

[54] **ARTERIOVENOUS SHUNT**

[76] Inventor: **Olga Berend**, 6311 Drexel Ave., Los Angeles, Calif. 90048

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[51] Int. Cl. **A61m 05/00**

[58] Field of Search **128/214 R, 214.2, 334 C, 128/348, 350 R; 138/39; 73/202**

[56] **References Cited**

UNITED STATES PATENTS

3,638,649	2/1972	Ersek	128/214 R
3,713,441	1/1973	Thomas	128/348 X
3,818,511	6/1974	Goldberg et al.	128/214 R

OTHER PUBLICATIONS

Goldberg et al. - Trans. Amer. Soc. Artific. Inter. Orgs., 1972, Vol. XVIII, pp. 441-447.

Primary Examiner—Dalton L. Truluck
Attorney, Agent, or Firm—Jessup & Beecher

[57] **ABSTRACT**

An arteriovenous shunt is provided which utilizes Venturi principles to provide a turbulent-free blood flow of virtually constant velocity through the shunt for hemodialysis, or other purposes. The embodiment to be described uses inlet and outlet cuffs which are sown to a severed artery and to a severed vein respectively, so as to receive blood from the artery and return the blood to the vein. Venturi tubes are coupled to the cuffs, and associated tubing completes the shunt. The Venturi tubes are located adjacent the inlet and outlet cuffs to provide turbulence-free blood flow at both ends of the shunt, thereby preventing clotting of the blood, and permitting the shunt to be used for extended periods of time.

5 Claims, 5 Drawing Figures

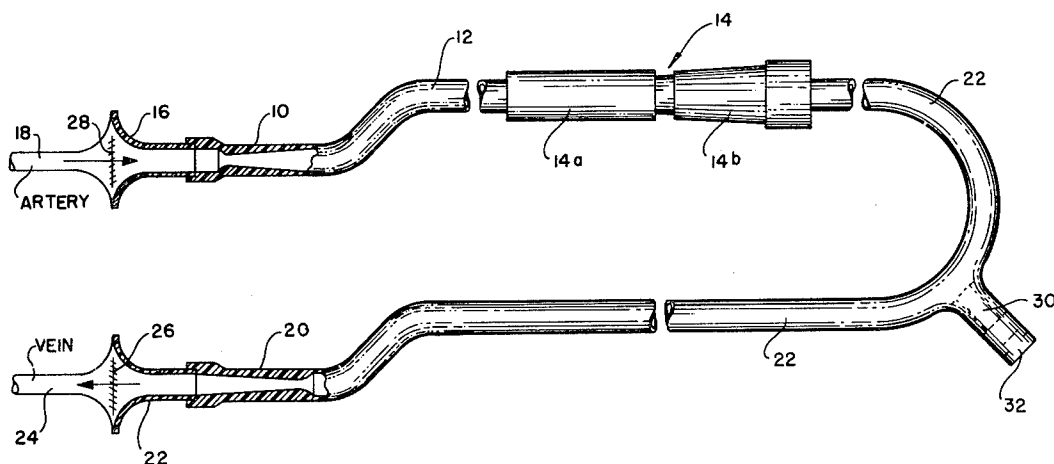
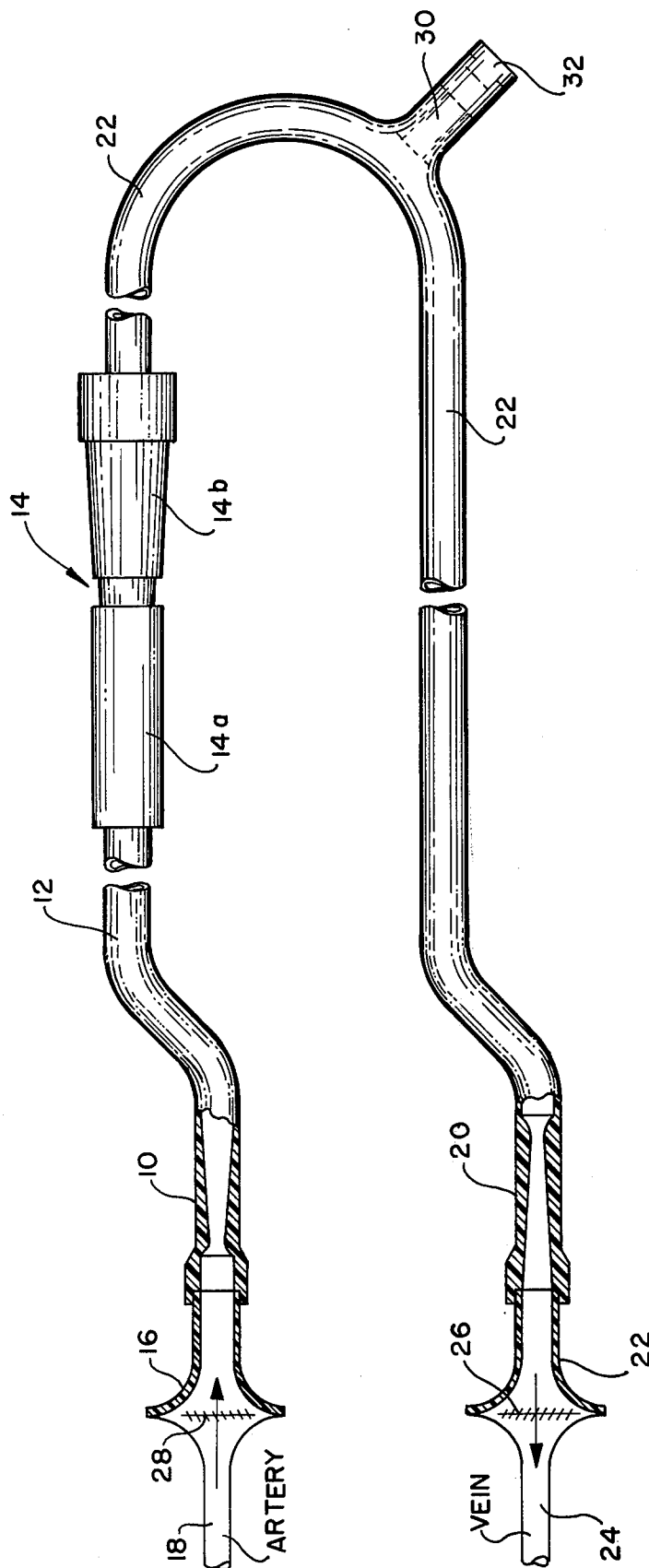


