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Bioavailability of Magnesium Diglycinate *vs* Magnesium Oxide in Patients with Ileal Resection

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ABSTRACT. *Background*: Patients who have undergone ileal resection are at risk for developing magnesium depletion/deficiency because of poor absorption and decreased intake as well as increased endogenous losses. Magnesium repletion is difficult to accomplish because of the cathartic action of most oral magnesium supplements at therapeutic doses. The results of *in vitro* and *in situ* studies show that magnesium diglycinate (chelate) represents a highly available form of magnesium that is absorbed in part as an intact dipeptide in the proximal small intestine. *Methods*: We conducted a double-blind, randomized crossover trial with 12 patients who had ileal resections in order to compare the bioavailability of a 100-mg dose of ^{26}Mg-labeled chelate with MgO in this patient population. *Results*: For the patient group as a whole, ^{26}Mg absorption was low but was not different for the two supplements (23.5% *vs* 22.8% for magnesium chelate and MgO, respectively). However, ^{26}Mg absorption was substantially greater from the chelate (23.5% *vs* 11.8%; $p < .05$) in the four patients who showed the greatest impairment of magnesium absorption with MgO and was better tolerated by all patients. Peak isotope enrichment also occurred significantly earlier after ^{26}Mg chelate than after ^{26}MgO ingestion (mean difference 3.2 ± 1.3 hours; $p < .05$), and the area under the enrichment *vs* time curve was greater after chelate ingestion ($p < .05$). *Conclusions*: Data from this study support the suggestion that some portion of magnesium diglycinate is absorbed intact, probably via a dipeptide transport pathway. Magnesium diglycinate may be a good alternative to commonly used magnesium supplements in patients with intestinal resection. (*Journal of Parenteral and Enteral Nutrition* **18**:430–435, 1994)

Approximately 80% of patients with Crohn's disease eventually undergo at least one small-bowel resection for their disease, with ileal resection the most prevalent.[1] Patients who have undergone ileal resection are at high risk for developing magnesium depletion/deficiency because of poor absorption and decreased intake as well as increased endogenous losses.[2,3] The prevalence of overt magnesium deficiency, or hypomagnesemia, in patients with inflammatory bowel disease ranges from 9% to 86%, depending on the population studied,[3,4] and is strongly associated with the presence of ileal resection.[4,5] The incidence of magnesium depletion without hypomagnesemia in this patient group is believed to be much higher.[6] Clinically speaking, magnesium depletion significant enough to result in hypomagnesemia can cause hypokalemia and hypocalcemia resistant to replacement therapy without prior or concomitant reversal of the underlying magnesium deficit. Magnesium deficiency can also result in neuromuscular symptoms such as Trousseau's and Chvostek's signs, muscle fasciculations, tremor, and muscle spasms, as well as other abnormalities such as anorexia, nausea, vomiting, and personality changes. Frank tetany, convulsions, and coma have been noted, but they occur primarily in acutely deficient infants.[7]

Magnesium repletion in many patients with ileal resection is difficult to accomplish with oral supplements because of the cathartic action of magnesium therapy, which exacerbates their diarrhea. Although intravenous magnesium is an effective therapy in the acute setting, the availability of a well absorbed and tolerated oral magnesium preparation would be invaluable in the long-term management of these patients. Such a supplement could be used both to prevent and to treat magnesium depletion.

In vitro absorption[8] and *in situ* perfusion studies[9,10] and analogy with other mineral amino acid chelates[11–13] show that magnesium diglycinate (chelate) represents a highly available form of magnesium absorbed at least in part as an intact dipeptide in the upper small intestine. Such a route of absorption would offer obvious benefit to patients who have undergone ileal resection.

The goal of the present investigation was to determine whether magnesium diglycinate is sufficiently bioavailable to represent a significant improvement in magnesium therapy for patients with ileal resections. We compared the absorption and retention of magnesium administered as ^{26}Mg-labeled magnesium diglycinate with that of ^{26}Mg-labeled MgO in patients who had at least one ileal resection. The use of isotopic techniques allowed us to

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measure magnesium absorption after a single oral dose of ^{26}Mg-labeled chelate or ^{26}Mg-labeled MgO and to compare postabsorptive retention.

