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(54) Title: MEDICAL TUBES FOR SELECTIVE MECHANICAL VENTILATION OF THE LUNGS

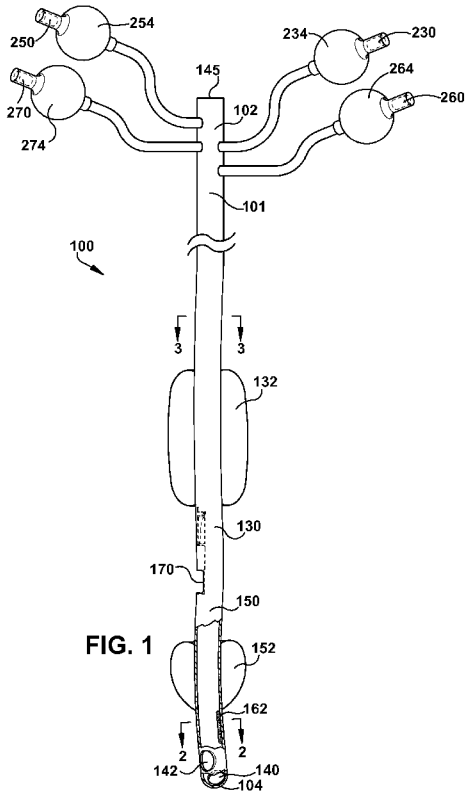

FIG. 1

(57) Abstract: A single lumen endobronchial tube 100 includes a medical tube having a single lumen with an opening at each of opposed distal 104 and proximal 102 ends of the tube, the opening 145 at the proximal end of the tube being adapted for connection to an external mechanical ventilation device, and the opening 140 at the distal end of the tube being adapted for delivery of a medical gas; a wall 110 extending throughout the tube's entire length having an internal wall surface, an external wall surface and a thickness therebetween, a portion of the wall having an aperture 170 and a shaft adapted to house a mechanism for sealing the aperture; a distal bronchial cuff 152 positioned along the external wall surface and adapted to expand radially outward; and at least a first proximal tracheal cuff 132 positioned along the external wall surface and adapted to expand radially outward.

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TITLE

MEDICAL TUBES FOR SELECTIVE MECHANICAL VENTILATION OF THE LUNGS

RELATED APPLICATIONS

This application claims the benefit of and priority to U.S. Provisional Application Serial No. 61/301,435, filed February 4, 2010, which is hereby incorporated herein by reference in its entirety for the teachings therein.

FIELD

The embodiments disclosed herein relate to medical tubes for selective mechanical ventilation of the lungs, and more particularly to single lumen endobronchial tubes for selective mechanical ventilation of the left lung or the right lung.

BACKGROUND

The body requires a certain volume of air to be inhaled and exhaled to maintain the correct levels of oxygen and carbon dioxide within the tissues. Tissue damage, which leads eventually to death, occurs if the level of oxygen becomes too low or the amount of carbon dioxide becomes too high. The body is therefore critically dependent on breathing to maintain life. In medicine, mechanical ventilation is a method to mechanically assist or replace spontaneous breathing. A medical ventilator moves breathable air into and out of the lungs, to provide the mechanism of breathing for a patient who is physically unable to breathe, or breathing insufficiently. Ventilators are chiefly used in intensive care medicine and emergency medicine (as standalone units) and in anesthesia (as a component of an anesthesia machine).

SUMMARY

Single lumen endobronchial tubes for selective mechanical ventilation of the left lung or the right lung are disclosed herein.

According to aspects illustrated herein, there is provided a single lumen endobronchial tube adapted for isolating a first lung of a patient and ventilating a second lung of the patient that includes a medical tube comprising a tracheal portion and a bronchial portion having a common single lumen and a common tube wall thickness, wherein a proximal end of the tracheal portion

includes an opening adapted for connection to an external mechanical ventilation device, and wherein a distal end of the bronchial portion includes an opening adapted for delivery of a medical gas; at least a first tracheal inflatable cuff positioned around an external surface of the tracheal portion and adapted to expand radially outward sealing against the trachea of the patient; a bronchial inflatable cuff positioned around an external surface of the bronchial portion and adapted to expand radially outward against the left main stem bronchi of the patient; an aperture positioned between the tracheal portion and the bronchial portion and adapted to deliver an amount of medical gas to the second lung of the patient; and a mechanism positioned within the wall of the tube, the mechanism adapted to control the amount of medical gas passing through the aperture.

According to aspects illustrated herein, there is provided a single lumen endobronchial tube adapted for isolating a first lung of a patient and ventilating a second lung of the patient that includes a medical tube comprising tracheal portion and a bronchial portion having a common single lumen and a common tube wall thickness, wherein a proximal end of the tracheal portion includes an opening adapted for connection to an external mechanical ventilation device, and wherein a distal end of the bronchial portion includes an opening adapted for delivery of a medical gas; a first tracheal inflatable cuff positioned around an external surface of the tracheal portion and adapted to expand radially outward sealing against the trachea of the patient; a bronchial inflatable cuff positioned around an external surface of the bronchial portion and adapted to expand radially outward against the left main stem bronchi of the patient; a bronchial balloon blocker positioned in the common single lumen of the bronchial portion adapted to expand radially outward sealing the common single lumen; a second tracheal inflatable cuff positioned around an external surface of the tracheal portion and adapted to expand radially outward at a respective distal location relative to the first tracheal inflatable cuff sealing against the trachea of the patient; and an aperture positioned between the first tracheal inflatable cuff and the second inflatable cuff and adapted to deliver an amount of medical gas to the second lung of the patient, wherein the second tracheal cuff is adapted to control the amount of medical gas passing through the aperture.

