United States Patent

Jackson

[15] **3,707,151**

[45] **Dec. 26, 1972**

[54] **SELF-INFLATING ENDOTRACHEAL TUBE**

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[21] Appl. No.: **115,249**

Related U.S. Application Data

[63] Continuation-in-part of Ser. Nos. 427,601, Jan. 25, 1965, abandoned, and Ser. No. 719,994, April 9, 1968, Pat. No. 3,565,079.

[52] **U.S. Cl.** .... **128/351,** 128/349 B
[51] **Int. Cl.** **A61m 25/00**
[58] **Field of Search** ..128/351, 348, 349 B, 350, 246, 128/325, 344

[56] **References Cited**

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Primary Examiner—Dalton L. Truluck
Attorney—John Noel Williams

[57] **ABSTRACT**

Endotracheal tubes with cuffs that self-inflate during inspiration and remain inflated during expiration, in which the Coanda effect is employed to lead air into the cuff for inflation. Shown is a tube having an opening through its wall into the cuff volume with a surface arranged to lead air into the cuff during inspiration, and a check valve to prevent outward flow of air. Also shown is a cuff having openings arranged to lead air into the cuff during expiration. The cuffs shown are substantially larger than the trachea and are of thin film material.

2 Claims, 8 Drawing Figures

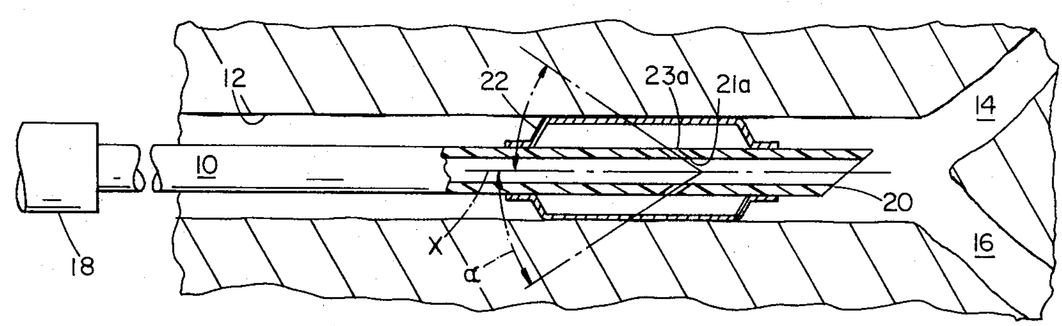
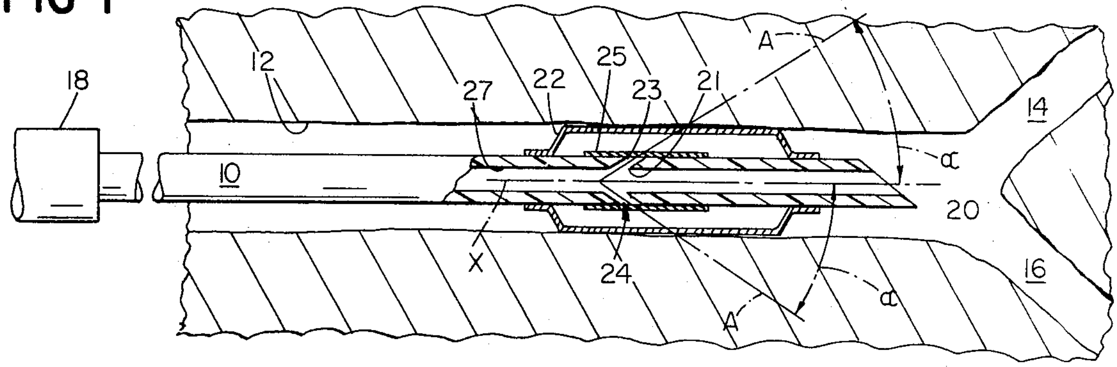