SUBJECTS AND METHODS

Subjects

Twelve adults were studied under this protocol, which was approved by the Institutional Review Board of The University of Chicago. (One additional subject was studied but was inadvertently given ^{26}MgO without unlabeled carrier MgO; data from this subject are not included.) Informed written consent was obtained from all subjects. All subjects had undergone at least one intestinal resection involving the ileum for the treatment of their underlying disease. Ten subjects had been diagnosed as having Crohn's disease, one had radiation-induced enteritis, and one had surgery for intestinal obstruction. All had been stable for at least 2 months before participation. Relevant clinical data for each subject is shown in Table I. All continued their usual medications throughout the study.

Experimental Design and Procedures

The study was conducted as a double-blind, crossover, randomized clinical trial in which the absorption in each subject was determined after a 100-mg dose of ^{26}Mg-labeled chelate and ^{26}Mg-labeled MgO; the magnesium supplements were administered in random order with a washout period of 2 weeks between absorption studies. The subjects entered the Clinical Research Center of the University of Chicago the night before the beginning of the study and fasted until the following morning. At ~8 A.M., each subject received a 50-mg dose (49.7 ± 0.1) of ^{26}Mg as ^{26}MgO or ^{26}Mg-chelazome (magnesium diglycinate, Albion Laboratories, Clearfield, UT) plus 50 mg (50.3 ± 0.3) of unlabeled oxide or chelate, all in gelatin capsules taken with deionized water. At the same time, each subject ingested 6 mg (5.57 ± 0.10) of dysprosium (Dy) as dysprosium chloride administered in a capsule that also contained ~0.5 g of glucose. Dy was administered as a nonabsorbable quantitative fecal marker.[14] Shortly after ingestion of the isotope dose, lean body mass and percentage of body fat were determined by bioelectrical impedance analysis.[15]

At 10:30 A.M. the subjects received a low-magnesium snack (up to 23 mg of magnesium), and at 12:30 P.M. they received a low-magnesium lunch (up to 41 mg of magnesium); distilled water was allowed throughout. At dinner and for the rest of the study the patients ate their normal diets. Complete urine and stool collections were initiated in the Clinical Research Center (for 12 hours) and then continued at home for a total length of time of 120 hours; a fasting urine sample was also collected before isotope administration. Two weeks after the initial visit, each subject returned to the Clinical Research Center and repeated the protocol with the alternative magnesium supplement.

Timed blood samples were obtained just before isotope ingestion and at 30 minutes and 1, 2, 4, 8, 12, 24, and 120 hours after isotope ingestion. Plasma and packed red blood cells were saved for ^{26}Mg enrichment and for total magnesium content determinations. Fasting plasma samples were also saved for 25-hydroxyvitamin D (25 OHD) and creatinine determinations.

Stools were collected individually and frozen until prepared for analysis. For most subjects, individual stools were homogenized with deionized water, as described previously,[16] and accurately weighed fractions were saved for analysis. For a few of the patients who had a large number of bowel movements, a small number of stools were sometimes combined in order to facilitate homogenization and sampling. Immediately after isotope dosing, urine was collected in 4-hour aliquots for 12 hours, followed by one 12-hour and four 24-hour collections. All were analyzed for total magnesium, ^{26}Mg, and creatinine.

TABLE I
Summary of clinical data

Subject	Age	Sex	Condition	% Body fat	Medications
1	28	M	Crohn's, multiple resections, total length unknown	18	None
2	34	M	Crohn's, multiple resections, ~100 cm of small bowel remaining	24	None
3	31	M	Crohn's, 5 cm of terminal ileum and 40 cm of large bowel resected	23	Metronidazole, loperamide hydrochloride
4	32	M	Crohn's, ~15 cm of small bowel resected but diffuse involvement	19	Prednisone, sulfasalazine
5	20	M	Crohn's, ~15 cm of terminal ileum resected	11	Prednisone, metronidazole, (Cortifoam enema)
6	36	F	Crohn's, ~15 cm of terminal ileum and 5 cm of large bowel resected	22	Prenatal vitamins
7	72	M	Crohn's, ~15 cm of terminal ileum and 5 cm of large bowel resected	24	None
8	51	F	Crohn's, two resections, unknown length	35	Prednisone, vitamins B_{12} and E Mercaptopurine
9	62	F	Radiation enteritis, small-bowel resection, unknown length	28	Thyroxine, cimetidine, Triamterene, MgO*
10	65	M	Rectal hernia with adhesions, multiple resections	11	Total parenteral nutrition†
11	40	F	Crohn's, chronic diarrhea, ~40 cm of terminal ileum resected	35	Cholestyramine
12	50	F	Crohn's, three small-bowel resections, ~40 cm of small bowel remaining	19	Prednisone, ranitidine hydrochloride, magnesium sulfate‡

* No MgO taken on the days in which isotope was administered.
† Total parenteral nutrition was discontinued for the evenings just before and just after each absorption study.
‡ Twice weekly magnesium sulfate injections; last treatment before each study administered 48 hours (before) isotope dose.

