survey among free-living Boston elderly showed that the prevalence of atrophic gastritis was 21% in the age group 60–69, 31% in the age group 70–79, and 37% in those above the age of 80 (52, 70).

Diagnosis

The diagnosis of atrophic gastritis and gastric atrophy may be made based on radiographic and endoscopic examination and/or histologic changes seen on biopsy specimens of the stomach. Through endoscopic examination, severe atrophic gastritis and gastric atrophy may be recognized by visualization of the submucosal vessels through the thinned mucosa. Radiographically, air contrast studies may reveal a paucity of mucosal folds in the distended gastric body and fundus. Only positive results of a biopsy of the fundic mucosa can establish accurately the diagnosis of atrophic gastritis. Such techniques are not amenable to widespread testing of large populations, however.

Gastric analysis, with histamine or pentagastrin stimulation, is a useful secretory function test. The degree of reduction in acid secretion, with maximal stimulation, parallels the severity of atrophic gastritis. Patients with advanced atrophic gastritis or gastric atrophy commonly exhibit achlorhydria with a poststimulation gastric pH above 7. Blood tests used in the diagnosis of atrophic gastritis and gastric atrophy include those for the presence of parietal cell antibodies, the presence of intrinsic factor antibodies, and elevated serum gastrin levels (1, 7, 16, 28, 30, 42, 51, 77, 83). The two antibody tests are specific for severe atrophic gastritis type B and gastric atrophy, but they are not sensitive enough to detect less severe forms of the disorder. Elevated serum gastrin levels are neither sensitive nor specific in diagnosing atrophic gastritis.

Samloff and colleagues (74) have recently described a radioimmunoassay for circulating pepsinogen I and pepsinogen II, and they have related these levels to measures of gastric secretory function and the histologic appearance of the gastric mucosa. Most pepsinogen I and pepsinogen II originates from the chief and mucous cells of the fundic gland mucosa. Pepsinogen II, however, is also produced by the glands in the cardiac portion of the stomach, the gastric antral glands, and Brunner glands of the proximal duodenum (73). Thus, higher levels of pepsinogen I than pepsinogen II normally circulate in blood. Loss of fundic glands in atrophic gastritis results in a fall in serum pepsinogen I levels, with little fall in serum pepsinogen II levels; indeed, pepsinogen II levels may increase in atrophic gastritis as a result of pyloric gland metaplasia of the fundus (74). Normal subjects have pepsinogen I:pepsinogen II ratios of greater than 4.0; whereas patients with gastric atrophy have pepsinogen I:pepsinogen II ratios of less than 2.9, and pepsinogen I concentration is less than 20 ng/L. In moderate atrophic gastritis, the pepsinogen I:pepsinogen II ratio is less than 2.9, but the serum pepsinogen I level is greater than 20 ng/L. With increasing severity of chronic atrophic gastritis, a progressive decrease occurs in the ratio of serum pepsinogen I to pepsinogen II. Because of the nonparallel changes in these levels, the ratio of pepsinogen I level is highly predictive of gastric mucosal histology (74).

The relation of gastric atrophy to pernicious anemia is well known. Other

nutritional consequences of this lesion are now being studied, however. The purpose of this chapter is to review current knowledge about the physiologic and nutritional consequences of atrophic gastritis with respect to vitamin and mineral absorption and bioavailability in humans and in animal models.

PHYSIOLOGIC CONSEQUENCES OF ATROPHIC GASTRITIS

Gastric Emptying Changes

Reports are conflicting on the influence of age alone on gastric emptying. In one study, the rate of gastric emptying was significantly different in young vs elderly volunteers (50 vs 123 min, respectively) (26). Further, in a study by Davies et al (18), gastric emptying time was significantly higher in individuals with gastric atrophy than in control subjects. A changed gastric emptying time could confound the interpretation of absorption data, if timed blood or urinary collections after a given dose of nutrient were employed to reflect absorption. With delayed gastric emptying, blood and urine collections might need to be extended for longer periods, and the area under a tolerance curve (rather than peak height) might better reflect absorption.

