United States Patent

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[54] **LIQUID INFUSION APPARATUS**
4 Claims, 4 Drawing Figs.

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[51] **Int. Cl.** **A61m 5/00**
[50] **Field of Search** 128/213-216, 274, 273, 1; 103/203; 222/76, 202, 203, 380; 23/258.5; 417/240, 435

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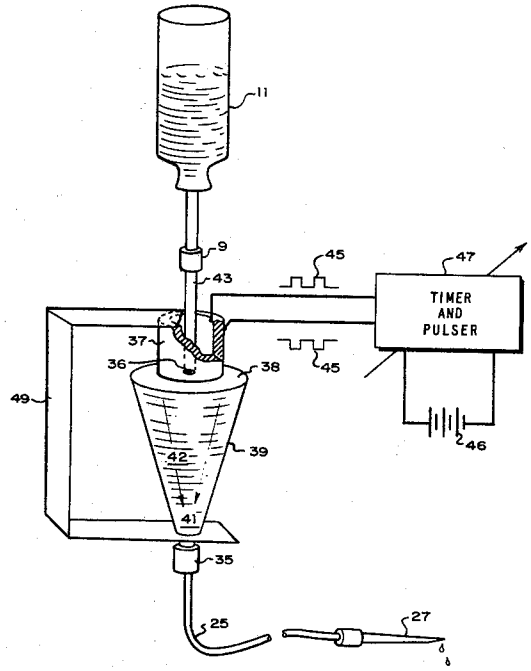
ABSTRACT: Liquid infusion apparatus provides reliable administration of liquids and blood transfusions into the body (intravenous, intraarterial or subcutaneous) at a preset and regulated rate in a convenient, inexpensive and completely safe manner. The apparatus includes liquid pumping and valving mechanisms and gas relief means which prevent both the back flow of liquid into the liquid reservoir and the injection of air into the blood stream of the patient.



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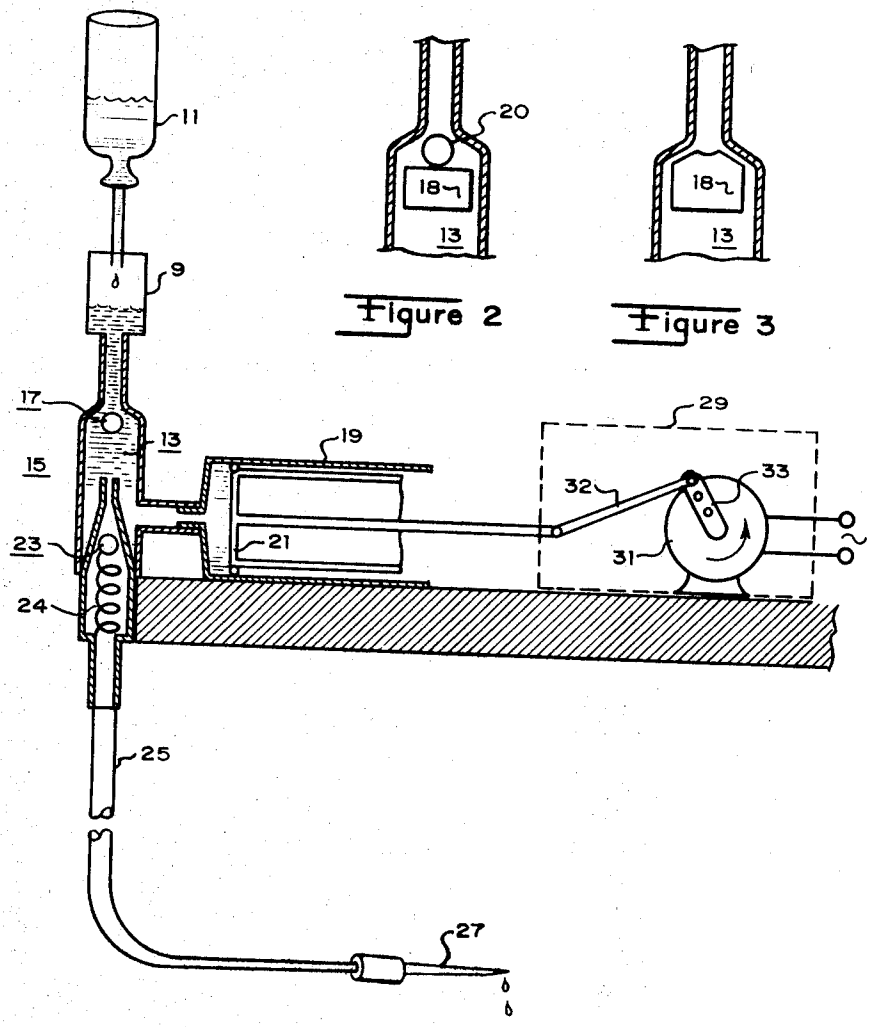

