Clearance of Tc-99m DTPA in Hemodialysis and Peritoneal Dialysis: Concise Communication

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The clearance of Tc-99m DTPA was studied in 14 patients undergoing hemodialysis (HD) or peritoneal dialysis (PD). Mean Tc-99m DTPA clearance during HD was 37.8% ± 10.1 of creatinine clearance. Mean Tc-99m DTPA clearance in PD was 65.1% ± 10.3 of creatinine clearance. Tc-99m DTPA, with a larger molecular weight than that of creatinine, is cleared relatively better during PD than during HD. Thus Tc-99m DTPA may be used in the assessment of the effectiveness of different dialytic treatments for substances of similar molecular weight. In addition, our study shows that clearance of DTPA both in HD and PD is sufficiently high to allow the removal of this chelating agent in patients with renal failure.

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The solutes usually used for the in vivo study of the effectiveness of dialytic therapy are endogenous substances of small molecular weight, such as urea, creatinine, uric acid, glucose, and phosphate (*1*). The dialysis of larger molecules is rarely analyzed in vivo, and when it is, exogenous substances such as inulin and radiolabeled vitamin B_{12} are used.

Diethylenetriaminepentacetate (DTPA), a chelating agent with a molecular weight of 500 Daltons, has been used for the treatment of patients accidentally exposed to heavy metals (*2*). When labeled with technetium-99m, this substance has been used in the determination of glomerular filtration rate (*3*).

The purpose of this study is to examine the dialytic properties of DTPA in order to ascertain whether it can be used in the measurement of the effectiveness of dialysis, and in order to see if it is therapeutically valuable as a decorporating agent in uremic patients.

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MATERIAL AND METHODS

In all the studies performed we used the trisodic-calcium salt of diethylenetriaminepentacetate, labeled with Tc-99m. A dose of 2 mCi of Tc-99m DTPA, which contains ~3–5 mg of the chelating agent, was injected intravenously at least 2 hr before the performance of the dialytic procedure. All the samples of blood and dialysate were counted in duplicate in tubes of fixed geometry in a scintillation spectrometer. The following studies were performed.

Hemodialysis. Dialysance of Tc-99m DTPA was determined in eight patients with chronic renal failure, maintained on hemodialysis. The study was carried out in a hospital hemodialysis unit using the clear cannister module* and a proportioning central supply system for dialysate†. A commercial concentrate* was used, and the final concentrations in the dialysate (all in mEq/L) were sodium 130, calcium 3.25, potassium 2, chloride 96.75, and acetate 39.5.

Two different coils were used: Ultra-FLO II Standard* (surface area 0.9 m^2) in five patients and C. D. Standard* (surface area 0.9 m^2) in the other three.

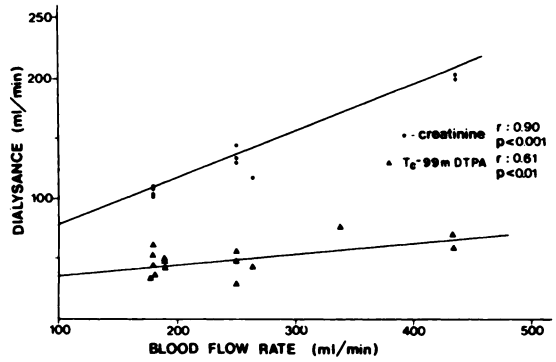

FIG. 1. Dialysance of creatinine and Tc-99m DTPA at different rates of blood flow.

Several times during each dialysis blood was taken from both the arterial and venous lines and simultaneously from the recirculated dialysate in the cannister. Blood-flow rate was measured by timing the passage of an air bubble through 0.5 m of the tubing and using standard tables. Dialysance of Tc-99m DTPA was calculated using the formula

$$D = \frac{A - V}{A - E} \times F,$$

where A is the concentration in arterial line (cpm/ml), V the concentration in venous line (cpm/ml), E the concentration of the dialysate within the cannister (cpm/ml), and F the blood-flow rate (cc/min).

Simultaneous determination of creatinine was performed in order to compare results.

Peritoneal dialysis. The peritoneal clearance of Tc-99m DTPA during peritoneal dialysis was determined in six patients undergoing peritoneal dialysis using a Tenckhoff peritoneal catheter. Commercial dialysate‡ was used in all patients; it contained 1.5 g dextrose per 100 ml, and (all in mEq/L) 141 of Na, 3.5 of Ca, 1.5 of Mg, 101 of Cl, and 45 of sodium lactate. Before the clearance period, and at least 2 hr after Tc-99m DTPA injection, the abdomen was drained of all residual peritoneal fluid. Thereafter two routine exchanges were performed in each patient using 2 L of dialysate. After leaving the dialysate in the abdomen for 40 to 50 min, the fluid was collected by gravity, stopping when the fluid no longer flowed freely. The volume of collected dialysate was measured and an aliquot obtained for subsequent determinations. At the midpoint of each dialysis period, a venous blood sample was obtained. Peritoneal clearance was then calculated using the formula

$$C = \frac{D \cdot v/t}{P},$$

where C is the peritoneal clearance, D the dialysate concentration (cpm/ml), v the volume of the dialysate (ml), t the dwelling time (including half of the inflow time and half of the drainage time), and P the plasma concentration at the midpoint of the dialysis period (cpm/ml).

Simultaneous determination of plasma and dialysate creatinine was performed in order to compare the results.