Intrinsic Factor Secretion

A decreased secretion of intrinsic factor is a second result of atrophic gastritis. The stomach with mild or moderate atrophic gastritis, however, continues to secrete sufficient intrinsic factor to permit normal crystalline vitamin B_{12} absorption. With total lack of intrinsic factor, as in severe atrophic gastritis or gastric atrophy, cobalamin malabsorption occurs. Vitamin B_{12} deficiency in atrophic gastritis may occur by mechanisms other than lack of intrinsic factor secretion, and such deficiency does not result only when complete atrophy is present, as was previously thought.

Bacterial Overgrowth of the Proximal Small Intestine

Small intestinal bacterial overgrowth is a third consequence of atrophic gastritis. Intestinal bacteria concentrations are elevated in 50–100% of subjects with hypo- and achlorhydria, since most bacteria swallowed or ingested in food are normally destroyed by a gastric acid pH < 3.0 (23). Bacteria that grow in the upper small bowel in atrophic gastritis (unlike the colonic anaerobes that complicate intestinal structural and motility changes) do not usually result in bile salt deconjugation and fat malabsorption (79). The bacteria present in atrophic gastritis, however, may affect the absorption of certain nutrients by binding or metabolizing these nutrients and/or reducing their bioavailability.

Altered Proximal Small Intestinal pH

Finally, the pH of the proximal small intestine may be raised in atrophic gastritis. If a nutrient's absorption process is pH sensitive and if the nutrient is absorbed in the proximal small intestine, the absorption of that nutrient might be greatly influenced by hypo- or achlorhydria. Also a high intraluminal pH of the stomach and proximal small intestine could prevent the release of specific nutrients from food complexes (e.g. fiber, protein) as a result of the lack of pH-dependent dissociation and/or acid pepsin digestion.

HYPOCHLORHYDRIA EFFECTS ON NUTRIENT METABOLISM

Calcium

For calcium absorption to occur, calcium must be dissociated from food complexes and calcium salts must remain dissolved. Both processes depend on an acid pH, and thus gastric acid secretion could presumably play an important role in calcium absorption (43, 61).

ROLE OF DIETARY FIBER In vitro studies suggest that dietary fiber binds calcium at a neutral pH (46). Since calcium is absorbed primarily in the proximal small bowel, alkalinization of the stomach and proximal small bowel secondary to hypochlorhydria could limit the bioavailability of calcium for absorption when the calcium is eaten with fiber. The effciency of absorption of calcium salts is becoming an important issue because of the increasing use of calcium supplements in the prophylactic treatment of osteoporosis.

Several short-term studies indicate that purified fiber preparations may induce negative Ca^{++}, Mg^{++}, Zn^{++}, and Fe^{++} balances (47, 64, 65). The uronic acid polymers of pectin, the noncellulose polysaccharide fraction of dietary fiber, and phytate, when whole foods have been used, are responsible for the metal binding (48).

Fiber-bound calcium is unlikely to be available for absorption in the small intestine in atrophic gastritis, because the neutral pH of the small bowel lumen would encourage the ionic binding of calcium to the charged carboxylic acid groups of uronic acid. Since the pH of the stomach and the proximal small bowel is elevated in atrophic gastritis, the fiber-calcium complex might remain undigested until it reaches the colon. In the colon, however, microbial fermentation of uronic acid could liberate calcium and allow some calcium absorption to take place.

An average western European diet has been estimated to contain 17.2 ± 5.1 grams of dietary fiber per day and 12.3 ± 3.1 mmoles of uronic acid (46). Such a diet could theoretically bind 152 ± 52 mg calcium. Since dietary fiber is commonly used for regulation of bowel habits in the elderly, the binding

capacity of fiber for calcium could be of potential nutritional significance in view of the high prevalence of atrophic gastritis in this population.

