ABSTRACT

A device for cleaning and sterilizing artificial kidneys. Pump means and at least some of the valve means are constructed for external actuation, so that the fluids they propel or control do not contact parts which are subject to corrosion, and so that leakage at joints is minimized. In a preferred embodiment, the pump means and at least some of the valve means are separable, parts of them being carried by an adapter which is attachable to base structure. Then the risk of cross-contamination of artificial kidneys of a plurality of persons through the base structure is eliminated.

28 Claims, 11 Drawing Figures
DEVICE FOR CLEANING AND STERILIZING ARTIFICIAL KIDNEYS

This invention relates to a device for cleaning and sterilizing artificial kidneys to permit their re-use.

The re-use of artificial kidneys can constitute a substantial economy for persons who must rely on hemodialysis as a substitute for the function of their own kidneys when their kidneys have failed. Devices exist which attempt to provide cleaning and sterilizing functions for artificial kidneys, but they have a number of shortcomings which in many cases are so serious that patients prefer not to rely on them, and instead use a new artificial kidney each time they undergo hemodialysis. Also, some of the prior art devices are so troublesome that their use in a functioning facility is impracticable. The consequence of single usage of artificial kidneys is a substantial economic waste, because many or most artificial kidneys can reliably be re-used at least several times if properly cleaned and sterilized, and if a practical device is available for doing it.

Prior art devices have suffered from various shortcomings, including (1) leaks at various of their fittings; (2) corrosion of their systems, especially that which is caused by sodium hypochlorite, which is frequently used as a cleaning solution; (3) unsuitability for use with more than one type of artificial kidney; and (4) the absence of adjustable time settings for each part of the cycle of cleaning and sterilizing. Devices with these problems are not practical for facilities where cleaning and sterilizing would routinely be done.

Another very serious shortcoming, and one which is common to presently-known prior art devices, is the risk of contamination of the cleaning and sterilizing device itself by fluids from the artificial kidneys cleaned by them. Infections present in one artificial kidney might then be transferred to another patient as a consequence of the transmission of infectious organisms from the device to another artificial kidney which is later cleaned by it.

It is an object of this invention to provide a device wherein a minimum of components are subject to corrosion, in which the device is only minimally subject to leaks, in which different programs for cleaning and sterilizing can be provided, and in which the cleaning device itself can include a portion unique to each individual user to which fluids from his own artificial kidney are restricted.

A device according to this invention operates to clean and to sterilize an artificial kidney of the type which has a blood chamber with an inlet and an outlet. It is adaptable for use with artificial kidneys which include a dialysate chamber with an inlet and an outlet, and also with those which do not have a dialysate chamber. It is a function of this invention to flush out, to clean, and to sterilize the blood chamber and, for artificial kidneys which include a dialysate chamber, to flush and if desired also to sterilize the dialysate chamber. For the foregoing purposes, the blood chamber inlet and outlet and the dialysate chamber inlet (when present) will be connected to the device.

According to this invention, the device has means for making the requisite connections to the artificial kidney and to supplies of water, cleaning solution, and sterilizing solution. It also has conduits for supplying fluids to the inlets of the blood chamber and dialysate chamber (when present) of the artificial kidney, and for draining the blood chamber.

Externally actuated, and preferably separable, pump means is provided for pumping the cleaning and sterilizing solutions. Conduit extending from a sterilizing solution inlet and from a cleaning solution inlet include pump plenum conduits, upon which pumping forces can be exerted by parts of the pump means. In the preferred embodiment of the invention, rotary pump impellers are adapted to pinch the plenum conduits so as to trap quanta of liquid and expel them from the respective plenum conduits. Other types of externally actuable pumps may instead be used.

Supply valves are provided for the water, for the cleaning solution, and for the sterilizing solution. Externally actuable, and preferably separable, valve means are provided for the dialysate chamber inlet (when a dialysate chamber is to be cleaned) and for the blood chamber drain.

According to a preferred but optional feature of the invention, an adapter unique to each patient is removably attachable to the base structure of the device. The base structure carries the actuating portions of the pump means and of certain of the valve means, and the adapter carries those portions which convey the fluids.

According to still another preferred feature of the invention, the various elements of the device are sequentially actuated through a programmed cycle that includes the steps of flushing, cleaning and sterilizing the blood chamber, and when a blood chamber is to be cleaned, for cleaning the same.

According to yet another preferred but optional feature of the invention, adjustable timing means is provided for adjustable setting the duration of each of the steps in the cycle.

The above and other features of the invention will be fully understood from the following detailed description and the accompanying drawings, in which:

FIG. 1 is a cross-section, taken at line 1—1 of FIG. 2, showing an adapter and a base structure according to the invention assembled together.

