THE CLINICAL INVESTIGATION OF 1α-OH-D_3 ON HEMODIALIZED PATIENTS

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ABSTRACT

The clinical effect of 1α-OH-D_3, a synthetic analogue of the active form of Vitamin D, was investigated in hemodialized patients. The administration of 1α-OH-D_3 with supplementary calcium therapy (at doses equivalent to 520 mg of elemental calcium per day) produced a significant biochemical improvement characterized by an increase in serum calcium concentration, lowered serum inorganic phosphate content and diminution of (Ca)×(Pi), without any appreciable increase in parathyroid hormone (PTH). There was actually no patient showing exacerbation in skeletal X-ray findings following the treatment. The reversal from a lowered serum calcium level might be largely ascribable to the improvement of the alimentary balance of calcium. Also, the decrease in serum inorganic phosphate value might have been brought about by the suppression of phosphorus absorption by supplementary calcium lactate administraion, by phosphorus deposition in bones, and by suppression of bone resorption by PTH. It was found that a calcium concentration of 3.5 mEq/L approx. in the dialysate was adequate for periodic hemodialysis. The data indicated the effectiveness of the administration of 1α-OH-D_3 with calcium supplementation for the prevention and treatment of renal osteodystrophy in the maintenance of hemodialized patients.

Key words: 1α-OH-D_3, renal osteodystrophy, secondary hyperparathyroidism, hemodialysis, calcium lactate

INTRODUCTION

Renal osteodystrophy in patients undergoing periodic hemodialysis has been attracting attention in recent years with the increase of hemodialized patients. With the prolongation of life by chronic hemodialysis these skeletal changes have emerged in a more overt and often progressive form. However, after the elucidation of an important finding on Vitamin D metabolism, there have been many reports purporting to demonstrate the usefulness of 1α-OH-D_3, a synthetic analogue of the active form of Vitamin D, in improving various biochemical and histologic parameters concerned with renal osteodystrophy. The active form of Vitamin D generally causes such effects as elevation of lowered serum calcium and inorganic phosphate concentrations, diminution of serum PTH and alkaline-phosphatase levels (Al-p), and enhancement of calcium and phosphorus absorption from the intestine.

Patients on maintenance hemodialysis generally have low dietary calcium intake.

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Therefore, the calcium concentration in the dialysate and the amount of calcium in foods become useful indicators in the management of patients undergoing maintenance hemodialysis. Balance studies on analysing of the dietary and dialysis balances of these inorganic elements are thought to be essential in evaluating the metabolism of calcium and phosphorus in hemodialized patients. However, reports of such investigations are yet few. Moreover, there is a possibility that increased phosphorus absorption caused by 1α-OH-D_3 may have an unfavorable influence on secondary hyperparathyroidism.

This study was performed to assess the effect of 1α-OH-D_3 administration with or without calcium supplementation on renal osteodystrophy in hemodialized patients and to investigate the optimal calcium concentration in dialysate for chronic hemodialized patients using balance studies.

SUBJECTS AND METHODS

To investigate the effect of 1α-OH-D_3 with or without calcium supplementation under the different dialysate calcium concentration, fifty-eight hemodialized patients, 38 males and 20 females, within an age range of 20 to 77 years and a history of stable maintenance hemodialysis were subdivided into six groups as shown in Table 1. In regard to biochemical data and age, no obvious differences were observed between each group. In Group B duration of maintenance hemodialysis was longer than other groups, but not to such a degree as to influence this study. This study was conducted for six months, and the biochemical and X-ray findings including balance studies were evaluated for each group.

The patients were maintained by hemodialysis three times a week, for 5 hours on each occasion with a personal supply unit. The dialyser used was a Kill-type device (11.5 μm, 1.0 m^2), and the dialysate was diluted with tap water. As tap water contains calcium, the dialysate calcium concentration was 2.93 $\pm$ 0.16 mEq/L (n = 195) in the group with the dialysate calcium level of 2.5 mEq/L, and in the group with the dialysate value of 3.0 mEq/L, it was 3.47 $\pm$ 0.16 mEq/L (n = 195).

