Jan. 24, 1961 C. R. BROMAN 2,969,150

ARTIFICIAL KIDNEY SYSTEM

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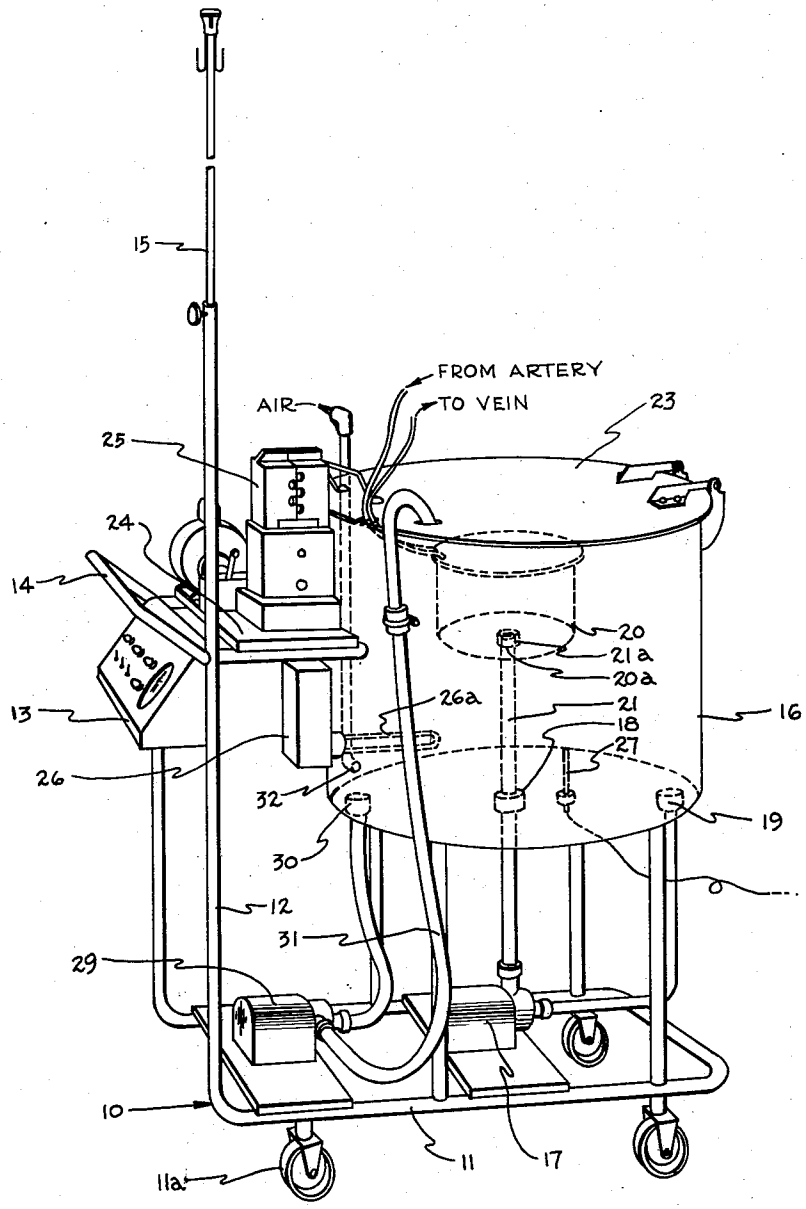

Fig. 1.