FIG. 2 is a cross-section taken at line 2—2 of FIG. 1;

FIG. 3 is a bottom view of the base structure with the adapter removed;

FIG. 4 is a cross-section taken at line 4—4 of FIG. 3;

FIG. 5 is a cross-section taken at line 5—5 of FIG. 2;

FIGS. 6 and 7 are cross-sections taken at lines 6—6 and 7—7, respectively, of FIGS. 2 and 1;

FIG. 8 is a fragmentary detail showing a means of connecting tubing to a structure according to the invention;

FIG. 9 is a combined circuit and schematic mechanical drawing illustrating a control means for the device;

FIG. 10 illustrates a timer circuit for use with the control means of FIG. 9; and

FIG. 11 is a schematic showing another embodiment of a separable pump useful with this invention.

FIG. 1 shows the presently preferred embodiment of a cleaning device 10, shown treating a schematically-illustrated artificial kidney 11. The artificial kidney includes a blood chamber 12 having a blood chamber inlet 13 and a blood chamber outlet 14. The artificial kidney also includes a dialysate chamber 15 having a dialysate chamber inlet 16 and a dialysate chamber outlet 17. The blood chamber and the dialysate chamber are separated by a membrane 18 across which the cleaning of the blood is accomplished. The dialysate chamber outlet 17 discharges to a sink which forms no part of the device. Some artificial kidneys do not include a dialysate chamber. Instead, they utilize a rela-
tively rigid coil for conveying the blood, the coil being immersed in a jar full of dialysate. The device of this invention can be programmed to treat both kinds of artificial kidneys.

Device 10 includes a base structure 20 having a receptacle 21 to receive an adapter 22. The base structure may be a cabinet which forms the receptacle and which houses control circuitry and actuating parts that are yet to be described.

The base structure includes a pair of plate-like retainers 23, 24 which slide on pins 25, 26 so as to be movable across or away from the open end of the receptacle. When placed across the open end, they hold the adapter therein. When moved away, they permit removal of the adapter. In FIG. 3, the retainers are shown in their open position, permitting insertion and removal of the adapter.

Portions of a dialysate chamber inlet valve 30, a blood chamber drain valve 31, a water inlet valve 32, a cleaning solution inlet valve 33, and a sterilizing solution inlet valve 34 are mounted in the receptacle. Valves 30 and 31 are externally actuated. Valves 30-34 are separable, i.e., part of these valves are mounted to the adapter and part to the base structure.

In each of the above valves, the portion which is mounted to the base structure comprises a solenoid-actuated plunger. For example, the blood chamber drain valve 31 includes and axially-slit sleeve 35 mounted to the base structure, and an axially-reciprocable magnetizable plunger 36 acting as an armature which is spring-loaded by a bias spring 37 downwardly in FIGS. 1 and 4 normally to close the valve. A post 37a passes through the plunger and through axial slit 37b so as to be engaged by the spring. The axial slit and the post prevent the plunger from turning in the sleeve. A solenoid winding 38 having leads 38a and 38b is adapted to retract the magnetic plunger upwardly in FIGS. 1 and 4 when energized by the passage of electricity through it. This will open the valve.

Dialysate chamber inlet valve 30 is similarly constructed and includes a sleeve 40, plunger 41 of magnetizable material, bias spring 42, and solenoid winding 43, with leads 43a and 43b all having functions like corresponding parts of valve 31.

Inlet valves 32, 33 and 34 are constructed identically to one another. Therefore, only sterilizing solution inlet valve 34 will be described in detail (FIG. 4). It includes a base 45, a solenoid winding 46 with leads 46a and 46b, and a magnetizable plunger 47. It is spring-loaded upwardly in FIG. 1 so that the valve is normally closed. Passage of electrical current through the winding moves the plunger downwardly in FIG. 1 to open the valve. Other parts of valves 32, 33 and 34 will be described below.

Pump impellers 50, 51 are provided as part of a respective separable, externally actutable, sterilizing solution pump 50a and a separable, externally actutable, cleaning solution pump 51a. Because pumps 50a and 51a are identical, only pump 50a will be described in detail (FIG. 3). It is mounted to a journal block 52 which journals it to the base structure. The impeller includes a wheel 53 with gear teeth 54 on its periphery that are engaged by a drive gear 55 (FIG. 4), which is in turn driven by a sterilizing solution pump motion 56. Sterilizing solution pump motor 56 drives impeller 50 to provide sterilizing solution under pressure. Cleaning solution pump motor 57 similarly but independently, drives pump impeller 51 to provide cleaning solution under pressure.

