(54) Title: LIVER PERFUSION SYSTEM AND BYPASS MEMBER

(57) Abstract

A liver perfusion bypass member (10) for use in a liver perfusion system comprising an elongate member (10) having first and second end portions (34, 38) proportioned for insertion into the vena cava (11). The elongate member (10) defines a first flow conduit (24), extending along its entire length, to carry vena cava blood, and lateral apertures (30) in the first flow conduit (24) to receive blood from the kidneys. The elongate member (10) also defines a second longitudinal flow conduit (40). A liver flow aperture (44) communicates with the second conduit (40) for receiving venous blood from the liver (46). A branch conduit (62) spaced from the liver flow aperture (44) receives the venous blood from the liver (46) through the second conduit (40). The bypass member (10) may be connected via its branch conduit (62) to a third conduit (64) to circulate the venous blood from the liver (46) through a blood oxygenator (68), a blood pump (66), and, if desired a heat exchanger.
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LIVER PERFUSION SYSTEM AND BYPASS MEMBER

Technical Field and Prior Art

In the article by Robert K. Ausman et al. entitled "Isolated Perfusion of the Liver with HN₂", Surgical Forum, Volume 10, pp. 77-79 (1959), there is disclosed a technique of isolating the blood flow of the liver of a patient and recirculating it through an oxygenator, the blood flow being driven by a pump. Heavy doses of an anticancer drug (chemotherapeutic agent) can then be placed into the isolated blood circuit so that heavy concentrations of the drug pass through the liver, with relatively low amounts of the anticancer drug entering into other parts of the body. The effect of this is to maximize the antitumor effect of the therapy while minimizing the typical and well known side effects of anticancer drugs on the patient.

Accordingly, heavier doses of chemotherapeutic agent can be provided to the liver for longer times than a patient could normally stand if such doses were administered bodywide, resulting in better antitumor effect than has been previously available.

However, the process of liver perfusion has proven to be very difficult from a technical viewpoint. The perfused liver tends to lose its blood flow capacity at its junction with the vena cava, and other significant difficulties have been encountered.

In accordance with this invention, a liver perfusion bypass member is provided which simplifies and renders more reliable the liver perfusion procedure in a living patient, with the result that liver perfusion, using the device of this invention, can be more widely used with better effect and reliability.
Description of the Invention

In accordance with this invention, a liver perfusion bypass member for use in a liver perfusion system comprises an elongated member having first and second end portions proportioned for insertion of both ends into the vena cava. The elongated member defines first flow conduit means extending the length thereof to carry vena cava blood therethrough, and lateral aperture means in the first flow conduit means to receive flowing blood from the kidneys while positioned in the vena cava.

The elongated member also defines a second longitudinal flow conduit, separate from the first flow conduit. A liver flow aperture communicates with the second conduit for receiving venous blood from the liver. A branch conduit is spaced from the liver flow aperture and communicates with the second conduit for receiving the venous blood from the liver through the second conduit.

In use, the liver perfusion bypass member may be connected at its branch conduit to a third conduit, to receive venous blood from the liver and to convey it to blood oxygenation means and a blood pump for driving blood through the circuit. A heat exchanger may also be included in the circuit to control the temperature of the blood.

The third conduit then leads to at least the hepatic artery for recycling the blood back to the liver, and also it may communicate with the portal vein, so that the bulk of the blood received by the liver is recirculated blood received from the liver by the perfusion bypass member, and passed to the third conduit for oxygenation, heat exchange, pumping, and return to the liver. Because of this, chemotherapeutic agent added to the blood circuit in the third conduit remains largely localized in the liver, and does not substantially spread through the body. As
stated above, the effect of this is to permit higher doses and longer exposures of chemotherapeutic agent to the liver without corresponding side effects of loss of hair, diminution of bone marrow activity, and the like.

It is preferred for the liver flow aperture to be covered with grating means to support the liver adjacent the flow aperture. Without this, the liver tends to collapse into the liver flow aperture with a consequent closeoff of blood flow ducts from the liver.

Also, the first flow conduit of the bypass member may define along at least part of its length a pair of separate lumens extending through the bypass member, the lumens each defining a separate lateral aperture of the lateral aperture means for communication with a separate kidney.

A first valve means preferably controls flow through the first flow conduit, while second valve means controls flow through the second conduit means.

