REMOVAL OF EDEMA FLUID BY ULTRAFILTRATION WITH THE DISPOSABLE TWIN-COIL ARTIFICIAL KIDNEY

Report of Two Cases

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THE artificial kidney is useful not only for the treatment of the uremic state but also in the removal of edema. The states of overhydration[1-3] in which hemodialysis can be effective are those in which the kidneys either cannot excrete water, as in advanced renal failure, or will not excrete water, as in intractable cardiac failure. The frequency of overhydration in azotemia is emphasized by the fact that of the last 100 patients who underwent dialysis at the Cleveland Clinic Hospital, 35 required ultrafiltration to remove excess fluid.

During hemodialysis, fluid can be removed either by raising the pressure in the dialyzing unit, which results in ultrafiltration, or by raising the solute concentration of the rinsing fluid which, by osmosis, causes a movement of water from the less concentrated plasma inside the cellophane tubing of the artificial kidney to the more concentrated fluid of the bath. To effect ultrafiltration, the pressure in the disposable twin-coil artificial kidney[4] can be increased by constricting the outflow tract with a screw clamp. The pressure in the outflow tract of the artificial kidney, proximal to the clamp, is measured by a Tycos manometer connected to the bubble-catcher system, as shown in *Figure 1*. The pressure in the bubble catchers can be safely increased to 300 mm. of Hg without rupturing the cellophane tube. The pressure at the point where the blood leaves the coil is approximately 40 mm. of Hg above that in the bubble catchers, with about 50 cm. of difference in height from the twin-coil artificial kidney to the bubble catchers. Fluid removal by ultrafiltration with a twin-coil artificial kidney can be easily measured when a known volume of blood is circulated through an artificial kidney from a calibrated reservoir *(Fig. 2)*. The rate of fluid removal can be increased approximately from 100 to 600 ml. per hour by increase of ultrafiltration, and further to 1200 ml. per hour by combination with osmosis, if dextrose is added up to 10 per cent in the rinsing solution. There is also, generally, an increase in the amount of fluid removal with an increase in blood flow rate through the artificial kidney.

During hemodialysis the rate of fluid exchange between the patient and the rinsing solution is an important factor in the clinical management of the patient's status of hydration. From *Figure 2* one can estimate the amount of fluid that will

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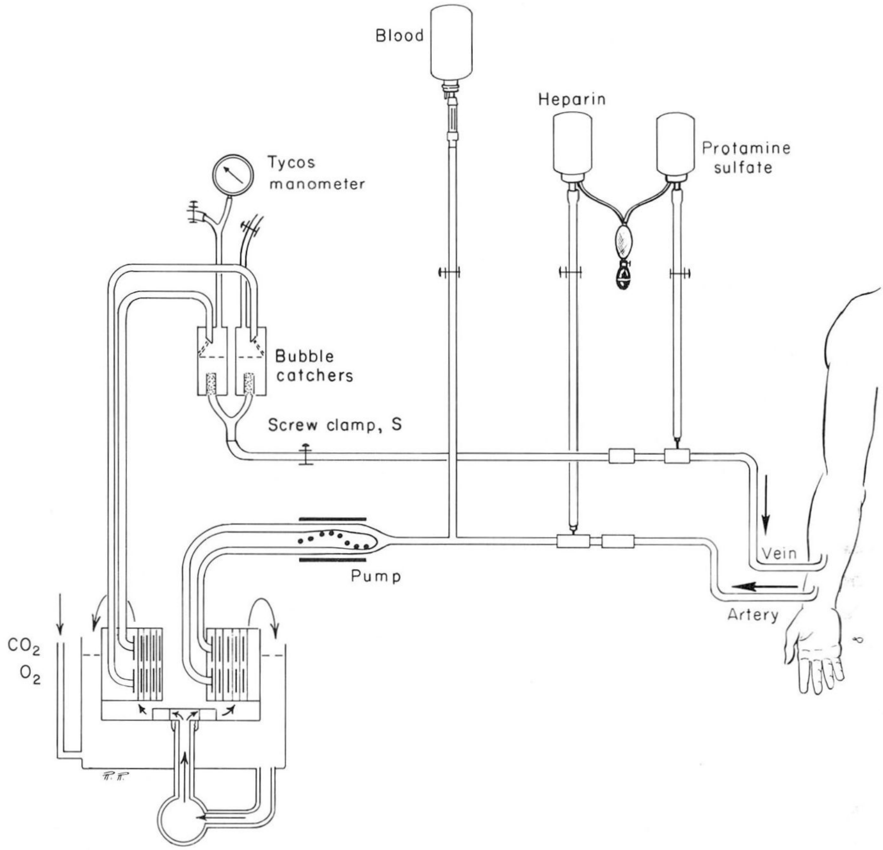