^{26}Mg-labeled diglycinate was synthesized from ^{26}Mg metal (99.20 atom% ^{26}Mg purchased from Oak Ridge National Laboratory, Oak Ridge, TN) by Albion Laboratories under the supervision of one of the authors (S.A.S.). Both labeled and unlabeled chelate contained 10.2% magnesium by weight. ^{26}MgO was purchased as ^{26}MgO (Oak Ridge National Laboratory; 99.53 atom% ^{26}Mg). For the MgO absorption study, the subjects received three gelatin capsules filled with microcrystalline cellulose along with the ^{26}MgO and MgO capsules so that the total number of capsules ingested was equal for the two absorption studies.

Analytical Procedures

Feces. The magnesium and Dy content of natural isotopic composition was determined by inductively coupled plasma mass spectrometry (ICP-MS) using isotope dilution procedures as previously described[14,17]; ^{25}Mg and ^{164}Dy were used, respectively, as *in vitro* spikes. ^{26}Mg excess was also determined by ICP-MS on the same samples used for isotope dilution.

Urine and plasma. Total magnesium content was determined by atomic absorption spectrometry (Perkin Elmer 5000, Norwalk, VA) on fresh plasma samples and on urine samples that had been acidified with nitric acid and stored at room temperature. ^{26}Mg content in excess of natural isotopic composition was determined by ICP-MS. Baseline fasting plasma samples and all urine samples were also analyzed for creatinine content by autoanalyzer (Astra-4 automated analyzer, Beckman Instruments, Inc, Fullerton, CA). Plasma 25-OHD levels were measured by competitive binding assay on a single blood sample taken at baseline for each of the absorption studies using normal human serum as the standard[18] (analyses were performed by the Vitamin/Bone Mineral Assay Laboratory, Clinical Nutrition Research Unit, University of Chicago).

Red blood cells. One-gram samples of packed red blood cells were frozen until ready for analysis. The total magnesium content was determined by isotope dilution and ICP-MS using ^{25}Mg as the *in vitro* spike; ^{26}Mg content in excess of natural isotopic composition was determined in the same samples.

All chemicals were reagent grade and were used as obtained from chemical supply houses. High purity water (>15 MΩ) was used throughout.

Calculations

Absorption of ^{26}Mg label was estimated using fecal isotope balance procedures described previously.[16,19] The method involves determination of the amount of any orally administered stable isotope appearing in stool collected for 5 days after the ingestion of the labeled supplement with the data having been corrected for contributions from sources with natural isotopic composition. Dy-marker excretion was determined in the same stool composites. Absorption data were corrected for Dy recovery as follows: ^{26}Mg absorption (%) = [1-(% ^{26}Mg excreted/% Dy excreted)] × 100 where excretion of ^{26}Mg and Dy are both expressed as percentage of administered dose. In a few cases, Dy recoveries were >100% because of the small errors inherent in the administration and quantification of the fecal marker; mineral absorption data from these collections were not adjusted for Dy recovery.

Urinary excretion of ^{26}Mg label was also determined for each urine collection using ^{26}Mg excess and total magnesium excretion data and was totaled for the 5-day collection period. The amount of ^{26}Mg label retained was calculated and expressed as mg ^{26}Mg or as percentage of absorbed dose.

^{26}Mg enrichment of plasma, red blood cells, and urine at various times after isotope ingestion was calculated as: % ^{26}Mg enrichment$_t$ = $[(R_{26/24,t} - R_{baseline})/R_{baseline}] \times 100$ in which $R_{26/24,t}$ = ^{26}Mg/^{24}Mg (wt/wt) of samples collected at time t and $R_{baseline}$ = ^{26}Mg/^{24}Mg of baseline samples collected just before isotope administration for each study. For plasma, the area under the curve of percentage enrichment *vs* time was then approximated as the sum of the trapezoids.

^{26}Mg present in stool, urine, plasma, or red blood cells in excess of natural isotopic composition is designated as the specific isotope throughout the manuscript.

The total number and weight of the stools passed in the first 24 hours after dosing were calculated as a measure of tolerability and compared for the two magnesium supplements.