Figure 1

Figure 2

Figure 3

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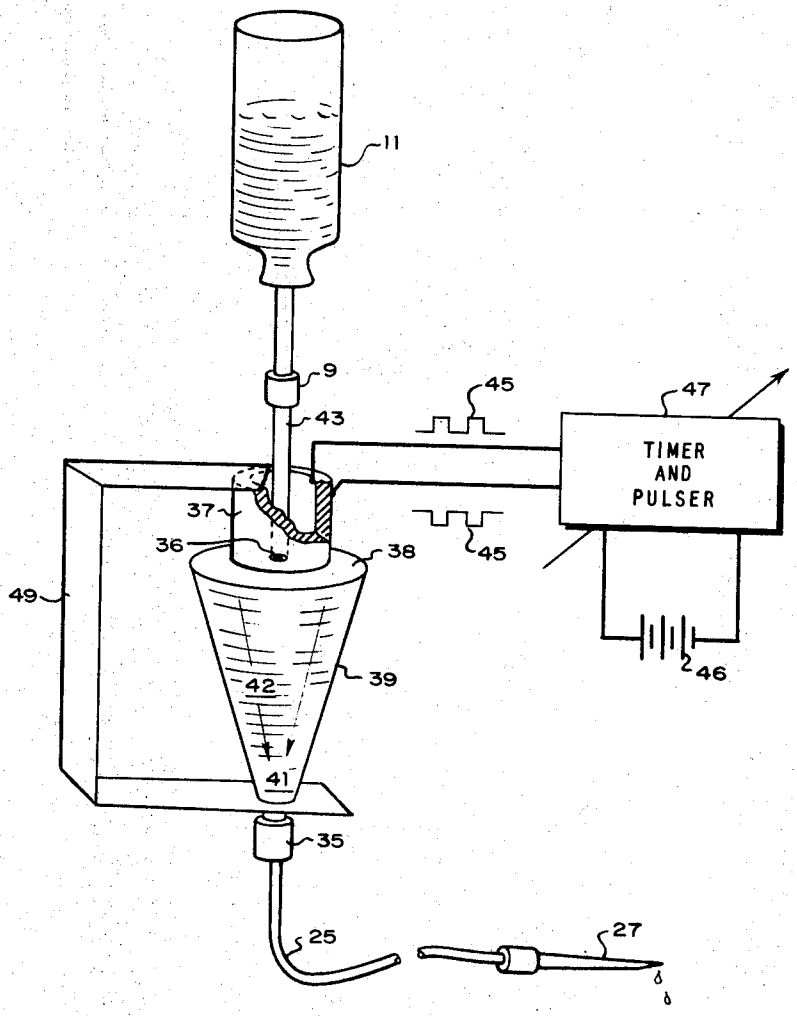

Figure 4

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LIQUID INFUSION APPARATUS

BACKGROUND OF THE INVENTION

Conventional infusion apparatus for administering fluids to a patient intravenously, intraarterially, or the like, commonly includes a fluid reservoir, an infusion needle or catheter connected to the reservoir by a drip chamber and a tubing clamp positioned along the length of the plastic tubing. The fluid reservoir is typically elevated well above the patient to provide fluid pressure and the fluid flow rate, observed in the fluid drip chamber as the number of drops per unit time, is set by squeezing the plastic tube a selected amount in the tubing clamp. The disadvantages encountered in conventional infusion apparatus of this type are that the fluid flow rate may decrease and stop due to formation of blood clots in or about the infusion needle, due to variations in resistance to flow through the needle or catheter caused by patient motion or change of bodily position and also due to variation in resistance to flow through the tubing within the tubing clamp caused by the cold flow of the plastic material forming the walls of the tubing within the tubing clamp. These effects tend to vary the flow rate of fluid administered to the patient, thereby requiring frequent inspection and readjustment of the apparatus.