According to aspects illustrated herein, there is provided a single lumen endobronchial tube adapted for isolating a first lung of a patient and ventilating a second lung of the patient that includes a medical tube comprising a tracheal portion and a bronchial portion having a common

single lumen and a common tube wall thickness, wherein a proximal end of the tracheal portion includes an opening adapted for connection to an external mechanical ventilation device, and wherein a distal end of the bronchial portion includes an opening adapted for delivery of a medical gas; at least a first tracheal inflatable cuff positioned around an external surface of the tracheal portion and adapted to expand radially outward sealing against the trachea of the patient; a bronchial inflatable cuff positioned around an external surface of the bronchial portion and adapted to expand radially outward against the left main stem bronchi of the patient; a bronchial balloon blocker positioned in the common single lumen of the bronchial portion adapted to expand radially outward sealing the common single lumen; an aperture positioned between the tracheal portion and the bronchial portion and adapted to deliver an amount of medical gas to the second lung of the patient; and an expandable balloon adapted to control the amount of medical gas passing through the aperture.

According to aspects illustrated herein, there is provided a single lumen endobronchial tube that includes a medical tube comprising a single lumen with an opening at each of opposed distal and proximal ends of the tube, the opening at the proximal end of the tube being adapted for connection to an external mechanical ventilation device, and the opening at the distal end of the tube being adapted for delivery of a medical gas; a wall extending throughout the tube's entire length having an internal wall surface, an external wall surface and a thickness therebetween, a portion of the wall having an aperture and a shaft adapted to house a mechanism for sealing the aperture; a distal bronchial cuff positioned along the external wall surface and adapted to expand radially outward; and at least a first proximal tracheal cuff positioned along the external wall surface and adapted to expand radially outward.

According to aspects illustrated herein, there is provided a single lumen endobronchial tube of the present disclosure that includes a medical tube comprising a single lumen with an opening at each of opposed distal and proximal ends of the tube, the opening at the proximal end of the tube being adapted for connection to an external mechanical ventilation device, and the opening at the distal end of the tube being adapted for delivery of a medical gas; a wall extending throughout the tube's entire length having an internal wall surface, an external wall surface and a thickness therebetween, a portion of the wall having an aperture; a distal bronchial cuff positioned along the external wall surface and adapted to expand radially outward; a first proximal tracheal cuff positioned along the external wall surface and adapted to expand radially

outward; and a second proximal tracheal cuff positioned along the external wall surface and adapted to expand radially outward at a respective distal location relative to the aperture.

According to aspects illustrated herein, there is provided a single lumen endobronchial tube of the present disclosure that includes a medical tube comprising a single lumen with an opening at each of opposed distal and proximal ends of the tube, the opening at the proximal end of the tube being adapted for connection to an external mechanical ventilation device, and the opening at the distal end of the tube being adapted for delivery of a medical gas; a wall extending throughout the tube's entire length having an internal wall surface, an external wall surface and a thickness therebetween, a portion of the wall having an aperture; an expandable balloon adapted to control the amount of medical gas passing through the aperture; a distal bronchial cuff positioned along the external wall surface and adapted to expand radially outward; and at least a first proximal tracheal cuff positioned along the external wall surface and adapted to expand radially outward.

According to aspects illustrated herein, there is provided a method for one-lung ventilation of a lung of an air-breathing animal that includes providing a single lumen endobronchial tube, the single lumen endobronchial tube comprising a medical tube having a single lumen with an opening at each of opposed distal and proximal ends of the tube, the opening at the proximal end of the tube being adapted for connection to an external mechanical ventilation device, and the opening at the distal end of the tube being adapted for delivery of a medical gas; a wall extending throughout the tube's entire length having an internal wall surface, an external wall surface and a thickness therebetween, a portion of the wall having an aperture and a shaft adapted to house a mechanism for sealing the aperture; a distal bronchial cuff positioned along the external wall surface and adapted to expand radially outward; at least a first proximal tracheal cuff positioned along the external wall surface and adapted to expand radially outward; and a distal intraluminal balloon blocker at a respective distal location relative to the aperture; positioning the single lumen endobronchial tube in the pulmonary airway of the animal such that the distal bronchial cuff is in the left main stem bronchus, and the first proximal tracheal cuff is in the trachea, wherein a distal end of the medical tube is positioned beyond the carina of the animal; connecting the proximal end of the medical tube to the external mechanical ventilation device; inflating the distal bronchial cuff radially outwardly to seal against the surrounding bronchus of the left lung; inflating the proximal tracheal cuff radially outwardly to

seal against the surrounding trachea of the animal; and performing a step selected from one of inflating the distal intraluminal balloon blocker radially outwardly to occlude the lumen of the tube and thereby effectively occlude the left lung, whereby an airway from the ventilation device to the animal's right lung is maintained via the aperture or sealing the aperture by activating the mechanism housed in the shaft of the wall of the tube to block the aperture and thereby effectively occlude the right lung, whereby an airway from the ventilation device to the anima's left lung is maintained via the opening at the distal end of the tube.