FIG I



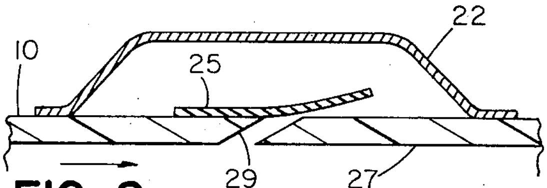


FIG 2

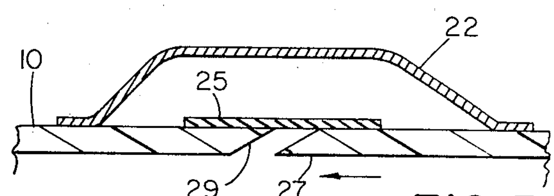
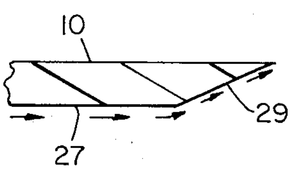


FIG 3

FIG 4



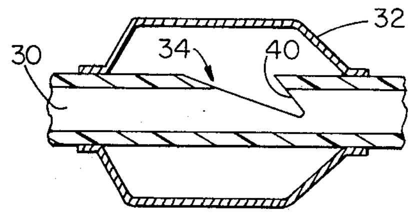


FIG 8

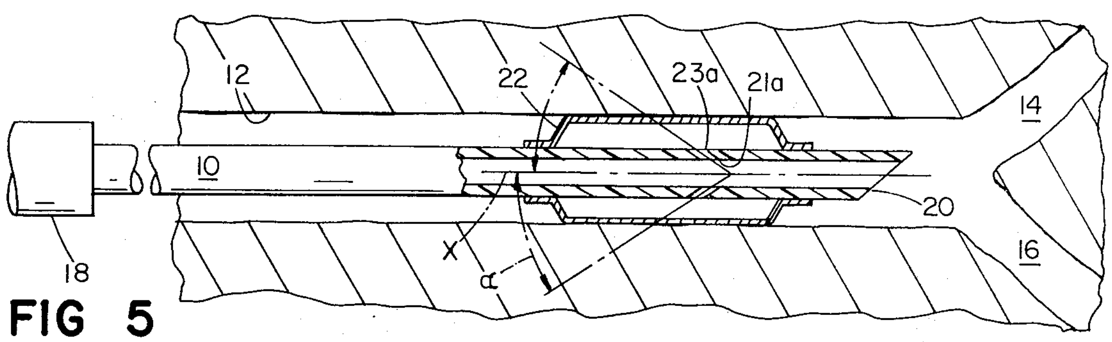


FIG 5

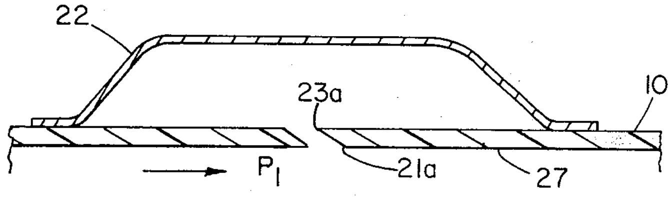


FIG 6

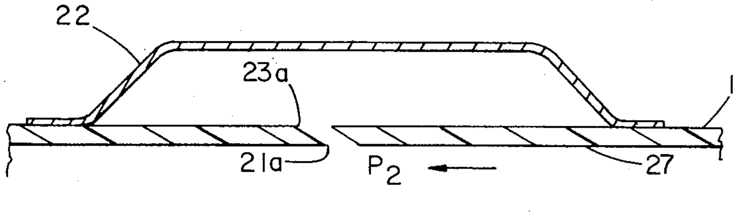


FIG 7

SELF-INFLATING ENDOTRACHEAL TUBE

This application is a continuation-in-part of my application of the same title, Ser. No. 427,601, filed Jan. 25, 1965, now abandoned, and of my application of the same title, Ser. No. 719,994, filed Apr. 9, 1968 now U.S. Pat. No. 3,565,079.

