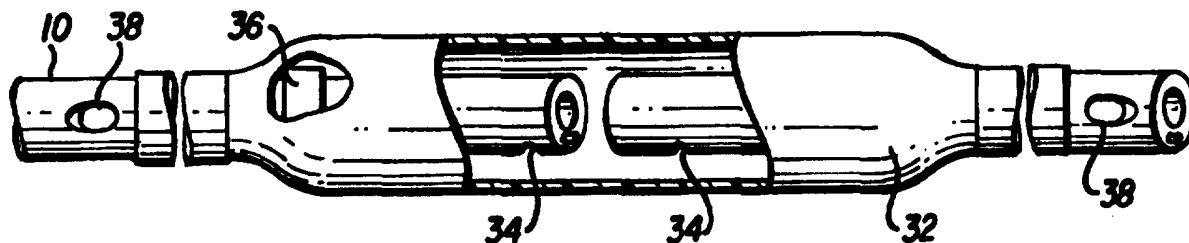




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(21) International Application Number: PCT/US95/15228 (22) International Filing Date: 6 December 1995 (06.12.95) (30) Priority Data: 08/352,318 8 December 1994 (08.12.94) US (71) Applicant: OMNITRON INTERNATIONAL, INC. [US/US]; Suite 200, 8990 Kirby Drive, Houston, TX 77054 (US). (72) Inventors: THORNTON, Richard, T.; 2668 Warwick Drive, League City, TX 77573 (US). BRADSHAW, Anthony, J.; 2938 Kennesaw Drive, Missouri City, TX 77459 (US). SNYDER, Wayne, W.; 914 Beachcomber, Houston, TX 77062 (US). (74) Agents: GREENE, Donald, R. et al.; Wigman, Cohen, Leitner & Myers, P.C., Suite 200, Crystal Square 3, 1735 Jefferson Davis Highway, Arlington, VA 22202 (US).		(81) Designated States: CA, JP, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Published <i>With international search report.</i>

(54) Title: INTRAVASCULAR RADIOTHERAPY EMPLOYING A LIQUID-SUSPENDED SOURCE

**(57) Abstract**

Apparatus and methods are provided for delivering an easily controllable inherently uniform dosage of radiation to the walls of a blood vessel for preventing restenosis after angioplasty. The apparatus comprises a catheter (10) having a balloon tip (32) which is inflatable with a liquid containing a suspended radioactive material such as I125 or P32. The catheter (10) is advanced through the patient until this treatment balloon (32) is disposed in the stenosed region of the blood vessel. The balloon (32) is filled with the radioactive fluid which simultaneously expands and relieves the stenosis while irradiating the tissue, or if the stenosis has previously been relieved, the target tissue is irradiated by filling the treatment balloon (32) with the radioactive fluid until the outer wall of the balloon engages, without substantially expanding, the inner wall of the blood vessel.

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**INTRAVASCULAR RADIOTHERAPY EMPLOYING
A LIQUID-SUSPENDED SOURCE**

Background of the Invention

This invention relates generally to treatment of
5 selected tissue by inter-vivo radiation, specifically to
radiation treatment of selected regions of the
cardiovascular system that have been subjected to trauma to
prevent restenosis of the traumatized region, more
specifically to radiation treatment to prevent restenosis of
10 an artery traumatized by percutaneous transluminal
angioplasty (PTA).

PTA treatment of the coronary arteries, percutaneous
transluminal coronary angioplasty (PTCA), also known as
balloon angioplasty, is the predominant treatment for
15 coronary vessel stenosis. Approximately 300,000 procedures
were performed in the United States (U.S.) in 1990 and an
estimated 400,000 in 1992. The U.S. market constitutes
roughly half of the total market for this procedure. The
increasing popularity of the PTCA procedure is attributable
20 to its relatively high success rate, and its minimal
invasiveness compared with coronary by-pass surgery.
Patients treated by PTCA, however, suffer from a high
incidence of restenosis, with about 35% of all patients
requiring repeat PTCA procedures or by-pass surgery, with
25 attendant high cost and added patient risk. More recent
attempts to prevent restenosis by use of drugs, mechanical
devices, and other experimental procedures have had limited
success.

Restenosis occurs as a result of injury to the arterial wall during the lumen opening angioplasty procedure. In some patients, the injury initiates a repair response that is characterized by hyperplastic growth of the vascular smooth muscle cells in the region traumatized by the angioplasty. The hyperplasia of smooth muscle cells narrows the lumen that was opened by the angioplasty, thereby necessitating a repeat PTCA or other procedure to alleviate the restenosis.

Preliminary studies indicate that intravascular radiotherapy (IRT) has promise in the prevention or long-term control of restenosis following angioplasty. It is also speculated that IRT may be used to prevent stenosis following cardiovascular graft procedures or other trauma to the vessel wall. Proper control of the radiation dosage, however, is critical to impair or arrest hyperplasia without causing excessive damage to healthy tissue. Overdosing of a section of blood vessel can cause arterial necrosis, inflammation and hemorrhaging. Underdosing will result in no inhibition of smooth muscle cell hyperplasia, or even exacerbation of the hyperplasia and resulting restenosis.

U.S. Patent No. 5,059,166 to Fischell discloses an IRT method that relies on a radioactive stent that is permanently implanted in the blood vessel after completion of the lumen opening procedure. Close control of the radiation dose delivered to the patient by means of a permanently implanted stent is difficult to maintain because the dose is entirely determined by the activity of the stent

at the particular time it is implanted. Additionally, the dose delivered to the blood vessel is non-uniform because the tissue that is in contact with the individual strands of the stent receive a higher dosage than the tissue between
5 the individual strands. This non-uniform dose distribution is especially critical if the stent incorporates a low penetration source such as a beta emitter.

U.S. Patent No. 5,302,168 to Hess teaches use of a radioactive source contained in a flexible carrier with
10 remotely manipulated windows. H. Böttcher, et al. of the Johann Wolfgang Goethe University Medical Center, Frankfurt, Germany report in November 1992 of having treated human superficial femoral arteries with a similar endoluminal radiation source. These methods generally require use of a
15 higher activity source than the radioactive stent to deliver an effective dose. Accordingly, measures must be taken to ensure that the source is maintained reasonably near the center of the lumen to prevent localized overexposure of tissue to the radiation source. Use of these higher
20 activity sources also dictates use of expensive shielding and other equipment for safe handling of the source.

What is needed then, is an IRT method and apparatus that delivers an easily controllable uniform dosage of radiation to the walls of the blood vessel without the need
25 for special measures to center a radiation source in the lumen, the need for expensive shielding to protect medical personnel, or the need for expensive remote afterloaders to handle the higher activity sources.

Summary of the Invention

According to the present invention the IRT procedure is accomplished either during or after the angioplasty procedure, by advancing a flexible catheter having a balloon at the distal tip through the cardiovascular system of the patient until this treatment balloon is positioned at a target area comprising the stenosed or recently re-opened region of the blood vessel. In the case of simultaneous-angioplasty IRT the treatment balloon is filled with a fluid containing a radioactive material which simultaneously expands and relieves the stenosis while irradiating the tissue in the target area of the blood vessel. In the case of post-angioplasty IRT, the stenosis is first relieved, then the target tissue is irradiated by filling the treatment balloon with the radioactive fluid until the outer wall of the balloon engages, without substantially expanding, the inner wall of the blood vessel.

In one embodiment of the present invention, the radioactive material is a suspension of a beta emitting material such as ^{125}I or ^{32}P . The substantially pure beta radiation emitted by such sources is quickly absorbed by surrounding tissue and will not penetrate substantially beyond the walls of the blood vessel being treated. Accordingly, incidental irradiation of the heart and other organs adjacent to the treatment site is substantially eliminated. Moreover, because the radioactive fluid has a substantially uniform suspension of radioactive material, the radiation emitted at the surface of the balloon in

contact with the target area of the blood vessel is inherently uniform. Accordingly, uniform irradiation of the blood vessel wall is also inherent. The catheter of the present invention may be equipped with perfusion ports proximal and distal of the balloon to permit blood flow past the balloon when inflated.