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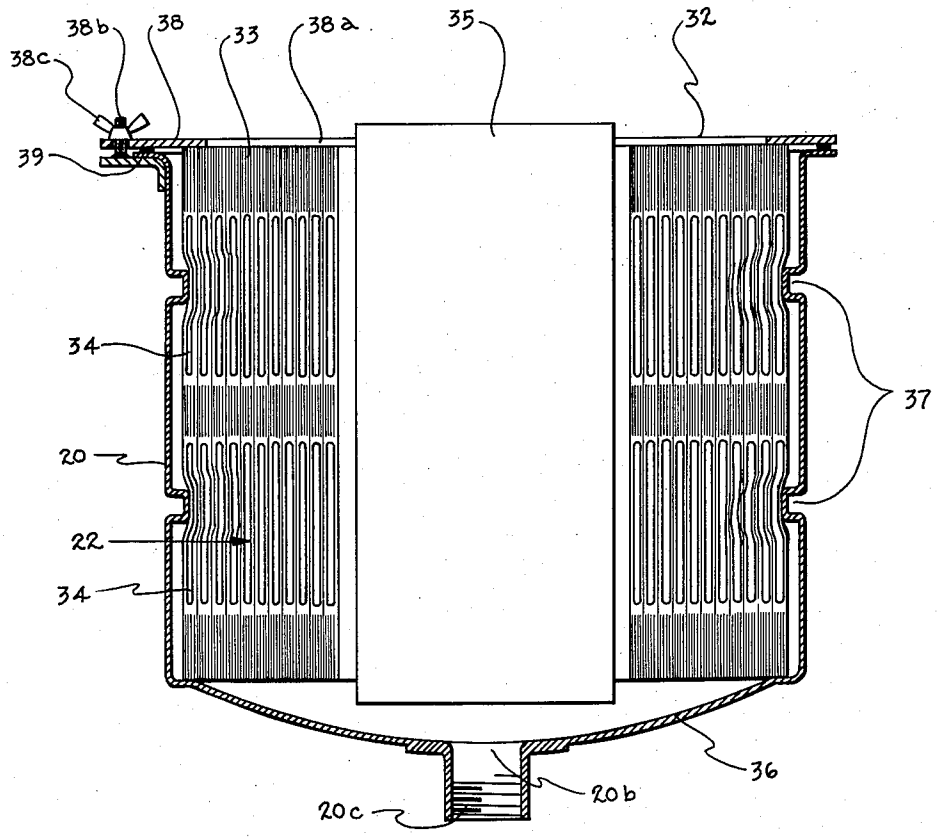

Fig. 2.

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ARTIFICIAL KIDNEY SYSTEM

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5 Claims. (Cl. 210—321)

This invention relates to an artificial kidney system, and more particularly, to a structure adapted to receive a coiled, artificial kidney and provide a source of dialyzing fluid for the artificial kidney.

The artificial kidney component of my system may take the form of a flat, elongated, perforate housing, such as non-toxic screening, wound upon itself to form a cylindrical coil. Contained within the screen envelope are two tubular septa, generally constructed of a cellulosic material so that they can conduct blood but permit the dialysis of deleterious substances from the blood such as urea.

It is, therefore, an object of my invention to provide a complete artificial kidney system capable of being interconnected into the blood circulatory system of a patient whose own kidneys are incapable of functioning properly. Another object of my invention is to provide an artificial kidney system characterized by low cost, portability, and ease of use. Yet another object is to provide a system having an arrangement of elements permitting substantially continuous use of the system during a prolonged dialysis of a patient's blood irrespective of the need for replacing the artificial kidney or dialyzing fluid. Other objects and advantages of my invention will be explained in conjunction with the accompanying drawing in which Fig. 1 is a perspective view of the artificial kidney system of my invention wherein certain internal elements of the system are shown in dotted line; and Fig. 2 is an enlarged fragmentary portion of the elements shown in dotted line in Fig. 1.

Referring now to the drawing, and in particular Fig. 1, the numeral 10 generally indicates the frame which supports the various elements of the artificial kidney system of my invention. Frame 10 is seen to consist of an interconnected arrangement of tubular members providing a horizontal platform 11 from which depend casters 12, permitting the frame to be wheeled from place to place and patient to patient very conveniently.

Frame 10, in addition to the horizontal platform 11, includes a vertical portion 12 which accommodates an instrument panel 13 and a handle 14. In the preferred embodiment, one element of vertical portion 12 is extended upwardly to provide a standard 15 for the mounting of parenteral solution equipment used in the operation of an artificial kidney system.

Mounted on frame 10 and spaced from horizontal platform 11 is tank 16. Intermediate tank 16 and horizontal platform 11 and mounted on platform 11 is circulating pump 17. Circulating pump 17 has its outlet connected to the central base portion of cylindrical tank 16 as at 18 and the inlet of circulating pump 17 is also connected to the base of tank 16 but at a point spaced from the pump outlet connection, the pump inlet connection being designated 19.

Mounted in tank 16 is receptacle 20. In the embodiment shown, the inner-central base of tank 16 is provided with a vertical riser 21 which is threaded as at 21*a* at its nonconnected end. Receptacle 20 is of generally cylindrical configuration and is provided with an axial opening in the base thereof as designated 20*a*, and which is internally threaded so as to mate with threaded portion 21*a* of vertical riser 21, which thus rigidly but removably supports receptacle 20 in tank 16.

Contained within receptacle 20 is an artificial kidney generally designated 22 and which can be seen in larger scale in Fig. 2. As pointed out above, the artificial kidney 22 intended for use in my artificial kidney system includes 2 flat cellulose tubes enveloped between non-toxic fiber glass screens, the tubes and screening forming an assembly that is tightly but uniformly coiled about itself and provided with suitable end connections leading from and to the body of the patient to be treated. These connections are indicated in dotted line also in Fig. 1 and the portions of the blood circulatory system to which they are connected are referred to.