THE ROLE OF HYDROCHLORIC ACID IN CALCIUM ABSORPTION Calcium carbonate reacts with hydrochloric acid to form soluble calcium chloride, which is subsequently absorbed in the proximal small intestine (15). Two recent studies yielded conflicting results on the role of hydrochloric acid in calcium absorption. In a study by Bo-Linn et al (8), 16 normal healthy subjects (12 men and 4 women ranging in age from 21 to 86 years) were studied, as well as a 57-year-old woman with pernicious anemia. Large doses of cimetidine were given to reduce gastric acid secretion. Each subject received, separately, two test meals: one, a normal calcium meal (852 mg from milk) and the other, a low-calcium meal (71 mg) supplemented with either calcium carbonate or calcium citrate. Each individual first received a preparatory lavage of the gastrointestinal tract. The subject was then given a mean containing calcium and polyethylene glycol, a nonabsorbable marker. After 12 hr, the intestine was cleansed by another washout. The rectal effluent was analyzed for calcium, and the completeness of the collection was evaluated by the recovery of the nonabsorbable marker. Net calcium absorption was calculated by using atomic absorption spectroscopy. Cimetidine, which markedly reduced gastric acid secretion in the normal subjects, had no effect on calcium absorption. The patient with pernicious anemia and achlorhydria was found to absorb calcium normally. This absorption was normal irrespective of the source of dietary calcium, i.e. whether the source was milk, insoluble calcium carbonate, or soluble calcium citrate. Furthermore, calcium absorption after calcium carbonate ingestion was the same whether the intragastric pH was maintained at 7.4 or 3.0. The researchers concluded that dietary calcium absorption is not increased by increasing intragastric acidity.

Using a different method, Recker (63) compared the absorption of calcium carbonate to calcium citrate in a group of 11 fasting subjects with achlorhydria and 7 fasting subjects without. Fractional calcium absorption was measured by using a double-isotope procedure with 250 mg of calcium used as the carrier. In the subjects with achlorhydria, calcium carbonate was markedly malabsorbed as compared with absorption in normal subjects. However, the absorption of calcium citrate (pH adjusted to 5.8) in achlorhydric subjects was higher than in normal subjects.

The studies of Bo-Linn et al (8) and Recker (63) differed in several respects. All Bo-Linn's patients except one were studied after receiving cimetidine, and their gastric pH levels were in the range of 5.5 to 4.9, whereas the gastric pH levels of the achlorhydric subjects in Recker's study were near 7.0. Also in Bo-Linn's study 7.2 liters of a balanced solution was used for lavage of each subject; this treatment could have dissolved some of

the calcium carbonate, thereby permitting its absorption. Although the Recker study suggested the use of a soluble form of calcium, such as calcium citrate in calcium supplements, further investigation is needed on the effect of atrophic gastritis on calcium absorption before implementing such recommendations, since the results of these studies remain in conflict.

Iron

Early studies reported decreased iron absorption with advancing age. These studies, however, were not well controlled for iron status nor for the presence of gastrointestinal disease.

The absorption of ferric iron clearly is impaired in achlorhydria and in gastrectomized subjects (14, 34, 44, 45). In addition ferric iron absorption may be enhanced by the administration of hydrochloric acid alone (5). The beneficial effect of acid on iron absorption may be to maintain the ferric iron in solution until it reaches the absorptive sites of the duodenal mucosa. While the ferrous iron and heme iron remain in solution at neutral or slightly alkaline pH (13), ferric iron is insoluble above pH 5 (45). Substances that form low-molecular-weight chelations with iron, such as ascorbic acid, amino acids, and sugars, tend to promote absorption of the ferric iron at a neutral or slightly alkaline pH range. The chelation with the ferric iron, however, occurs only when the iron is in solution, that is, at an acid pH (17). Thus, normal gastric acidity is needed for the chelation of the ferric ion, and this requirement helps slow the precipitation of ingested iron at the alkaline pH of the proximal small intestine (75).

In contrast, patients with atrophic gastritis show no diminished ability to absorb heme iron, and the administration of hydrochloric acid does not enhance nonheme absorption (5, 6, 45). H_2-receptor blockers such as cimetidine have a depressive effect on ferric iron absorption. Also, antacids reportedly cause a 50% impairment in ferric iron absorption.

