CATHETER FOR USE IN DETECTING DISSOLVED GAS IN FLUIDS SUCH AS BLOOD

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Filed: Aug. 28, 1969

Appl. No.: 853,784

U.S. Cl. 128/2 G, 128/2 L

Int. Cl. A61b 05/00

Field of Search 128/2, 2.05, 2.1, 344, 348; 73/23

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ABSTRACT

A blood catheter including a cannula covered with a thin layer of silicone rubber or other material permeable to one or more of the gases that are or might be found in blood and wherein the cannula preferably includes a helical arrangement of apertures for enabling the diffusion of gas through the membrane and into the center portion of the cannula. The helical pattern of apertures around the periphery of the cannula enables the catheter to contact the interior wall of a blood vessel without restricting blood flow past more than a small fraction of the total number of apertures. Other hole configurations can be used, for example, when a plurality of holes are located at spaced axial locations along the cannula and at spaced intervals around the circumference of the cannula at the various axial locations.

11 Claims, 4 Drawing Figures
CATHETER FOR USE IN DETECTING DISSOLVED GAS IN FLUIDS SUCH AS BLOOD

The present invention relates to a catheter and more particularly to a blood catheter which may be used in enabling the determination of the amount and type of dissolved gas in blood.

Those concerned with the development of blood catheters have long been faced with the problem of providing a catheter which enables the sampling of dissolved gas in the blood stream with minimal error due to local depletion of the gas by diffusion into the catheter and for providing a catheter which minimizes the effect of contact of the permeable area thereof with the wall of the blood vessel while not significantly increasing the time-constant for the response of the membrane-cannula system.

Accordingly, the general purpose of this invention is to provide a catheter which embraces all the advantages of similarly employed catheters and possesses none of the aforedescribed disadvantages. To attain this, the present invention contemplates a unique cannula structure wherein the cannula includes a plurality of apertures arranged sequentially in a generally helical pattern around the cannula and wherein the cannula is covered by a gas-permeable membrane to enable the diffusion of gas through the membrane and into the cannula via the apertures therein.

An object of the present invention is the provision of a catheter which permits sampling of dissolved gas in the blood stream by diffusion into the cannula of the catheter with minimal error due to local depletion of the gas.

Another object is to provide a blood catheter which minimizes the effect of contact of the permeable area of the cannula with the wall of the blood vessel while not significantly increasing the time-constant for the response of the membrane-cannula system.

Other objects and features of the invention will become apparent to those of ordinary skill in the art as the disclosure is made in the following description of a preferred embodiment of the invention as illustrated in the accompanying sheet of drawing in which:

FIG. 1 is a perspective view of a preferred embodiment of the invention;

FIG. 2 is an enlarged fragmentary sectional view of the catheter of this invention;

FIG. 3 is a section of the catheter taken on the line 3—3 of FIG. 2 looking in the direction of the arrows; and

FIG. 4 is a perspective view of another embodiment of the invention.

With reference now to the drawings, wherein like reference characters designate like or corresponding parts throughout the several views, there is shown in FIGS. 1-3 a catheter 10 embodying in continuous and unitary structural relationship a tube member 14 and a cannula 16, both of which may be comprised of stainless steel or appropriate plastic material, for example. The cannula 16 has a plurality of apertures 18 therein preferably arranged sequentially in a generally helical pattern around the cannula. The apertures are preferably but not necessarily spaced at 120° around the cannula. The catheter also includes a gas-permeable membrane 20 of silicone rubber or other material, Teflon, permeable to one or more of the gases that are to be diffused into the catheter. The membrane 20 is fitted over the end of the cannula 16 and extends the entire length of the catheter over the tube 14. The silastic membrane can be affixed to the tubular structure of the tube 14 and cannula 16 by solvent expansion and evaporation for example. This is easily accomplished by first soaking the silastic material in a solvent such as diethyl ether, placing the wetted membrane over the tubular structure and then permitting the solvent to evaporate so that the membrane shrinks and tightly embraces the tubular structure. The event materials such as Teflon are used for the membrane, the membrane can be affixed to the tubular structure by heat shrinkage.