Statistical Evaluation

^{26}Mg absorption, retention, and isotope enrichment data (urine, plasma, and red blood cells) were compared using a t test for paired observations. Comparisons between subgroups of the subjects or with magnesium-absorption data from the literature were made using an unpaired Student's t test. Correlations were performed using least squares regression. All statistical calculations were performed using Systat Version 2.1. Data are presented as mean ± SEM throughout, except for isotope-dose information.

RESULTS

Percentage of ^{26}Mg absorption for all subjects from both magnesium supplements is shown in Table II. For the patient group as a whole, magnesium absorption from magnesium chelate (23.5% ± 1.8%) was not different from the value observed for MgO (22.6% ± 2.8%). However, for the four patients whose absorption of magnesium from MgO was the lowest, absorption increased dramatically with the chelate from a mean of 11.8% to 23.5% ($p < .05$). This was especially apparent in subject 12, who was known to have only 40 cm of small bowel; magnesium absorption in this patient increased from a value of 4.3% for MgO to a value of 12.0% for the chelate. For the remaining eight subjects with more normal magnesium absorption, absorption tended to be lower with the chelate, but the difference between the supplements was not significant.

Magnesium absorption from both supplements was significantly less ($p < .05$) in this patient group than in the healthy subjects studied by Roth and Werner[20] under similar experimental conditions; magnesium absorption averaged 29.0% ± 1.5% in 11 healthy subjects who received a tracer dose of ^{28}Mg plus a 100-mg dose

TABLE II
^{26}Mg absorption from both supplements

Subject	^{26}MgO	^{26}Mg Diglycinate
1	22.8	16.0
2	15.9	25.2
3	13.3	33.2
4	21.2	30.6
5	20.4	16.8
6	13.7	23.4
7	29.4	21.0
8	28.6	25.1
9	30.5	24.4
10	36.4	28.7
11	35.2	25.3
12	4.3	12.0
Mean	22.6	23.5
± SEM	2.8	1.8

All data are shown as percentage of administered dose.

of $MgCl_2$. Only 1 of 11 healthy subjects had an absorption value less than 20%, whereas 4 of 12 patients in our study had absorption values less than 16%, one had values less than 5% for MgO, and three had a value less than 20% for magnesium chelate.

There was a statistically significant difference ($p < .05$) between the two supplements in the number of stools passed during the first 24 hours after magnesium dose; on average, 2.4 ± 0.4 stools were passed after chelate ingestion *vs* 3.7 ± 0.6 stools after the MgO. The weight of the stools passed during this time period was not significantly different between treatments, but was greater in 8 of 12 subjects after the MgO dose. In addition, the 100-mg dose of magnesium (^{26}Mg plus unlabeled Mg) caused only one subject to have severe diarrhea and only after the MgO was consumed.

Five-day urinary excretion and retention of ^{26}Mg were not different for the two supplements, whether the data were expressed as absolute milligrams of ^{26}Mg or as percentage of absorbed dose. Mean urinary ^{26}Mg excretion was 0.84 ± 0.17 mg or 8.5% ± 1.8% and 0.99 ± 0.18 mg or 8.1% ± 1.3% for ^{26}MgO and ^{26}Mg diglycinate, respectively. Urinary ^{26}Mg excretion (peak, 24-hour or 5-day total) was not significantly correlated with ^{26}Mg absorption. Five-day ^{26}Mg retention averaged 10.4 ± 1.3 mg and 10.7 ± 0.8 mg for the oxide and chelate, respectively, or 91.5% ± 1.8% and 91.9% ± 1.3% of the absorbed dose.

For each individual we compared the magnitude and timing of plasma peak isotope enrichment as well as the area under the enrichment *vs* time curve (0 to 24 hours) between supplements. The magnitude of peak plasma isotope enrichment was not significantly different between treatments; the mean values were 6.6% ± 0.7% and 8.3% ± 1.0%, respectively, for the ^{26}MgO and ^{26}Mg chelate treatments. However, peak isotope enrichment occurred significantly earlier after ^{26}Mg chelate than after ^{26}MgO ingestion (mean difference 3.2 ± 1.3 hours; $p < .05$). The area under the enrichment *vs* time curve was also significantly greater after chelate ingestion ($p < .05$). The latter point is illustrated in Figure 1, which depicts the group average values of plasma isotope enrichment *vs* time. Percentage of ^{26}Mg absorption was not correlated with peak plasma isotope enrichment or with the area under the enrichment *vs* time curve. Isotope enrichment of red blood cells was too low to permit comparisons between treatment groups.