Fig. 1. Schematic drawing of the blood circuit for a twin-coil artificial kidney. The blood comes from an artery or a vein and is pumped into the coils of the artificial kidney. After dialysis the blood proceeds to the bubble catchers, and beyond those a screw clamp, S, regulates the pressure as measured by a Tycos manometer. This pressure determines the degree of ultrafiltration. For so-called regional heparinization, heparin is administered to the arterial line, and protamine sulfate, enough to neutralize the heparin, is administered to the venous line. Thus, the clotting time of the blood in the artificial kidney is prolonged, but the clotting time of the blood in the patient is normal.

be removed from the patient with ultrafiltration. It is important that even with zero pressure in the bubble catchers, approximately 100 ml. of fluid per hour is still removed from the patient during dialysis. The pressure responsible for ultrafiltration is produced by a Sigmamotor pump that is located in the tubing system between the patient and the twin-coil artificial kidney. The patient's blood is pumped into the coil and has to overcome the resistance in the cellophane tubing. Moreover, since the blood flow of 300 ml. per minute is relatively large to

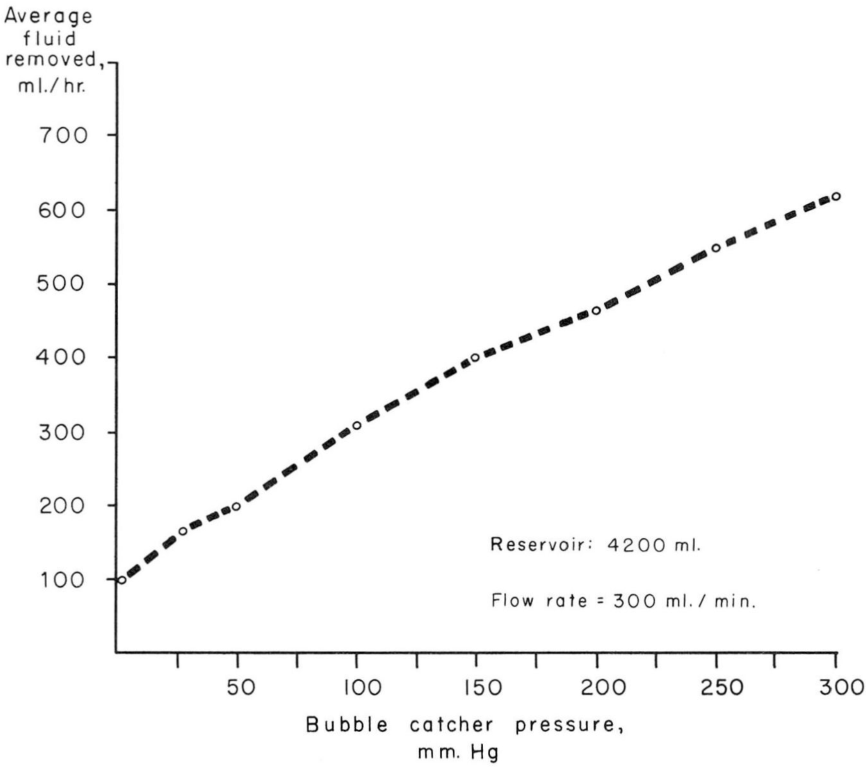

Fig. 2. Plasma water removed when blood was circulated from a calibrated reservoir through a twin-coil artificial kidney, with the usual rinsing fluid on the outside. Only one coil of a twin-coil artificial kidney was used. When the filtration pressure increased as indicated by the pressure measured in the bubble catchers, the amount of fluid removed by utlrafiltration increased from 100 to 600 ml. per hour (it would be more if two coils were used).

be accommodated by the patient's forearm vein, there is usually a resistance to overcome, which will also affect the ultrafiltration. Some patients require replacement of the fluid removed by the unavoidable ultrafiltration, in order to avoid becoming dehydrated during hemodialysis.

In the 35 patients, mentioned before, who required ultrafiltration, clinical improvement was apparent within the first two hours of dialysis, and the removal of body fluid was reflected in a weight loss of from 5 to 12 pounds. Patients who were greatly overhydrated required more than one treatment with a short interval between dialyses.