Also, a branch conduit is desirably sealed in communication with the second flow conduit means and in rotatable communication therewith with the second valve being defined by structure that opens and closes flow through the branch conduit in a manner dependent upon its rotational position.

Description of the Drawings

Figure 1 is a diagramatic view of a liver perfusion apparatus in accordance with this invention utilizing the liver perfusion bypass member disclosed herein.

Figure 2 is an enlarged longitudinal sectional view of the liver bypass member of Figure 1 emplaced in the vena cava of a patient.

Figure 3 is a sectional view taken along line 3-3 of Figure 2.
Figure 4 is a sectional view taken along line 4-4 of Figure 2.

Figure 5 is a sectional view taken along line 5-5 of Figure 2.

Figure 6 is a fragmentary elevational view of the structure of Figure 4.

Figure 7 is a fragmentary plan view of the structure of Figure 4.

Figure 8 is a perspective view of a portion of the liver perfusion bypass member disclosed in the previous drawings, with parts broken away.

**Description of Specific Embodiment**

Referring to Figures 1 and 2, liver perfusion bypass member 10 is disclosed. Bypass member 10 is shown inserted into the vena cava 11 of a patient through first and second incisions 12, 14 with circumferential ties 16, 18 cooperating with annular grooves 20, 22 of bypass member 10 to seal the incision sites, with the bypass member mounted within the vena cava.

The bypass member 10 of this invention may be made of any desired material which is susceptible to sterilization, typically semi-rigid or rigid materials such as stainless steel or an autoclavable plastic such as polysulfone. Also a one-use, disposable version of a plastic such as polypropylene may be used.

As specifically shown in Figures 4 and 5, first flow conduit means 24 defines through a substantial portion of bypass member 10 a pair of lumens 26, 28, each of which defines a side aperture 30 in an adjacent outer wall, positioned to receive blood from a hepatic vein where it joins the vena cava, so that blood from the kidneys can flow freely into first flow conduit 24, i.e., lumens 26, 28. Lumens 26, 28 join together into a common flow lumen.
32 adjacent first end portion 34 of bypass member 10. The lumens 26, 28 also join into a common second end flow passage 36 at second end 38 of the bypass member. Accordingly, venous blood flowing through the vena cava is not seriously hindered by the presence of bypass member 10, since there is an open flow path passing from end to end thereof, to permit flow along the length of the vena cava during the bypass procedure.

Bypass member 10 also defines second longitudinal flow conduit 40, which is separate from first flow conduit 24. Second conduit 40 may have both ends closed respectively with plug 42 and end wall 43. Second conduit 40 also defines liver flow aperture 44, which is positioned and proportioned to receive venous blood from liver 46 through the venous blood vessels that naturally provide flow communication between the liver and the vena cava. Accordingly, since bypass member 10 is positioned within the vena cava, aperture 44 can receive the flowing venous blood from the liver 46 within second flow conduit 40, isolating such blood from the flowing blood of the first flow conduit 24. Annular grooves 48, 50 are provided in bypass member 10 to receive circular ties 52, 54, to tie the vena cava 11 at these points to prevent the substantial leakage of blood within the vena cava, but outside of bypass member 10, so that substantially all blood flow from the liver passes through second conduit 40.

Liver flow aperture 44 defines a grating 56 to support the liver tissue 46, and to prevent the collapse of the liver into aperture 40, as can otherwise take place during liver perfusion or bypass procedures. While the reason for collapsing of the liver is not entirely understood, it is believed, without wishing to be limited to any particular theory, that siphon effects in the artificial bypass system may cause negative or suction pressures to
act on the liver in an unnatural manner, causing the liver to collapse inwardly through aperture 44 by suction effects. The effect of this is to cut off flow of liver blood vessels, which, of course, is a potentially very serious occurrence.

Grating 56 may comprise a series of apertures 58 defined by upstanding, spaced support members 60 therebetween, to support portions of the liver and prevent it from collapse. The liver-contacting surfaces of the support members 60 are preferably rounded as shown, to avoid abrasion or other damage of the liver tissue. Support members 60 may define an outer surface that is generally of convex shape so as to support the liver 46 with central portions being slightly higher than the edge portions. Support members 60 also define a plurality of slots 61, with the central portions of support members 60 being approximately 1/4 inch high and slots 61 being typically 0.075 inch wide. Central portions of support members 60 may be tied together by cross piece or pieces 63 for structural stability.

