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Glucose absorption during continuous ambulatory peritoneal dialysis

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Glucose absorption during continuous ambulatory peritoneal dialysis. Patients undergoing continuous ambulatory peritoneal dialysis (CAPD) are exposed to a continuous infusion of glucose via their peritoneal cavity. We performed studies to quantitate the amount of energy derived from dialysate glucose. Net glucose absorption averaged 182 ± (SD) 61 g/day in 19 studies with a dialysate dextrose concentration of 1.5 or 4.25 g/dl. The amount of glucose absorbed per liter of dialysate (y) varied with the concentration of glucose in dialysate (x), ($y = 11.3x - 10.9$, $r = 0.96$). The amount of glucose absorbed per day during a given dialysis regimen was constant. Energy intake from dialysate glucose was 8.4 ± 2.8 kcal/kg of body wt per day, or 12 to 34% of total energy intake. This additional energy may contribute to the anabolic effect reported during CAPD. The ability to vary glucose absorption by altering the dialysate glucose concentration may prove a useful tool to modify energy intake.

Absorption de glucose au cours de la dialyse péritonéale continue ambulatoire. Les malades soumis à la dialyse péritonéale continue ambulatoire (CAPD) sont exposés à une administration continue de glucose via leur cavité péritonéale. La quantité d'énergie qui dérive du glucose du dialysat a été quantifiée. L'absorption nette de glucose est en moyenne de 182 ± (SD) 61 g/jour au cours de 19 études avec un dialysat contenant du dextrose, 1,5 ou 4,25 g/dl. La quantité de glucose absorbée par litre de dialysat (y) varie avec la concentration de glucose dans le dialysat (x), ($y = 11{,}3x - 10{,}9$, $r = 0{,}96$). La quantité de glucose absorbée par jour pour un type donné de dialyse a été constante. L'entrée d'énergie à partir du glucose du dialysat était de 8,4 ± 2,8 kcal/kg de poids par jour, soit 12 à 34% de l'entrée totale d'énergie. Cette énergie supplémentaire peut contribuer à l'effet anabolique rapporté au cours de CAPD. La possibilité de faire varier l'absorption de glucose en modifiant la concentration de glucose dans le dialysat peut être un moyen utile pour influencer l'entrée d'énergie.

Patients undergoing intermittent peritoneal dialysis absorb large quantities of glucose [1–4]; but, the relatively short duration of each treatment limits the nutritional significance of glucose absorption from dialysate. Continuous ambulatory peritoneal dialysis (CAPD) is a new and increasingly used form of maintenance dialysis therapy [5–9]. With CAPD, dialysis is performed 24 hours a day, 7 days a week; and thus, glucose absorption during dialysis may provide a valuable source of energy to uremic patients who are often undernourished. Despite the potential value of glucose absorption during CAPD, there is surprisingly little information about the quantities of glucose absorbed. DeSanto el al studied glucose absorption in four patients undergoing CAPD [10]. Each was studied for one day with the same quantities of dextrose in dialysate.

We, therefore, measured glucose absorption in seven patients treated with CAPD in whom the glucose concentration of the dialysate was varied. The results indicate that substantial quantities of glucose are absorbed during CAPD (182 ± [SD] 61 g/day), and this represents a major fraction of total energy intake. The quantity absorbed was directly correlated with the amount of glucose in the dialysate and was quite constant for any given dialysis regimen.

Methods

Nineteen studies of 4 to 21 days' duration were carried out in seven clinically stable, chronically uremic men undergoing CAPD. During each study, the patients had fixed CAPD regimens, with the number and duration of exchanges and the glucose concentration in dialysate kept constant. The patients' ages ranged from 27 to 59 years, and body weight varied from 71.3 to 89.8 kg (mean, 79.1 kg). The seven patients had undergone intermittent peritoneal dialysis and/or CAPD for 6 to 50 months prior to the study. During the study, patients lived in either the Special Diagnostic and Treatment Unit

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at VA Wadsworth Medical Center or the Clinical Research Center at UCLA Center for the Health Sciences (CHS). They ingested constant diets providing either 1.0 ± 0.11 or 1.4 ± 0.08 g of protein per kg of body wt per day and 32.9 ± 3.5 kcal/kg of body wt per day.