The present invention relates generally to medical and surgical equipment and is more particularly concerned with the provision of means for maintaining normal breathing of the patient during surgical operations and the like.

A primary object of the instant invention is the provision of a novel and improved endotracheal tube.

An important object of the instant invention is the provision of an endotracheal tube having a self-inflating cuff.

Another object of this invention is the provision of an endotracheal tube having a self-inflating cuff that automatically inflates during inspiration through the tube and which remains inflated during expiration therethrough.

Another object is the provision of an endotracheal tube having a self-inflating cuff that makes a good seal with the wall of the trachea but which nevertheless minimizes the likelihood of trauma at the area of the trachea wall where the seal is made.

A further object of the instant invention is the provision of a self-inflating endotracheal tube having novel and improved structural means for automatically causing inflation of the inflatable cuff during inspiration of the patient and for maintaining the cuff inflated during expiration.

Another object is the provision of an endotracheal tube of the character described that is relatively simple and inexpensive to manufacture and which therefore may be disposable after use.

According to the invention it is realized that the Coanda effect, by which a laminar flow stream of air tends to hug and follow the direction of a surface, may be employed advantageously to guide air into the cuff for inflation purposes.

According to other aspects of the invention the Coanda surfaces comprise walls defining openings, with the axes of the openings forming acute angles with the axis of the tube. According to one feature the entrances of these openings to the bore of the tube are spaced distally from the outlet of the openings into the volume of the cuff. According to another feature the entrances of these openings are spaced proximally of the outlets into the volume of the cuff and a check valve lying over this outlet is arranged to prevent backflow of air from the cuff back through the opening.

Preferred embodiments of the invention feature generally tubular cuffs having diameter substantially larger than that of the trachea in which the tube is adapted to be inserted, and feature cuffs formed of thin film material.

Other objects, features and advantages of the invention will become apparent as the description thereof proceeds when considered in connection with the accompanying illustrative drawings.

Although the instant invention is illustrated and described in connection with an endotracheal tube, it will be understood that forms of the invention function also in connection with tracheotomy tubes used as an

artificial airway in the neck to create a direct passage for air to enter the trachea without passing through the mouth. Thus, it will be understood that all reference in the specification and claims herein to endotracheal tubes, applies equally to tracheotomy tubes, and hence, for the purpose of this application, the term endotracheal tube is construed broadly as covering tracheotomy tubes as well.

In the drawings which illustrate the best mode presently contemplated for carrying out the instant invention:

FIG. 1 is a fragmentary elevational view, partly in section, showing an endotracheal tube embodying the instant invention in operation position within the trachea of a patient;

FIG. 2 is a view of a large scale of a portion of the tube of FIG. 1 during inspiration and FIG. 3 is a similar view during expiration;

FIG. 4 is a diagrammatic view illustrating the Coanda effect;

FIG. 5 is a fragmentary elevational view, partly in section, of a further endotracheal tube;

FIGS. 6 and 7 are views similar to FIGS. 2 and 3 respectively but related to the embodiment of FIG. 5;

FIG. 8 is a view similar to FIG. 2 of another embodiment.

Referring now to FIG. 1, there is shown an endotracheal tube **10** in operative position in the trachea **12** of a patient, having passages **14** and **16** leading to the left and right lungs of the patient. The tube **10** is of conventional construction in that it comprises a hollow open-ended tube of any flexible non-toxic material, such as certain well known types of plastic that are used for this purpose. The tube **10** has a proximal end **18** and a distal end **20**, the latter terminating in a beveled form, as is well known and conventional in the art.