Alternatively, grating 56 may comprise a mesh of plastic or metal strands without upstanding support members, if such is desired.

Branch conduit 62 projects outwardly from bypass member 10, and may be proportioned to receive a third conduit 64 in flow relationship therewith. Third conduit 64 may be simple plastic tubing defining a conventional access port or injection site 66 to permit the administration of chemotherapeutic agent to flowing blood in branch conduit 64. Third conduit 64 also passes through oxygenator means 68, which may be any desired oxygenator for blood, preferably also carrying a heat exchanger, or, if desired, a separate heat exchange member may be placed in the third conduit 64. Conduit 64 also
passes through pump means 66, which may be a conventional roller pump for blood and, as shown, conduit 64 may branch into a pair of added branches 68, 70, one of which may communicate, for example at the portal vein and the other at the hepatic artery of liver 46.

As the result of this, a complete, substantially isolated, independent blood flow circuit is created through liver 46, with the blood being oxygenated to the degree necessary for the liver's needs and recirculated through the liver, powered by roller pump 66, since the recirculating system is substantially disconnected from the pumping action of the heart. Accordingly, the blood circulates and recirculates through a third conduit 64 and the other stations of the conduit, plus second conduit 40 of bypass member 10, while the chemotherapeutic agent or other material is inserted through injection site 66. Thus the isolated blood circulating through the liver may carry a concentration of chemotherapeutic agent which could normally practically kill the patient if such concentration were on a bodywide basis, for increased effectiveness against tumors in the liver and the like.

First flow conduit means 24 desirably carries a first stopcock-type valve 72 which may, per se, be of conventionally designed rotational valve of the on-off type, having a handle 74 for manual control thereof and a valve barrel 75. Valve 72 will be shut off during implantation of bypass member 10 in the vena cava. After vena cava 11 is tied in place surrounding bypass member 10, valve 72 can be opened to once again permit blood flow through the vena cava by means of first flow path 24.

Second flow path 40 also carries a second valve means which may be defined by the mounting of branch conduit 62. Branch conduit 62 defines a rotation ball 76 sealingly and rotatably fitting in socket 78 of housing
so that branch conduit 62 can be rotated about its axis back and forth between first and second positions. Second conduit 40 defines a second aperture 82 of housing 81 leading into socket 78. A third aperture 84 extends through rotation ball 76, and communicates with the remainder of branch conduit 62.

Handle 79 is attached to branch conduit 62 to facilitate its axial rotation for opening and closing of the second valve means.

Accordingly, when branch conduit 62 is in the position shown in Figure 2, flow is permitted between second flow path 40 and branch conduit 62, because apertures 82 and 84 are in registry with each other. However, branch conduit 62 can be rotated about its axis to move aperture 84 out of registry with aperture 82, with the result that blood flow is no longer possible through second flow path 40 and branch conduits 62. The second valve would, of course, be closed during installation of the bypass member in the vena cava until connection and set up of third conduit 64 and the connection of branches 68, 70 to liver 46 was complete. Then it would be opened, permitting flow of blood through second conduit 40, branch conduit 62, and third conduit 64 for the desired liver perfusion.

Side conduit 80 may also be provided, if desired, for communication between the exterior and first flow path 24, side conduit 80 communicating typically at second end flow passage 36. Side conduit 80 may be used to receive bypass blood flow from splanchnic circulation, i.e., flow from the intestines, spleen and stomach, being connected to the portal vein via the inferior mesenteric vein, for example. Thus blood flow in the portal vein is not occluded by the temporary diversion of normal blood flow provided herein, but can be returned to the heart by a shunt line communicating through side conduit 80, if
deemed necessary by the surgeon. Side conduit 80 may be of a design substantially identical to branch conduit 62, with a third valve being provided in a similar manner as in branch conduit 62.

When the liver perfusion is complete, the two valves would be closed; circular ties 16, 18, 52, and 54 would be released; and bypass member 10 would be removed from the vena cava. The incisions 12, 14 in the vena cava would be sewn up and the patient routinely surgically closed.

Typically, blood in the bypass circuit defined in member 10 and third conduit 64 would not be returned to the patient in view of its high loading of chemotherapeutic agent.