Pump impeller 50 carries four rollers 57a which are journaled to the wheel and are adapted to bear against a plenum conduit yet to be described.

The adapter is proportioned to fit in the opening of the receptacle. Stops 61 (FIG. 1) limit the depth of insertion of the adapter into the receptacle. With further reference to sterilizing solution inlet valve 34, a sterilizing solution inlet 65 (FIGS. 1 and 8) enters the adapter body. A plug valve 66, forming the actuated part of valve 34, is placed in inlet 65. Valve 34 thereby receives sterilizing solution from a source thereof. The plug valve has a tapered valve member 67 which is biased by spring 68 to a valve-closed position. Any upstream pressure from the sterilizing solution pressure would also tend to close the valve member.

FIG. 8 shows bars 160 formed inside passage 65 to receive, engage and releasably hold outside external wall of supply conduit 71a. Conduit 71a can be forced into these bars, thereby to form a convenient fluid sealing connection. This type of connection can be used for all of the conduit connections in the device.

A headed stud 69 is slidably disposed in a bore 70 and is borne against by plugger 47. Downward movement of plunger 47 as the consequence of energizing the respective solenoid winding will cause the stud to press against valve member 67 to move it off its seat and open inlet 65 to permit sterilizing solution to flow into a sterilizing solution conduit 71 and thence to pump 50a. Similar valve parts are provided for valves 32 and 33.

Cleaning solution is supplied from a source thereof to a cleaning solution inlet 72 and is controlled by cleaning solution inlet valve 33. Cleaning solution flows from valve 33 to a cleaning solution pump plenum conduit 73 and thence to a manifold connection 74.

Water is supplied from a source thereof to a water inlet 75. Water valve 32 controls the passage of water. Water which is passed by water valve 32 flows through conduit 77a and discharges into manifold 74.

Sterilizing solution passed by valve 34 enters sterilizing pump plenum conduit 76. Conduit 76 also discharges into manifold 74.

Both plenum conduits are lengths of flexible elastic tubing chemically resistant to the solutions which they carry, and are proportioned to restore themselves to a round configuration unless pinched closed. A full ¾ inch inside diameter is a useful size. About 1/16 inch wall thickness usually supplies sufficient resiliency for these conduits, and the conduits at valves 30 and 31. Theses conduits can be pinched to be closed, and form part of their respective pumps.

Pump blocks 77, 78 respectively complete pumps 50a and 51a. They respectively include arcuate pinch surface 79, 80. As shown in FIG. 1, when the rollers roll along their respective plenum conduits, the tubing is pinched closed between the rollers and pinch surface, but an open length of plenum conduit remains between them which contains a "slug" of liquid to be pumped. The moving rollers advance the pinch portion so as to transport the slug of liquid along the plenum conduit. These are positive displacement pumps. The roller and pinch surface also act as a check valve preventing reverse flow of liquid through these plenum conduits. The pumping is a pulse type in the sense that successive slugs of liquid are moved through the pump.
pumps are separable in that some parts are carried by the adapter and some by the base structure.

Cleaning and sterilizing solution can be provided to their respective inlets from any suitable source, such as a supply bottle. Because pumps 50a and 51a are positive delivery pumps, and can lift fluid by a substantial height, such as up to about 6 feet, the bottles need not be placed above the device, but could be. Instead, they may be placed in a cabinet below the device. The water inlet may be connected to any suitable source of water. It will usually be connected to the domestic supply, suitably screened and filtered, so a pump is not needed for the water. A pump could be provided should a non-pressurized source be used.

Sodium hypochlorite is the most-frequently used cleaning solution. A 6% solution is diluted to about a 50:1 dilution with water (50 parts water to one part of 6% solution). It readily dissolves blood clots and fibers.

Formaldehyde is the usual sterilizing material. A 37% concentrated solution is usually diluted to about a 5% aqueous solution of formaldehyde.

The speed of the pumps and the water pressure are suitably related to produce solutions at manifold 74 of the appropriate strength.

Manifold 74 discharges to a tee joint 81. The tee joint connects to both the blood chamber supply outlet 81a (which is in turn connected to the blood chamber inlet 13 of the artificial kidney) and to a dialysate chamber supply conduit 82.

Conduit 82 is a flexible elastomeric tubing which passes over a pinch block 83 to complete the separable and externally actuated dialysate chamber inlet valve 31. The plunger of valve 31 tends normally to bear against the dialysate chamber inlet conduit so as to pinch it closed against the pinch block when the plunger is down in FIG. 1. The pinch block, the dialysate chamber supply conduit 82 connects to the dialysate chamber supply outlet 82a which in turn is connected to the dialysate chamber inlet 16.