Tank 16 is provided with a hinged transparent cover 23 which permits visual checking of the operation of the artificial kidney system at any time. If either of the above-mentioned septa should rupture, the dialyzing solution circulated by pump 17 would become discolored and the system's operation discontinued.

A second horizontal platform 24 is provided spaced from horizontal platform 11 which accommodates a pair of pumps operating on the blood conduits leading from and to the patient, the pumps being designated 25.

Mounted on the side wall of tank 16 is heater 26 having element 26*a* extending inwardly of tank 16. The control for heater 26 is a toggle switch mounted on instrument panel 13 which is also provided with a signal light indicating that the heater is on. In like fashion a control and signal light is provided on instrument panel 13 for circulating pump 17. Instrument panel 13 also accommodates a dial thermometer connected with a thermometer mounted in tank 16 as at 27.

Also mounted on horizontal platform 11 is drain pump 29, an inlet to which is connected to tank 16 as at 30. The outlet from drain pump 29 is provided with a hose 31 that can be conveniently positioned on any drain facilities such as a sink or the like. It is considered desirable to have a drain pump separated from the circulating pump since, in the course of the ordinary usage of my artificial kidney system on a particular patient, it is necessary to replace substantially all of the circulating fluid at least once. During the drain of the first charge of circulating fluid, it is still possible to keep the kidney in operation since only a small quantity of fluid is circulated by the circulating pump.

Tank 16 is also provided with an air inlet as at 32 which permits aeration of the circulating fluid.

Referring now to Fig. 2 which shows in enlarged form the internal portion of tank 16 and, more particularly, receptacle 20, it is to be noted that receptacle 20 is generally cylindrical in configuration and is provided with a depending axial neck portion 20*b* which is internally threaded as at 20*c*. Neck 20*b* is thereby adapted to be mounted on vertical riser 21 and therefore be communicated with the outlet of circulating pump 17.

Received within receptacle 20 is artificial kidney 22 which has a screen envelope 33 enclosing spaced septa 34. Kidney 22 is mounted on a core 35 which conveniently can take the form of a stainless steel cylinder such as a can. Receptacle 20 is chamfered or outwardly bowed or dished as at 36 to permit the ready inflow of dialyzing fluid from circulating pump which might otherwise be obstructed by the contact of the base of can 35 with the inner base of receptacle 20. The side wall of receptacle 20 is provided with a pair of annular indentations designated 37 which are so positioned with respect to the base of receptacle 20 that when kidney 22 is received therein, indentations 37 will press against that

portion of kidney 22 carrying septa 34. This results in restricting the flow of dialyzing fluid to between the various coils of kidney 22 and prevents bypass of fluid external to the outer convolution of kidney 22. The flow of dialyzing fluid is therefore directed along a path parallel to the axis of receptacle 20. At the same time it permits ready access to the outer wall of kidney 22 adjacent the top thereof to permit a convenient gripping surface for removal of the kidney from receptacle 20. It is to be noted from a comparison of Figs. 1 and 2 that receptacle 20 when kidney 22 is received therein has a comparatively small unfilled volume compared to tank 16.

Receptacle 20 is partially closed by a circular ring 38 having a central opening 38*a* and which is bolted to receptacle 20 by bolts 38*b* which are in turn secured by wing nuts 38*c*. Annular ring 38 is of sufficient width to overlap at least one soil of kidney 22 to restrict the flow of dialyzing fluid through the coils of kidney 22 rather than allow bypass around kidney 22. Interspersed between ring 38 and the top lip of receptacle 20 is gasket 39, insuring no leakage of dialyzing fluid through that joint.

Operation

To operate the artificial kidney system of my invention, the tank unit which has a capacity somewhat in excess of 100 liters is filled with a suitable dialyzing liquid. Such a fluid might include the following constituents per liter:

NaCl	gm.	570
$NaHCO_3$	gm.	300
KCl	gm.	40
$CaCl_2$	gm.	28
$MgCl_2$	gm.	15

0.4% invert sugar

Bactic acid to adjust pH to 7.4

This fluid is circulated by pump 17 so that it enters the central base of receptacle 20, overflows the top and is returned through connection 19 to circulating pump 17. The temperature of the liquid is maintained by heater 26 to about 39° C. and the solution is aerated by using about 10% carbon dioxide in oxygen.

The kidney 22 is then inserted into the receptacle 20 and septa 34 become fully wetted. An electrolyte solution is then pumped through septa 34 by establishing connections through the conduits that eventually will lead to the vein and from the artery of the patient. When the septa are fully wetted, approximately 6 liters of isotonic (i.e., 0.7% NaCl) electrolyte should be pumped into the septa. If desired, the septa may be tested for leaks by pumping about 100 cc. of heparinized blood through them, followed by more saline. To the last quantity of saline, a small quantity of heparin should be added.