According to another embodiment of the present invention, a second balloon is provided that completely envelopes the treatment balloon. This containment balloon acts as a containment vessel in the event the inner treatment balloon ruptures when filled with the radioactive fluid. In use, prior to filling the treatment balloon with the radioactive fluid, the containment balloon is filled, preferably with a non-toxic radio-opaque liquid, to verify the integrity of the containment balloon. The radio-opaque fluid filled containment balloon may also be used to verify correct positioning of the catheter within the target area of the blood vessel.

According to another embodiment of the present invention, an inner inert expansion balloon is provided inside the treatment balloon. The inert expansion balloon reduces the amount of radioactive fluid that must be used to fill the treatment balloon by occupying space within the middle balloon that would otherwise be filled with radioactive fluid. In use, prior to filling the treatment balloon with the radioactive fluid, the inert expansion balloon is filled with an inert liquid, thereby forcing the radioactive fluid to the periphery of the treatment balloon.

Because of the self-attenuation of the radioactive fluid itself, most of the radioactivity originates at the surface of the treatment balloon. Accordingly, the surface radiation is not reduced substantially as a result of the center being filled with an inert material. Accordingly, the same radiation level can be achieved as if the treatment balloon were completely filled with radioactive fluid, while using substantially less radioactive fluid. A further refinement of this embodiment, especially suited to larger lumens, incorporates a substantially hollow cylindrical balloon having a relatively small cavity between the inner and outer wall of the cylinder into which the radioactive fluid is injected.

According to another embodiment of the present invention, a proximal and distal blocking balloon are also provided to contain the radioactive fluid in the target area in the event of a total failure of all containment systems.

Brief Description of the Drawings

The above and other objects, aspects, features and attendant advantages of the present invention will become apparent from a consideration of the ensuing detailed description of presently preferred embodiments and methods thereof, taken in conjunction with the accompanying drawings, in which:

FIG. 1A-1C are plan and cross sectional views of an apparatus according to the present invention;

FIG. 2A-2C are plan and cross sectional views of an alternate embodiment of an apparatus according to the present invention incorporating a containment balloon;

FIG. 3A-3C are plan and cross sectional views of an alternate embodiment of an apparatus according to the present invention incorporating an inner inert expansion balloon;

FIG. 4A-4C are plan and cross sectional views of an alternate embodiment of an apparatus according to the present invention incorporating proximal and distal blocking balloons;

FIG. 5A-5C are plan and cross sectional views of an alternate embodiment of an apparatus according to the present invention incorporating an inflatable sleeve;

FIG. 6A-6C are plan and cross sectional views of an alternate embodiment of an apparatus according to the present invention incorporating a sleeve suitable for positioning with an angioplasty balloon..

Description of Preferred Embodiments and Methods

FIGs. 1A and 1B illustrate a suspended-isotope IRT catheter according to the present invention. The IRT catheter comprises shaft 10 having a longitudinal inflation lumen 12, a conventionally formed tip, and may include longitudinal guidewire/ injection/perfusion lumen 14. Shielded injector 16, which may be a manual or automated syringe containing a radioactive liquid 30, or a pump connected to a reservoir of radioactive liquid 30, is

connected to the proximal end of shaft 10 and is in fluid communication with inflation lumen 12. To prevent possible spillage and corresponding radioactive contamination of the operating room and/or its personnel, the shielded injector 5 16 is permanently attached to shaft 10, or preferably, injector 16 is equipped with a fail-safe non-detachable connector 18, which cannot be detached from the corresponding receptacle 20 of shaft 10 once it is attached thereto. Non-detachable connector 18 also prevents the 10 radioactive fluid 30 from being discharged from injector 16 until the connector is connected to the receptacle in shaft 10. Connectors having ring-detents and other non-detachable fluid fittings are well known in the art, as are piercing valves and other common methods of preventing fluid flow 15 prior to attachment of a fluid fitting. The proximal end of shaft 10 also includes guidewire lumen luer fitting 15 in fluid communication with guidewire lumen 14, through which drugs may be injected directly into the patient's blood stream.

20 FIG. 1C is an enlarged view of the distal end of the present embodiment of the catheter. Treatment balloon 32 comprises an elastic or preferably an inelastic balloon, which may preferably be made from polyethylene terephthalate (PET), polyvinyl chloride (PVC), or other medical grade 25 material suitable for constructing a strong non-compliant balloon. Treatment balloon 32 is sealed at its proximal and distal ends to catheter shaft 10 in fluid communication with inflation lumen 12 via inflation lumen ports 34.

Immediately inside proximal and distal ends of balloon 32 are markers 36, comprising bands of silver or other suitable x-ray opaque material. Markers 36 aid in the proper positioning of balloon 32 within the target area of the blood vessel under fluoroscopy. Immediately adjacent to and outside the ends of balloon 32 are perfusion ports 38, which are in fluid communication with guidewire lumen 14.

Perfusion ports are well known in the art as a means of permitting some blood flow past a balloon that is inflated within and otherwise blocking a blood vessel.

In operation, after the angioplasty or other unblocking procedure has been performed, a suspended-isotope IRT catheter having a treatment balloon of the appropriate size is selected. The catheter is positioned within the patient's blood vessel by conventional means so that the balloon is within the target area. The shielded injector is connected to the receptacle at the proximal end of the catheter shaft and the air evacuated air from the balloon and inflation lumen, in the case of a shielded syringe, by withdrawing the plunger. The balloon is then filled with the liquid containing the suspended isotope until the outer wall of the balloon engages the inner wall of the blood vessel. The balloon is maintained in this inflated state for a predetermined period of time calculated to deliver an effective dose of radiation to the wall of the blood vessel. The fluid is then withdrawn from the balloon and the catheter withdrawn from the patient's body. To reduce the chances of overpressurizing the treatment balloon and

causing a rupture, pressure feedback device 22 is connected to the proximal end of inflation lumen 12. Pressure feedback device 22 may be a pressure gauge, or preferably a solid-state pressure transducer that operates an alarm 24 and/or a waste gate 26 in the event an overpressure condition is detected. Alternately, the solid state pressure transducer may be positioned at the distal end of the inflation lumen to monitor pressure in the balloon directly. It may also be possible to combine the angioplasty steps with the radiation treatment by using a catheter according to the present invention to perform the unblocking procedure.

FIGS. 2A-2C illustrate an alternate embodiment of the present invention further including an outer containment balloon 42. Containment balloon 42 is an inelastic or preferably an elastic balloon, which is preferably made of latex or other medical grade material suitable for constructing puncture-resistant elastic balloons. Containment balloon 42 is attached at its proximal and distal ends to shaft 10 and completely surrounds treatment balloon 32. Containment balloon 42 is in communication with containment balloon inflation lumen 44 via containment balloon inflation lumen port 46, which in turn is in fluid communication with containment balloon luer fitting 48 at the proximal end of shaft 10.

In operation, after the IRT catheter is in position but before treatment balloon 32 is filled with the radioactive liquid, containment balloon 42 is filled with a commonly

used non-toxic radio-opaque contrast medium injected through containment balloon luer fitting 48. The integrity of containment balloon is verified by fluoroscopy, pressure, or other suitable means and, if integrity is confirmed, the radio-opaque liquid is withdrawn and the procedure for injecting the radioactive fluid into treatment balloon 32 carried out. If the integrity of the containment balloon has been compromised (for example by sharp edges in guide catheters, guide wires, stents, etc.) a new catheter is selected and repositioned. By verifying integrity of the containment balloon after the balloon is in position, but before the radioactive fluid is injected, a substantial degree of safety against accidental injection of radioactive fluid into the patient's blood stream is achieved. Where a containment balloon is used (or blocking balloons as discussed with reference to FIGs 4A-4C are used), pressure feedback device 22 may also be used to activate an emergency evacuation system. In the event the pressure feedback device detected a sudden drop in pressure (indicating rupture of the treatment balloon) the pressure feedback device would initiate an immediate withdrawal of all radioactive fluid from the patient, for example by opening a valve to a vacuum accumulator 28. It may also be practicable to perform the angioplasty and the radiation treatment with a single catheter by using the containment balloon of the invention to perform the unblocking procedure prior to filling the treatment balloon with the radioactive

fluid. In such a case, the containment balloon would preferably be inelastic and the treatment balloon elastic.