Finally, administration of neutral gastric juice iron to patients with achlorhydria who receive ferric iron can increase the absorption of ferric iron (44). This observation raises the question of whether gastric juice itself can promote absorption of ferric iron even when the effect of acid is eliminated. Gastric juice may possibly contain a chemically unidentified stabilizing factor, probably an endogenous chelator that combines with iron especially at a low pH. Thus, the iron absorption produced by neutral gastric juice is greater when all iron is first incubated with gastric juice at an acid pH prior to neutralization than when the iron is incubated with already neutralized gastric juice (44).

The significance of the role of atrophic gastritis in reducing iron absorption in the elderly population remains unknown. Clearly, population studies are needed to relate iron status to atrophic gastritis.

Folic Acid

Among elderly people (age 65–75) studied in the US Health and Nutrition Examination Survey (Hanes I), the prevalence of low serum folate levels was 6% (55). Most dietary folates are in the form of folate polyglutamates. The polyglutamate side chain must be digested off the folic acid molecule (pteryolmonoglutamic acid) prior to absorption by the intestinal epithelial cell. This digestion takes place by intestinal conjugases within the lumen of the small intestine or at the surface of the small intestinal epithelial cell. Conjugases are present in the pancreas and in the small intestinal mucosa, although in humans, the small intestinal source of conjugase appears to be more important (68).

The transport of pteryolmonoglutamic acid across the small intestine occurs by two mechanisms: (*a*) an energy-dependent and saturable transport system, and (*b*) a non–energy-dependent, linear process of passive diffusion. The former occurs when folate is presented to the small intestinal epithelial cell at physiologic concentrations, whereas the latter occurs when pharmacologic concentrations of folate are presented. Folic acid absorption by the small intestine is highly influenced by the intraluminal pH. The pH optimum for pteryolmonoglutamic acid uptake by the small intestinal epithelial cell is 6.3 (69). If the intraluminal pH is altered to above or below 6.3, there is a marked decrease in the amount of folic acid taken up by the small intestinal cell. This phenomenon has been demonstrated in both animals and humans (69). Although pH effects on folate absorption were originally thought to be due to changes in ionization of the molecule (which would primarily affect the passive process of uptake), it is now known that the most important effect of pH is exerted on the energy-dependent saturable system of folic acid transport (69). Thus, the pH effect is most important when one considers the levels of folic acid contained in a meal rather than the levels in a vitamin pill.

Rats have been shown to have a decreased ability to absorb folate polyglutamates with age, but this work has not been repeated by others (49). Age appears to have no effect on absorption of folic acid, i.e. pteryolmonoglutamic acid (4). Russell et al (71, 72) have recently shown, however, that malabsorption of folic acid can occur in elderly humans with gastric atrophy. The absorption defect was related to a higher intraluminal pH in the proximal small intestine of individuals with gastric atrophy caused by lack of gastric acid secretion. Moreover, this malabsorptive defect was correctable by administration of the folic acid with 0.1 normal hydrochloric acid. Surveys of elderly people with or without gastric atrophy subsequently showed that serum levels of folate were not lower in individuals with gastric atrophy than in those without gastric atrophy. This finding was a surprise because individuals with atrophic gastritis had a demonstrable absorptive defect for folate acid. The bacterial overgrowth in the proximal small bowel that occurs

in atrophic gastritis is now postulated to make up for the relative defect in absorption of folate and thus to prevent a folate deficiency state from occurring in individuals with atrophic gastritis. High serum folate levels in patients with the blind loop syndrome were first described by Hoffbrand et al (37). Thus, a built-in mechanism might protect elderly individuals with atrophic gastritis from developing folic acid deficiency.