FIG. 1



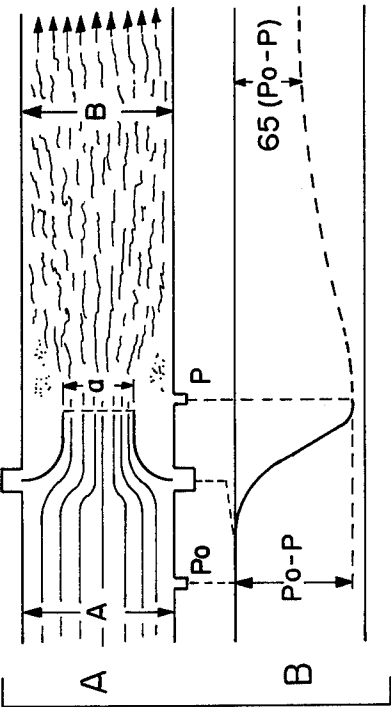


FIG. 3

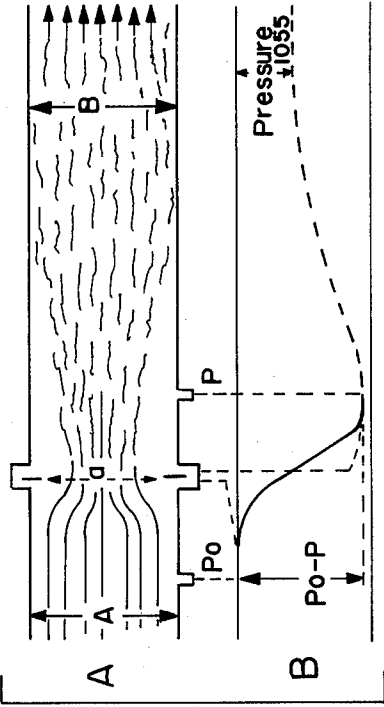


FIG. 4

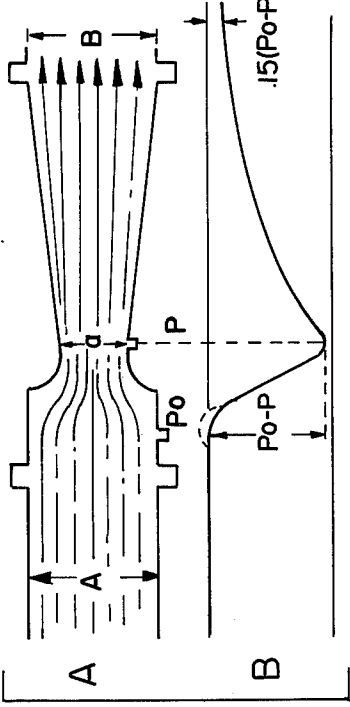


FIG. 5

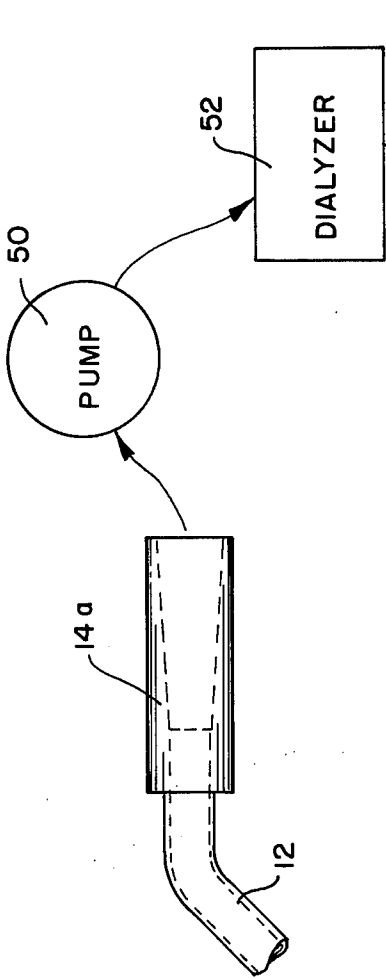
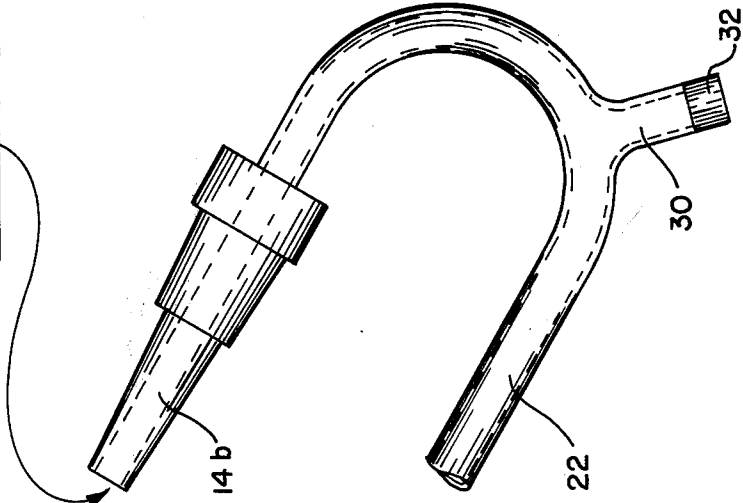


FIG. 2



ARTERIOVENOUS SHUNT

BACKGROUND OF THE INVENTION

The placement of indwelling arterial and venous cannulas in the arm or leg of a patient for hemodialysis purposes, and which are shunted when not in use, is a technique which is known to the art. This technique enables multiple hemodialysis treatments to be made from a single cannulation. It is usual in the prior art to insert the entrance end of the cannula percutaneously into an artery, and to insert the exit end of the cannula percutaneously into a vein, in the arm or leg of the patient. The radial artery is usually cannulated in accordance with present day practice at a distance from the wrist to the antecubital fossa. The exit end of the prior art shunt, as stated above, is usually inserted subcutaneously into an appropriate vein.

The longevity of the indwelling prior art cannulas is, in part, determined by the susceptibility of the blood circulating through the cannulas to turbulence and resulting clotting. However, the success of such a shunt depends on a long term use thereof, if it is to be of any substantial aid to patients with chronic renal disease who require long-term intermittent hemodialysis. In the last 10 years there has been extensive experience in the field, and many improvements in the implanting techniques of arteriovenous shunts for chronic hemodialysis patients have resulted.

Malfunctions of the prior art arteriovenous shunts are contributable generally to blood clotting, intimal damage caused by insertion or frictional trauma, angulation, phlebotic narrowing, and aneurysms. While some of the malfunctions can, at least be temporarily alleviated or controlled in the prior art shunts, the life sustaining nature of this prosthesis stimulated the more reliable and durable shunt of the present invention. The prior art shunts have suffered from a relatively short clot-free life time on the order of 29 days, and even with heparin treatments the average life time of the prior art shunt does not exceed 2.7 months.