Several important considerations must be balanced in the design of an apparatus for safely and effectively
5 injecting a radioactive fluid into a patient to irradiate a blood vessel to prevent restenosis. Although both ^{125}I and ^{32}P are substantially pure beta radiation emitters, ^{32}P is the preferred isotope for suspended-isotope IRT because it has a half-life of only 14.3 days as compared with the 60
10 day half-life of ^{125}I . A shorter half life renders ^{32}P safer to use because, in the event of a catastrophic failure involving leakage of radioactive fluid into the patient's blood stream, for a given calculated dose rate, a shorter half life will result in a lesser total body dosage.
15 Additionally, ^{32}P has been used in the treatment of chronic leukemia, where it is injected directly into a patient's blood stream. Accordingly, substantial medical knowledge exists as to the effects of ^{32}P in the blood stream.

In the leukemia treatment, depending on the patient's
20 weight, a suspended radiation source of about 6 to 15 millicuries of ^{32}P is used. Accordingly, for maximum safety, the preferred suspended-isotope IRT catheter should also use a source of no more than 6 millicuries. Prior experiments have shown that a dose of about 1000 to 3500
25 rads delivered to the blood vessel wall from a gamma radiation source is effective to inhibit the smooth muscle cell hyperplasia that causes restenosis. For low penetration sources, such as beta radiation emitters, it is

believed a dosage up to 5,000 rads may be tolerated. For a 6 millicurie ^{32}P source to deliver such a dose to the surface of the blood vessel, the balloon must be in position for substantially in excess of one minute, thus necessitating the perfusion ports.

For example, it is estimated that the balloon will absorb approximately 15% of the radiation delivered by the radioactive liquid. Accordingly, to deliver 2000 rads to the blood vessel wall, 2350 rads must be delivered to the inner wall of the balloon. A typical treatment balloon comprises a cylindrical balloon having an internal diameter of 3 millimeters, a length of about 30 millimeters, and an interior volume of approximately 0.2 cubic centimeters. Accordingly, to limit the total source to no more than 6 millicuries, 0.2 cubic centimeters of a liquid having a source concentration of no more than 30 millicuries per cubic centimeter must be used. A 30 millicurie per cubic centimeter source, however, requires about 6 minutes to deliver 2350 rads to the interior of the 3 millimeter diameter treatment balloon and thus requires about 6 minutes to deliver 2000 rads to the interior wall of the blood vessel.

The larger the balloon, the lower the concentration of the radiation source in the liquid must be to maintain the safe limit of 6 millicuries. However, the lower the concentration, the lower the dose rate and the longer the balloon must remain inflated to deliver an effective dose to the blood vessel wall.

FIGs. 3A-3C illustrate an embodiment of the present invention incorporating an inner inert expansion balloon 52. Inert expansion balloon 52 is an elastic or preferably an inelastic balloon, which may preferably be made from PET, PVC, or other medical grade material suitable for constructing a strong non-compliant balloon. Expansion balloon 52 is sealed at its proximal and distal ends to catheter shaft 10 completely within treatment balloon 32 and is in fluid communication with inert expansion balloon lumen 54 via expansion lumen ports 56. Inert expansion balloon lumen 54 is, in turn, in fluid communication with inert expansion balloon luer fitting 58 at the proximal end of shaft 10.

In operation, before treatment balloon 32 is filled with radioactive fluid, inert expansion balloon 52 is filled with an inert liquid injected through expansion balloon luer fitting 58. Because the fluid near the center of a body of radioactive fluid does not contribute significantly to the radiation emitted from the surface of the body, by filling the center of the balloon with an inert filler, a smaller volume of radioactive liquid can be used without significantly affecting the radiation delivered to the vessel wall. Without the inert filler, to avoid exceeding the 6 millicurie limit, the same size treatment balloon would require a larger volume of lower concentration radioactive fluid, with a commensurately lower dose rate and longer required treatment interval.

FIGs. 4A-4C illustrate an additional embodiment of the present invention incorporating blocking balloons 62.

Blocking balloons 62 are inelastic or preferably elastic balloons, which are preferably made of latex or other

5 medical grade material suitable for constructing puncture-resistant elastic balloons. Blocking balloons 62 are sealed to shaft 10 proximal and distal of treatment balloon 32 between perfusion ports 38, and are in fluid communication with a common blocking balloon inflation lumen 64 via
10 blocking balloon inflation ports 66. Blocking balloon inflation lumen 64 is, in turn, in fluid communication with blocking balloon luer fitting 68 at the proximal end of shaft 10.

In operation, blocking balloons 62 are inflated in the
15 blood vessel until the blood flow past the balloons is substantially stopped (the flow of blood in the vessel itself continues through the perfusion ports). The treatment balloon 32 is then inflated with the radioactive fluid for treatment of the blood vessel walls. In the event
20 treatment balloon 32 ruptures and containment balloon 42 fails, the radioactive fluid is still contained in the blood vessel between blocking balloons 62. The fluid can then be withdrawn either through any of the inflation lumens that, because of the breach, are in fluid communication with the
25 interior of the blood vessel between the blocking balloons 62, or preferably withdrawn automatically using the emergency evacuation system discussed with reference to FIGs 2A-2C. Blocking balloons may also be used in lieu of

containment balloon 42, especially in particularly small lumens where a small profile is desirable.

FIGs. 5A-5C illustrate an additional embodiment of the present invention incorporating a sleeve-shaped treatment
5 balloon 72. The sleeve-shaped balloon 72 comprises a hollow cylindrical balloon having an inner wall and an outer wall defining an interior cavity 70 therebetween. Sleeve-shaped balloon is preferably inelastic, and may be preferably made from PET, PVC, or other medical grade material suitable for
10 constructing a strong non-compliant balloon. Sleeve-shaped balloon 72 is sealed to catheter shaft 10 along a longitudinal line of contact between its interior surface and catheter shaft 10. The interior cavity 70 is in fluid communication with inflation lumen 74 via inflation lumen
15 ports 76 at points along the length of the area of contact between shaft 10 and sleeve shaped balloon 72. As with the inflation lumen 12 discussed in connection with other embodiments discussed herein, inflation lumen 74 is in fluid communication with fail-safe non-detachable receptacle 20
20 for receiving radioactive liquid 30.

FIGs. 6A-6C illustrate an additional embodiment of the present invention incorporating a sleeve-shaped balloon 82, comprising an inner and outer wall defining an interior chamber 80, similar to the embodiment of FIGs. 6A-6C. The
25 sleeve-shaped balloon of the present embodiment is suitable for positioning by means of a separate catheter, such as an angioplasty balloon catheter. Accordingly, shaft 10 with guidewire lumen 14 is eliminated in favor of a low profile

shaft 88 having inflation lumen 84 in fluid communication with interior chamber 80 via inflation ports 86 located along the longitudinal area of contact between shaft 88 and balloon 82.

5 Thus, the present invention provides a safe and effective IRT method and apparatus, which delivers an easily controllable inherently uniform dosage of radiation to the walls of a blood vessel, without the need for special measures to center a radiation source in the lumen, the need
10 for expensive shielding to protect medical personnel, or the need for expensive remote afterloaders to handle the higher activity sources.

 Although certain preferred embodiments and methods have been disclosed herein, it will be apparent from the
15 foregoing disclosure to those skilled in the art that variations and modifications of such embodiments and methods may be made without departing from the true spirit and scope of the invention. Accordingly, it is intended that the invention shall be limited only to the extent required by
20 the appended claims and the rules and principles of applicable law.

