

## METABOLIC EFFECTS OF HAEMODIALYSIS AGAINST GLUCOSE- AND ACETATE-CONTAINING SOLUTIONS

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### SUMMARY

Blood acetate, lactate, pyruvate and glucose have been measured in two groups of patients undergoing haemodialysis; five patients with acute or terminal chronic renal failure who had not previously been dialysed and five patients on chronic haemodialysis. There were significant rises in blood levels of all these compounds, with no significant differences between the two groups. It is concluded that the body is capable of metabolising the acetate received during haemodialysis even in advanced uraemia.

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During haemodialysis blood is dialysed against solutions which frequently contain high concentrations of glucose and acetate. Impaired glucose tolerance in renal failure is well recognised (see <sup>1-3</sup>), but few studies have been published on the metabolic effects of the glucose and acetate or lactate in haemodialysis or peritoneal dialysis solutions<sup>4-6</sup>. The subject of this paper is the effect of haemodialysis against solutions containing glucose and acetate in two groups of patients; those who had not previously been dialysed and those who had been dialysed at least ten times before. These two groups were studied because it has been shown<sup>2</sup> that regular haemodialysis can reverse the glucose intolerance found in renal failure.

### METHODS

Dialysis was carried out using the Lucas proportionating and monitoring unit and twin minicoil kidney<sup>7,8</sup> against solutions containing 35 mmoles acetate and 90 mmoles glucose. Arterial blood samples were taken from the shunt immediately before dialysis and from the arterial line after one hour of dialysis; these were analysed for blood glucose/l. acetate, lactate and pyruvate and for plasma total organic anions. On three occasions blood samples were taken from the venous line to estimate glucose and acetate in the blood returning from the artificial kidney to the patient. In addition, arterial blood acetate was measured in three patients after 10 h of dialysis.

Blood lactate and pyruvate were measured by enzyme spectrophotometric

techniques<sup>8</sup>, glucose on the AutoAnalyser using the neocuproine<sup>10</sup> method, and plasma total organic anion using an adaptation of the titration method of Davis and Jacobs<sup>11</sup>. Acetate was measured by gas chromatography<sup>12</sup> on a column of 20% neopentyl glycol succinate and 1.7% phosphoric acid on Chromosorb W, 60–80 mesh, using a Perkin-Elmer F11 chromatograph with flame ionisation detector. The injection temperature was 200° with an oven temperature of 158° and the retention time of acetate was 2.8 min. It was found that this method could be used to measure acetate concentrations down to approximately 0.5 mM (the standard deviation was 0.1 mM at a level of 0.45 mM). For comparison with the pre-dialysis figures acetate was also measured in five normal subjects.

The patients in the first group had either acute renal failure (four cases, patients 2–5) or advanced chronic renal failure requiring dialysis (patient 1). They had not previously been peritoneally dialysed or haemodialysed and the mean pre-dialysis blood urea was 350 mg/100 ml. Those in the second group were undergoing chronic dialysis prior to transplantation, and the mean pre-dialysis blood urea was 100 mg/100 ml. All had had at least ten previous haemodialyses.

## RESULTS

The results for the arterial blood samples are shown in Table I; patients 1–5 were having their first dialysis while patients 6–10 had been previously dialysed. The three venous blood samples were found to contain: acetate 10.6, 12.3, 12.2 mmoles/l and glucose 21.2, 22.4, 21.7 mmoles/l. The three arterial blood acetates after 10 h of dialysis were 1.05, 1.35, 0.80 mmoles/l. Venous blood acetate in five normal hospital staff members averaged 0.51 mmoles/l, range 0.45–0.60 mmoles/l.

## DISCUSSION

There was no significant difference between the results in the two groups, although the rise in blood glucose was slightly greater in the first group ( $0.1 < p < 0.2$ ). This may have been related to potassium deficiency<sup>4</sup> or to the effects of some

TABLE I  
METABOLIC EFFECTS OF HAEMODIALYSIS

Patient	Acetate (mM)		Lactate (mM)		Pyruvate (mM)		Glucose (mM)		Organic anion (mequiv/l)	
	I	II	I	II	I	II	I	II	I	II
1	0.65	0.95	0.78	0.58	0.060	0.075	8.50	14.45	17.8	18.5
2	1.05	2.20	0.58	0.90	0.062	0.110	7.85	14.45	18.7	23.5
3	0.25	1.30	0.31	2.16	0.034	0.110	6.95	15.55	12.6	18.1
4	0.40	1.10	0.62	0.68	0.057	0.060	3.70	8.00	9.0	12.0
5	0.50	1.40	3.12	3.80	0.312	0.294	7.90	12.10	21.5	21.7
6	0.60	1.15	0.58	0.80	0.068	0.076	6.20	10.45	14.5	19.0
7	1.15	1.30	1.10	1.48	0.090	0.153	7.35	10.45	17.6	21.3
8	0.45	1.95	1.24	2.64	0.129	0.229	6.10	12.65	18.7	25.2
9	0.65	1.75	0.60	0.96	0.065	0.100	6.85	11.10	14.7	14.4
10	0.75	1.85	0.88	0.64	0.094	0.082	9.25	6.85	15.4	16.4
Mean	0.645	1.495	0.981	1.464	0.097	0.129	7.065	11.605	16.05	19.01
	$p < 0.001$		$p < 0.05$		$p < 0.05$		$p < 0.001$		$p < 0.01$	