The blood chamber drain port 85 is connected to a blood chamber drain line 86 which receives effluent fluids from the blood chamber outlet 14 of the artificial kidney. Drain line 86 passes over a pinch block 87 to complete the separable blood chamber drain valve 30. It is closed by being pinched between the block and plunger 41 except when opened by retraction of the plunger. The blood chamber effluent is returned by drain line 86 to a drain port 88 in the adapter from which it flows to any desired place of disposal.

It will be appreciated from the foregoing that an adapter can be issued for each respective patient, and only the fluids from his own artificial kidney need ever contact his own adapter. No part of the fluids which contacts the blood chamber also contacts the more permanent parts of the device. Instead, all of the fluid conduits downstream from the inlet valves, including all means for pumping and for supply and drain, are carried by the adapter. The adapter can be used indefinitely by one person for his own artificial kidneys on the same or on different devices, because there is no risk of cross-infection.

The more expensive control and actuating means are contained in the base structure where they can be used with anybody's adapter, and can be kept in use nearly continuously. It will also be noted that when externally actuable pumps and valves are used, few if any parts that might be subject to serious corrosion are included in the fluid circuitry. Even when merely separable valves are used for valves 32, 33 and 34 the only such parts are the spring-loaded mechanisms. These are so few in number that they can be made of high quality, relatively expensive materials without unduly increasing the purchase price of the mechanism. Corrosion is therefore not a significant problem.

An additional significant economy can be achieved by dividing the adapter into two parts. It is shown constructed in two parts in the drawings, but has been discussed herein as though it were unitary, which it may in fact be. However, best practice is to form the adapter body 60, shown assembled as unit in FIG. 1, into a connector section 90 and a flow section 91. The flow section is comparatively cheap and can be discarded when worn or faulty at minimum cost. The connector section can readily be removed for service and/or replaced on the infrequent occasion that it might leak or malfunction.

The flow section is unique to each patient's own artificial kidneys. It contains a conduit which circulates fluid from the artificial kidney, and is in fluid connection therewith. However, the connector section contains only inlet valving which closes when the adapter is removed. Also, the water upstream is under positive pressure and pumps 50a and 51a act as check-valves. Therefore the connector section can be used with flow sections respective to the artificial kidneys of a plurality of patients without contamination. This is a considerable economy in construction. It is, of course, possible to build the connector section integral with the base structure and this arrangement is contemplated by the invention. However, one objective of the invention is to make the device convenient to use and to service, and its use and service are greatly facilitated by making the connector section separate from the base structure.

The valves in the connector section remain closed unless the connector section is installed in the receptacle and a valve is actuated by the flow of current through a respective solenoid wiring. The adapter is quite easily connected to an artificial kidney and to the base structure. As can best be seen in FIG. 5, the various conduits, such as pleum conduits 73 and 76, and conduits 77a and 86 are press-fitted into flexible nipples 92 which, in turn, can be pressed into recesses such as recess 93 (FIG. 1) to make a tight, fluid sealing fit, which is readily separable. The construction of FIG. 8 can be used for these connections. The press-fitted arrangement as shown does provide an elegantly simple and inexpensive connector.

If connector section 90 forms a permanent part of the base structure, then the valving respective to it need not be separable. The separability of the connector section to form a part of the adapter is a preferred feature of the invention, and when used, separability of valving will then be provided. The invention comprehends an arrangement wherein only the flow section is removable from the base structure.

It is a significant advantage of this invention that it is readily adaptable for use with a variety of programs for cleaning and sterilizing artificial kidneys. This enables it to clean and to sterilize different types of artificial kidneys or to subject a given type of artificial kidney to more than one style of treatment. Persons skilled in the art will recognize that any suitable sequencing control means can be provided so long as it operates to perform the function of connecting the artificial kidney to a preselected source of fluid, or to drain a predetermined port in a predetermined sequence, and for a predeter-
mined period of time. A matrix showing the presently preferred steps for cycling the device to clean and to sterilize one well-known type of artificial kidney is as follows:

<table>
<thead>
<tr>
<th>DIALYSATE</th>
<th>BLOOD</th>
<th>WATER</th>
<th>CLEANING</th>
<th>STERILIZING</th>
<th>CLEANING</th>
<th>STERILIZING</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHAMBER</td>
<td>CHAMBER</td>
<td>SOLUTION</td>
<td>SOLUTION</td>
<td>SOLUTION</td>
<td>SOLUTION</td>
<td>SOLUTION</td>
</tr>
<tr>
<td>INLET</td>
<td>INLET</td>
<td>INLET</td>
<td>INLET</td>
<td>PUMP</td>
<td>PUMP</td>
<td>PUMP</td>
</tr>
<tr>
<td>VALVE 30</td>
<td>VALVE 31</td>
<td>VALVE 32</td>
<td>VALVE 33</td>
<td>MOTOR 57</td>
<td>MOTOR 56</td>
<td>MOTOR 56</td>
</tr>
<tr>
<td>1</td>
<td>X</td>
<td>Open</td>
<td>Open</td>
<td>X</td>
<td>X</td>
<td>Off</td>
</tr>
<tr>
<td>2</td>
<td>X</td>
<td>Open</td>
<td>Open</td>
<td>X</td>
<td>X</td>
<td>Off</td>
</tr>
<tr>
<td>3</td>
<td>X</td>
<td>X</td>
<td>Open</td>
<td>X</td>
<td>X</td>
<td>Off</td>
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<tr>
<td>4</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Off</td>
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<tr>
<td>5</td>
<td>X</td>
<td>Open</td>
<td>Open</td>
<td>X</td>
<td>X</td>
<td>Off</td>
</tr>
<tr>
<td>6</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<td>X</td>
<td>Off</td>
<td>On</td>
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<tr>
<td>8</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Off</td>
<td>Off</td>
</tr>
</tbody>
</table>

In the foregoing matrix, the symbol "X" means closed to flow. The word "open" means open to flow. The words "off" mean the device is driving the pump, or not driving the pump, respectively.

The artificial kidney being treated has a blood chamber inlet and outlet, and dialysate chamber inlet and outlet. The device is set to clean and sterilize both chambers, and to leave them full. Another type of sequence will later be described.

An examination of FIGS. 1–8 will show that valves 32, 33 and 34 will be open to flow when their respective plungers are extended as a consequence of energizing the respective windings to unseat the valve members. Therefore, the control over these valves is attained by energizing or by not energizing their solenoid windings.

Valves 30 and 31 are normally closed by their spring bias. Their control is by means of energizing or not energizing their windings. Energizing their windings retracts the plungers to open the previously pinch-closed flexible conduit to flow.

The pump motors are operated when electrical current is supplied to them. The control over pump means 50a and 51a is the connection or disconnection of its pump motor to a source of electrical current. When the current is off, the pump is not driven. When the current is on, it is driven and supplies the respective fluid. The roller pumps cannot be reversely moved, and their pinching effect acts as a reverse-flow check valve. Water flows through the water conduit whenever the water inlet valve, and whatever valve is downstream, is open.

A suitable control circuit for accomplishing the foregoing cycle is shown in FIGS. 9 and 10. A stepping switch 100, for example a drum switch, has eight sets of two each contacts, labeled 1 through 8, and a and b, to provide for eight steps. A rotatable electrically conductive wiper arm 101 makes individual contact with the respective sets of contacts and can be rotated clockwise to make successive contacts with these sets. The wiper arm is connected to a source of energy, such as a battery 102, for actuating the control circuit. One pole of the battery is grounded.

Potentiometers 103–109 are individually connected to one of the contacts of each set for timing purposes yet to be described. A timer circuit 110 determines, depending upon the setting of the respective potentiometer, the period of time the stepping switch remains at any given setting. When the period is concluded, the timer circuit provides a stepping current to a stepping motor 111, which motor operates to rotate the wiper arm to the next set of contacts.

Set 8 of the contacts is a dummy set, wherein all circuits are disabled.

The first contacts of each set 1–7, labeled "a", are connected to respective potentiometers 103–109, and the potentiometers are all connected to a lead 112 that is connected to the timing circuit 110. Lead 113 from the timer connects to motor 111, the motor being grounded at ground 114.

The second contacts of each set 1–7, labeled "b", are connected variously to elements of the device as shown. These settings of the wiper arm provide the connections to actuate the means appropriate to each step. For convenience, source 102 is shown supplying power for the timer, for the stepping motor, and for all valves and pump motors. Persons skilled in the control art will recognize this as a relatively rudimentary circuit. Relay circuits and the like may be substituted as appropriate. Also, solid-state sequential devices may readily be substituted for the rotary switch. Mechanical timers may be substituted for the electronic timer.

Pump motors 56 and 57 are shown under the control of motor speed controls 120, 121. The speed adjustment is by means of the potentiometers shown as part of these controls. Any suitable speed control can be used should adjustability of speed be desired. One reason to adjust the speed is to be able to vary the concentration of cleaning solution or of sterilizing solution by varying the quantity of the concentrated solution pumped into the manifold per unit of time. These pumps are positive displacement pumps, and the liquid they expel will be greater in quantity for a given time the faster they operate. Should only a single speed be desired, concentration could be adjusted by adjusting the strength of the solutions, and the motor speed control could be eliminated. Motors 56 and 57 are grounded at common ground 122. Leads 123 and 124 are part of the motor speed controls, and will be eliminated if the speed controls are eliminated. When the control is stepped sequentially from contacts 0 through 8, the illustrated circuitry will cause the mechanism to perform the following functions in the same order, all as indicated in the matrix. The step and contact numbers are identical.