In the event that throw-away catheter types are to be used, an alternative arrangement may be utilized (as shown in FIG. 4) wherein the cannula 16 is coupled in a conventional manner by fitting 12 to tube member 14 and then the membrane is fitted over the cannula and a ligature 22 of surgical silk, for example, is used to make a leak proof seal at the end of the cannula adjacent to the tube at fitting 12. In view of the above, the term "cannula" as used herein refers to the end portion of the tubular structure of the catheter, excluding the membrane, within which the apertures are formed.

The arrangement of the apertures 18 in a generally helical pattern around the periphery of the cannula 16 permits sampling of the dissolved gas in the fluid or blood passing over the catheter by diffusion thereof into the cannula and with minimal error due to local depletion of the gas since the gas is diffused over the surface layer of the fluid which is partially depleted of gas in passage over one aperture will have its gas content substantially restored to that of the bulk fluid or blood passing by the catheter either by turbulent mixing or by diffusion of gas from the bulk fluid during passage from one aperture to the next.

In addition, the arrangement of apertures in a generally helical pattern minimizes the effect of blockage of certain of the apertures by the wall of the blood vessel. For example, since the apertures are located around the entire periphery of the cannula with only a small number of apertures being located in linear alignment along the length thereof the amount of gas which is diffused through the permeable membrane is not significantly reduced when the membrane is placed into contact with the vessel wall. Furthermore, as a result of this configuration the time-constant for response of the membrane-cannula system is not significantly increased so that substantially the same amount of gas is diffused through the membrane and into the cannula over a predetermined time period when the catheter is in contact with the wall of a blood vessel as is diffused through the membrane when the catheter is not in contact with the blood vessel wall for the same time period.

Alternative geometric configurations of apertures are also possible although not as efficient as the helical pattern. For example, the apertures can be spaced circumferentially around the catheter with groups of these circumferentially spaced apertures being located at spaced axial locations along the catheter as shown in FIG. 4.

In designing the catheter of this invention the dimensions of the various portions thereof are important to the successful operation of the catheter in the manner desired. For example, the apertures 18 must be sufficiently small in dimension in the direction of blood flow so that the surface layers of blood flowing over the permeable membrane 20 will not be excessively depleted in gas content during time of passage over one aperture. In addition, the apertures must be sufficiently well separated along the length of the cannula in the direction of blood flow so that the surface layer of blood which has been partially depleted of gas in passage over one aperture will have its gas content substantially restored to that of the bulk blood either by turbulent mixing or by diffusion of gas from the bulk fluid during passage from one aperture to the next. Furthermore, the total number of apertures must be adequate to give the gas flow required by the detecting instrument, e.g., a mass spectrometer. The choice of the size of the apertures and of the spacing between the apertures is also influenced by the ease of manufacture and resultant strength of the apertured cannula.

The catheter of this invention preferably utilizes apertures having dimensions along the direction of flow of the fluid in the range of from 0.006 inch to 0.012 inch in being preferably preferable dimension since they can be easily cut with coping saws. The depth of the apertures are preferably approximately one-third of the outside diameter of the cannula 16 so as to give adequate opening into the center space of the cannula consistent with minimum weakening thereof. The apertures 18 are also preferably spaced a distance apart from one another such that the ratio of the distance between apertures to the linear dimension of each of the apertures is five to one-
3 Accordingly, with an aperture linear dimension of 0.008 inch the apertures are typically spaced 0.040 inch apart with the apertures preferably being arranged sequentially at 120° around the cannula. The number of apertures used may vary considerably with the number preferably in the range of from six to 24 but generally 14 apertures are utilized in the blood catheter. The gas-permeable membrane 20 is typically a medical grade silastic tubing having a thickness in the range of from 0.0085 inch to 0.0105 inch.

The catheter of this invention thus provides for a unique arrangement of apertures in a cannula whereby the apertures are helically arranged around the cannula to permit sampling of the dissolved gas in a fluid with minimal error due to local depletion of the gas by diffusion into the cannula. The catheter also minimizes the effect of contact of the catheter with the wall of a blood vessel, for example, while not significantly increasing the time-constant for the response of the membrane-cannula system due to the helical arrangement of the apertures in the cannula since the blood flow is restricted only past a small fraction of the total number of apertures. Furthermore, this invention provides for important dimensional relationships between the apertures, the spacings therebetween and the gas-permeable membrane wherein the linear dimension of the apertures in the direction of fluid flow is sufficiently small such that the surface layers of fluid flowing over the permeable membrane covering the apertures will not be excessively depleted of gas content during time of passage over one aperture. The apertures are also sufficiently well separated along the length of the cannula in the direction of fluid flow so that the surface layer of fluid partially depleted of gas in passage over one aperture will have its gas content essentially restored either by turbulent mixing or by diffusion of gas from the bulk flow of fluid during passage from one aperture to the next aperture.