Fasting plasma magnesium and 25-OHD levels, erythrocyte magnesium content, and urinary magnesium/creatinine ratios for all subjects are shown in Table III. Because there was no treatment effect on these parameters, the data from both absorption studies were pooled for each subject, and the mean value was listed. Plasma magnesium levels were near or slightly below normal for 9 of 12 subjects, and three subjects were clearly hypomagnesemic. The latter was true for subject 12, despite her twice weekly intramuscular $MgSO_4$ injections. Erythrocyte magnesium content was normal in nine subjects but low in three. The lowest values were observed for subject 9 who seemed to have renal wasting, as evidenced by a high urinary magnesium/creatinine ratio in the face of hypomagnesemia, and for subject 12, who had only 40 cm of small bowel. Plasma 25-OHD levels fell within the normal range for 9 of 12 subjects but was low in three. None of these parameters were significantly correlated with magnesium absorption.

The fasting urinary magnesium/creatinine ratios were within the range reported by other investigators.[21] Four of 12 subjects had ratios <0.025, which has been reported to be indicative of magnesium depletion.[21] Mean magnesium absorption (mean of the values obtained from the MgO and magnesium chelate period) was lower in the four subjects with magnesium/creatinine ratios <0.025 than in the remaining subjects ($p < .05$), exclusive of data from subject 12 who received intramuscular $MgSO_4$. Magnesium absorption averaged 20.8% in the low-ratio subjects *vs* 25.4% in the remaining subjects. Low plasma or erythrocyte magnesium content was not predictive of low magnesium absorption.

DISCUSSION

As expected, magnesium absorption for this group of patients as a whole was low, but it varied greatly among individuals. With the exception of subject 12, who was known to have only 40 cm of small bowel remaining, clinical evaluation did not predict those individuals whose absorption of magnesium was very low.

On average, magnesium absorption from the two supplements was similar, indicating that for most individuals the bioavailability of magnesium chelate is equivalent to that of MgO. However, there were some differences in response to the two supplements, which may have important clinical implications. In the four patients whose magnesium absorption from MgO was less than 16%, magnesium absorption from the chelate was substantially greater. For these same subjects, the number of stools passed during the 24 hours after magnesium supplement ingestion was reduced, and for three of the four, fecal weight was 36% to 59% lower after chelate ingestion. Thus for those patients with the greatest impairment in magnesium absorption, magnesium chelate seems to offer both greater bioavailability and tolerability. The chelate was also absorbed more rapidly and seemed to be cleared from the plasma compartment more slowly. The latter conclusion is made

on the basis of the observations that absorption and retention of ^{26}Mg from the two supplements was not different for the group as a whole, yet the area under the plasma enrichment *vs* time curves was consistently greater for the chelate. Whether more rapid absorption and sustained elevation of plasma magnesium after larger, more therapeutic doses of magnesium chelate would be of benefit in repleting body magnesium stores remains to be established.

Data from *in vitro* studies[8-13] suggest that magnesium diglycinate and other metal amino acid chelates may be absorbed via dipeptide absorption pathways in the upper small intestine. That the absorption of magnesium in the form of magnesium diglycinate occurred, at least in part, by a different mechanism than did the absorption of inorganic MgO is supported by our observations that timing of plasma appearance and the area under the enrichment *vs* time curves were both significantly different for the two forms of magnesium. Previous investigators have shown that a sizable portion of diglycine peptide is absorbed intact when the human small intestine is perfused with a solution containing glycylglycine.[22] We also observed that magnesium chelate absorption was less variable with a smaller range of values and coefficient of variation for this group of patients. Dipeptide absorption occurs predominately in the jejunum and has been shown to be relatively unaffected in a number of gastrointestinal disease states.[23]

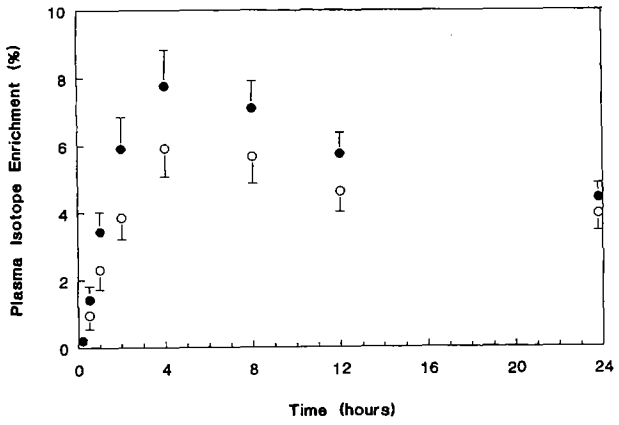

FIG. 1. Plasma isotope enrichment *vs* time for the first 24 hours after ^{26}Mg ingestion. Data for both ^{26}Mg-labeled chelate (●) and ^{26}MgO (○) are shown as the group average ± SEM for all time points. The area under the curve was significantly greater after ^{26}Mg chelate ingestion ($p < .05$). Although not well depicted in the group average values, on a paired basis, peak isotope enrichment occurred significantly earlier ($p < .05$) after chelate ingestion, but the magnitude of peak isotope enrichment was not different between treatments.