What is claimed is:

1 1. An apparatus for localized intravascular
2 radiotherapy of a blood vessel, such as a coronary artery,
3 comprising:
4 a catheter, said catheter comprising an elongate member
5 having a proximal and a distal end, said elongate member
6 being sized and of sufficient flexibility to be introducible
7 into a patient's body through a cardiovascular lumen until
8 the distal end is disposed at a target area within the blood
9 vessel, said elongate member further including a
10 longitudinal hole therethrough defining a treatment balloon
11 inflation lumen;
12 a treatment balloon, said treatment balloon comprising
13 an inflatable balloon having an interior chamber, said
14 treatment balloon being sealed to the distal end of said
15 elongate member with the interior chamber of said treatment
16 balloon in fluid communication with said treatment balloon
17 inflation lumen; and
18 means for introducing a fluid containing a radioactive
19 material into said treatment balloon inflation lumen to fill
20 the interior chamber of said treatment balloon for exposure
21 of said target area to said radioactive material for a
22 predetermined period of time.

1 2. The apparatus of claim 1 further including means
2 for detecting pressure in said treatment balloon inflation
3 lumen.

1 3. The apparatus of claim 1 further including means
2 for perfusion of blood past said treatment balloon when the
3 interior chamber of said treatment balloon is filled.

1 4. The apparatus of claim 1 further including a fluid
2 containing a radioactive material, said fluid being
3 introduced into said balloon by said introducing means for
4 exposure of said target area.

1 5. The apparatus of claim 4 wherein said fluid
2 containing a radioactive material comprises a fluid
3 containing a material chosen from the group consisting of
4 iodine and phosphorous.

1 6. The apparatus of claim 1 wherein said introducing
2 means comprises a shielded syringe.

1 7. The apparatus of claim 6 wherein said shielded
2 syringe is permanently attached to said catheter.

1 8. The apparatus of claim 7 wherein said shielded
2 syringe further includes a fail-safe non-detachable fluid
3 coupling and said catheter includes a corresponding fail-
4 safe non-detachable receptacle.

1 9. The apparatus of claim 1 wherein said introducing
2 means comprises a pump.

1 10. The apparatus of claim 9 wherein said pump is
2 permanently attached to said catheter.

1 11. The apparatus of claim 10 wherein said pump
2 further includes a fail-safe non-detachable fluid coupling
3 and said catheter includes a corresponding fail-safe non-
4 detachable receptacle.

1 12. The apparatus of claim 1 further including a
2 containment balloon, said containment balloon comprising an
3 inflatable balloon having an interior chamber, said
4 containment balloon being sealed to the distal end of said
5 elongate member with said interior chamber surrounding said
6 treatment balloon.

1 13. The apparatus of claim 12 wherein said elongate
2 member further includes a longitudinal hole therethrough
3 defining a containment balloon inflation lumen, the interior
4 chamber of said containment balloon being in fluid
5 communication with said containment balloon inflation lumen,
6 and further including means for introducing a contrast
7 medium into said containment balloon inflation lumen to fill
8 the interior chamber of said containment balloon for
9 verifying integrity of said containment balloon.

1 14. The apparatus of claim 13 further including means
2 for perfusion of blood past said containment balloon when
3 the interior chamber of said containment balloon is filled.

1 15. The apparatus of claim 1 further including a inert
2 expansion balloon said inert expansion balloon comprising an
3 expandable balloon having an interior chamber, said inert
4 expansion balloon being sealed to the distal end of said
5 elongate member and contained within the interior chamber of
6 said treatment balloon.

1 16. The apparatus of claim 15 wherein said elongate
2 member further includes a longitudinal hole therethrough
3 defining an inert expansion balloon inflation lumen, the
4 interior chamber of said inert expansion balloon being in
5 fluid communication with said inert expansion balloon
6 inflation lumen, and further including means for introducing
7 a liquid into said inert expansion balloon inflation lumen
8 to fill the interior chamber of said inert expansion balloon
9 for reducing the volume of fluid containing a radioactive
10 material used to fill the interior chamber of said treatment
11 balloon.

1 17. The apparatus of claim 1 further including a first
2 and second blocking balloon each having an interior chamber,
3 said first blocking balloon being sealed to the distal end
4 of said elongate member distal of said treatment balloon,
5 said second blocking balloon being sealed to the distal end

6 of said elongate member proximal of said treatment balloon;
7 and

8 wherein said elongate member further includes a
9 blocking balloon inflation lumen, said blocking balloon
10 inflation lumen comprising a longitudinal hole through said
11 elongate member, the interior chambers of said first and
12 second blocking balloons being in fluid communication with
13 said blocking balloon inflation lumen, and further including
14 means for introducing a liquid into said blocking balloon
15 inflation lumen to fill the interior chambers of said first
16 and second blocking balloons.

1 18. An apparatus for localized intravascular
2 radiotherapy of a blood vessel, such as a coronary artery,
3 comprising:

4 a catheter, said catheter comprising an elongate member
5 having a proximal and a distal end, said elongate member
6 being sized and of sufficient flexibility to be introducible
7 into a patient's body through a cardiovascular lumen until
8 the distal end is disposed at a target area within the blood
9 vessel, said elongate member further including a
10 longitudinal hole therethrough defining a treatment balloon
11 inflation lumen;

12 a sleeve-shaped balloon, said sleeve-shaped balloon
13 comprising an expandable, substantially cylindrical hollow
14 sleeve having an inner wall and an outer wall defining a
15 chamber therebetween, said sleeve-shaped balloon being
16 attached to the distal end of said elongate member with the

17 chamber in fluid communication with said treatment balloon
18 inflation lumen;

19 means for expanding said sleeve against an interior
20 wall of said blood vessel; and

21 means for introducing a fluid containing a radioactive
22 material into said inflation lumen to fill the chamber of
23 said sleeve for exposure of said target area to said
24 radioactive material for a predetermined period of time.

1 19. A method of preventing stenosis and restenosis of
2 a selected portion of a blood vessel in a patient
3 comprising:

4 selecting a catheter comprising an elongate member
5 having a proximal and a distal end, and including a
6 treatment balloon, said treatment balloon comprising an
7 inflatable balloon attached to the distal end of said
8 catheter, said catheter being sized and of sufficient
9 flexibility for introduction into the selected portion of
10 the blood vessel;

11 advancing the catheter along a cardiovascular
12 lumen of the patient until said treatment balloon is
13 disposed in the selected portion of the blood vessel;

14 inflating said treatment balloon with a liquid
15 containing radioactive material;

16 maintaining said treatment balloon inflated with
17 said liquid for a predetermined period of time;

18 withdrawing the liquid from said treatment balloon
19 to allow said treatment balloon to collapse; and

20 withdrawing said catheter from the patient.

1 20. The method of claim 19 further including relieving
2 a stenosed region of the selected portion of the blood
3 vessel by inflating said treatment balloon with said
4 radioactive liquid to force said balloon against the walls
5 of said selected portion to expand said stenosed region
6 radially outward.

1 21. The method of claim 19 wherein said catheter
2 further includes a containment balloon disposed about said
3 treatment balloon and further including:

4 inflating said containment balloon with a radio-
5 opaque contrast medium to verify integrity of said
6 containment balloon prior to inflating said treatment
7 balloon.

1 22. The method of claim 21 further including relieving
2 a stenosed region of the selected portion of the blood
3 vessel by inflating said containment balloon with liquid to
4 expand said containment balloon against the walls of said
5 selected portion to expand said stenosed region radially
6 outward.