Step 1: Open the water inlet valve 32 and the blood chamber drain valve 31, thereby admitting flushing water under pressure to the blood compartment and exhausting the effluent fluid through the conduit 86. This flushes the artificial kidney.

Step 2: Open the water inlet valve 32, blood chamber drain valve 31 and cleaning solution inlet valve 33. Simultaneously operate cleaning solution pump motor 57, thereby pumping cleaning solution into water ad-
mitted through the water inlet valve in manifold 74. The resulting solution flows into, through, and out of the blood compartment. The effluent exhausts through conduit 86. This cleans the artificial kidney.

Step 3: This is a brief step, lasting for about a second. Its purpose is to provide a quick pressure pulse to expand the cellophane membranes of many types of conventional artificial kidneys. It should not last so long as to rupture the membranes. This step differs from the settings of step 2 in that the blood compartment drain valve 31 is closed momentarily. If preferred, the cleaning solution motor can be stopped at the same water pressure is sufficient to provide the pulse. If it is not, the pump will be used to provide the pulse.

Step 4: All valves closed and all pump motors stopped. This is a holding period which will hold the cleaning solution in the artificial kidney under pressure provided by step 3.

Step 5: The water inlet valve 32 and the blood compartment drain valve 31 are both open. The artificial kidney will again be flushed with water, the effluent exhausting from conduit 86.

Step 6: Water inlet valve 32, dialysate chamber inlet valve 30, and blood chamber drain valve 31 are all open. Under these conditions, the flushing of the blood compartment continues, and there is a simultaneous flushing of the dialysate chamber. The effluent from the dialysate chamber discharges to the sink or any other suitable place. The blood chamber effluent leaves through conduit 86.

Step 7: Water inlet valve 32, dialysate valve 30, blood chamber drain valve 31, and sterilizing solution inlet valve 34 are all open. Sterilizing solution pump motor 56 is operated to pump the sterilizing solution into manifold 74 where it mixes with water, and from which it flows into the artificial kidney, into both the blood chamber and into the dialysate chamber. The blood chamber effluent exhausts through conduit 86. The effluent from the dialysate chamber discharges to the sink or any other suitable place.

Step 8: All valves are closed and pumps inactivated, leaving sterilizing solution in the blood chamber and the dialysate chamber. The artificial kidney may then be disconnected from the adapter and its lines plugged or closed as desired. The adapter may be placed aside until it is again needed by the patient. If the adapter is formed in two sections, only the flow section is taken away. The connector section would then await the next artificial kidney of any patient. The base mechanism also awaits the next artificial kidney of any patient.

Because any suitable timer circuit can be used for timing each step, the timer circuit of FIG. 10 will be only briefly described. It includes a transistor 130, whose function is to control current from lead 112 to lead 113 and operate the stepping motor after the expiration of a predetermined period of time. It includes a conventional RC network which, upon the attainment of a given potential, will cause the unijunction transistor to switch from a normally non-conducting to a conducting condition. The period of time is determined by the setting of the respective one of potentiometers 103–109, which is at the setting in series connection with the timer circuit. Its resistance determines the length of time. Adjusting the potentiometer thereby adjusts the period of time for the respective step. The pulse produced is of sufficient duration to cause the motor to move the wiper arm to the next set of contacts, even though the circuit would be broken by movement of the arm. Alternatively, a conventional power and latch circuit can maintain the motor in operation until released as a consequence of moving the arm to the next set of contacts.

Pumps 50a and 50b are two convenient examples of a general type of pump known in the pumping arts wherein the mechanical actuating portions and the portions which contact the fluids are separate, and are externally actuated. Sometimes these are called "pulsing" or "lozenge" pumps. The roller pumps of FIG. 1 are one such type. Another such type is shown in FIG. 11. It constitutes a flexible reservoir 130, such as the plenum conduits herein, with an upstream and downstream check valve 151, 152, both valves being spring-loaded closed, but which can be opened by sufficient upstream pressure or downstream suction. Force means, such as a reciprocable plunger 153 that is motor-driven against and away from the plenum, compresses and releases the plenum to provide the pumping action in accordance with standard pump practice. Both of these types of separable pumps, and also all other types of separable pumps, are contemplated for use in the invention. The pump of FIG. 11 suffers from the disadvantage that its check valves are exposed to corrosive fluids.