We were concerned about the undercollection of stool and thus the overestimation of absorption in this patient group because of the large number of stools passed (mean, 11; range, 3 to 29 stools per 120 hours) and the episodes of diarrhea. To circumvent these concerns, we used dysprosium chloride as a quantitative fecal marker and corrected estimates of magnesium absorption for Dy recovery. Dy has been shown to be nonabsorbed both in mice[24] and in humans.[14] In addition, Dy and magnesium have been shown to follow similar excretion kinetics.[14]

For our patient group as a whole, Dy recovery averaged 85% and was ≥90% for 16 of the 24 individual absorption studies. For three of the subjects, however, Dy recovery was low for both test periods, averaging 73%, 43%, and 56% for subjects 10, 11, and 12, respectively. Subject 10 excreted close to 500 g of stool per day as three to five individual stools, subject 11 lost some diarrheal stool after both magnesium supplements, and subject 12 excreted >800 g of stool per day as three to four stools. For these three subjects, the mean corrected and uncorrected estimates of ^{26}Mg absorption were 22.0% *vs* 44.1% and 25.3% *vs* 60.6% for the magnesium chelate and MgO treatments, respectively, a twofold to threefold difference. The corrected values fell within the range of values observed for the remainder of the patient group and represent accurate estimates of true ^{26}Mg absorption. For the remaining subjects, Dy recovery averaged 95%. In these subjects, the use of Dy minimized any overestimation of ^{26}Mg absorption, but the magnitude of the correction was relatively small; corrected and uncorrected ^{26}Mg absorption values for subjects 1 through 9 were 24.0% *vs* 30.4% and 21.8% *vs* 24.8%, respectively, for the magnesium chelate and MgO treatments.

TABLE III
*Pertinent blood and urine parameters related to Mg and vitamin D status**

Subject	Plasma Mg* (mmol/L)	Erythrocyte Mg† (mmol/L packed cells)	Mg/creatinine‡ (mg/mg)	25-Hydroxyvitamin D† (ng/mL)
1	0.85	2.49	.023	37
2	0.79	2.12	.037	32
3	0.77	2.25	.022	28
4	0.81	2.03	.032	15
5	0.77	1.85	.014	<5
6	0.81	1.89	.056	30
7	0.73	2.05	.071	24
8	0.65	1.97	.018	22
9	0.63	1.43	.069	34
10	0.78	1.82	.035	6
11	0.74	2.32	.088	19
12	0.65	1.73	.044	16

* Data are shown as mean of fasting values obtained from both absorption studies.
† The normal ranges for plasma and erythrocyte Mg as well as for plasma 25-hydroxyvitamin D are 0.80–1.20 mmol/L, 1.82–2.78 mmol/L packed cells,[25] and 16–60 ng/mL, respectively.
‡ A Mg/creatinine ratio of <0.025 mg/mg has been suggested to be indicative of Mg deficiency or depletion.[21]

Although on average magnesium absorption was lower in those patients with low magnesium/creatinine ratios, poor magnesium absorption was not strictly predictive of magnesium status. In addition, as has been observed by other investigators,[21,25] the correspondence between "indicators" of magnesium status was poor. In this patient group, 6 of the 12 subjects had some evidence of magnesium deficiency/depletion regardless of whether it was the result of poor absorption, poor intake, increased urinary excretion, or a combination of factors. As a whole then, these patients would likely benefit from magnesium supplementation.

In conclusion, magnesium absorption in patients who have had ileal resection was generally lower than has been reported for healthy controls, but it varied greatly among individuals and was low in some patients. In most patients, magnesium diglycinate and MgO were found to be of similar bioavailability. However, the magnesium diglycinate was better tolerated by the group as a whole and better absorbed in those patients with the greatest impairment of magnesium absorption. Data from this *in vivo* study also support the suggestion that some portion of magnesium diglycinate (chelate) is absorbed intact, probably via a dipeptide transport pathway.

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