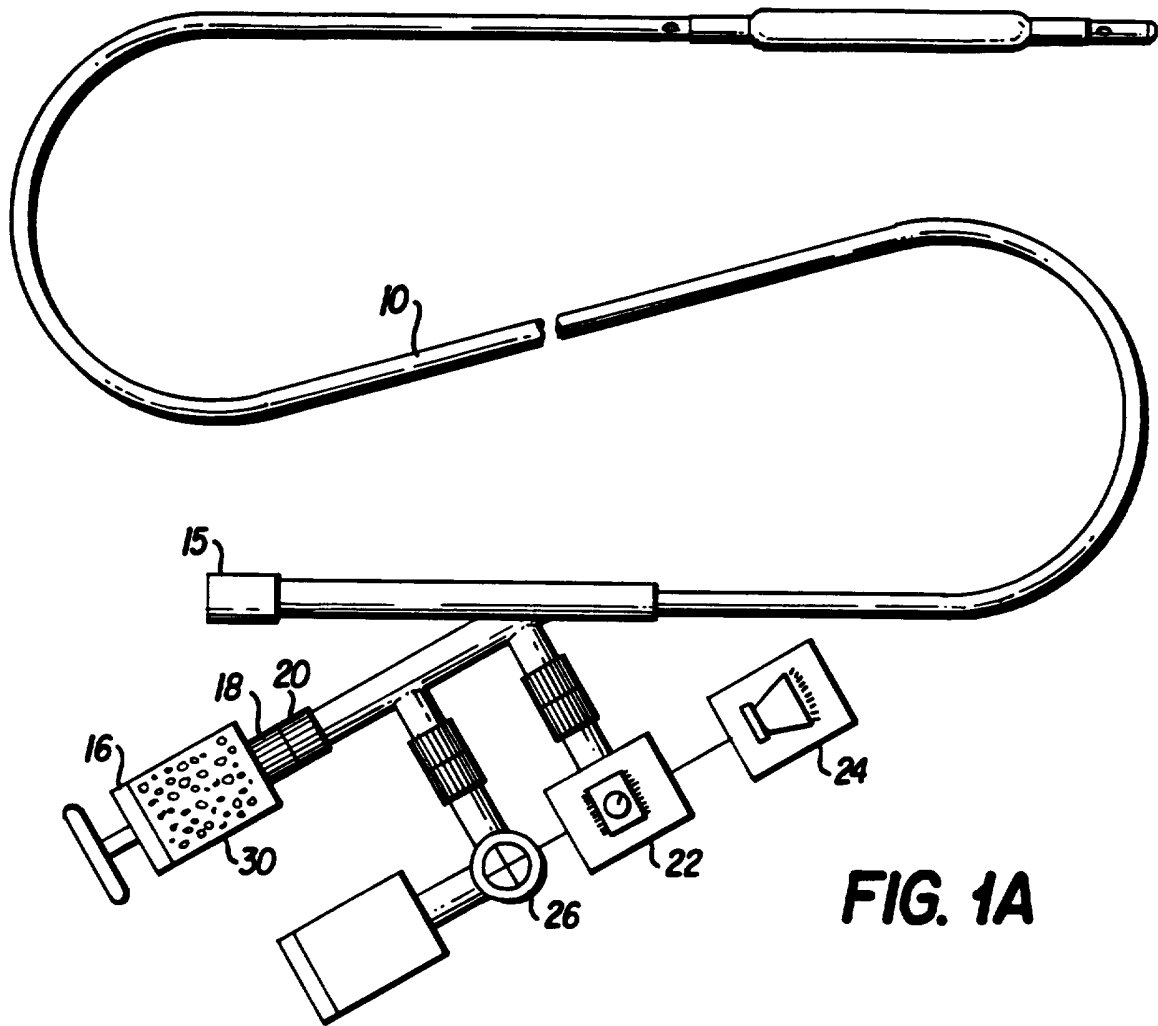


FIG. 1B

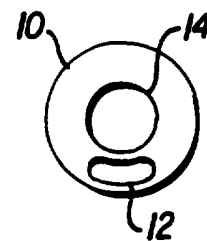
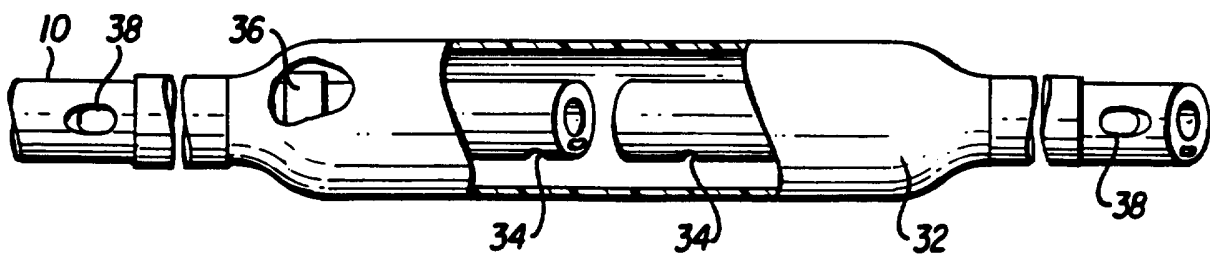


FIG. 1C



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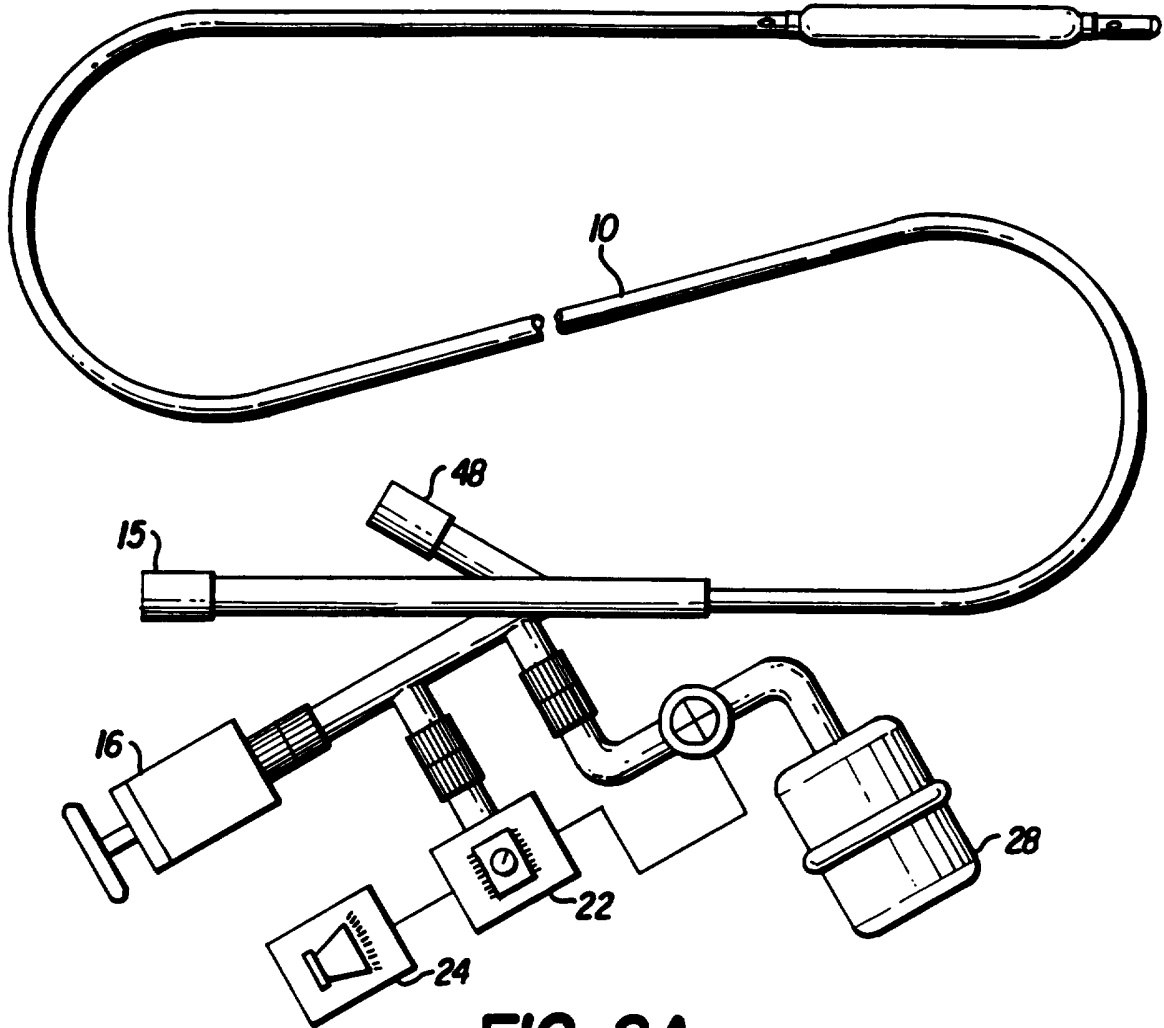