1α-OH-D_3 was administered with an initial dose of 0.25 μg/day for each patient, and the dosage was individualized thereafter, so that the predialysis serum calcium level did not exceed the upper limit of normal range. (normal value; $<$5.4 mEq/L) The administration of 1α-OH-D_3 was discontinued temporarily once a patient had developed hypercalcemia.

The serum phosphate level was controlled within a normal range from 4 to 6 mg/dl by administration of aluminum hydroxide.

Calcium lactate, as a calcium supplement, was administered in doses of 4 g/day (equivalent to 520 mg elemental calcium per day). The tracer absorption study with ^{47}Ca, as we reported previously,[26] revealed that the absorption of calcium in hemodialized patients after administration of 1α-OH-D_3 was improved only to an extent of about 60% of that in normal subjects. Meanwhile, the calcium intake of Japanese is usually low (average in normal adults: 500 mg/day) and a nutritional survey made at this institution revealed it to be 323 $\pm$ 93 mg/day (n = 40) for hemodialized patients. Therefore, in order to provide a calcium absorption proximate to normal level, a 4g/day dose of calcium lactate was given to each patient.

Blood samples for serum biochemical testing were obtained biweekly before hemodialysis. Serum PTH was determined by radioimmunoassay with C-terminal assay (Wellcome 211/41) before and after treatment. (normal value: $<$0.5 ng/ml) Skeletal X-ray examinations were performed in all cases before and after treatment. Bone resorption, metastatic calcification and other X-ray findings were evaluated by three physicians.

	Dialysate Ca (mEq L)	1α-OH-D_3	Supplement Ca-lactate	Age (Y)	Duration of H.D.(M)
A (n=9)	2.5	−	−	38 ±10	38 ±19
B (n=10)	2.5	+	−	46 ±13	51 ±22
C (n=10)	2.5	+	+	39 ± 7	27 ±23
D (n=11)	3.0	−	−	43 ±15	25 ±23
E (n=10)	3.0	+	−	38 ±16	30 ±19
F (n=8)	3.0	+	+	38 ±11	29 ±19

Table 1. The method of classification into 6 groups.

Footnote: The number of patients in each group, mean age, and past history of maintenance hemodialysis are listed in the table.

Balance studies, including dialysate and alimentary balance of calcium and phosphorus were performed before and after treatment.

i) Dialysate Balance Study (dialysis transfer)

The external calcium balance during dialysis was determined on a total of 33 occasions in the group with the dialysate calcium level of 2.5 mEq/L or 3.0 mEq/L. The dialysate after a single passage through the Kill-type dialyser after beginning the patient's dialysis, was collected in a plastic tank. The volume and concentration of calcium and phosphorus were determined using the eliminated fluid in the reservoir. At each time of hemodialysis, five serial samples were obtained from the dialyzing solution before contact with the dialyser, and their calcium and phosphorus concentrations were determined in order to calculate the dialysis transfer by the formula as follows.

$$\text{Net transfer of calcium} = \left(\begin{array}{c}\text{Dialysate calcium}\\ \text{concentration}\end{array}\right) \times (\text{Dialysate amount}) - \left(\begin{array}{c}\text{Collected dialysate}\\ \text{calcium concentration}\end{array}\right) \times (\text{Reservoir amount})$$

$$\text{Dialysate amount} = (\text{Reservoir amount}) - (\text{Drip infusion}) - (\text{Loss of body weight}) - (\text{Amount of food intake})$$

ii) Alimentary Balance Study

One patient selected from each group was maintained on a diet containing the same amount of calcium and phosphorus as those of his usual meals for 7 days. Thereafter, samples of the food, and all the stools and urine during an observation period of 6 days were collected using a Carmine marker similar to that in Tomida's report.[27] These samples were reduced to ash and assayed to study the alimentary balance of calcium and phosphorus. The net absorption of calcium and phosphorus was determined by a difference between the intake in the food and the output in the feces and urine. The alimentary balance and dialysis transfer were measured simultaneously. For the patient in Group A, the alimentary balance study was carried out only before treatment.

iii) Net Balance Study

Hemodialysis was conducted on each patient three times a week, therefore daily dialysis transfer was estimated by dividing the sum of three consecutive determinations of dialysis transfer during the measurement of alimentary balance study by 7. The average daily alimentary balance was estimated by dividing the sum of the six days determinations of the alimentary balance by 6. The daily net balance was estimated by adding the former and latter.