For artificial kidneys which do not have a dialysate chamber, the control connections respective to it may be disconnected or otherwise not used; that is, the dialysate chamber inlet valve will remain closed. It is convenient to provide a complete second set of contacts, and a second wiper blade, which are selectable for treating such artificial kidneys. Then one can readily switch from one program to another. The specific circuit design of other programs can readily be determined by a person skilled in the art. Such kidneys usually do not require the pulsing of step 3, which can also be eliminated from the cycle.

The term "externally actuable" as applied to valves 30 and 31 and to pumps 50a and 50b means that no valving mechanism is internal to the valve or pump and in contact with the fluid. In all such cases, the entire valving function is attained by a compressive action on a flexible conduit which tends to reopen when force is released. Valves 32, 33 and 34 are not externally actuable, because their plunger valves are bathed in fluid.

Attention is called to a particular advantage of the blood chamber outlet valve 30. Clots and fibers washed from the blood chamber must be passed by it. The full-open tubular cross-section of this valve and its downstream line significantly reduce the tendency of the circuit to clog. Clogging of internally-controlled valves has plagued prior art devices, and has discouraged the usage of valving downstream from the blood chamber. Significant advantages of placing the blood chamber valve downstream from the blood chamber are the opportunities to apply a pressure pulse to the blood chamber, and to leave the blood chamber full of liquid at the end of the treatment.

The term "separable" as used herein means that the pump or valve is completed only by joining parts attached to two different bodies, one of which is removable relative to the other. This separability enables a removable adapted to be used.

The device shown herein provides for patient isolation from the organisms of other persons by means of an elegantly simple physical construction. It enables an artificial kidney to be used a plurality of times with con-
fidence that there will be no cross infection from other artificial kidneys. It is subject only to minimal corrosion, and can be programmed for various types of artificial kidneys.

Some of the advantages of external actuation can obviously be provided by pumps and valves which are permanently installed in base structure. This would be equivalent to the permanent installation of the adapter, and the joiner of the artificial kidney to a permanently-installed set of conduits, rather than to conduits which are unique to a specific adapter.

It is also evident that some of the objectives of this invention can be secured by utilizing pumps 50a 51a, and valves 30 and 31 which, while separable, are not externally actuable.

This invention is not to be limited by the embodiments shown in the drawings and described in the description, which are given by way of example and not of limitation, but only in accordance with the scope of the appended claims.

1. A device for treating artificial kidneys of the type which have a blood chamber with an inlet and an outlet, said device supplying liquid to flush, to clean, and to sterilize the blood chamber, and comprising: a base structure; an externally actuable blood chamber drain valve which includes flow conduit and actuable valve means; externally actuable cleaning solution pump means and externally actuable sterilizing solution pump means, each including plenum means and actuating means; water conduit means; a manifold receiving water and also receiving cleaning solution and sterilizing when the respective pump is operated, said manifold discharging to an outlet for connection to the blood chamber inlet of an artificial kidney; conduit means for draining the outlet port of the blood chamber discharging to the blood chamber outlet valve; selectively actuable inlet valve means for controlling the supply of water, cleaning solution and sterilizing solution to the manifold; and control means effective selectively to operate said valve means and pump means so as to clean and sterilize an artificial kidney.

2. A device according to claim 1 in which the pump means is a pulse type.

3. A device according to claim 1 in which the pump plenum means is compressible, and in which the actuating means comprises said plenum means.

4. A device according to claim 1 in which an upstream and a downstream check valve are placed at opposite ends of the plenum means, and in which the actuating means compresses the plenum means between the check valves.

5. A device according to claim 1 in which the actuating means comprises a rotary impeller and an arcurate pinch surface on the side of the plenum means opposite from the rotary impeller, the impeller pinching the plenum means closed at spaced-apart points along its length, rotation of the impeller moving the points so as to discharge slugs of fluid.

6. A device according to claim 1 in which the blood chamber valve means and a dialysate chamber valve means ends comprises a respective flexible conduit and a respective pinch block, a respective plunger, and respective means to move the plunger toward and away from the pinch block to close and to open the conduit to flow.

7. A device according to claim 6 in which said last-named means comprises a solenoid.

8. A device according to claim 1 in which the pump means and the blood chamber drain valve are separable.

9. A device according to claim 1 in which portions of the pump means and blood chamber drain valve are carried by an adapter, and the remainder by the base structure, the adapter being removable mountable to the base structure.