BRIEF DESCRIPTION OF THE DRAWINGS

The presently disclosed embodiments will be further explained with reference to the attached drawings, wherein like structures are referred to by like numerals throughout the several views. The drawings shown are not necessarily to scale, with emphasis instead generally being placed upon illustrating the principles of the presently disclosed embodiments.

FIG. 1 is a side view of an embodiment of a single lumen endobronchial tube of the present disclosure.

FIG. 2A and **FIG. 2B** are cross-sectional plan views taken along line 2-2 of **FIG. 1**. **FIG. 2A** shows a distal intraluminal balloon of the single lumen endobronchial tube in an inflated state. **FIG. 2B** shows a distal intraluminal balloon of the single lumen endobronchial tube in a deflated state.

FIG. 3 shows a cross-sectional plan view taken along line 3-3 of **FIG. 1**.

FIG. 4 shows a partial perspective view of the single lumen endobronchial tube of **FIG. 1** showing an embodiment of a mechanism adapted to control the amount of medical gas passing through an aperture provided through a wall of the tube.

FIG. 5 shows a component of the mechanism of **FIG. 4** adapted to control the amount of medical gas passing through the aperture provided through the wall of the tube.

FIG. 6 shows a cutaway side view taken along line 6-6 of **FIG. 4** when the mechanism is adapted to allow the passage of medical gas through the aperture provided through the wall of the tube.

FIG. 7 shows a cutaway side view taken along line 6-6 of **FIG. 4** when the mechanism is adapted to prevent the passage of medical gas through the aperture provided through the wall of the tube.

FIG. 8 shows a cross-sectional view taken along line 8-8 of **FIG. 6**.

FIG. 9 shows a cross-sectional view taken along line 9-9 of **FIG. 7**.

FIG. 10 shows a cross-sectional plan view taken along line 10-10 of **FIG. 4**.

FIG. 11 shows a cutaway side view of the single lumen endobronchial tube of **FIG. 1** showing an embodiment of a mechanism adapted to control the amount of medical gas passing through an aperture provided through a wall of the tube.

FIG. 12 shows a cutaway side view of the single lumen endobronchial tube of **FIG. 1** showing an embodiment of a mechanism adapted to control the amount of medical gas passing through an aperture provided through a wall of the tube.

FIG. 13 shows a cross-sectional view taken along line 13-13 of **FIG. 12**.

FIG. 14 and **FIG. 15** show cutaway side views of the single lumen endobronchial tube of **FIG. 1** showing an embodiment of a mechanism adapted to control the amount of medical gas passing through an aperture provided through a wall of the tube. As illustrated in **FIG. 14**, the mechanism is adapted to allow the passage of medical gas through the aperture provided through the wall of the tube. As illustrated in **FIG. 15**, the mechanism is adapted to prevent the passage of medical gas through the aperture provided through the wall of the tube.

FIG. 16 shows a cutaway side view of the single lumen endobronchial tube of **FIG. 1** showing an embodiment of a mechanism adapted to control the amount of medical gas passing through an aperture provided through a wall of the tube. As illustrated in **FIG. 16**, the mechanism is adapted to allow the passage of medical gas through the aperture provided through the wall of the tube.

FIG. 17 and **FIG. 18** show cutaway side views of the single lumen endobronchial tube of **FIG. 1** showing an embodiment of a mechanism adapted to control the amount of medical gas passing through an aperture provided through a wall of the tube. As illustrated in **FIG. 17**, the mechanism is adapted to allow the passage of medical gas through the aperture provided through

the wall of the tube. As illustrated in **FIG. 18**, the mechanism is adapted to prevent the passage of medical gas through the aperture provided through the wall of the tube.

FIG. 19 shows a cutaway side view of the single lumen endobronchial tube of **FIG. 1** showing an embodiment of a mechanism adapted to control the amount of medical gas passing through an aperture provided through a wall of the tube.

FIG. 20 shows a cutaway side view of the single lumen endobronchial tube of **FIG. 1** showing an embodiment of a mechanism adapted to control the amount of medical gas passing through an aperture provided through a wall of the tube.

FIG. 21 and **FIG. 22** show cutaway side views of the single lumen endobronchial tube of **FIG. 1** showing an embodiment of a mechanism adapted to control the amount of medical gas passing through an aperture provided through a wall of the tube. As illustrated in **FIG. 21**, the mechanism is adapted to allow the passage of medical gas through the aperture provided through the wall of the tube. As illustrated in **FIG. 22**, the mechanism is adapted to prevent the passage of medical gas through the aperture provided through the wall of the tube.

FIG. 23 and **FIG. 24** show cutaway side views of the single lumen endobronchial tube of **FIG. 1** showing an embodiment of a mechanism adapted to control the amount of medical gas passing through an aperture provided through a wall of the tube. As illustrated in **FIG. 23**, the mechanism is adapted to allow the passage of medical gas through the aperture provided through the wall of the tube. As illustrated in **FIG. 24**, the mechanism is adapted to prevent the passage of medical gas through the aperture provided through the wall of the tube.