Secured to the tube **10** adjacent its distal end **20** is an inflatable cuff or balloon **22**, said cuff being generally tubular in configuration and being constructed of any suitable flexible film material, such as extremely thin latex, e.g., of less than 0.002 inch thickness. The cuff **22** is secured to the tube **10** by any suitable means, so as to tightly bind the cuff to the tube in air-tight relation with respect thereto. In the form of my invention illustrated in FIGS. **1**, **2** and **3**, it is important to note that there is communication between the interior of tube **10** and the interior of cuff **22**. Expressed differently, the wall of the tube **10** is perforate. It is also important to note that the length of the cuff is preferably short relative to the overall length of the tube within the trachea. Furthermore, the diameter of the cuff **22** is substantially larger than the diameter of the trachea **12**, e.g. of 1½ inch diameter in comparison to a trachea of ¾ inch diameter, and even though this may result in some folding of the cuff **22** on itself when inflated, this is not detrimental in any way, since the extreme thinness of the material of which cuff **22** is constructed enables the cuff to easily fold upon itself, even at low pressures, while at the same time maintaining a good air-tight seal with the surrounding trachea.

The openings **24** into the cuff, of which there are four in this embodiment, have axes A set at acute angles α e.g., of 35° to the axis X of the bore of the tube, and the entrance **21** at the bore is spaced substantially proximally from the outlet **23** into the cuff **22**.

These openings may comprise drilled holes of 3/32 inch diameter.

Over the outlet **23** is a check valve **25**, here in the form of a loose-fitting latex sleeve secured air-tight about the tube at the left end and free to open up at the right end to allow air into the tube and free to close down and seal to prevent loss of air from the cuff.

In operation and use, the endotracheal tube **10** is inserted into the trachea in the usual manner, using sterile lubricant to facilitate introduction. The fact that the cuff **22** is not inflated during introduction of the tube **10** further facilitates its insertion into the trachea. Once the tube **10** has been positioned in the patient's trachea, the air flow produced when respiration is being assisted by the anesthesiologist, will automatically cause inflation of the cuff **22**, and it will stay inflated. Expressed differently, the flow of air toward the lungs tends to lie close and follow the tube inner wall **27**. The slope of the wall **29** defining the opening is in effect a continuation of wall **27** and the air tends to follow wall **29** see FIG. **4**, and enter the cuff see FIG. **2** where it is trapped. As a result of the preferred character of the cuff, i.e., its high flexibility, its oversize shape relative to the trachea, and its short length, the air creates an effective seal between the cuff and the surrounding wall of the trachea. The effectiveness of this seal is further enhanced by the adhesion of the thin latex cuff **22** to the surrounding portion of the trachea, this adhesion being caused by mucous normally present on the wall of the trachea.

Thus it will be seen that the cuff **22** automatically inflates immediately and effectively as soon as assisted or controlled respirations are initiated to the patient. The cuff remains inflated during expiration through tube **10** as a result of the air trapped in the cuff by the check valve. Passage of air into and out of the patient's lungs may therefore by effectively controlled during surgical procedures. The extreme thinness of the cuff **22** minimizes the likelihood of trauma at the portion of the trachea at which the seal is made. Furthermore, the self-inflating characteristics of the endotracheal tube prevent over-or under-inflation of the cuff.

The endotracheal tube may be withdrawn while still inflated. The "squashy" or pliable character of the cuff permitting it to pass softly past the vocal chords without damage to the chords.

Referring to FIG. **5** in this embodiment the entrance **21***a* to the opening is distal of the outlet **23***a* into the cuff, the opening again lying at acute angle α to the axis X of the bore of the tube.

On inspiration, Coanda effect does not work in this embodiment. But during inspiration the force of the respirator or other pressure source is at work inflating the lungs. Hence a positive pressure P_1 exists in the tube while near-atmospheric pressure exists between the tube and the trachea. The result is inflation of the cuff. Air flows into the cuff and seals the cuff against the tracheal wall as a result of pressure differential despite the fact that the air has reversed its flow path.

On expiration things are different. Here the Coanda effect acts to guide air in, using the somewhat less forceful flow of air to advantage.

It will be understood that during lulls—i.e., while there is neither expiration or inspiration, air may flow out of the cuff, but no matter since there is no flow at that time to keep captured.