10. A device for treating artificial kidneys of the type which have a blood chamber with an inlet and outlet, a dialysate chamber with an inlet and outlet, and a membranes between the chambers, said device supplying liquid to flush, to clean, and to sterilize the blood chamber, and to flush the dialysate chamber, and comprising: a base structure; an adapter flow section; a separable blood chamber drain valve and a separable dialysate chamber inlet valve, which include flow conduit carried by the adapter flow section and actuable valve means carried by the base structure; separable cleaning solution pump means and separable sterilizing solution pump means including plenum means carried by the adapter flow section and actuating means carried by the base structure, said separable valve means and separable pump means being assembled for use by attaching the adapter flow section to the base structure; water conduit means carried by the adapter flow section; a manifold carried by the adapter flow section receiving water and also receiving cleaning solution and sterilizing solution when the respective pump is operated, said manifold discharging to an outlet for connection to the blood chamber inlet of an artificial kidney, and to the dialysate chamber inlet valve; conduit means for draining the outlet port of the blood chamber discharging to the blood chamber outlet valve; selectively actuable inlet valve means for controlling the supply of water, cleaning solution and sterilizing solution to the manifold; and control means effective selectively to operate said valve means and pump means so as to clean and sterilize an artificial kidney.

11. A device according to claim 10 in which the pump means is a pulse type.

12. A device according to claim 10 in which the pump plenum means is compressible, and in which the actuating means comprises said plenum means.

13. A device according to claim 10 in which an upstream and a downstream check valve are placed at opposite ends of the plenum means, and in which the actuating means compresses the plenum means between the check valves.

14. A device according to claim 10 in which the actuating means comprises a rotary impeller, and in which an arcurate pinch surface is carried by the adapter on the side of the plenum means opposite from the rotary impeller, the impeller pinching the plenum means closed at spaced-apart points along its length, rotation of the impeller moving the points as to discharge slugs of fluid.

15. A device according to claim 10 in which the blood chamber valve means and the dialysate chamber valve means each comprises respective flexible conduit and a respective pinch block carried by the adapter flow section, a respective plunger carried by the base structure, and respective means to move the plunger toward and away from the pinch block to close and to open the conduit to flow.

16. A device according to claim 15 in which said last-named means comprises a solenoid.
17. A device according to claim 10 in which the inlet valves are separable, parts of said valves being carried by the base structure, and their other parts by a body removable therefrom.

18. A device according to claim 17 in which the pump means is a pulse type.

19. A device according to claim 17 in which the pump plenum means is compressible, and in which the actuating means comprises said plenum means.

20. A device according to claim 17 in which an upstream and a downstream check valve are placed at opposite ends of the plenum means, and in which the actuating means comprises the plenum means between the check valves.

21. A device according to claim 17 in which the actuating means comprises a rotary impeller, and in which an arcuate pinch surface is carried by the adapter on the side of the plenum means opposite from the rotary impeller, the impeller pinching the plenum means closed at spaced-apart points along its length, rotation of the impeller moving the points so as to discharge slugs of fluid.

22. A device according to claim 17 in which the blood chamber valve means and the dialysate chamber valve means each comprises a respective flexible conduit and a respective pinch block carried by the adapter flow section, a respective plunger carried by the base structure, and respective means to move the plunger toward and away from the pinch block to close and to open the conduit to flow.

23. A device according to claim 17 in which the parts carried by the base structure includes means to actuate the respective valves.

24. A device according to claim 17 in which the adapter includes a connector section removably attachable both to the base structure and to the adapter flow section, the said inlet valve means being carried by the said connector section.

25. A device according to claim 24 in which the parts carried by the base structure includes means to actuate the respective valves.

26. A device according to claim 10 in which said control means comprises a control having a plurality of sequential settings, and timer means determining the length of time the control maintains each setting.

27. A device for treating artificial kidneys of the type which have a blood chamber with an inlet and an outlet, said device supplying liquid to flush, to clean, and to sterilize the blood chamber, and comprising: a base structure, a separable blood chamber drain valve which includes flow conduit and actuable valve means; separable cleaning solution pump means and separable sterilizing solution pump means, each including plenum means and actuating means; water conduit means; a manifold receiving water and also receiving cleaning solution and sterilizing solution when the respective pump is operated, said manifold discharging to an outlet for connection to the blood chamber inlet of an artificial kidney; conduit means for draining the outlet port of the blood chamber discharging to the blood chamber outlet valve; selectively actuable and separable inlet valve means for controlling the supply of water, cleaning solution, and sterilizing solution to the manifold; and control means effective selectively to operate said valve means and pump means so as to clean and sterilize an artificial kidney; and an adapter carrying parts of at least the blood chamber drain valve and the pump means, the remainder being mounted to the base structure.

28. A device according to claim 27 in which a separable dialysate chamber inlet valve is provided, at least part of it being mounted to the adapter, and the remainder to the base structure.