FIG. 25 and **FIG. 26** show cutaway side views of the single lumen endobronchial tube of **FIG. 1** showing an embodiment of a mechanism adapted to control the amount of medical gas passing through an aperture provided through a wall of the tube. As illustrated in **FIG. 25**, the mechanism is adapted to allow the passage of medical gas through the aperture provided through the wall of the tube. As illustrated in **FIG. 26**, the mechanism is adapted to prevent the passage of medical gas through the aperture provided through the wall of the tube.

FIG. 27 shows a schematic view of the single lumen endobronchial tube of **FIG. 1** positioned in a person for the selective ventilation of the right lung.

FIG. 28 shows a schematic view of the single lumen endobronchial tube of **FIG. 1** positioned in a person for the selective ventilation of the left lung.

FIG. 29 is a side view of an embodiment of a single lumen endobronchial tube of the present disclosure.

FIG. 30 shows a schematic view of the single lumen endobronchial tube of **FIG. 29** positioned in a person for the selective ventilation of the left lung.

FIG. 31 is a side view of an embodiment of a single lumen endobronchial tube of the present disclosure.

FIG. 32 shows a cross-sectional plan view taken along line 32-32 of **FIG. 31**.

FIG. 33 and **FIG. 34** show cutaway side views of the single lumen endobronchial tube of **FIG. 31** showing an embodiment of a balloon adapted to control the amount of medical gas passing through an aperture provided through a wall of the tube. As illustrated in **FIG. 33**, the balloon is adapted to allow the passage of medical gas through the aperture provided through the wall of the tube. As illustrated in **FIG. 34**, the balloon is adapted to prevent the passage of medical gas through the aperture provided through the wall of the tube.

FIG. 35 shows a schematic view of the single lumen endobronchial tube of **FIG. 31** positioned in a person for the selective ventilation of the left lung.

FIG. 36 is a side view of an embodiment of a single lumen endobronchial tube of the present disclosure.

FIG. 37 shows a cross-sectional plan view taken along line 37-37 of **FIG. 36**.

FIG. 38 shows a schematic view of the single lumen endobronchial tube of **FIG. 36** positioned in a person for the selective ventilation of the right lung.

While the above-identified drawings set forth presently disclosed embodiments, other embodiments are also contemplated, as noted in the discussion. This disclosure presents illustrative embodiments by way of representation and not limitation. Numerous other modifications and embodiments can be devised by those skilled in the art which fall within the scope and spirit of the principles of the presently disclosed embodiments.

DETAILED DESCRIPTION

Mechanical ventilation has become the most commonly used mode of life support in medicine today. Widely used in management of acutely ill surgical and ICU patients, mechanical ventilation can also be used in the chronic support of patients with a wide spectrum of chronic diseases that can cause respiratory failure.

As used herein, the term "anesthesia machine" refers to a machine used by an anesthesiologist to support the administration of anesthesia. The most common type of anesthesia machine, the continuous-flow anesthesia machine, is designed to provide an accurate and continuous supply of medical gases (such as oxygen and nitrous oxide), mixed with an accurate concentration of anesthetic vapor (such as isoflurane), and deliver this to the patient at a safe pressure and flow. Modern machines incorporate a medical ventilator, suction unit, and patient-monitoring devices.

As used herein, the term "positive airway pressure" or "PAP" refers to a method of respiratory ventilation used primarily in the treatment of sleep apnea. PAP ventilation is also commonly used for critically ill patients in hospital with respiratory failure, and in newborn infants (neonates). "Bi-level Positive Airway Pressure" or "BIPAP" refers to a form of temporary respiratory support for patients that have difficulty breathing. Each time the patient breathes, the BIPAP machine assists the patient by applying air pressure to the lungs while the patient is breathing out (exhaling or expiration) in order to hold open the air sacs in the lungs. "Continuous Positive Airway Pressure" or "CPAP" refers to the application of positive pressure to the airways of the spontaneously or mechanically breathing patient throughout the respiratory cycle. A CPAP machine uses continuous air pressure to produce added oxygen or simply to help keep the airways in the lungs open. The air pressure keeps the airways functioning properly and helps the individual breathe additional oxygen more easily. CPAP machines were initially used mainly by patients for the treatment of sleep apnea at home, but now are in widespread use across intensive care units as a form of ventilation.

As used herein, the term "mechanical ventilation" refers to a method to mechanically assist or replace spontaneous breathing.

As used herein, the term "external mechanical ventilation device" refers to a machine to mechanically assist or replace spontaneous breathing. Examples of external mechanical

ventilation devices include, but are not limited to, hand-controlled ventilators and mechanical ventilators such as transport ventilators, ICU ventilators, and PAP ventilators (BiPAP machine, CPAP machine).

As used herein, the term "medical gas" includes gases such as compressed air, oxygen, carbon dioxide, helium, nitrogen and nitrous oxide.

As used herein, the term "one-lung ventilation", "OLV", "independent lung ventilation" or "ILV" consists of mechanical ventilation of a selected lung and exposure or intentional airway blocking to the other. OLV is required for a number of thoracic procedures, including, but not limited to, lung surgery, esophageal surgery, aortic surgery, mediastinal surgery, minimally invasive lung surgery, minimally invasive heart surgery, robotic heart surgery and robotic lung surgery. In a conventional OLV procedure, a double-lumen endotracheal tube, an endobronchial blocker, or a single lumen tube may be used. Double-lumen endotracheal tubes and endobronchial blockers function differently. Double-lumen endotracheal tubes isolate ventilation, separating the right and left pulmonary units using two separate endotracheal tubes. An endobronchial blocker blocks ventilation to a pulmonary segment. Endobronchial blockers are typically balloon tipped catheters that are placed in the portion of the pulmonary tree that is to be blocked (usually the right or left main stem bronchus). Ventilation to the pulmonary unit is blocked when the balloon is inflated.

