

Clinical Evaluation of A Wearable Artificial Kidney

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INTRODUCTION

The University of Utah's Artificial Organs Division has been experimenting with a Wearable Artificial Kidney (WAK) since 1973. This work has been funded by an NIH-NIAMDD-75-8 grant and private funds. The advantage of this type of machine over conventional dialysis machines is mostly one of psychological effect on the patient. Patients feel tied to the machine for the great lengths of time they are dialyzed and are unable to perform some of their duties and responsibilities; so the trend has been toward smaller, more compact, portable machines. (Figure 1.) This gives the patient a sense of freedom even though he or she still must be dialyzed. If the patient has the capability of moving about, performing his daily task while on dialysis, he can gain further freedom from the machine.

There are several criteria which have to be met before a machine can be wearable. First, components must be small enough and light enough for the patient to carry for sustained periods of time. Secondly, the machine can use only small volumes of dialysate which requires some type of dialysate regeneration system; and thirdly, the machine must be operated by a built-in power source.

CONCEPT

The WAK meets these criteria through the following innovations: (Figure 2.) 1) a dialysate regeneration system consisting of activated charcoal and a detachable 20 liter tank of standard dialysate eliminates the usual 120 liters of dialysate or the need for a proportioning system. Activated charcoal will remove creatinine, uric acid, and other nitrogenous wastes while the 20 liters of dialysate presently acts as a urea and potassium removal system. (Figure 3.) Other components of the dialysate system are: 2) a standard Cordis-Dow Model IV dialyzer; 3) an accumulator which acts as a dampener to expand and contract with the pulsations of the pump; 4) an ultrafiltration valve to adjust the vacuum for fluid removal; 5) an ultrafiltrate collection bag; and 6) a pumping segment to move the dialysate through the system.

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Compactness of the equipment is attained by using a single pump for both blood and dialysate. (Figure 4.) The pump operates by utilizing a pumping ventricle of 3/4 inch diameter silastic tubing with unidirectional flap valves in either end. The "squash plate" of the pump will squeeze first one pump segment then the other giving a pulsatile flow to both blood and dialysate. Power is supplied to the pump by 10 rechargeable nickel-cadmium C size flashlight batteries which generate 12 volts of direct current. The battery pack will maintain power enough to drive the pump for five to six hours. The total dialysate system is shown in Figure 5.