The usual prior art arteriovenous shunt includes an arterial cannula and a venous cannula which are respectively inserted into a selected artery and into a selected vein in the arm or leg of the patient, as described above. The insertion of the prior art cannula, due to the reduction in size of the orifice presented by the cannula, as compared with the corresponding blood vessel, creates a turbulent blood flow condition at both the entrance and the exit of the prior art shunt. Such turbulence is instrumental in causing trauma and subsequent pathological conditions in the prior art shunt.

The turbulence is obviated in the embodiment of the invention to be described by integrating Venturi tubes at each end of the shunt of the invention, and by coupling the Venturi tubes to the corresponding blood vessels by appropriate cuffs which, as will be described, are sutured to the blood vessels.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a somewhat schematic representation of an arteriovenous shunt constructed in accordance with the concepts of the invention and shown in its shunted condition between hemodialysis treatments;

FIG. 2 is a schematic representation of the shunt of FIG. 1 intercoupled to a dialyzer for a dialysis treatment of the patient;

FIG. 3 is a representation of the cross section of the entrance of a prior art shunt, and illustrates the resulting turbulence, and associated pressure curve;

FIG. 4 is a cross sectional representation of the entrance of another prior art shunt, also showing the resulting turbulence and associated pressure curve; and

FIG. 5 is a representation of the entrance to the shunt of the present invention, and showing the resulting smooth flow of the blood at the entrance and exit of the shunt, and associated pressure curve.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENT

The arteriovenous shunt of the embodiment of the invention shown in FIG. 1 comprises a first Venturi tube 10 which may, for example, be formed of hard silastic material, and which is molded to a piece of flexible silastic tubing 12. The remote end of the silastic tubing 12 may be terminated in the female portion 14a of a beveled connector 14 which, likewise, may be formed of hard silastic material. Both the Venturi tube 10 and the portion 14a of the connector 14 may be integrated with the flexible silastic tubing 12.

The Venturi tube 10 is attached to a short cuff 16 formed, for example, of seamless woven Dacron. Care should be taken that the mating inner surfaces of the cuff 16 and Venturi tube 10 are smoothly formed. The other end of the cuff 16 is sutured to a separate artery 18 in the arm or leg of the patient to receive blood from the artery. The end of the cuff 16 adjacent the artery is heat treated to offer a smooth surface to the blood flow. A continuous over-and-over suture of 5-0 or 6-0 arterial silk should be used.

A similar Venturi tube 20 is formed in the end of a second piece of flexible silastic tubing 22, the throat of the Venturi tube 20 extending in the opposite direction to the throat of the Venturi tube 10. The Venturi tube 20 is attached to a cuff 22 which, likewise, may be formed of Dacron, and the attachment is made in the same manner as described above. The cuff 22 is sutured to a vein 24 which receives blood from the shunt. The suture 26 between the cuff 22 and the vein 24 may be the same as the suture 28 between the artery 18 and cuff 16. For optimum hemodynamic efficiency, the ratio of the inside diameter of the cuffs 16, 22 and the respective blood vessels 18, 24 should be of the order of 1.5:1.0.

The tube 22 is attached to the male portion 14b of the beveled connector 14 which may be formed of hardened silastic material integral with the end of the tubing 22, as may the Venturi tube 20. An outlet 30 may be formed in the tubing 22. The outlet 30 may be plugged by an appropriate stopper 32.

The shunt of the invention, as an alternative, may take the form of a single piece of silastic tubing between the Venturi tubes 10 and 20, with two outlets such as the outlet 30 formed at spaced position along the tubing. This provides a structure similar in some respects to the Buselmeier shunt described in the publication *Dialysis and Transplantation*, for August/September 1973. Alternately, the shunt may incorporate the connector 14, as shown in FIG. 1, and which may be easily separated to permit a pump 50 and dialyzer 52 (FIG. 2) to be included in the circulating path of the shunt during the dialysis treatment. The shunt of the invention provides a smooth constant internal cross section when so connected.

For various reasons, a direct arteriovenous fistula is not feasible for many patients. These reasons include, for example, the need for immediate usage, cardiac pathology, distal ischemia, vascular inadequacy, venous aneurysms, venous damage due to repeated venipuncture, extensive intraluminal clotting or repeated infiltration, and so on. However, since the shunt of the invention will, in the course of usage, be lined by a thin layer of fibrous tissue and endothelium, the hemodynamic characteristics of the shunt, due to the unique features of the Venturi tubes, provide a resulting flow-field superior to an arteriovenous fistula, and yet being applicable under the various conditions outlined above, in which the direct arteriovenous fistula is not feasible.