RESULTS

i) (Calcium); The serum calcium concentrations increased significantly in the groups treated with 1α-OH-D_3, except Group B. In Group B, the increase of serum calcium was not significant because low dialysate calcium was used. On the contrary, in Groups A and D, which served as controls, the serum calcium tended to fall. The maintenance dose of 1α-OH-D_3 was the lowest in Group F, and that in the combined E and F groups (0.40 ± 0.26 μg/day) was significantly lower than that in the combined B and C groups (0.65 ± 0.44 μg/day). This result revealed that high dialysate calcium concentration had a sparing effect on the maintenance dose of 1α-OH-D_3. The prevalence of hypercalcemia during the study treatment was high in Groups D and F. In Group D, patient with overt secondary hyperparathyroidism affected the prevalence of hypercalcemia. (Table 2.) High dialysate calcium and Vitamin D

	Ca (mEq L)		Maintenance dose of 1α-OH-D$_3$ (μg day)	prevalence of hypercalcemia (t-Ca > 5.4mEq L)
	Pre	Post		
A (n=9)	4.71 ±0.33	4.61 ±0.22		7 116 (6.0%)
B (n=10)	4.64 ±0.22	4.73 ±0.34	0.63 ±0.41	7 132 (5.3%)
C (n=10)	4.64 ±0.27	4.78** ±0.25	0.72 ±0.49	4 121 (3.3%)
D (n=11)	4.66 ±0.27	4.58 ±0.33		14 131 (10.7%)
E (n=10)	4.65 ±0.21	4.81*** ±0.27	0.45 ±0.33	7 132 (5.3%)
F (n=8)	4.49 ±0.30	4.87* ±0.39	0.34 ±0.13	11 106 (10.3%)

*P<0.05 **P<0.01 ***P<0.005

Table 2. Serum calcium, maintenance dose of 1α-OH-D$_3$, and the prevalence of hypercalcemia in each group before and after therapy.

Footnote: All values are presented as mean ± S.D. p value was obtained between before and after treatment in each group by paired student t test. The prevalence of hypercalcemia was the chance during 6 months observation. (Samples were taken biweekly from each patient.)

	Pi (mg/100mℓ)		Dose of Aluminum hydroxide (g/day)	
	Pre	Post	Pre	Post
A (n=9)	5.30 ±1.38	4.98 ±1.56	3.5 ±1.5	4.3 ±1.4
B (n=10)	5.65 ±1.03	5.22 ±1.16	2.9 ±0.5	3.2 ±1.4
C (n=10)	5.49 ±1.30	4.42** ±0.95	2.8 ±0.5	2.0 ±1.3
D (n=11)	6.01 ±1.30	4.88* ±0.79	2.5 ±1.4	3.0 ±1.2
E (n=10)	6.25 ±1.78	5.17 ±1.20	2.9 ±1.5	3.1 ±1.6
F (n=8)	6.43 ±1.68	3.92* ±1.28	3.1 ±0.7	2.3 ±1.1

*P<0.05 **P<0.01

Table 3. Serum inorganic phosphate concentration and the dose of aluminum hydroxide before and after treatment.

Footnote: All data are presented as mean ± S.D. and p value was obtained between before and after treatment in each group by student paired t test.