Three to five 2-liter bags of commercially available dialysate solution were instilled each day into the peritoneal cavity by the method of Oreopoulos et al [11]. The number of exchanges was adjusted in each patient to obtain a total urea clearance, calculated from the sum of dialysate urea plus urinary urea, of 11 liters/day. As shown in Table 1, two studies were performed with 3 exchanges/day, six studies with 4 exchanges/day, and 11 studies with 5 exchanges/day. The number of exchanges containing either 1.5 g/dl or 4.25 g/dl of dextrose was prescribed according to the need for fluid removal in each patient.

Blood for glucose analysis was drawn into sodium fluoride tubes every other morning before breakfast. Glucose determinations were made in both the inflow dialysate and in a pool of the daily effluent dialysate. Serum and dialysate glucose concentrations were measured enzymatically with a glucose analyzer (Beckman). The glucose concentrations of the commercial dialysate (Travenol Laboratories, Deerfield, Illinois) measured repeatedly in different lots, were 1.30 ± 0.11 g/dl (N = 12) for the 1.5% dialysate and 3.76 ± 0.12 g/dl (N = 12) for the 4.25% dialysate. Accuracy of analysis was confirmed by recovery studies, which accounted for 100.9 ± 7.8% of glucose, added to dialysate in concentrations of 1.0 and 4.0 g/dl.

With each exchange, the inflow and outflow dialysate bags were weighed, and volumes were calculated from the weight and the specific gravity of the solutions. The measured volumes in 2-liter inflow bags were 2.05 ± 0.008 liters for 1.5% dialysate and 2.06 ± 0.012 liters for the 4.25% solution. Daily glucose absorption was calculated as the difference between the quantity of glucose instilled into the peritoneal cavity and the amount drained each day. The average concentration of glucose (expressed in grams per deciliter) in infused dialyste for each day is defined as the total quantity of glucose divided by the total volume infused. For calculation of the energy derived from dialysate, the formula, 3.7 kcal/g glucose absorbed, was used [12]. All procedures were approved by the Committee on Human Experimentation at VA Wadsworth and UCLA, CHS and informed written consent was obtained from each patient.

Results

In the 19 studies, the amount of glucose present in the inflow dialysate averaged 252 ± 62 g and varied from 185 to 395 g/day (Table 1). An average of 182 ± 61 g of glucose was absorbed each day. In each patient, the amount of glucose absorbed per day on any given dialysis regimen was quite constant; the average coefficient of variation was 4.9% (range, 1.8 to 11.9%). Also, glucose absorption was quite predictable on any particular regimen. (Fig. 1).

The quantity of glucose absorbed each day (y) was highly correlated with the amount of glucose instilled (x) with (y) (g/day) = 0.89x (g/day) − 43, r = 0.91, N = 19. The amount of glucose absorbed (in grams per liter of infused dialysate) correlated closely with the average concentration of glucose in dialysate (in grams per deciliter per day) (r = 0.96) (Fig. 2). The energy intake from dialysate glucose absorption varied from 4.6 to 14.4 kcal/kg of body wt per day and averaged 8.4 ± 2.7 kcal/kg of body wt per day. In comparison, energy intake from food averaged 2755 ± 120 kcal/day (27.9 to 36.8 kcal/kg of body wt per day). Thus, the glucose absorbed from dialysate accounted for 20.3% (range, 12 to 34%) of total energy intake. The serum glucose concentration in each patient varied from 88 to 144 mg/dl and was correlated weakly with glucose absorbed, r = 0.62, $P < 0.01$.