Arterial blood acetate, lactate, pyruvate and glucose and plasma total organic anion before (I) and after 1 h of dialysis (II).

unidentified toxic substances<sup>2</sup>. Significant changes between pre-dialysis values (I) and those found after one hour's dialysis (II) were found in all five parameters measured. The pre-dialysis values did not differ from those of normal subjects, except in the case of the plasma total organic anion<sup>13</sup>. The blood acetate had not risen above the 1-h levels when estimated at 10 h.

The acetate concentration in the blood returning from the artificial kidney to the patients averaged 11.7 mM and the arterial concentration 1.5 mM. The glucose concentration was 21.8 mM venous and 11.6 mM arterial and a blood flow rate of 170 ml/min was used, and hence the patients were metabolising 1.7 mmoles of acetate and 1.7 mmoles of glucose per min, or 100 mmoles of each per hour. It has been estimated by Lundquist<sup>14</sup> that the maximum amount of free acetate which can be metabolised in the human is 300 mmoles per hour, so that if there is any impairment of acetate metabolism in uraemia, at least a third of the capacity of the system must be retained.

The rises found in blood lactate and pyruvate may be due to administration of glucose or acetate or both; it is known that glucose administration can cause elevation of blood pyruvate in normal subjects<sup>15,16</sup> of the same order as the rise found in these patients. On the other hand, Huckabee<sup>17</sup> showed that procedures which raised the blood pH brought about a rise in blood lactate and pyruvate, and the use of acetate in dialysis is intended to raise the pH. It is also possible that oxidation of acetate results in reduced oxidation of pyruvate.

The changes in plasma total organic anion are difficult to interpret since this is a heterogeneous group of compounds which will be dialysed at differing rates. The increases may be accounted for by the observed changes in acetate and lactate concentrations.

It is concluded from these results that although there is a measurable increase in arterial blood acetate during haemodialysis this is small in relation to the acetate entering the blood during passage through the artificial kidney, and that there is no difference in this respect between patients who are in the terminal stages of uraemia and those stabilised on chronic haemodialysis. All the patients were able to metabolise approximately 100 mmoles per hour of acetate.

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#### REFERENCES

- 1 J. P. O'BRIEN AND A. R. SHARPE, *Metabolism*, 15 (1965) 1294.
- 2 C. L. HAMPERS, J. S. SOELDNER, P. B. DOAK AND J. P. MERRILL, *J. Clin. Invest.*, 45 (1966) 1719.
- 3 R. H. HUTCHINGS, R. M. HEGSTRON AND B. H. SCRIBNER, *Ann. Internal Med.*, 65 (1966) 275.
- 4 Y. K. SEEDAT, *Lancet*, ii (1968) 1166.
- 5 D. L. EARNEST, J. H. SADLER, R. H. INGRAM AND E. J. MACON, *Trans. Am. Soc. Artificial Internal Organs*, 14 (1968) 434.

- 6 H. A. LEE, L. F. HILL, V. HEWITT, A. J. RALSTON AND G. M. BERLYNE, *E.D.T.A. Proceedings*, 4, Excerpta Medica Foundation, Amsterdam, 1968, p. 150.
- 7 K. M. SIMPSON, J. D. BLAINNEY, P. DAWSON-EDWARDS, D. D. HILTON, B. T. WILLIAMS, A. C. SUTHERLAND AND K. A. CANTRILL, *Lancet*, i (1967) 1247.
- 8 K. M. SIMPSON, J. D. BLAINNEY, P. DAWSON-EDWARDS, D. D. HILTON AND B. T. WILLIAMS, *Lancet*, i (1967) 1244.
- 9 H. VARLEY, *Practical Clinical Biochemistry*, 4th Ed., Heinemann, London, 1969, pp. 615, 618.
- 10 D. BILTNER AND M. MCCLEARY, *Am. J. Clin. Pathol.*, 40 (1963) 432.
- 11 H. DAVIS AND H. R. JACOBS, *Am. J. Clin. Pathol.*, 23 (1953) 464.
- 12 F. MEDZIHRADESKY AND W. LAMPRECHT, *Z. Physiol. Chem.*, 343 (1965) 35.
- 13 D. SELIGSON, L. W. BLEUMLE, C. D. WEBSTER AND D. SENESKY, *J. Clin. Invest.*, 39 (1958) 1042.
- 14 F. LUNDQUIST, *Nature*, 193 (1962) 579.
- 15 C. L. JOINER, B. MCARDLE AND R. H. S. THOMPSON, *Brain*, 73 (1950) 431.
- 16 M. J. H. SMITH AND K. W. TAYLOR, *Brit. Med. J.*, ii (1956) 1035.
- 17 W. E. HUCKABEE, *J. Clin. Invest.*, 37 (1958) 244.

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