RESULTS

Hemodialysis (Fig. 1, Table 1). Mean Tc-99m DTPA dialysance was 49.6 ± 13.0 ml/min (range 29–77 ml/min), determined in 16 periods with blood-flow rate ranging from 179 to 434 ml/min. Mean creatinine dialysance, determined concurrently in 11 periods, was 143 ± 44.7 ml/min (range 103–223 ml/min). The relationship between DTPA dialysance and creatinine dialysance was determined in all periods where both tests were performed; it ranged from 21% to 59% (mean 37.8%), the correlation being significant ($r = 0.70$, $p < 0.01$).

Dialysance of creatinine in hemodialysis correlated significantly with the blood-flow rate ($r = 0.90$, $p < 0.001$; Fig. 1) and increased from a mean of 106 ml/min at the lowest blood-flow rate to a mean of 202 ml/min at highest blood flow. There was also a linear correlation between blood-flow rate and the dialysance of Tc-99m DTPA ($r = 0.7$, $p < 0.01$; Fig. 1), and this value increased from a mean of 45.6 ml/min at the lowest blood-flow rate to a mean of 69.2 ml/min at the highest. Thus the dialysance of creatinine increased 91% with

TABLE 1. CREATININE AND Tc-99m DTPA CLEARANCES IN HEMODIALYSIS

Blood-flow rate (ml/min)	Creatinine clearance (ml/min)	Tc-99m DTPA clearance (ml/min)	$\frac{C_{DTPA}}{C_{cr}} \times 100$
179	—	34.9	—
180	108	52.4	48.5
180	103	60.9	59
180	103	44.3	43
180	109	35.4	32
190	—	42.3	—
190	—	49.2	—
200	—	42.5	—
200	—	47.3	—
250	144	57.4	41
250	133	29	21
250	130	48.3	37
264	117	43	36
338	223	77	34
434	200	71.5	35.7
434	205	59	28.7
Mean 267	143	49.6	37.8
s.d. 95.9	44.7	13.0	10.1

TABLE 2. CREATININE AND Tc-99m DTPA CLEARANCES IN PERITONEAL DIALYSIS

Creatinine clearance (ml/min)	Tc-99m DTPA clearance (ml/min)	$\frac{C_{DTPA}}{C_{cr}} \times 100$
16.8	10.6	63
17.9	11.5	64
22	16.3	74
18.2	12.1	66
27	15.3	56
21	12.4	59
12.9	10	77
19.5	15	77
28.4	14.7	52
25.8	12.2	47.2
30.4	18.3	60
25.9	20.1	77
Mean 22.15	14.04	65.1
s.d. 5.3	3.1	10.3

increasing flow rate while the dialysance of DTPA increased 52%.

Peritoneal dialysis (Table 2). Mean Tc-99m DTPA peritoneal clearance in 12 dialysis periods was 14.0 ± 3.1 ml/min. Mean creatinine clearance determined concurrently was 22.15 ± 5.3 ml/min. The relationship of the Tc-99m DTPA clearance to the creatinine clearance ranged from 47.2% to 77% (mean 65.1%). The correlation between both clearances was significant ($r = 0.73$, $p < 0.01$).

DISCUSSION

Renal failure results in the accumulation of various metabolic products in the body. Most of these substances, which have small molecular weights, are effectively removed by hemodialysis. The effectiveness of their removal is determined by measuring the dialysance of endogenous small molecules such as urea and creatinine (*1*). Substances with larger molecules (more than 500 Daltons) also accumulate, and their removal may be of importance in the treatment of the uremic patient (*4*). The effectiveness of the removal of these substances is determined by measuring the dialysance of vitamin B_{12} or inulin.

Technetium-99m DTPA is a chelating agent with a molecular weight of 500–700 Daltons. Upon i.v. injection, less than 5% of DTPA is protein bound, and its distribution seems limited to the extracellular compartment (*5*). Since the size of the DTPA complex is in the range of the smaller substances with middle molecular weights, it could be used to determine the effectiveness of removal of these substances using various dialyzers. The minimal protein binding would cause a small but insignificant decrease in the measured dialysance, whereas the distribution of DTPA in the extracellular fluid would have no effect on the results. This determination of dialysance would simplify the selection of the most suitable dialyzer.

Our study demonstrates that the dialysance of Tc-99m DTPA is significantly less than that of creatinine in the dialyzer tested. The dialysance of DTPA increased relatively less with increase in blood-flow rate than did that of creatinine. This is because the dialysance of larger molecules is related to the membrane permeability and its surface area, and is less dependent on blood flow (*6*).

In peritoneal dialysis, the clearance of DTPA was 64.3% of that of creatinine, whereas in hemodialysis it was only 37.8%. These findings agree with others showing that the peritoneum is relatively more permeable to larger molecules than is the cuprophan membrane used in hemodialysis (*6,7*).

Technetium-99m DTPA is thus a good marker for studying the permeability of hemodialysis membranes and the peritoneal membrane for middle-sized molecules. This test can be used to assess the efficacy of new dialyzers and thus to improve patient care.

In the patient who is being treated with chronic peritoneal dialysis, periodic checking of the peritoneal dialysance of DTPA will allow an assessment of the permeability of the peritoneal membrane, and thus permit a decision as to the continuation of treatment. This is of utmost importance in the newer methods of peritoneal dialysis such as the continuous ambulatory type, where the long-term effects of dialysis on the permeability of the peritoneum are still unknown.

This study, showing a relatively high dialysance for DTPA in both peritoneal and hemodialysis, is important in that the DTPA might be used therapeutically as a decorporator of heavy metals in patients with reduced renal function.

FOOTNOTES

* Travenol.
† Fresenius.
‡ Dianeal, Travenol.

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