Discussion

The data from the present study demonstrate that large quantities of glucose are absorbed from the peritoneal cavity during CAPD. The quantity of glucose absorbed contributed considerably to total energy intake even though in the present study dietary calorie intake was quite high. Most dialysis patients ingest much less than 2700 kcal/day [13, 14], and thus dialysate glucose could constitute a considerably greater fraction of their total energy intake. Patients undergoing CAPD who ingest high-protein intakes (1.4 g of protein/kg of body wt per day) may be markedly anabolic [15], and such positive nitrogen balances could be related to their high total energy intake. Because wasting and malnutrition occur commonly in chronic renal failure [13, 14], the added glucose calories from CAPD may be beneficial. But the absorption of large quantities of glucose may contribute to hypertriglyceridemia and obesity, which have been reported in patients undergoing CAPD [8]. If hypertriglyceridemia and obesity were to develop, these complica-

Table 1. Glucose absorption and energy intake during continuous ambulatory peritoneal dialysis[a]

Patient	Age yr	Study no.	No. and type bag[b] (1.5%/ 4.25%)	Duration of study days	Glucose inflow g/day	Glucose absorbed g/day	Serum glucose mg/dl	Energy intake kcal/kg of body wt per day: Diet	Dialysate	Total
1	59	1	2/2	7	211	180 ± 2.6	114 ± 6.9	27.9	8.9	36.8
		2	1/3	14	264	218 ± 3.7	126 ± 10.7	27.9	10.8	38.7
2	47	3	4/1	13	187	102 ± 10.5	102 ± 5.6	35.1	5.2	40.3
		4	3/2	4	239	124 ± 11.0	92 ± 8.6	35.1	6.5	41.6
		5	4/1	19	187	89 ± 4.8	86 ± 6.6	33.1	4.6	37.7
3	51	6	2/3	4	291	184 ± 6.4	154 ± 2.0	36.3	8.9	45.2
		7	3/2	16	239	143 ± 7.6	103 ± 2.1	36.3	6.9	43.2
4	36	8	0/4	21	316	273 ± 4.1	132 ± 17.3	34.6	12.4	47.0
		9	0/5[c]	20	395	313 ± 7.2	141 ± 20.5	30.1	14.2	44.3
		10	0/5	7	395	316 ± 9.8	145 ± 10.6	28.3	14.4	42.7
5	27	11	1/2	11	185	159 ± 4.0	122 ± 31.0	36.3	7.6	43.9
		12	2/2	10	212	161 ± 6.0		36.3	7.7	44.0
		13	1/2	10	185	150 ± 3.5	122 ± 21.8	36.8	7.1	43.9
		14	2/2	11	212	163 ± 8.3		36.8	7.8	44.6
6	37	15	2/2	8	211	144 ± 7.1	101 ± 16.0	32.1	6.5	38.6
		16	3/2	7	238	148 ± 4.5	102 ± 9.2	32.1	6.6	38.7
7	41	17	2/3	9	291	203 ± 6.3	98 ± 8.6	24.6	8.3	32.9
		18	3/2	14	238	170 ± 10.5	93 ± 6.8	32.5	7.0	39.5
		19	2/3	6	291	216 ± 8.1	95 ± 3.6	32.5	8.9	41.4
Mean ± SD				11 ± 5	252 ± 62	182 ± 61	113 ± 19.8	32.9 ± 3.5	8.4 ± 2.7	41.3 ± 3.5

[a] All values are mean ± SD. Patients 1, 2, 4, 6 and 7 were anuric; residual GFR in patients 3 and 5 was 1.0 and 3.0 ml/min, respectively.
[b] Actual measured glucose concentrations were 1.30 and 3.76 g/dl.
[c] Diets varied slightly in separate studies performed at UCLA and VA Wadsworth.