FIG. 2A

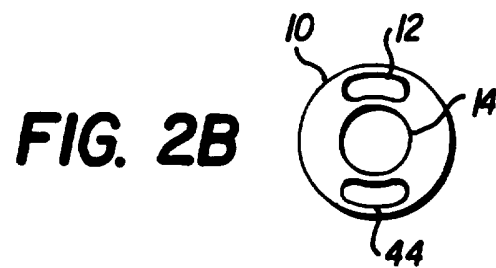


FIG. 2B

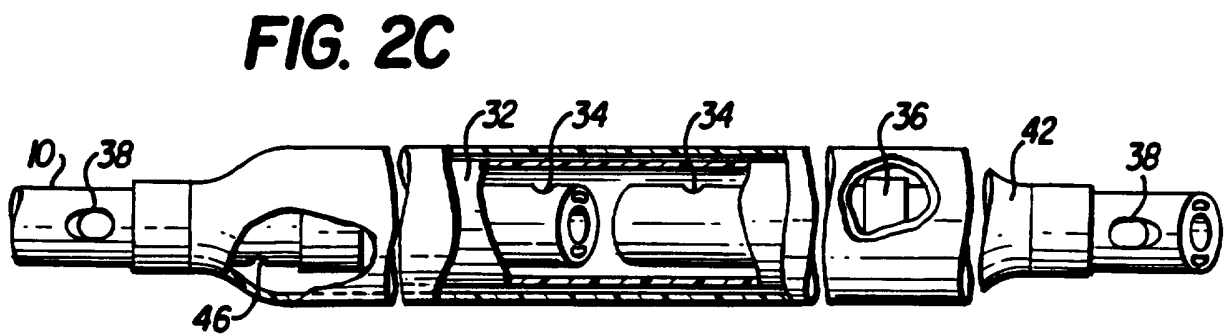


FIG. 2C

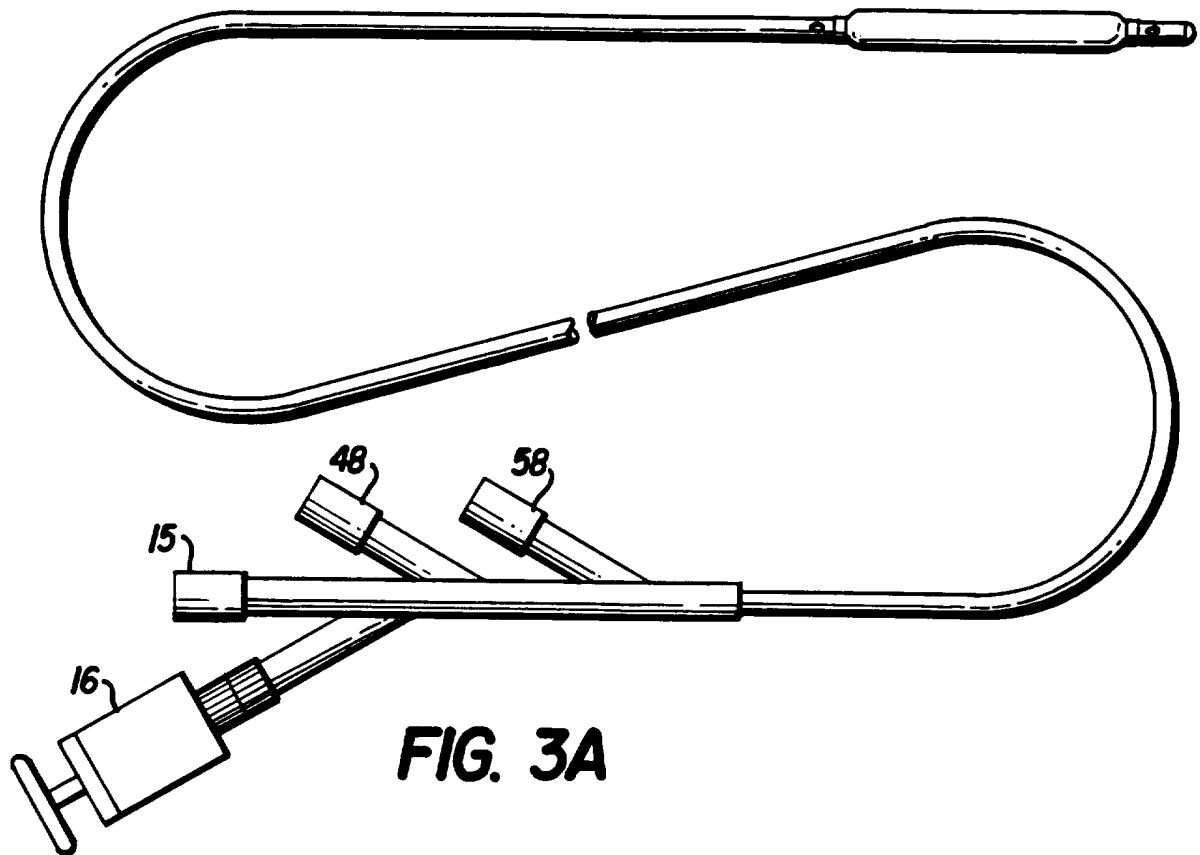


FIG. 3A

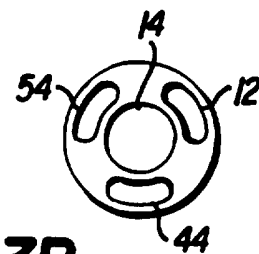