Obviously many modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:
1. A catheter operable with a detecting instrument to provide a continuous in vivo measurement of blood gases by mass spectrometry or the like comprising an elongated tubular structure having a blood vessel entering portion terminating in a distal end, said portion including an inner cannula and an outer membrane extending thereover throughout the longitudinal extent thereof, said cannula and membrane being operable to be inserted and maintained in a blood vessel in an operative position wherein the longitudinal extent thereof is generally aligned with the longitudinal extent of the blood vessel, the transverse size and longitudinal extent of said cannula and membrane being such that when disposed in said operative position blood will flow through the longitudinal coextensive portion of the vessel with a surface layer of substantial longitudinal extent in contact with the exterior surface of said membrane defining a longitudinally elongated exterior periphery and a substantially longitudinally coextensive interior gas passage adapted to be communicated with a means on the detecting instrument for inducing a gas flow in a direction away from said gas passage and toward the detecting instrument, said membrane being in intimate contact with said exterior periphery and being formed of a material impervious to blood but pervious to the blood gases to be continuously measured, said cannula including a material substantially impervious to the blood gases to be continuously measured disposed between said exterior periphery and said gas passage throughout the longitudinal extent thereof, said cannula having apertures extending from said exterior periphery into communication with said interior gas passage in spaced relation throughout substantially the entire longitudinal extent thereof defining with the portions of said membrane extending thereover a plurality of spaced discrete blood impervious gas diffusion paths extending transversely from the exterior of said membrane to said gas passage, said gas diffusion paths having a total area providing for a continuous flow of blood gases to the detecting instrument adequate to insure continuous measurement thereof, each aperture being sufficiently small in longitudinal dimension so that the blood in said surface layer flowing over the gas diffusion path associated therewith will not be excessively depleted of gas content during the time of passage thereby, the spacing between apertures in the direction of blood flow being such that blood which has been partially depleted of gas content by passing over one gas diffusion path will have its gas content substantially restored to that of the bulk blood by turbulent mixing and/or by diffusion of gas from the bulk flow before passing over another gas diffusion path.

2. A catheter as defined in claim 1 wherein said apertures are spaced with respect to each other both longitudinally and circumferentially about said exterior periphery of said cannula and are provided in a sufficient number to enable substantially the same amount of gas to pass through the sum of all of the gas diffusion paths per unit time irrespective of the blockage of certain of said gas diffusion paths resulting from local contact of the exterior periphery of said membrane with the blood vessel walls when said cannula and said membrane are disposed in said operative position therein.

3. A catheter as defined in claim 2 wherein the ratio of the longitudinal spacing between apertures aligned longitudinally to the longitudinal dimension of each aperture is substantially one to one.

4. A catheter as defined in claim 3 wherein the longitudinal dimension of each of said apertures is in the range of from 0.006 inch to 0.012 inch.

5. A catheter as defined in claim 4 wherein the longitudinal dimension of each of said apertures is approximately 0.008 inch.

6. A catheter as defined in claim 2 wherein said elongated tubular structure comprises a unitary cylindrical tube of metal having a closed distal end formed in the portion thereof defining said cannula.

7. A catheter as defined in claim 6 wherein said apertures are formed by a coping saw to a depth substantially one-third the outside diameter of said cannula to provide adequate opening into said gas passage consistent with minimum structural weakening of said cannula.

8. A catheter as defined in claim 7 wherein said apertures are arranged sequentially in a generally helical pattern throughout the exterior periphery of said cannula, adjacent apertures being angularly spaced with respect to each other approximately 120° and longitudinally spaced from one another a distance generally five times the longitudinal dimension of each aperture.

9. A catheter as defined in claim 8 wherein the longitudinal dimension of each of said apertures is approximately 0.008 inch and the number of apertures is approximately 14.

10. A catheter as defined in claim 9 wherein said membrane extends throughout the longitudinal extent of said cylindrical tube.

11. A catheter as defined in claim 10 wherein said cylindrical tube is formed of stainless steel and said membrane is comprised of silicone rubber.

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