SUMMARY OF THE INVENTION

The apparatus of the present invention overcomes these disadvantages by providing liquid-pumping means which provides the required pressure and flow rates independent of variations in the resistance to flow encountered. The liquid-pumping means includes apparatus for introducing sufficiently large pressure pulse in the liquid within a storage chamber to overcome the resistance to flow through an outlet valve and thereby provide the selected liquid infusion pressure and flow rate. The liquid pressure pulses may be generated by a mechanically actuated plunger or may be generated by an electromechanical element which is electrically pulsed to pump the infusion liquid from a storage chamber. In these and other embodiments of the invention, gas relief means are coupled to the storage chamber for preventing the buildup of liquid pressure within the chamber sufficient to produce liquid flow through the outlet valve when the chamber is not filled entirely with the infusion liquid.

DESCRIPTION OF THE DRAWING

FIG. 1 is a side view of the liquid infusion apparatus according to one embodiment of the present invention showing a cross section of the disposable pumping subassembly;

FIGS. 2 and 3 show alternate embodiments of the flotation of valve of FIG. 1; and

FIG. 4 is a pictorial view of liquid infusion apparatus according to another embodiment of the present invention which includes an electromechanical pumping element.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1 the liquid infusion apparatus includes a conventional drip chamber 9 connected to receive the infusion liquid from reservoir 11. Liquid from the drip chamber 9 is supplied to the storage chamber 13 of the pumping means 15 through the inlet valve 17 which includes a ball or other valve element that floats into closed position in the infusion liquid within the chamber 13.

A pump cylinder 19 with a slidable piston 21 therewithin is connected to receive the liquid in the chamber 13 and an outlet valve 23 is coupled to the chamber 13 to control the outflow of liquid from the chamber. A suitable length of flexible tubing 25 connects the outlet end of chamber 13 to the infusion needle or catheter 27. Actuating means 29 for the piston 21 may include a spring motor or electric motor 31 coupled to the piston 21 through a connecting rod 32 which is pivotally attached to the crank arm 33 on the rotatable shaft of the motor 31 at a selected distance from the shaft. Of course, the

actuating means may also include other suitable prime movers such as electrical solenoids or the like for reciprocatingly actuating the piston 21 within the cylinder 19.

In operation, the actuating means 29 moves the piston 21 within the cylinder 19 in a direction away from the chamber 13 to draw fluid from the chamber 13 into the cylinder 19. This causes fluid to be drawn from the drip chamber 9 past the inlet valve 17 into the chamber 13 and cylinder 19 while the outlet valve 23 remains closed. When the piston 21 is moved toward the chamber 13 by the actuating means 29, the increase in liquid pressure produced thereby aids in closing the inlet valve 17 and opens the outlet valve 23 when the liquid pressure in chamber 13 overcomes the slight bias against outflow through the outlet valve 23 produced by the spring 24. This spring bias against outflow through the outlet valve 23 assures that liquid does not flow to the needle under the pressure head provided by the elevation of the reservoir above the outlet valve. A selected amount of liquid thus flows past the outlet valve 23 and through the tubing 25 to the needle 27 only upon the return stroke of piston 21. For a cylinder 19 of given internal diameter, the amount of liquid supplied to the needle 27 may thus be regulated by altering the stroke of the piston, for example, by altering the position along crank arm 33 of the connecting rod 32 coupling to the crank arm or by altering the rotational speed of the motor 31.