	Ca (mg/100mℓ) × Pi (mg/100mℓ)		PTH (ng/mℓ)		Al-P (K-Au)	
	Pre	Post	Pre	Post	Pre	Post
A (n=9)	53.9 ± 13.2	46.0 ± 14.9	1.54 ± 1.40	2.74** ± 2.03	11.9 ± 4.6	17.4 ± 7.5
B (n=10)	52.5 ± 9.1	49.8 ± 11.2	1.91 ± 1.23	2.58 ± 2.32	12.1 ± 4.7	13.4 ± 4.6
C (n=10)	51.6 ± 9.0	42.0* ± 7.5	1.47 ± 1.05	1.16 ± 1.26	11.8 ± 5.9	8.5 ± 2.4
D (n=11)	54.5 ± 13.3	47.8 ± 7.6	2.01 ± 2.60	2.19 ± 2.30	11.9 ± 4.2	12.3 ± 6.6
E (n=10)	56.5 ± 13.4	52.1 ± 12.4	0.85 ± 0.42	0.98 ± 0.68	9.9 ± 3.1	14.5 ± 9.5
F (n=8)	57.5 ± 13.7	37.9* ± 12.7	1.15 ± 0.66	1.05 ± 0.68	8.5 ± 2.5	9.1 ± 3.0

*P<0.05 **P<0.01

Table 4. The data of(Ca)×(Pi), i-PTH and alkaline phosphatase in each group before and after treatment.

Footnote: All data are presented as mean ± S.D. and p value was obtained between before and after treatment in each group by student paired t test.

	X-ray findings		
	aggravate	no change	improved
A (n=9)	6	2	1
B (n=10)	7	3	0
C (n=10)	1	9	0
D (n=11)	3	7	1
E (n=10)	1	8	1
F (n=8)	0	8	0

Table 5. Comparison of X-ray findings between before and after treatment.

		Dose of Drug			Ca			P		
		Aluminum hydroxide (g day)	1α-OH-D_3 (μg day)	Calcium lactate (g day)	Alimentary balance (mg/day)	Dialysis transfer (mg/day)	Net balance (mg/day)	Alimentary balance (mg/day)	Dialysis transfer (mg/day)	Net balance (mg/day)
A (n=1)	Pre	3.0	—	—	−25	−12	−37	+232	−102	+130
	Post	—	—	—	—	—	—	—	—	—
B (n=1)	Pre	3.0	—	—	−148	− 2	−150	+113	−154	−41
	Post	3.0	1.0	—	+73	−56	+17	+235	−145	+90
C (n=1)	Pre	1.5	—	—	−256	+38	−218	+395	−117	+278
	Post	0.9	1.0	4.0	+103	−197	−94	+135	−73	+62
D (n=1)	Pre	—	—	—	−131	+21	−110	+222	−151	+71
	Post	2.0	—	—	−465	+101	−364	+211	−169	+42
E (n=1)	Pre	3.0	—	—	−83	+47	−36	+216	−171	+45
	Post	6.0	0.75	—	−25	−20	−45	+354	−149	+205
F (n=1)	Pre	3.0	—	—	−106	− 1	−107	+250	−25	+225
	Post	3.0	0.25	4.0	+218	+25	+243	+137	−150	−13

Table 6. Balance data of one patient in each group

Footnote: Data were obtained before and after treatment in same patient. Drug dosage administered during observation period are listed at left part of table.

therapy with calcium supplementation was liable to induce hypercalcemia. But in groups treated with 1α-OH-D_3, hypercalcemia was easily returned to normal by discontinuing the administration of 1α-OH-D_3.

ii) (Inorganic phosphate); Groups C, D and F displayed a significant decrease in serum phosphate value. In the remaining groups, this parameter also showed a decrease although the decrease did not reach statistical significance. The fall of serum phosphate values observed in all groups was ascribable to the strict control of phosphate level within the range of 4 to 6 mg/dl by aluminum hydroxide. But the dose of aluminum hydroxide diminished only in those groups receiving calcium supplementary treatment (Groups C and F). Conversely, the diminution in serum phosphate value in the four Groups A, B, D and E could be attributed to the increased dose of aluminum hydroxide. (Table 3.)