As mentioned above, the insertion of the cannulas of the prior art arteriovenous shunts, due to the reduction in size of the orifices, creates a turbulent flow of the blood, both at the entrance and at the exit of the prior art shunts. The resulting stress in the prior art shunt is instrumental in causing intimal trauma and subsequent undesirable pathological conditions.

The flow-fields of the blood in the prior art shunts, and related pressure drops, are shown in FIGS. 3 and 4. The representation A in FIG. 3 shows the flow-field in a rounded approach orifice, and the representation A in FIG. 4 shows the flow-field in a sharp edge approach orifice, in the prior art type of shunts. Each of the orifices of FIGS. 3 and 4 show considerable turbulence. Moreover, each of the prior art orifices show a relatively high pressure drop, as illustrated by the curves B in FIG. 3 and 4.

According to Bernoulli's equation, the entrance flow velocity (w) at the orifice cross section (a) is:

$$w = \sqrt{(1/1 - (a^2/A^2)) \cdot \sqrt{(2(p_0 - p)/S)}}$$

where: A is the blood vessel cross section; p_0 is the pressure in the blood vessel; p is the pressure at the orifice exit; and S is specific density of the blood. The exit flow velocity (w_b) at the cross section B of the prior art cannulus can be calculated by the same equation.

As shown in the illustrated examples of FIGS. 3 and 4, the pressure drop in the prior art assemblies is 60-70% when compared with the entry orifice pressure, and consequently there is an undesirable increase in exit flow velocity w_b in the prior art structures due to the disturbed flow-field, as shown in FIGS. 3 and 4.

When Venturi tubes 10 and 20 are used in the shunt of the present invention, the resulting flow-field is smooth with minimum turbulence, as shown in the representation A of FIG. 5. Moreover, as shown by the curve B of FIG. 5, practically all the pressure drop is recovered at the exit of the Venturi tube. Thus, the case where the cross sectional area A approximately equals the cross sectional area B, in the representation A of FIG. 5, then an almost constant flow velocity will result, so that turbulence will be avoided.

The diameter of the Venturi tubes 10 and 20 can be

selected to match the difference in diameters between the artery 18 and vein 24, so that, in each instance, an undisturbed fluid flow may be achieved both at the entrance and at the exit of the shunt. The ends of the shunt which penetrate the skin may be enclosed in Teflon casings of roughened outer surfaces, so as to lessen the danger of infection, to promote tissue ingrowth, and to effect a firm mechanical seal. Such a technique is described, for example, in an article by R. A. Ersek et al., entitled "A New Arteriovenous Shunt Design" appearing in the transactions of the American Society of Artificial Organs 15:267, 1969.

The invention provides, therefore, an improved arteriovenous shunt which has certain advantages over built in fistula in the elimination of the maturity period, and of the necessity for needle penetration during hemodialysis.

It will be appreciated that although particular embodiments of the invention have been shown and described, modifications may be made. It is intended in the claims to cover the modifications which come within the spirit and scope of the invention.

What is claimed:

1. An arteriovenous shunt for hemodialysis patients, and the like, comprising: elongated tubular means having an entrance end and an exit end creating a fluid-circulating path between the entrance end and the exit end; an elongated tube having one end attached to the entrance end of said elongated tubular means and having an inner surface flared outwardly from the other end thereof towards said one end to create a Venturi effect and thereby prevent turbulence in the fluid circulating therethrough; and a flexible tubular cuff having one end attached to the other end of said elongated tube and having an outwardly flared opposite end to be sutured to a severed duct in the body of the patient.

2. The arteriovenous shunt defined in claim 1, in which said tubular means is formed of flexible silastic tubing and said tube is formed of hard silastic material, and in which said cuff is formed of a plastic fabric material.

3. The arteriovenous shunt defined in claim 1, and which includes a second elongated tube having one end connected to the exit end of said tubular means, and having an inner surface flared outwardly toward the other end thereof to create a Venturi effect and thereby prevent turbulence in the fluid circulating therethrough.

4. The arteriovenous shunt defined in claim 1, in which said tubular means comprises a first tubular member and a second tubular member, and separable connector means intercoupling said first and second tubular members.

5. The arteriovenous shunt defined in claim 1, and which includes at least one outlet formed in said tubular means.

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