Ring cover 38 for receptacle 20 is then applied and wing nuts 38*c* are dogged down to insure a tight fit of kidney 22 within receptacle 20.

The patient is cannulated about an hour prior to connecting my artificial kidney system to his circulating system. This minimizes the chances of clotting at the points of cannulation. The vein cannula is first inserted, followed by the arterial cannula. The artificial kidney 22 is then primed with about a liter of citrated bank blood which can be conveniently mounted on standard 15. The patient's blood is then caused to flow through the kidney 22, the rate of flow being determined by visual examination of the flow in an air-trap-filter-drip unit which is interconnected into the vein conduit. The drip unit should be mounted in a vertical position and can be conveniently suspended also from standard 15.

After about two to three hours of circulation of the patient's blood, it becomes necessary to change the dialyzing fluid. This is done simply by actuating drain pump 29 without stopping circulating pump 17 or the flow of blood in kidney 32. The entire unit can be drained without danger to the patient's life. However, in practice a small quantity of dialyzing fluid is not drained which permits the kidney 22 to remain immersed in fluid throughout the dialysis which may last six hours or more. The comparatively small unfilled volume of receptacle 20 when kidney 22 is mounted therein, in comparison with the volume of tank 16, permits substantial drainage of tank 16 without exposing the exterior of septa 34 to air which would halt the dialysis and possibly stress septa 34. Once it is drained, a new charge of dialyzing fluid can be added to tank 16, and the remainder of the dialysis of the patient's blood continued.

At the end of the dialysis, the used artificial kidney can be removed by merely removing cover 38 and lifting out kidney 22. Drain pump 29 removes all fluid and, after the tank 16 is rinsed, it is ready for use on another patient. The kidney 22 along with its connections and filter-drip-air-vent units are disposable, so no cleaning is required for them. The blood circulating pumps 25 operate on the exterior of tubing so no cleaning is required for them either. The ease of removal and replacement of kidney 22 in the system of my invention permits a blood dialysis to continue without substantial interruption even though a septum should fail, and thus the kidney 22 would have to be replaced in the course of a dialysis.

The foregoing detailed description has been given for clearness of understanding only and no unnecessary limitations are to be inferred therefrom.

I claim:

1. In an artificial kidney system, means for circulating a dialyzing liquid, a cylindrical receptacle for a coiled artificial kidney, said receptacle being operatively interconnected in said circulating means, said receptacle having an annular indentation intermediate its ends whereby said kidney is tightly but readily-removably received in said receptacle, and an annular ring cover mounted on said receptacle whereby said cover and said indentation co-operate to cause all dialyzing liquid to flow between the coils of said kidney along the entire length thereof.

2. An artificial kidney system comprising a frame, wheel means on said frame permitting the frame to be transported, a tank mounted on said frame, a circulating pump mounted in said frame, the outlet of said pump being operatively connected to central base of said tank and the inlet of said pump being operatively connected to the base of said tank at a point spaced from said outlet connections, a tank discharge pump on said frame having its inlet connected to the base of said tank, a cylindrical receptacle removably mounted above the central base of said tank but within said tank and communicating with said circulating pump outlet, an artificial kidney removably mounted in said receptacle, said receptacle having a larger internal diameter than the outer diameter of said kidney, permitting ready removal of said kidney from said receptacle and retention of dialyzing fluid from said circulating pump when said discharge pump is operative to drain said tank, said kidney comprising an elongate, perforate flat envelope housing a spaced pair of flat permeable tubular septa, said envelope being wound upon itself to form a cylindrical coil with connection means to the ends of said septa extending outward of said coil, said receptacle having a pair of annular indentations in the side wall thereof so positioned as to compress the septal portions of said kidney, a removable cover for said receptacle provided with a central opening whereby fluid from said pump is caused to flow upward through said receptacle and kidney and substantially no fluid bypasses the septal portions of said kidney.

3. In an artificial kidney system in which a flat septum is wound on itself to provide a blood dialyzing conduit, a septum-receiving receptacle having an open top and a connection in the bottom thereof for introducing dialyzing fluid therein, said receptacle being generally cylindrical with the side wall thereof having an annular indentation intermediate the ends thereof and of a height less than the width of said septum.

4. The structure of claim 3, in which the said indentation is so located along the height of said receptacle as to abut the central portion of the width of a septum received in said receptacle.

5. The structure of claim 4, in which a plurality of indentations are provided corresponding to a similar plurality of superpositioned wound septa received in said receptacle.

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