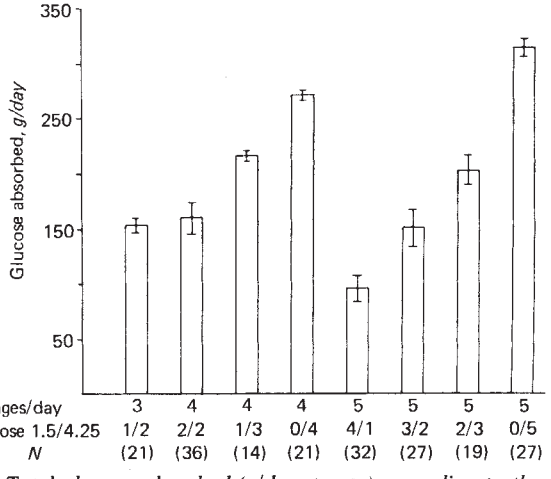

Fig. 1. *Total glucose absorbed (g/day ± S.D.) according to the total number of exchanges and the number of exchanges with 1.5% or 4.25% glucose-containing dialysate. N* is the total number of study days.

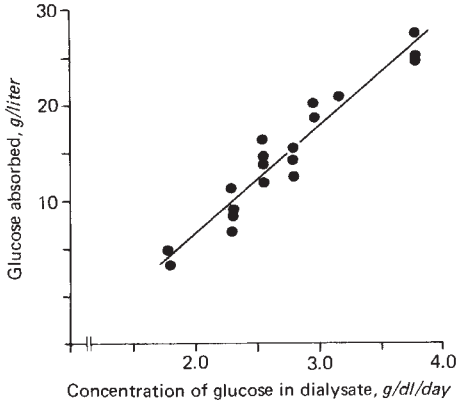

Fig. 2. *Glucose absorbed per liter of instilled dialysate (in grams per liter) in relation to the average glucose concentration of the dialysate used each day (in grams per deciliter per day).* Each *circle* represents a separate study; the *solid line* depicts the regression analysis, $y = 11.3x - 10.9$, $r = 0.96$, $P < 0.001$.

tions might be treated by reducing carbohydrate intake, as has been reported for patients undergoing hemodialysis [16].

Because there is a high correlation between the amount of glucose absorbed each day and the average concentration of glucose in dialysate, the net glucose uptake can be predicted from the concentration of glucose in the inflow. For example, a CAPD patient performing 5 exchanges/day with two 2-liter exchanges of 1.5% dextrose (1.30 g/dl) and three 2-liter exchanges of 4.25% dextrose (3.76 g/dl) will have an average daily dialysate glucose concentration of 2.80 g/dl. The quantity of glucose absorbed from each liter of inflow can be predicted

from the equation, $y = 11.3x - 10.9$ (Fig. 2), as follows:

Glucose absorbed = 11.3 (2.8) − 10.9 = 20.7 g of glucose/liter of dialysate inflow

or 20.7 g/liter × 10 liters of inflow = 207 g/day

DeSanto et al reported that in four patients, each receiving an average daily glucose concentration of 2.6 g/dl, glucose absorption averaged 217 ± 4.7 g/day (range, 214 to 224) [10]. This is similar to the quantity that would be predicted from our equation. It is also noteworthy that, as in the present study, the coefficient of variation for glucose absorption from their four patient studies was low, 2.2%. This finding supports the conclusion that the quantity of net glucose absorption during CAPD can be accurately predicted.

The ability to vary the quantity of net glucose absorbed by altering the dialysate glucose concentrations may prove useful. In a malnourished patient, it may be advisable to increase the number of hypertonic exchanges to increase his energy intake. Such a patient could increase dietary fluid and salt intake so that he can receive an increased number of 4.25% dialysate exchanges. On the other hand, a patient with obesity and/or an elevated triglyceride level could restrict his fluid intake and use fewer hypertonic exchanges, with a reduction in dialysate glucose absorption. Thus, the critical dependence of dialysate glucose absorption on dialysate glucose concentration may allow the clinician to modify the energy intake, depending on the patient's nutritional status and the limits imposed by his need for ultrafiltration and fluid removal.

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