As used herein, the term "positive pressure ventilation" or "PPV" refers to the process of forcing air into the lungs of a patient.

As used herein, the term "pulmonary airway" refers to those parts of the respiratory system through which air flows, conceptually beginning (on inhalation from the external environment) at the nose and mouth, and terminating in the alveoli. From the mouth or nose, inhaled air passes through the pharynx into the trachea, where the air separates into the left and right main bronchi at the carina, situated at the level of the second thoracic vertebra. The main bronchi then branch into large bronchioles, one for each lobe of the lung. Within the lobes, the bronchioles further subdivide some 20 times, ending in clusters of alveoli.

As used herein, the term "tracheal intubation" refers to the placement of a flexible plastic tube into the trachea to protect the patient's airway and provide a means of mechanical ventilation. The most common tracheal intubation is orotracheal intubation where, with the

assistance of a laryngoscope, an endotracheal tube is passed through the mouth, larynx, and vocal cords, into the trachea. Another possibility is nasotracheal intubation where a tube is passed through the nose, larynx, vocal cords, and trachea.

Disclosed herein are medical tubes for selective mechanical ventilation of the left lung or the right lung. **FIG. 1** in conjunction with **FIG. 2A**, **FIG. 2B** and **FIG. 3**, show an embodiment of a single lumen endobronchial tube **100** of the present disclosure. The single lumen endobronchial tube **100** is a medical tube that includes a proximal end **102**, a distal end **104**, and a primary flow passage or lumen **160** passing therebetween. The distal end **104** of the tube **100** has a bronchial opening **140**. In an embodiment, the bronchial opening **140** is smooth and beveled, thus minimizing risk of tracheal intubation airway trauma. The distal end **104** of the tube **100** can optionally include a Murphy eye **142**, which is a distal opening in a wall **110** and through an outer surface **101** of the tube **100** which can allow airflow in the event of the bronchial opening **140** lying against the tracheal wall or being obstructed in other ways. Located at the proximal end **102** of the tube **100** is an opening **145** sufficiently designed to connect with a mechanical ventilation device, including, but not limited to, an anesthesia machine or a PAP machine, with or without the use of an adaptor. The tube **100** includes a tracheal portion **130** and a bronchial portion **150**. The tube **100** may be made from a flexible material including, but not limited to, latex, silicone, polyvinyl chloride (PVC), polyurethane (PU), polytetrafluoroethylene or a similar material that has met the American National Standard for Anesthetic Equipment; ANSI Z-79 standard and implant-tested to ensure nontoxicity. In an embodiment, the tube **100** is made from a non-toxic, clear, PVC material. In an embodiment, the tracheal portion **130** is adapted to follow the natural contour of a patient's trachea, and the bronchial portion **150** is adapted to follow the natural contour of a patient's left main stem bronchi. In an embodiment, to facilitate passage of the bronchial portion **150** into the left main stem bronchi, the tube **100** is curved or bent and resembles the shape of a hockey stick. In an embodiment, the angle of the bend is about 45°. The lumen **160** of the tube **100** is sized and dimensioned to allow other instrumentation to pass through the lumen **160** as required. The removal of mucous, the injection of medication, or the insertion of fiberoptic scopes for viewing within the tube **100** are examples of the additional instrumentation capability which is afforded by the tube **100**. In an embodiment, the single lumen endobronchial tube **100** may be referred to as a left-sided single lumen endobronchial tube.

A tracheal cuff **132** and a bronchial cuff **152** are spaced longitudinally along an exterior surface of the tracheal portion **130** and the bronchial portion **150**, respectively. In an embodiment, the tracheal cuff **132** and the bronchial cuff **152** are thin walled, high volume low pressure (HVLP) balloon-like members sealed from fluid communication with the tube **100** and adapted not to compromise the blood flow in the tracheal or bronchial wall when inflated. The tracheal cuff **132** and the bronchial cuff **152** are shown in an expanded state in **FIG. 1**. In an embodiment, the balloon-like members are spherical or elliptical in shape, although any desired shape is possible and within the scope and spirit of the present disclosure. In an embodiment, the walls of the tracheal cuff **132** and the bronchial cuff **152** are on the order of about 5 μm to about 500 μm, about 5 μm to about 250 μm, about 5 μm to about 100 μm, about 5 μm to about 50 μm, about 5 μm and about 20 μm, about 5 μm and about 15 μm. It is also contemplated that the walls may have a thickness of less than about 5 μm. Additionally, although the thickness of the walls may vary, it is desirable that the thickness of the material remain consistent throughout the cuff. A distal intraluminal balloon blocker **162** adapted to inflate and deflate is positioned along an inner surface of the tube **100** and when inflated acts to block flow by blocking ventilation to the left main stem bronchus. In an embodiment, the distal intraluminal balloon blocker **162** is a low volume high pressure member. In an embodiment, the member is spherical or elliptical in shape, although any desired shape is possible and within the scope and spirit of the present disclosure.