Vitamin B_6

Recent studies in rats (60) suggest that the intraluminal environment produced by gastric acid secretion plays an important role in the absorption of pyridoxal-5-phosphate (PLP) from normal dietary sources. The study evaluated the effects of PLP protein binding and pH on intestinal hydrolysis. Models included in vitro PLP decay with incubation in the presence of added alkaline phosphatase and in vivo PLP disappearance from perfused luminal segments of jejunum. Results indicated that albumin bound to PLP inhibited phosphatase-mediated hydrolysis of PLP at high pH (5–7.4) but not at low pH (3–4). Because vitamin B_6 is absorbed largely as nonphosphorylated forms, the normal secretion of gastric acid appears to be essential for the hydrolysis and absorption of dietary PLP. Hence, questions were raised about the implications of widespread use of acid-lowering therapeutic modalities on vitamin B_6 nutritional status.

Ribaya et al (67) studied vitamin B_6 nutriture in a group of elderly men and women (60 years and older) who had varying degrees of atrophic gastritis. Atrophic gastritis was defined as a ratio of serum levels of pepsinogen I to pepsinogen II of less than 2.9 (52). Within this group, a pepsinogen I value above 20 ng/liter was considered indicative of mild to moderate atrophic gastritis and below that was considered indicative of severe atrophic gastritis. The vitamin B_6 parameter measured was in vitro stimulation of red blood cell glutamic oxaloacetic transaminase (RBC-GOT) activity by PLP. The greater the degree of enzymatic stimulation or activity coefficient, the greater the degree of coenzyme deficiency. Dietary intake of vitamin B_6 was obtained using a three-day food record. Only subjects who did not take vitamin B_6 supplements for at least 6 months before the study were included in the data analysis. After age, sex, and dietary intake of vitamin B_6 were controlled for, the observed differences between the three groups were not statistically significant ($p > 0.05$). In fact, the RBC-GOT activity coefficient tended to decrease with severity of atrophic gastritis. This result indicates better vitamin B_6 nutriture among subjects with atrophic gastritis than among normal subjects. Of the normal subjects tested, 5% had an RBC-GOT activity coefficient of more than 2.2. This value is indicative of vitamin B_6 deficiency. In contrast, none of the subjects with atrophic gastritis had an RBC-GOT activity coefficient of more than 2.2.

The authors speculated that despite possible impaired PLP hydrolysis and absorption, increased bacterial flora in the stomach and proximal small intestine of elderly subjects with atrophic gastritis may synthesize enough vitamin B_6 to maintain normal nutriture. Hence, as is the case for folic acid (67), a possible malabsorption of dietary PLP in atrophic gastritis could be compensated for by increased bacterial synthesis of vitamin B_6.

Vitamin B_{12}

The prevalence of low serum vitamin B_{12} levels among the elderly ranges from 0 to 23% (3, 25, 32, 36, 56). Dietary vitamin B_{12} is attached to food protein. In the stomach, acid and pepsin digestion of dietary protein releases the vitamin B_{12}. At the acid pH of the stomach, vitamin B_{12} is bound to R-binders, which are non–intrinsic factor vitamin B_{12} binding proteins present in saliva, gastric juice, and other body secretions (2, 80). When vitamin B_{12} bound to R-binder reaches the proximal small intestine, dissociation of the R-binder protein and vitamin B_{12} occurs as a result of the higher intraluminal pH in the proximal small intestine and the digestion of the R-binder protein by pancreatic proteases. Vitamin B_{12} is then free to form a complex with intrinsic factor, which travels to the terminal ileum for active absorption. In the terminal ileum, specific receptors are present for the vitamin B_{12}–intrinsic factor complex, and binding to this receptor requires the presence of calcium and a pH greater than 5.6 (39).

Vitamin B_{12} absorption from the gut does not decline with age in normal elderly subjects (29, 33, 40, 59). In humans with atrophic gastritis, however, vitamin B_{12} malabsorption may occur by several mechanisms. In severe atrophic gastritis and gastric atrophy, with total lack of secretion of intrinsic factor, B_{12} malabsorption results, and B_{12} deficiency and pernicious anemia develop over time. In mild atrophic gastritis, lack of intrinsic factor secretion is not an issue, since the stomach usually secretes excess intrinsic factor (2).