Referring now to FIG. **8**, a slightly modified form of the present invention is illustrated. In this form, a tube **30**, generally similar to the aforedescribed tube **10**, has secured thereto a cuff **32** which is generally similar to the aforedescribed cuff **22**. In this construction, too, the cuff is imperforate, while the tube **30** is provided with an opening **34**, said opening providing communication between cuff **32** and the interior of tube **30**. The opening **34** is in the form of a notch or cutout which extends angularly toward the distal end **36** of the tube and which is sufficiently deep so as to extend substantially diametrically across the tube **30**. The cutout **34** inclines back toward the proximal end **38** of the tube to a slight degree, as illustrated at **40**.

In operation and use, the tube **30** is inserted into the trachea of the patient in the usual manner. Firm pressure on the breathing bag immediately causes inflation of cuff **32** since the opening **34** permits passage of air from the tube into the cuff during the inspiratory phase of assisted or controlled respirations. The specific configuration of the opening **34**, as hereinbefore described, enables the opening to perform as an air guide, which maintains inflation of the cuff during expiration. Expressed differently, the air guide **34** directs air into the cuff **32** during expiration, thus maintaining the cuff inflated during this phase. Here again, although the pressure differential is slight, the preferred shape and character of the cuff enables its proximal end to distend. If the patient is allowed to breathe spontaneously, an occasional assisted respiration may be necessary in order to keep the cuff inflated. It has been found that the cuff **32** provides an extremely effective seal during inspiration, but is not quite as effective during expiration, although still effective enough to provide a satisfactory seal. The seal formed by cuff **32**, as is true also in connection with the seal formed by the aforedescribed cuff **22**, is not normally sufficiently effective to prevent the passage of secretions and blood through the trachea, although, as hereinbefore stated, these seals are sufficiently effective to enable good respiratory control to be achieved.

As will be seen, all forms of the present invention provide for automatic inflation of the cuff during the inspiratory phase of the respiration cycle, and at the same time, the cuff is maintained sufficiently inflated during expiration to retain an effective seal. The simplicity of construction of the various forms of the instant invention hereinbefore described make it feasible for the tubes to be disposable after each use.

While there is shown and described herein certain specific structure embodying the invention, it will be manifest to those skilled in the art that various modifications and rearrangements of the parts may be made without departing from the spirit and scope of the underlying inventive concept and that the same is not limited to the particular forms herein shown and described except insofar as indicated by the scope of the appended claims.

What is claimed is:

1. A self-inflating endotracheal tube comprising an elongated, flexible, open-ended hollow tube having a proximal and distal end, an inflatable cuff of generally tubular configuration and a diameter substantially larger than that of the trachea in which the tube is adapted to be inserted, said cuff being of thin, film material and secured to said tube adjacent the distal end thereof, and means for automatically causing inflation of said cuff in response to inspiration through said tube and for maintaining said cuff inflated during expiration therethrough, the portion of said tube extending through said cuff having an opening including a coanda surface exposed to air flow toward the proximal end in the expiration direction to guide air flowing through said tube into said cuff, said coanda surface comprising a surface sloped at an acute angle to the axis of said tube, said surface being on the upstream side, relative to flow of air in the expiration direction, of said opening and sloping from the interior of the tube outwardly in the downstream direction relative to said flow whereby air flowing in the expiration direction tends to hug and follow said surface through an obtuse angle path into said cuff for maintaining inflation.

2. A self-inflating endotracheal tube comprising an elongated, flexible, open-ended hollow tube having a proximal and distal end, an inflatable cuff secured to said tube adjacent the distal end thereof, and means for automatically causing inflation of said cuff in response to inspiration through said tube and for maintaining said cuff inflated during expiration therethrough, the portion of said tube extending through said cuff being perforate and including a Coanda surface exposed to air flow toward the proximal to guide end expiration air flowing through said tube into said cuff, said Coanda surface defined by walls defining a plurality of openings through the wall of said tube, said openings sloped at an acute angle to the axis of said tube, with the entrance of the opening within the bore of said tube spaced substantially distally of the outlet of said opening into the volume of said cuff.

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