iii) (Ca) × (Pi); This parameter is considered to be related to metastatic calcification. The high titer of this parameter suggests a possibility to induce soft tissue calcification. Table 4 shows a decline of the parameter after treatment in all six groups. The deduction was statistically significant in Groups C and F which were receiving supplemental calcium therapy with 1α-OH-D_3.

iv) (PTH); There was a significant elevation of PTH in Group A. The increase of PTH value was observed in Groups B, D and E but not significantly. In Group B, overt secondary hyperparathyroidism was observed in 2 patients in spite of 1α-OH-D_3 treatment. Meanwhile, the decrease in PTH value was observed in Groups C and F, but not significantly. In Groups C and F, both of which were receiving calcium supplementation, there were only 2 patients who showed a rise in PTH value.

v) (Al-p); The serum Al-p level increased in Groups A and E though not significantly. The increase of PTH and Al-p values in Group A may indicate the exacerbation of secondary hyperparathyroidism. In Groups C and F, however, the serum Al-p values remained at normal level. (Table 4.)

vi) (Skeletal X-ray findings); Exacerbation in skeletal X-rays were noted in a majority of cases in Group A and B after the study treatment, viz., chiefly, enhanced subperiosteal bone resorption of phalanges and augmented vascular calcification. In Group B, 1α-OH-D_3 failed to improve bone X-ray findings. One of the reasons may be the low dialysate calcium concentration. In Group C, calcium supplementation may have prevented the aggravation of bone X-ray findings despite low dialysate calcium concentration. In the groups of high dialysate calcium concentration the rate of aggravation of X-ray findings was low except for Group D, which served as a control. Especially, there was no patient showing aggravation of X-ray findings in Group F, and no radiographic evidence of enhancement of metastatic calcification was found in any case in the calcium supplementary treated Groups C and F. (Table 5.)

vii) (Balance study); The dialysis transfer of calcium was negative (mean = −60.8 mg/each hemodialysis) in the groups with 2.5 mEq/L of dialysate calcium concentration (n = 33), but was positive (mean = +193.3 mg/each hemodialysis) in the groups with 3.0 mEq/L (n = 33). The values of the difference between serum calcium concentration and dialysate calcium concentration showed negative correlation to the values of the dialysis transfer of calcium. ($r = -0.480$) (Fig. 1)

In regard to the alimentary balance, the patient (n = 1) in each group showed a negative balance for calcium before the study treatment. After the study treatment, all four groups receiving 1α-OH-D_3 (B, C, E and F) displayed an improvement in alimentary calcium balance. The degree of improvement was especially remarkable in the groups with calcium supplementation. However, the net balance of calcium remained negative in the patient of Group C. In Group F, both alimentary balance and dialysis transfer became positive with a

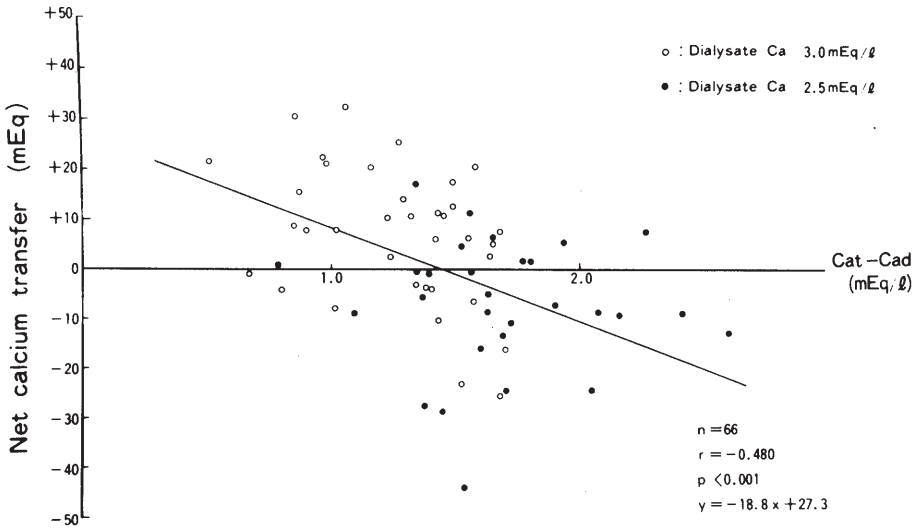

Fig. 1 Correlation between dialysis transfer of calcium and the difference of serum total calcium (Cat) and dialysate calcium (Cad).