The inlet valve 17 is selected to displace on amount of the infusion liquid which weighs more than the valve element 17 so that the element is urged into the closed position by the buoyant force thus produced. Thus, if air is drawn into the chamber 13 and the liquid level drops, for example, when the reservoir 11 and drip chamber 9 are empty, the floating element 17 is no longer urged into closed position and thereby provides a gas relief opening back to the reservoir and drip chamber for air within the chamber 13. The return stroke of piston 21 thus is unable to create sufficient liquid pressure in chamber 13 to overcome the bias against outflow provided by outlet valve 23 and thus no air can be administered to the patient. Other embodiments of floating inlet valve means according to the present invention are shown in FIGS. 2 and 3. In these embodiments, the floating element 18 may actuate a nonfloating valve 20 or may be the valve element 18 which forms the sealing engagement with the upper walls of the chamber. In each of these embodiments, when the liquid level in the chamber 13 drops due to air being drawn into the chamber, the floating inlet valve is no longer buoyed into closed position and the air within the chamber is thus vented back toward the reservoir 11 so that liquid pressure cannot build up within the chamber 13 to overcome the bias against liquid outflow through outlet valve 23.

Referring now to FIG. 4, there is shown another embodiment of the present infusion apparatus in which the liquid pressure to overcome the bias against outflow of liquid through outlet valve means 35 is provided by a mechanical or electromechanical element 37. This element 37 is disposed on the top 38 of a conical or nozzlelike chamber 39 remote from the outlet means 35 positioned at the apex 41 of the conical chamber 39 for mechanically displacing the top 38 in response to an applied electrical signal. The element 37 may thus be a solenoid having a movable armature coupled to the surface 38 or, preferably, may be a piezoelectric element. A fluid conduit including tube 43 and drip chamber 9 connects the reservoir 11 to the internal region of the conical chamber 39 through an aperture 36 in the top surface 38 of the chamber 39. The element 37 may have a toroidal shape to facilitate symmetrical location of the inlet aperture 36 and fluid conduit 43 substantially at the center of the top surface 38. Suitable excitation signals 45 are applied to the element 37 by the timer and pulser 47. The top surface 38 of the conical chamber 39 is flexible in the direction along the central axis of the conical symmetry of the chamber 39 to enable the mechanical displacement produced by the element 37 to establish a pressure pulse in the liquid within the chamber 39. The mounting bracket 49 which supports the chamber 39 also supports the

element 37 in engagement with the top surface 38 so that longitudinal extension of the element 37 in response to excitation signal applied thereto from timer and pulser 47 are coupled to the fluid within the chamber 39 through the diaphragmlike or plungerlike movement of top surface 38. The conduit 43, drip chamber 9, chamber 39, outlet valve 35 and the tubing 25 and needle 27 may all be conveniently disposable and replaceable with similar presterilized replacement parts.

In operation, the element 37 displaces the top surface 38 upward in response to an excitation signal of sufficient amplitude and proper polarity applied to the element 37 by the timer and pulser 47. This upward movement of the top surface 38 with respect to the chamber 39 increases the internal volume of the chamber 39. The drop in internal pressure produced thereby causes liquid to be drawn through the aperture 36 in the top surface 38 from the chamber 39. OUtlet valve 35 remains closed so no liquid is administered to the patient during this phase of operation. When the polarity of the drive signal applied to the element 37 from timer and pulser 47 reverses, the top surface 38 is suddenly driven downward. This causes a pressure wavefront to propagate through the liquid in chamber 39 in a focused or converging direction predominantly toward the outlet valve 35 at the apex end of chamber 39. This pressure wave momentarily overcomes the bias against outflow through valve 35 and expels a small amount of liquid into the tube 25 and out through needle 27. If this pressure wavefront is suitably focused there will be no expulsion of liquid from the chamber 39 back toward the drip chamber 9 through the small aperture 36.

If, however, focusing of this pressure wavefront is inadequate to assure unidirectional propagation of the pressure pulse, then a small amount of liquid may be expelled from the chamber 39 back toward the drip chamber 9 through the small aperture 36. However, since the element 37 may produce short pulses and since the aperture 36 may be very small in diameter, such backflow is negligibly small and produces no deleterious effects. Thus, the flow rate of infusion liquid into a patient may thus be regulated by setting the pulse amplitude and repetition rate of signals 45 applied to the element 37 by the timer and pulser 47. This latter element 47 may include a conventional multivibrator circuit arranged to operate from a power source 46 to provide the necessary driving signals 45 at variable pulse amplitude and repetition rate.