The tracheal cuff **132**, the bronchial cuff **152**, and the distal intraluminal balloon blocker **162** are each remotely and selectively inflatable through pilot tubes **232**, **252** and **262**, respectively, running longitudinally through the wall **110** of the tube **100** as shown in **FIG. 3**. The wall **110** has an internal wall surface, an external wall surface and a thickness therebetween. Each pilot tube **232**, **252** and **262** emerges from the outer surface **101** of the tube **100** near the proximal end **102** of the tube **100**. Attached to a proximal end of each pilot tube **232**, **252** and **262** is a non-return valve **230**, **250** and **260** which is adapted to receive the nozzle of a syringe (not visible) and a complementary indicator bladder **234**, **254** and **264** which enables an anesthesiologist to confirm that each of the tracheal cuff **132**, the bronchial cuff **152**, and the distal intraluminal balloon blocker **162** has been inflated or deflated. The non-return valves **230**, **250** and **260** may be attached to a syringe for injecting a predetermined quantity of air. Various materials may be used to form the tracheal cuff **132**, the bronchial cuff **152** and the distal intraluminal balloon blocker **162**. These materials include, but are not limited to, polyurethane

(PU), low-density polyethylene (LDPE), polyvinyl chloride (PVC), silicone, neoprene, polyisoprene, polyamid (PA) or polyethylene teraphthalate (PETP). Additionally, copolymer admixtures for modifying the characteristics of the material may be used, for example a low density polyethylene and ethylene-vinylacetate copolymer (LDPE-EVA), or blends of the above mentioned materials (e.g. PU with PVC or PU with PA) would be considered suitable for forming the tracheal cuff **132**, the bronchial cuff **152** and the distal intraluminal balloon blocker **162**.

An aperture **170** is provided through the wall **110** of the tube **100** between the tracheal balloon cuff **132** and the bronchial balloon cuff **152**, as best illustrated in **FIG. 1**. The aperture **170** can be of any shape or size. In an embodiment, the aperture **170** is dimensioned so that a fiberoptic scope can pass through the aperture **170**. A shaft adapted to house components of a mechanism, the components of the mechanism sufficiently designed to seal the aperture **170**, is created in the wall **110** of the tube **100**. Various embodiments of shafts and mechanism components are described in detail below. In the embodiments described in **FIGS. 4-13** below, the shaft is made up of two compartments, a chamber and a track housing. In the embodiments described in **FIGS. 14-20** below, the shaft is made up of one compartment, a track housing. The components of the mechanism are adapted to control the amount of medical gas passing through the aperture **170**. In an embodiment, the components of the mechanism are adapted to completely close and seal the aperture **170** such that the amount of medical gas passing through the aperture **170** from the lumen **160** is 0%. In an embodiment, the components of the mechanism are adapted to partially close the aperture **170** such that the amount of medical gas passing through the aperture **170** from the lumen **160** is greater than 0% but less than 100%. In an embodiment, the components of the mechanism for controlling the flow of medical gas through the aperture **170** are remotely controlled through a pilot tube **272** running longitudinally through the wall **110** of the tube (see **FIG. 3**). The pilot tube **272** emerges from the outer surface **101** near the proximal end **102** of the tube **100**. Attached to a proximal end of the pilot tube **272** is a non-return valve **270** which is adapted to receive the nozzle of a syringe (not visible), and an indicator bladder **274** which enables an anesthesiologist to confirm that the mechanism has moved to close or seal the aperture **170**. The non-return valve **270** may be attached to a syringe for injecting a predetermined quantity of air, saline or any other fluid.

In some embodiments, the single lumen endobrochial tube is adapted for use with a PAP machine. In such embodiments, conduits **282** and **292** (see **FIG. 3**) run longitudinally through the wall **110** of the tube **100** to deliver gas to a patient at positive pressure in order to hold open alveoli that would normally close at the end of expiration. The tube **100** can be manufactured to various sizes and adapted to provide mechanical ventilation to an air-breathing animal in need thereof. In an embodiment, the tube **100** is manufactured for human use and ranges in size from about 1.5 mm to about 11.0 mm in internal diameter (ID). In an embodiment, the tube **100** is manufactured for human use and ranges in size from about 3 mm to about 10 mm in internal diameter (ID). In an embodiment, the tube **100** is manufactured for non-human use and ranges in size from about 1.5 mm to about 40.0 mm in internal diameter (ID). In an embodiment, the tube **100** is manufactured for non-human use and ranges in size from about 6.0 mm to about 40.0 mm in internal diameter (ID).

Various embodiments of shafts and mechanism components adapted to control the amount of medical gas passing through the aperture **170** will now be discussed. The mechanism components disclosed herein are adapted to partially or completely close the aperture **170** such that the amount of medical gas passing through the aperture **170** from the lumen **160** ranges from about 0% to about 100%. In an embodiment, the aperture **170** is fully closed and adapted to provide 100% of the medical gas to ventilate the left lung (i.e., 0% of the medical gas ventilates the right lung). In an embodiment, the aperture **170** is fully open and adapted to provide 100% of the medical gas to ventilate the right lung (i.e., % of the medical gas ventilates the left lung). In an embodiment, the aperture **170** is partially open and adapted to provide about 50% of the medical gas to ventilate the left lung and about 50% of the medical gas to ventilate the right lung. Such an embodiment can be beneficial during the final stage of a medical procedure where a medical practitioner does not have to reposition the tube **100** to ventilate both the left lung and the right lung. A mechanism of the present disclosure is controlled by a user of the tube **100**, typically an anesthesiologist, such that selective ventilation of the left lung or the right lung is achievable without the need to move or reposition the tube **100**. This is highly beneficial to a patient, since postintubation repositioning of a medical tube can be highly dangerous.