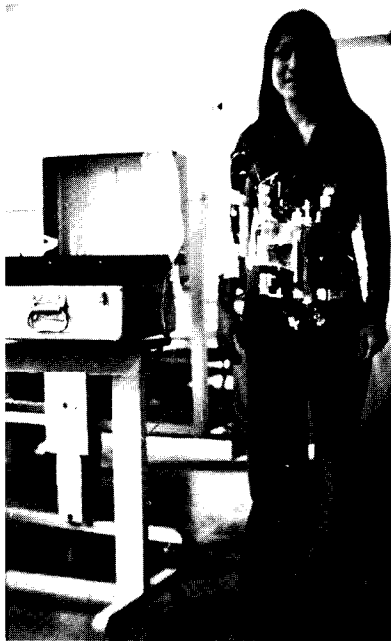


Fig.1

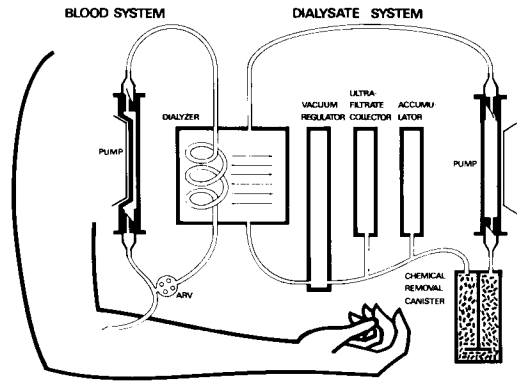


Fig.2

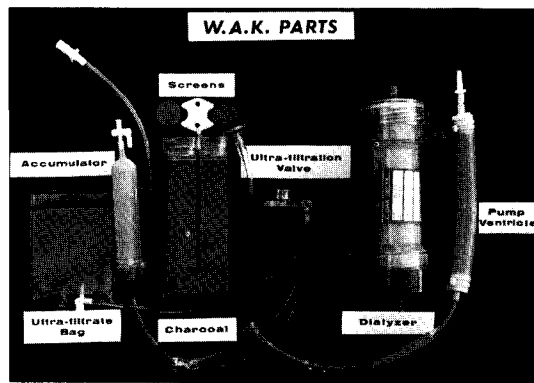


Fig.3

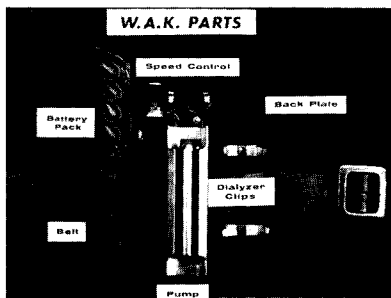


Fig.4

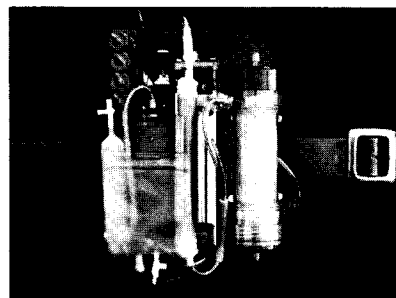


Fig.5

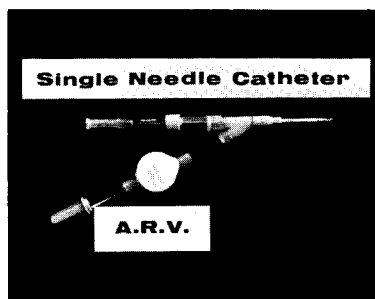


Fig.6

Table 1

WAK pump - double needle

Length of dialysis = 2 hours

Blood flow rate = 150 to 240 cc/min.

Dialysate flow rate = 150 to 240 cc/min.

Creatinine concentration = Pre 15.4 mEq/L; Post 13.4 mEq/L

Creatinine removed = 13.2%

Table 2

Travenol pump, single needle, ARV

Length of dialysis = 4 hours

Blood flow rate = 160 to 230 cc/min.

Dialysate flow rate = 180 cc/min.

Creatinine concentration = Pre 15.1 mEq/L; Post 11.5 mEq/L

Recirculated volume = 12 to 13%

Creatinine removed = 43.5%

Table 3

WAK pump, single needle, ARV, 250 gm charcoal

Length of dialysis = 1 1/2 hours

Blood flow rate = 150 to 250 cc/min.

Dialysate flow rate = 150 to 250 cc/min.

Creatinine concentration = Pre 10.6 mEq/L; Post 9.3 mEq/L

Creatinine removed = 11.7%

Table 4

WAK pump, single needle, ARV, 100 gm charcoal

Length of dialysis = 1 1/2 hours

Blood flow rate = 100 to 250 cc/min.

Dialysate flow rate = 100 to 250 cc/min.

Creatinine concentration = Pre 16.3 mEq/L; Post 14.8 mEq/L

Creatinine removed = 9.3%

Table 5

WAK single needle, ARV, 250 gm charcoal, ultrafiltration valve

Length of dialysis = 4 hours

Valve Setting	Positive Pressure	Negative Pressure	Ultrafiltration Rate
0	0 to 100 mmHg	-25 to -110 mmHg	4 cc/hr.
1/4	25 to 100	-75 to -175	180 cc/hr.
1/2	25 to 110	-160 to -210	360 cc/hr.
1	25 to 110	-200 to -260	700 cc/hr.

Table 6

WAK pump, 20 liter dialysate, no charcoal

Length of dialysis = 1 1/2 hours

Blood flow rate = 230 cc/min.

Dialysate flow rate = 230 cc/min.

BUN removal = 10.3 gm

Potassium removed = average of 1 mEq/L/hr.

The blood compartment is a very simple circuit coming from the patient into the pumping ventricle, to the top of the dialyzer, into the bubble catcher, and returning to the patient. This system can be used with either a fistula or a shunt. If a fistula is used, a single needle with anti-recirculation valve (ARV) is applied. The ARV is placed in the venous line just distal to the catheter "y" which eliminates most of the recirculation of blood back through the machine. (Figure 6.)

The clinical evaluating of components for the WAK started in the fall of 1973. Components were initially tested as additions to the conventional dialysis system. This method was used to evaluate the effectiveness of the combination blood and dialysate pump, clearance efficiency of the charcoal, removal capacity of the 20 liter dialysate tank, ultrafiltration characteristics of the ultrafiltration valve in combination with the Cordis-Dow Model IV dialyzer and the percentage of recirculation using the ARV.

RESULTS

All tests were using Cordis-Dow Model IV dialyzer (Tables 1 - 6).

Following the initial evaluation of the WAK components, the patient was subjected to 28 consecutive days of dialysis for an average of 2 1/2 hours per dialysis. The machine was able to maintain the necessary waste removal and ultrafiltration rate comparable to dialysis on conventional machines. The patient felt better during the 28 days of dialysis than with 3 day per week dialysis on conventional machines. During one 4-hour dialysis, a high pump speed was maintained to determine the maximum removal of urea and potassium. This resulted in removal of 24 grams urea and nearly 80 mEq of potassium.

CONCLUSION

It is feasible to dialyze patients with a wearable artificial kidney. The advantages of this type machine over conventional dialyzers are: 1) portability of the machine enabling the patient to gain some freedom from the machine; 2) possibility of everyday short term dialysis, which would dampen the blood concentration peaks of waste products and fluid; 3) less expense for maintenance and repair of the equipment; 4) utilization of much less space and a greater ease of operation involving less time for the patient and helper.