Open circles represent cases using 3.0 mEq/L dialysate. Closed circles represent cases of 2.5 mEq/L dialysate. The abscissa is the difference of Cat and Cad. The ordinate is the net calcium transfer during one dialysis (about 5 hours).

positive net balance. This suggests that the use of dialysate with a calcium concentration of 3.5 mEq/L (for actual concentration) yielded more gratifying results for net calcium balance.

All patients showed a positive alimentary phosphorus balance before the study treatment. After treatment, the balance became more positive in Groups B and E, whereas it became less positive in Groups C and F. In Group E, the positive alimentary balance of phosphorus was remarkable despite increased dosage of aluminum hydroxide. These results showed that 1α-OH-D_3 alone induced an increase of the positive alimentary phosphorus balance, but 1α-OH-D_3 with calcium supplementation induced a decrease in the positive alimentary phosphorus balance.

Therefore, regard to calcium balance, treatment with 1α-OH-D_3 together with oral calcium supplementation and dialysate calcium concentration of 3.5 mEq/L is recommendable for patients on hemodialysis, and in regard to of phosphorus balance, treatment with 1α-OH-D_3 alone may involve a risk of producing an excess positive alimentary phosphorus balance.

DISCUSSION

In renal osteodystrophy (1) malabsorption of calcium, (2) alterations of Vitamin D metabolism, (3) secondary hyperparathyroidism, and (4) acidosis are considered to be intricately associated in producing the pathologic condition.[1] Among these factors, the abnormalities in Vitamin D metabolism are generally believed to be of prime importance. The 1α-OH-D_3 used in this study is a synthetic analogue of the active form of Vitamin D and has

been shown by many studies to be of clinical value in the treatment of renal osteodystrophy.[2,3,4,5,6] Similarly, our results revealed that the use of 1α-OH-D$_3$ was beneficial for hemodialized patients. However, the single use of 1α-OH-D$_3$ failed to produce sufficient improvement in biochemical and/or X-ray findings for the patients. In Group B, low dialysate calcium induced skeletal X-ray exacerbation despite treatment with 1α-OH-D$_3$.

In connection with calcium metabolism, patients with renal failure were mainteined on a low-protein diet. Moreover, the dietary calcium intake was still inadequately low even in those patients undergoing hemodialysis who were released from the limitation of dietary protein.[7] Coburn *et al.*[8] reported that the average calcium intake was 795 ± 350 mg/day in 47 normal subjects, 300 ± 240 mg/day in 96 patients with advanced renal failure, and 500 ± 235 mg/day in 58 hemodialized patients. The results of our nutritional survey for the hemodialized patients was 323 ± 93 mg/day, less than that of Coburn's. Kopple[9] described that the calcium balance was found apparently negative in the patients with a calcium intake of 300 mg/day. Although the administration of 1α-OH-D$_3$ led to increased intestinal absorption of calcium, the amounts of calcium in the diet seemed to be still inadequate for the present series of patients. Therefore, we added calcium supplementation therapy in the present series as a means of augmenting the calcium intake without an increase of phosphorus intake. The combined regimens yielded effective results in the patients with a significant conversion to a positive alimentary balance. According to Clarkson,[11] doses equivalent to 30 mg of elemental calcium per Kg body weight per day are required to maintain a positive calcium balance. The findings in our study indicated that such large doses of calcium preparations are not neccessary if 1α-OH-D$_3$ is used concomitantly with the calcium supplement.