The embodiment of FIG. 4 also includes gas relief means which prevents infusion of air when the reservoir 11 is empty. If liquid is expelled from chamber 39 to an extent that air is present in the chamber, then the compressibility of the air and the gas relief opening at aperture 36 which presents negligible resistance to gas flow prevent the movement of element 37 and surface 38 from establishing a sufficient pressure wave 42 within the remaining liquid in the chamber 39 to overcome the bias against outflow through valve 35.

Therefore, the apparatus of the present invention may be left unattended without risk of administering air into a patient when the reservoir is empty and without risk of the liquid infusion rate changing due to such factors as the formation of blood clots about the needle. Also, if blood clots tend to develop about the needle tending to block the infusion of liquid, the liquid pressure within the tubing and needle builds up with each pumping phase until the blockage is cleared by the liquid under pressure.

We claim:

1. Liquid infusion apparatus for use with source means containing a liquid to be administered to a patient, the apparatus comprising:

a chamber for confining a volume of fluid;

compressor means coupled to said chamber and having a movable boundary wall disposed to communicate with fluid within said chamber for changing the volume of fluid within said chamber at a selected rate in response to movement of said boundary wall;

outlet valve means coupled to said chamber for providing outlet flow of fluid therethrough only for values of fluid pressure exerted thereon above a selected value of bias pressure;

conduit means coupled to said outlet valve means for supplying the outlet flow of fluid to a patient; and

fluid inlet means connecting said source means with said chamber, said fluid inlet means consisting only of an aperture in the upper portion of said chamber for permitting bilateral flow of fluid therethrough between said source means and said chamber in response to movement of said secondary wall, the size of said aperture introduces less resistance to flow therethrough of gas than of liquid:

a. the selected change of volume of fluid within said chamber in response to movement of said boundary wall with said chamber filled with liquid exceeds the back flow of liquid through said aperture for producing a buildup of pressure within said chamber to overcome said selected value of bias pressure of said outlet valve and permit outlet flow of liquid through said conduit means to a patient, and

b. the selected change of volume of fluid within said chamber in response to movement of said boundary wall with gas enclosed in the upper portion of said chamber in the region of said aperture is less than the backflow of the gas through said aperture for preventing buildup of pressure within said chamber adequate to overcome said selected value of bias pressure of said outlet valve.

2. Liquid infusion apparatus for use with source means containing a liquid to be administered to a patient, the apparatus comprising:

a chamber for confining a volume of fluid and including converging walls forming an internal region of decreasing cross-sectional area with length of the chamber for focusing a pressure wave at an outlet disposed near the end of said chamber of smallest cross-sectional area;

outlet valve means disposed at said outlet and coupled to said chamber for providing outlet flow of liquid therethrough only for values of pressure exerted thereon above a selected value;

fluid inlet means connected for receiving liquid from the source means and coupled to said chamber for supplying fluid therethrough to said chamber;

transducer means disposed with respect to said chamber near the end thereof of largest cross-sectional area for increasing the fluid pressure in the internal region of said chamber to a value above said selected value for producing outflow of liquid through said outlet valve means in response to an electrical signal applied to said transducer means;

gas relief means including an aperture of selected cross section disposed at the fluid inlet in a wall of said chamber near the end thereof of largest cross-sectional area; and

conduit means coupled to said outlet valve means for supplying the outlet flow of liquid to a patient.

3. Liquid infusion apparatus as in claim 2 wherein:

said transducer means is a piezoelectric element arranged on a wall of said chamber disposed near the end thereof of largest cross section to displace a portion of said wall in response to electrical signal applied to said element for producing a pressure increase in the infusion liquid within said chamber near the end thereof of smallest cross section in excess of said selected value.

4. Liquid infusion apparatus as in claim 3 wherein:

said chamber is conically shaped;

said transducer means includes a toroidally shaped piezoelectric element disposed on the upper wall of said chamber remote from said outlet valve for producing a pressure wave in infusion liquid within said chamber in response to electrical signal applied to said piezoelectric element, whereby the pressure wave is confined and focused by the conically shaped chamber to exert liquid pressure on said outlet valve in excess of said selected value; and

said aperture is disposed in said upper wall of said chamber within the inner area of said toroidally shaped piezoelectric element.