The above has been offered for illustrative purposes only, and it is not intended to limit the scope of the invention of this application, which is as defined in the claims below.
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THAT WHICH IS CLAIMED IS:

1. A liver perfusion bypass member for use in a liver perfusion system, which comprises:

   an elongated member having first and second end

5 portions proportioned for insertion of both ends into the vena cava, said elongated member defining first flow conduit means extending the length thereof, to carry vena cava blood flow therethrough, and lateral aperture means in the first flow conduit means to receive flowing blood from the kidneys while positioned in the vena cava;

   said elongated member also defining a second longitudinal flow conduit, separate from the first flow conduit, a liver flow aperture communicating with said second conduit for receiving venous blood from the liver, and a branch conduit spaced from the liver flow aperture and communicating with the second conduit, for receiving said venous blood from the liver.

   2. The liver perfusion bypass member of Claim 1 in which said liver flow aperture is covered with grating means to support the liver adjacent said flow aperture.

   3. The liver perfusion bypass member of Claim 1 in which said first flow conduit defines along at least part of its length a pair of lumens extending through said member, each lumen defining a separate lateral aperture of the lateral aperture means.

   4. The liver perfusion bypass member of Claim 1 in which first valve means controls flow through said first flow conduit means.
5. The liver bypass member of Claim 4 in which second valve means controls flow through said second flow conduit means.

6. The liver perfusion bypass member of Claim 5 in which said branch conduit defines a rotation ball sealingly and rotatably fitting in socket means, a second aperture communicating with the second conduit and extending through the socket means; a third aperture extending through said rotation ball and communicating with the branch conduit, said second valve being defined by said rotation ball, socket means, and second and third apertures.

7. The liver perfusion bypass member of Claim 1 as part of a bypass system including a third conduit communicating with said branch conduit and blood oxygenation means, and pump means for conveying blood through said third conduit and for conveying said blood back to the liver through at least the hepatic artery.

8. A liver perfusion bypass member for use in a liver perfusion system, which comprises:
   an elongated member having first and second end portions proportioned for insertion of both ends into the vena cava, said elongated member defining first flow conduit means extending the length thereof to carry vena cava blood flow therethrough, and lateral aperture means in the first flow conduit means to receive flowing blood from the kidneys while positioned in the vena cava;
   said elongated member also defining a second longitudinal flow conduit separate from the first flow conduit, a liver flow aperture communicating with said second conduit for receiving venous blood from the liver,
said liver flow aperture being covered with grating means to support the liver adjacent said flow aperture, a branch conduit spaced from the liver flow aperture and communicating with the second conduit for receiving said venous blood from the liver, first valve means controlling flow through said first flow conduit means and second valve means controlling flow through said second flow conduit means.

9. The liver perfusion bypass member of Claim 8 in which said branch conduit defines a rotation ball sealingly fitting in socket means to permit rotation of the branch conduit, a second aperture communicating with second conduit and extending through the socket means, a third aperture extending through said rotation ball and communicating with the branch conduit, said second valve being defined by said rotation ball, socket means, and second and third apertures, flow being permitted when the second and third apertures are rotated into registry.

10. The liver perfusion bypass of Claim 9 in which said first flow conduit defines along at least part of its length a pair of lumens extending through said member, each lumen defining a separate lateral aperture of the lateral aperture means.

11. The liver perfusion bypass member of Claim 9 in which a side conduit communicates with said first flow conduit means, and third valve means controlling flow through said side conduit, for receiving blood from from the intestines, spleen and stomach and directing said blood flow into the first flow conduit for conveyance through the vena cava into the heart.
## INTERNATIONAL SEARCH REPORT

**International Application No.** PCT/US83/00390

### I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) 2

According to International Patent Classification (IPC) or to both National Classification and IPC:

US: 604/9, 27, 32, 93, 248, 264  
128/1R, Digest 3  

**IPC: 3** A61B 19/00  
A61B 17/00

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### IV. CERTIFICATION

**Date of the Actual Completion of the International Search 3**  
16 June 1983

**Date of Mailing of this International Search Report 3**  
29 Jun 1983

**International Searching Authority 1**  
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**Signature of Authorized Officer 15**  
C. FRED ROSENBAUM

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