Illustrative Case Reports

Case 1. A 36-year-old housewife was admitted to the Cleveland Clinic Hospital on the eleventh postpartum day because of acute renal failure that had followed a trans-

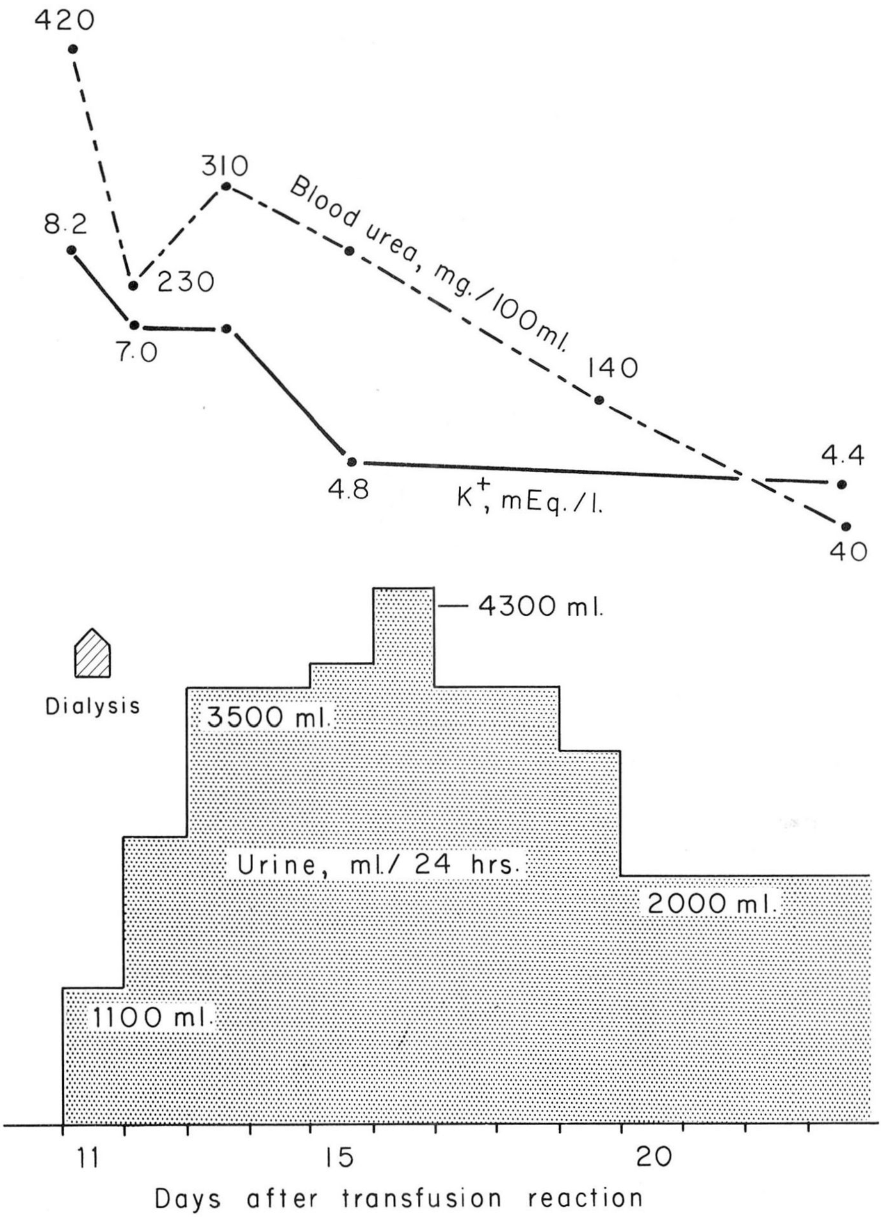

Fig. 3. Case 1. Acute renal failure developed following reaction to a blood transfusion. Graph shows the reduction of blood urea and serum potassium concentrations during dialysis, and the daily urinary output. Most important was the dramatic improvement of pulmonary edema during dialysis and ultrafiltration.