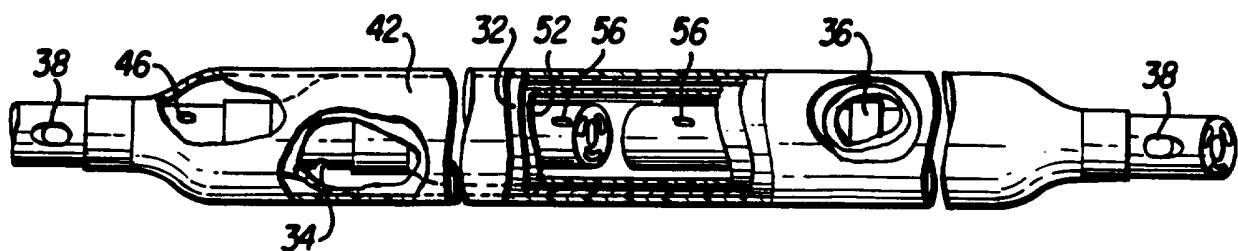
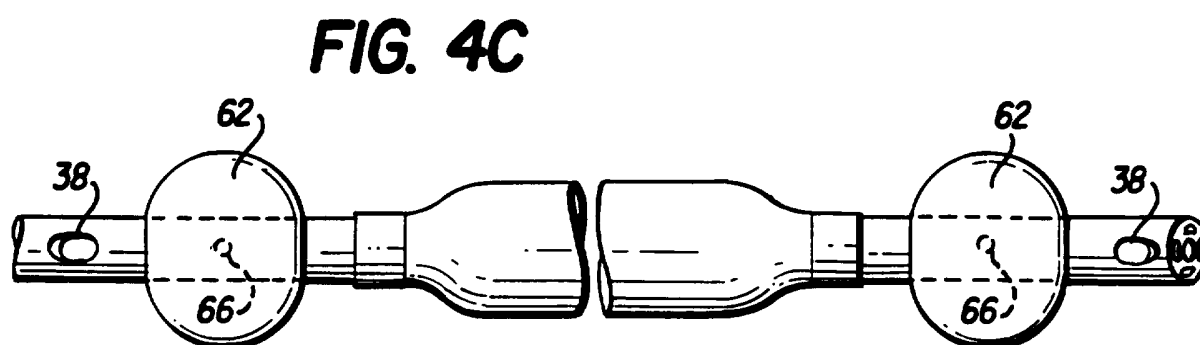
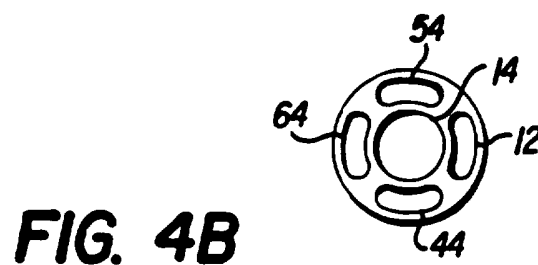
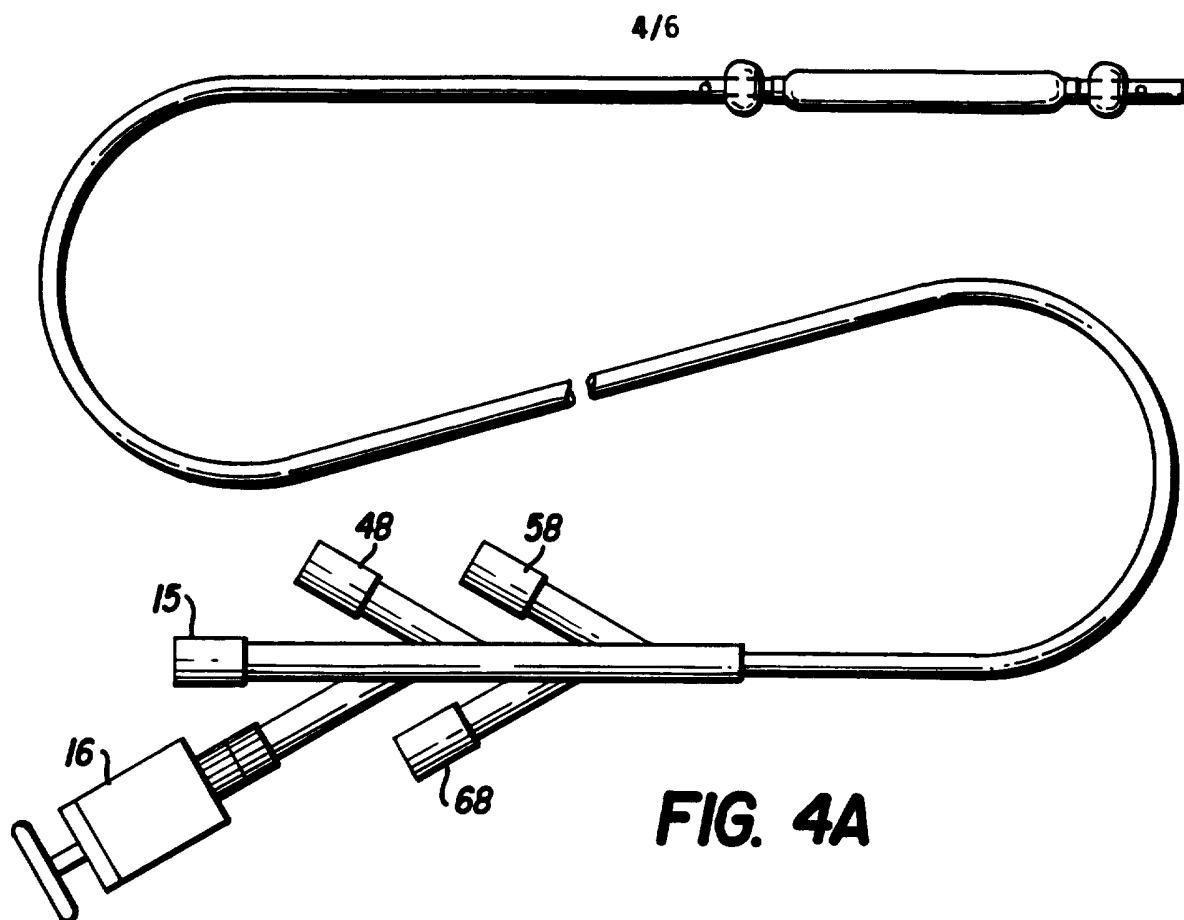