A second mechanism whereby B_{12} absorption may occur in people with atrophic gastritis is via lack of acid pepsin digestion of cobalamin from dietary protein. Failure of B_{12} release from dietary protein precludes the binding of B_{12} with B_{12} binding proteins (i.e. R-binders, intrinsic factor). King et al (50) have demonstrated a subset of patients with gastric atrophy who malabsorb protein (chicken serum)-bound vitamin B_{12} but not crystalline vitamin B_{12}. Similar results have been reported by Doscherholmen et al (22), who used vitamin B_{12} bound to egg, ovalbumin, and chicken meat (20, 21). The exogenous administration of acid and pepsin to some of these individuals corrected the vitamin B_{12} malabsorption. Thus, in subjects with gastric atrophy the Schilling test, when conducted using crystalline vitamin B_{12}, may produce normal results, whereas if the Schilling test is carried out using protein-bound vitamin B_{12}, the test results may be abnormal. This phenom-

enon has also been noted among individuals receiving long-term cimetidine therapy, which suppresses acid secretion by the stomach.

Carmel et al (12) recently described malabsorption of food-bound or protein-bound cobalamin with normal absorption of free cobalamin in patients with no known gastric disorders. A significant number of these patients had neuropsychiatric abnormalities. Nearly half of their patients (8/19 subjects tested) who had low serum cobalamin levels with normal crystalline Schilling test results had no evidence of gastric dysfunction, i.e. subtotal gastrectomy, gastric achlorhydria, or treatment with H_2-receptor blocking drugs. However, the serum pepsinogen I/II ratio was subnormal in 40% of such patients. Lindenbaum et al (54) recently described patients with neuropsychiatric disorders who had borderline low serum cobalamin levels but no anemia or macrocytosis. These patients had elevated serum methylmalonic acid and homocysteine levels that became normal following vitamin B_{12} administration. Conceivably, mild hypochlorhydria, upper intestinal abnormalities, or occult pancreatic insufficiency may sometimes be responsible for this subtle form of cobalamin malabsorption.

Bacterial overgrowth of the proximal small bowel could also contribute to malabsorption of B_{12}. Bacteria could bind cobalamin (free and/or protein bound) and make it unavailable for absorption at the ileal receptor. Also, bacteria could synthesize analogs from the dietary vitamin B_{12}, which are inactive in humans. Bacteria in the small intestine can synthesize vitamin B_{12} analogs as well as modify ingested vitamin B_{12} even in the presence of intrinsic factor (10). Therefore, binding of vitamin B_{12} and/or production of vitamin B_{12} analogs by bacteria in atrophic gastritis could significantly reduce the bioavailability of vitamin B_{12} and thus contribute to vitamin B_{12} deficiency in this elderly group.

Other Micronutrients

Gastric atrophy could theoretically affect the absorption of vitamins A and E. Hollander (38) has shown that the absorption of these vitamins is decreased at an increased intraluminal pH. There are sporadic case reports of thiamin deficiency, ariboflavinosis, and pellagra in patients with hypoachlorhydria and post–partial gastrectomy. These studies, however, were based on the urinary excretion of these vitamins and not on their intestinal absorption (57). Eldert et al (24) studied the intestinal uptake of nicotinic acid in isolated strips of rat jejunum and demonstrated that the amount of the diffusible nonionic form of nicotinic acid is a function of the microclimate pH of the absorptive surface. At pH values of 5.4–5.8, absorption of nicotinic acid was higher than at surface pH values of 5.95–6.8. Burr et al (11) found no direct relationship between ascorbate concentration and the presence of severe atrophic gastritis in British patients living in an area of high stomach cancer risk.

Clearly, the nutritional effects of atrophic gastritis, which commonly occurs in the elderly, need further study. Because the bioavailability of several nutrients could be altered in this condition, the dietary recommendations for many micronutrients may need to be adjusted for a large subgroup of elderly people.

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