In regard to the problem of calcium transfer from the dialysate, Wing[12] described the optimal calcium concentration in the dialysate to be 3.0 ± 0.1 mEq/L, and Goldsmith[13] described it to be 3.5 mEq/L. The data obtained in this study suggested that the use of dialysate with a calcium concentration of 3.5 mEq/L might be optimal, even if 1α-OH-D$_3$ and supplementary calcium therapy were done concomitantly. It is believed that if low calcium concentration is used, the net balance of calcium is apt to be negative despite improvement in the alimentary calcium balance by 1α-OH-D$_3$ treatment.

There is a possibility that the administration of 1α-OH-D$_3$ might result in enhanced intestinal absorption of phosphorus.[6,10] Elevated plasma phosphate levels are considered to stimulate parathyroid hormone secretion.[14] Sébert *et al.*[15] reported the importance of proper phosphate control on Vitamin D therapy. In our study there was an increase of the positive alimentary phosphorus balance among the patients receiving 1α-OH-D$_3$ alone. On the other hand, in the group receiving calcium supplementation with 1α-OH-D$_3$ treatment, the positive alimentary balance of phosphorus was inhibited. The decline of serum phosphate observed in the groups receiving the supplementary calcium regimen is considered to have been produced by the following mechanisms: 1) the concomitant administration of calcium lactate suppressed the intestinal absorption of phosphorus; 2) the deposition of calcium and phosphorus in bones; and 3) the inhibition of bone resorption by PTH. Previously, Meyrier[18] and Makoff[19] reported the decline of serum phosphate after the administration of high doses of calcium carbonate equivalent to 1400–1800 mg of elemental calcium per day. Also, it has been considered that calcium and phosphorus form a complex which can not be easily absorbed from the alimentary tract.[16,17] It is interesting, therefore, that the calcium supplement with doses of only 520 mg of elemental calcium per day, which is comparable to the daily calcium intake in normal subjects, did suffice for the suppression of phosphorus absorption.

An epidemic outbreak of aluminum poisoning with pathological changes in the bone has

recently been reported.[21] Since the possibility of aluminum absorption from the alimentary tract exists, it is advisable to minimize the dose of aluminum hydroxide. The results that, the dose of aluminum hydroxide was low in the groups of receiving calcium supplementation, supported the effectiveness of supplementary calcium therapy.

It has been reported that it is most necessary to control the (Ca)×(Pi) value below a level of 75 throughout dialysis for prevention of metastatic calcification.[22] Eastwood[20] and Fournier *et al.*[23] demonstrated that elevation of the (Ca)×(Pi) did not bring about any significant improvement of the calcification front. Increased values of (Ca)×(Pi) are undesirable for prevention of metastatic calcification unless the (Ca)×(Pi) has no influence upon the calcification front. Therefore, we are of the opinion that it is more advisable to control the (Ca)×(Pi) level to about 45.

The possibility that 1α-OH-D_3 increases bone resorption exists, and experimental evidence of enhancement of bone resorption has been given.[24,25] The findings suggest that it is important to avoid high-dose Vitamin D therapy. Fairly low doses of 1α-OH-D_3 seem to suffice for proper control of serum calcium concentration as long as supplementary calcium therapy is undertaken concomitantly. Vitamin D therapy is considered to be of clinical value in the management of patients with chronic renal failure whose Vitamin D metabolism has been chronically altered. However, it is thought to be important to start therapy at a low dose level and then individualize the dosage according to laboratory data and clinical symptoms in order to ward-off adverse reactions such as hypercalcemia.

To summarize the present findings, 1α-OH-D_3 with calcium supplementation and high dialysate calcium concentration is useful for the treatment and prevention of renal osteodystrophy. Although alimentary balance study was done for only one patient in each group, the data obtained were useful to evaluate the biochemical data and skeletal X-ray findings. For an understanding of calcium metabolism in hemodialized patients, it is necessary to examine dialysis transfer along with alimentary balance.

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