FIG. 4 in conjunction with **FIG. 5**, **FIG. 6** and **FIG. 7** show an embodiment of a mechanism adapted to control the amount of medical gas passing through the aperture **170**. The components of the mechanism are positioned within the wall **110** of the tube **100** such that the

components are adapted to move in a frontal plane parallel to the central longitudinal axis of the tube **100**. An inner sealed diaphragm **340** is in fluid communication with the pilot tube **272** and separates a chamber **320** from the pilot tube **272**. A piston **300** having a base portion **362** engaging the diaphragm **340**, and a rod portion **364** engaging a door portion **366**, is powered by leaf springs **370** surrounding the rod portion **364**, and is moveable along a longitudinal plane substantially parallel to a central longitudinal axis of the tube **100**. By pushing fluid (such as air) through pilot tube **272**, the diaphragm **340** is inflated (as illustrated in **FIG. 6** and **FIG. 7**). The base portion **362** and the rod portion **364** of the piston **300** move within the chamber **320** and the door portion **366** moves within a track housing **190**. **FIG. 8** shows a cross-sectional view taken along line 8-8 of **FIG. 6**. **FIG. 9** shows a cross-sectional view taken along line 9-9 of **FIG. 7**. **FIG. 10** shows a cross-sectional plan view taken along line 10-10 of **FIG. 4**.

FIG. 11 shows a cutaway side view of an embodiment of a mechanism adapted to control the amount of medical gas passing through the aperture **170**. The components of the mechanism are positioned within the wall **110** of the tube **100** such that the components are adapted to move in an axial plane perpendicular to the central longitudinal axis of the tube **100**. An inner sealed diaphragm **440** is in fluid communication with the pilot tube **272** and separates the chamber **320** from the pilot tube **272**. A piston having a base portion **462** engaging the diaphragm **440**, and a rod portion **464** engaging a door portion **466**, is powered by fluid (air), and leaf springs **470** surrounding the rod portion **464** bring the piston back when the fluid pressure is off. The piston is moveable along a plane substantially parallel to a central longitudinal axis of the tube **100**. By pushing fluid (such as air) through pilot tube **272**, the diaphragm **440** is inflated. The base portion **462** and the rod portion **464** of the piston move within the chamber **320** and the door portion **466** moves within the track housing **190**.

FIG. 12 shows a cutaway side view of an embodiment of a mechanism adapted to control the amount of medical gas passing through the aperture **170**. The components of the mechanism are positioned within the wall **110** of the tube **100** such that the components are adapted to move in a frontal plane parallel to the central longitudinal axis of the tube **100**. An inner sealed diaphragm **540** is in fluid communication with the pilot tube **272** and separates a chamber **320** from the pilot tube **272**. A piston having a base portion **562** engaging the diaphragm **540**, and a rod portion **564** engaging a door portion **566**, is powered by fluid (air), and spring **570** surrounding the rod portion **564** bring the piston back when the fluid pressure is off. The piston

is moveable along a longitudinal plane substantially parallel to a central longitudinal axis of the tube **100**. By pushing fluid (such as air) through pilot tube **272**, the diaphragm **540** is inflated. The base portion **562** and the rod portion **564** of the piston move within the chamber **320** and the door portion **566** moves within the track housing **190**.

In an embodiment, the sealed diaphragm described in any of **FIGS. 4-13** is made of a flexible or stretchable elastomeric material, including, but not limited to, silicone rubber. In an embodiment, the piston described in any of **FIGS. 4-13** is fabricated from a non-degradable biocompatible natural or synthetic polymer, a biocompatible flexible metal, or combinations thereof. In an embodiment, the piston is manufactured from a polystyrene material. In an embodiment, the piston is manufactured from a nitinol material. In an embodiment, the piston described in any of **FIGS. 4-13** is sufficiently shaped to follow the radius of curvature of the tube **100** (see, for example, **FIG. 5**). In an embodiment, the sealed diaphragm described in any of **FIGS. 4-13**, the piston described in any of **FIGS. 4-13**, and the spring described in any of **FIGS. 4-13** may be fabricated from a disposable material and suitable for one-time use. In an embodiment, the sealed diaphragm described in any of **FIGS. 4-13**, the piston described in any of **FIGS. 4-13**, and the spring described in any of **FIGS. 4-13** may be fabricated from a sterilizable material and suitable for re-use.