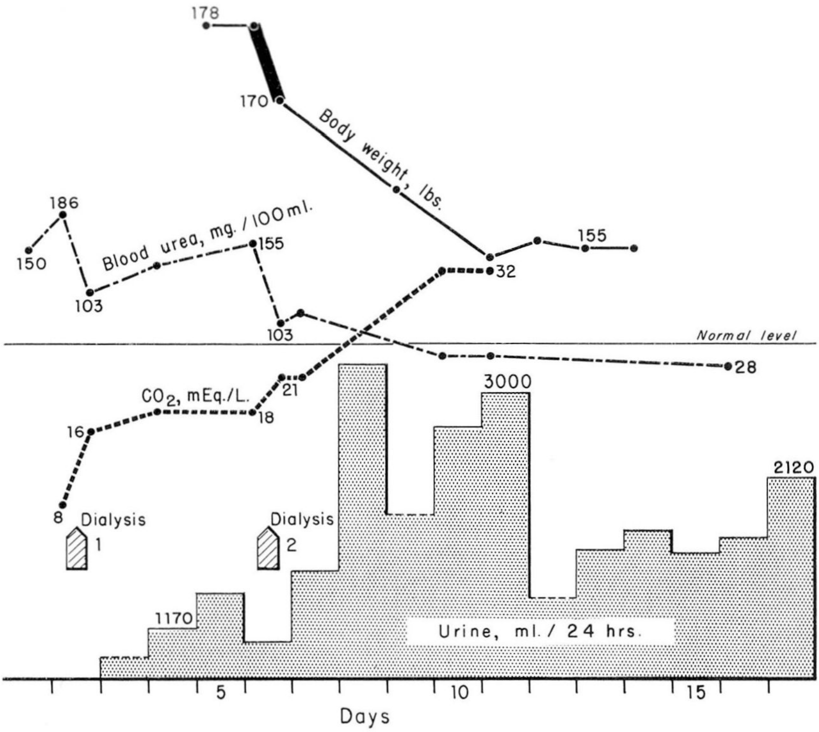

Fig. 4. Case 2. The patient had primary cardiac failure with intractable edema and secondary renal failure. Graph shows the changes, resulting from hemodialysis, in blood urea concentration and plasma carbon dioxide content. Note the reduction in body weight during the second dialysis and ultrafiltration, and the large urinary output thereafter when the patient became responsive to diuretics.

fusion of incompatible blood. The congestive failure and pulmonary edema that developed had been treated with digitalis and oxygen without apparent response. Upon admission here she was severely ill with pulmonary edema and uremia, and she was immediately treated with dialysis and ultrafiltration. Since no compatible blood could be obtained, even after crossmatching more than 40 pints of blood, a single coil of the twin-coil artificial kidney was primed with 6 per cent dextran in 5 per cent dextrose solution instead of with blood. She underwent hemodialysis plus ultrafiltration without complication. Within two hours her clinical condition had improved and the signs of pulmonary edema had disappeared. She recovered from acute renal failure and was discharged 13 days after admission. Because she was critically ill, she was not weighed either before or after dialysis but the improvement of the pulmonary edema showed the effect of ultrafiltration. *Figure 3* shows the decrease in concentration of blood urea and in serum potassium during the dialysis.

Case 2. A 52-year-old man, with a history of angina pectoris and progressive cardiac failure for nine years, was admitted to the Cleveland Clinic Hospital with severe congestive cardiac failure. Despite intensive medical management, including administration of digitalis and mercurial diuretics, the urinary output decreased to less than 500 ml. per 24 hours; body weight increased rapidly and azotemia developed. He became stuporous and dyspneic with the Kussmaul type of respiration. (Serum carbon dioxide content was 8 mEq. per liter.) So-called "intractable" cardiac edema developed, and his clinical condition rapidly deteriorated. As a last resort on the fifteenth and nineteenth hospital days the patient was treated with hemodialysis and ultrafiltration. As he was severely ill he was not weighed at the time of the first dialysis; however, during the second dialysis he lost 8 pounds in weight. After removal of fluid by ultrafiltration and correction of electrolyte concentration (shown in *Figure 4)* by hemodialysis, he responded to mercurial diuretics. Two days after the second dialysis the urinary output was 3000 ml. per 24 hours. The ensuing hospital course was uncomplicated, and he was discharged 22 days after the second dialysis.

Summary

The artificial kidney has been used successfully in removing edema fluid in overhydrated patients. Up to 600 ml. of fluid can be removed by ultrafiltration alone, and up to 1200 ml. per hour by ultrafiltration and osmosis when dextrose is added up to 10 per cent in the rinsing solution. Two cases are reported of patients who were treated with hemodialysis and ultrafiltration. One of the patients had uremia and pulmonary edema; the pulmonary edema improved within two hours; recovery ensued. The other patient had cardiac failure with "intractable" edema and secondary oliguria; this patient became responsive to diuretics to which he had been unresponsive before dialysis.

References

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