FIG. 3B

FIG. 3C





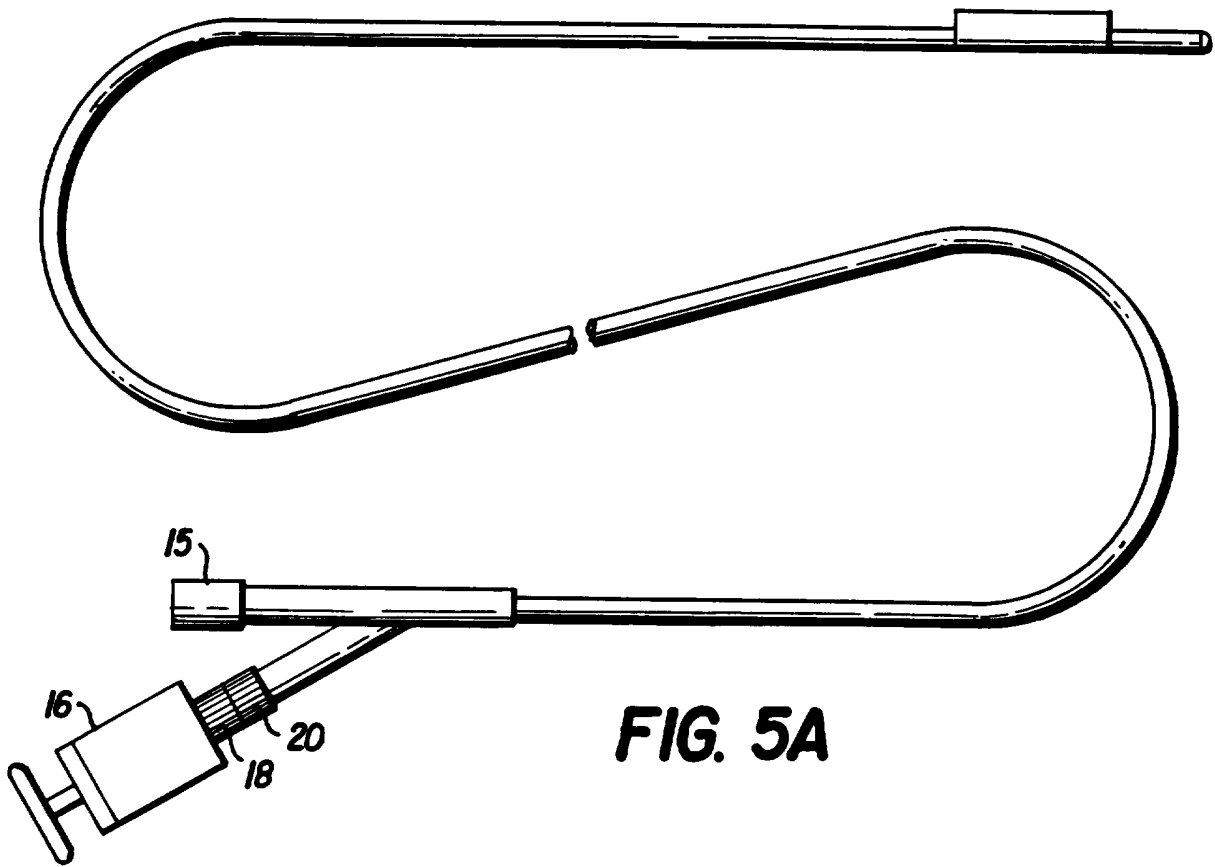


FIG. 5A

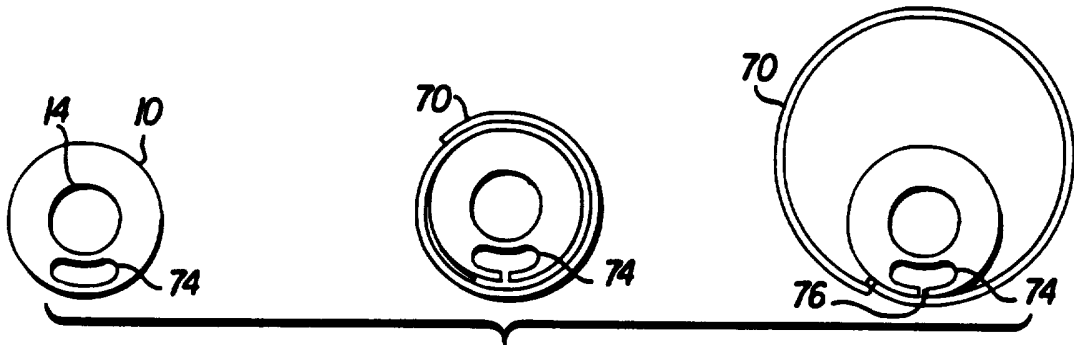


FIG. 5B

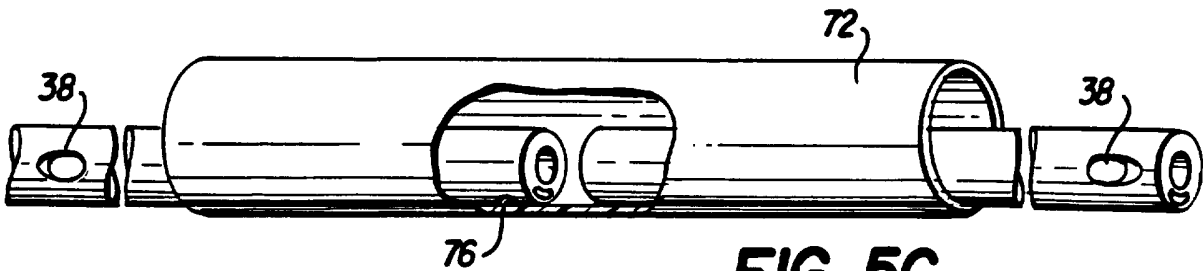


FIG. 5C

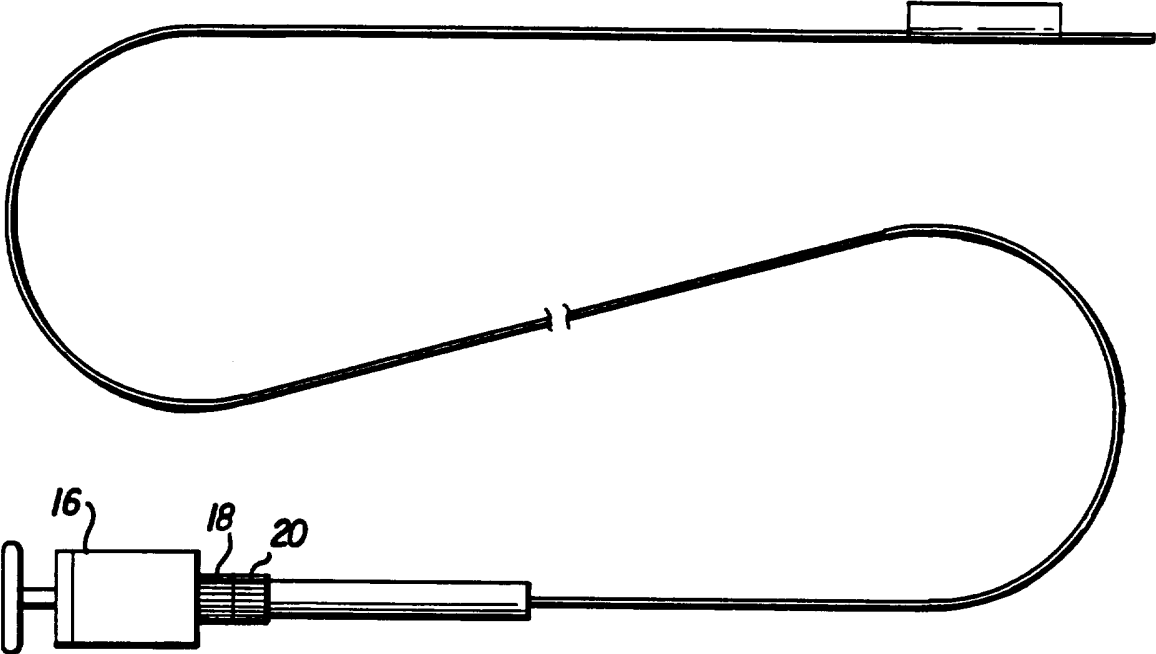


FIG. 6A

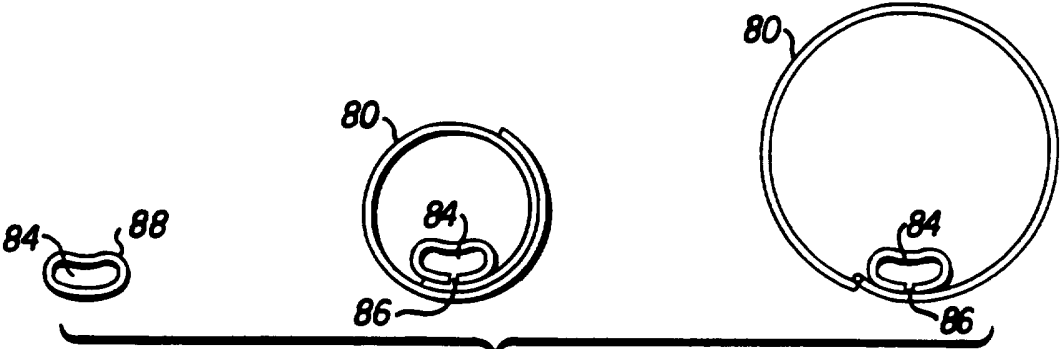


FIG. 6B

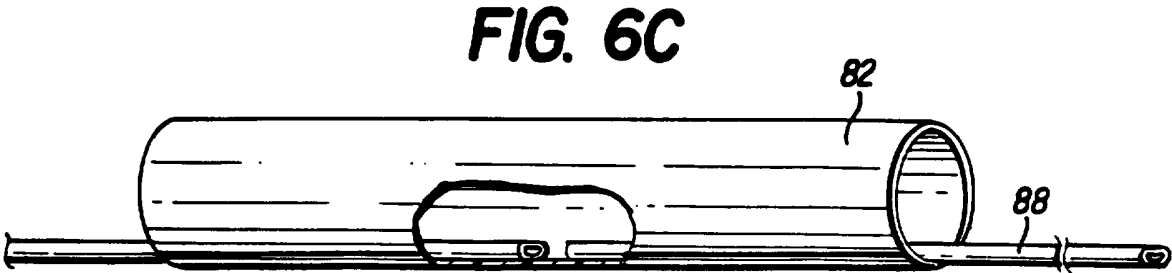


FIG. 6C

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US95/15228

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :A61N 5/00

US CL :600/003

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 128/772; 600/001-008; 604/096-101; 606/007,108,191,194, 195

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US, A, 3,324,847 (E. G. ZOUMBOULIS) 13 June 1967 see entire document.	1, 4, 5, 18 ----- 3, 6-11, 19, 20
Y	US, A, 4,364,376 (BIGHAM) 21 December 1982, see entire document.	6, 9
Y	WO, A, 93/04735 (HESS) 18 March 1993, see entire document.	19, 20



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
A document defining the general state of the art which is not considered to be part of particular relevance	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
E earlier document published on or after the international filing date	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*G* document member of the same patent family
O document referring to an oral disclosure, use, exhibition or other means	
P document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

21 JANUARY 1996

Date of mailing of the international search report

04 MAR 1996

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