FIG. 14 in conjunction with **FIG. 15** shows cutaway side views of an embodiment of mechanism adapted to control the amount of medical gas passing through the aperture **170**. . The components of the mechanism are positioned within the wall **110** of the tube **100** such that the components are adapted to move in a frontal plane parallel to the central longitudinal axis of the tube **100**. A balloon (or inner sealed diaphragm) **640** is in fluid communication with the pilot tube **272** and engages a door portion **666** moveable within the track housing **190**. In an embodiment, the balloon **640** is a low volume high pressure member. The door portion **666** is controlled by pushing fluid (such as air) through pilot tube **272** to inflate the balloon **640** which moves the door portion **666** to cover the aperture **170** (**FIG. 15**). As illustrated in **FIG. 14** and **FIG. 15**, the door portion **666** is sufficiently shaped to follow the radius of curvature of the tube **100**. As described above, the door portion **666** can be fabricated from a non-degradable biocompatible natural or synthetic polymer, a biocompatible flexible metal, or combinations thereof. In an embodiment, the door portion **666** is manufactured from a polystyrene material. In an embodiment, the door portion **666** is manufactured from a nitinol material. In an alternative

embodiment, as illustrated in **FIG. 16**, a wire **650** can be attached to the door portion **666** through the balloon **640** to aid movement of the door portion **666**. The wire **650** can be manufactured from a host of materials, including, but not limited to, stainless steel, aluminum, copper, nickel, nitinol, teflon, polypropylene or similar material. Although the embodiments illustrated in **FIG. 14** and **FIG. 15** show the components adapted to move in a frontal plane parallel to the central longitudinal axis of the tube **100**, it should be understood that the components of the mechanism can be positioned within the wall **110** of the tube **100** such that the components are adapted to move in an axial plane perpendicular to the central longitudinal axis of the tube **100**, similar to what was illustrated in **FIG. 11**.

FIG. 17 in conjunction with **FIG. 18** shows cutaway side views of an embodiment of mechanism adapted to control the amount of medical gas passing through the aperture **170**. The components of the mechanism are positioned within the wall **110** of the tube **100** such that the components are adapted to move in a frontal plane parallel to the central longitudinal axis of the tube **100**. A door portion **766** engages a first wire **730** at a proximal end of the door portion **766**, the first wire **730** traveling through pilot tube **272** and exiting at the proximal end **102** of the tube **100**; and also engages two wires at a distal end of the door portion **766** that combine to form wire **740** traveling through channels generally represented by **720** leading to pilot tube **272** and exiting at the proximal end **102** of the tube **100**. The door portion **766** is controlled by a user controlling the wires **730** and **740** at the proximal end **102** of the tube **100**. In such an embodiment, the components labeled **270** and **274** in **FIG. 1**, along with the tube leading into pilot tube **272**, are not necessary. The wire **730** moves within the pilot tube **272** and the two wires that combine to form wire **740** move within the channels generally represented by **720**. To move the door portion **766** from the resting position in track housing **190** to over the aperture **170**, wire **740** is pulled relative to wire **730**. To move the door portion **766** so that the door portion **766** no longer covers the aperture **170**, wire **730** is pulled relative to wire **740**. As illustrated in **FIG. 17** and **FIG. 18**, the door portion **766** is sufficiently shaped to follow the radius of curvature of the tube **100**. As described above, the door portion **766** can be fabricated from a non-degradable biocompatible natural or synthetic polymer, a biocompatible flexible metal, or combinations thereof. In an embodiment, the door portion **766** is manufactured from a polystyrene material. In an embodiment, the door portion **766** is manufactured from a nitinol material. Although the embodiments illustrated in **FIG. 17** and **FIG. 18** show the components adapted to move in a

frontal plane parallel to the central longitudinal axis of the tube **100**, it should be understood that the components of the mechanism can be positioned within the wall **110** of the tube **100** such that the components are adapted to move in an axial plane perpendicular to the central longitudinal axis of the tube **100**, similar to what was illustrated in **FIG. 11**.

FIG. 19 shows an embodiment of a mechanism adapted to control the amount of medical gas passing through the aperture **170**. The mechanism includes a first electromagnet **800** having a conductor (coiled wire **820**) wound around a core, a second electromagnet **850** having a conductor (coiled wire **870**) wound around a core, and a door portion **866**. As illustrated in **FIG. 19**, the door portion **866** includes ferrous metal plates **840** and **860** that can either be added to the door portion **866** or built-in to the door portion **866**. The ferrous metal plates **840** and **860** can magnetically engage the electromagnets **850** and **800**. The electromagnets **850** and **800** can be connected to an external current source (for example an AC or DC current source) via wires **828** and **875** travelling through channels running longitudinally through the wall **110** of the tube **100** to create a magnetic field capable of moving the door portion **866** to either cover the aperture **170** or maintain the aperture **170** open, as illustrated in **FIG. 19**.

FIG. 20 shows an embodiment of a mechanism adapted to control the amount of medical gas passing through the aperture **170**. The mechanism includes a door portion **966** having teeth **968**, the teeth **968** engaging teeth **948** of a rotatable shaft **940**. A proximal end (not visible) of the shaft **940** emerges from the proximal end **102** of the tube **100**, where a user can rotate the shaft **940** causing the teeth **948** to catch the teeth **968** of the door portion **960**, thus moving the door portion **960** as necessary to control the amount of medical gas passing through the aperture **170**.

FIG. 21 in conjunction with **FIG. 22** shows cutaway side views of a mechanism adapted to control the amount of medical gas passing through the aperture **170**. The components of the mechanism are positioned within the wall **110** of the tube **100** such that the components are adapted to move in a frontal plane parallel to the central longitudinal axis of the tube **100** to cover the aperture **170** when required. As illustrated in **FIG. 21**, the mechanism includes a first expandable balloon **900** and a second expandable balloon **910** both in fluid communication with the pilot tube **272** via tubes **272a** and **272b**, respectively. By pushing fluid (such as air) through pilot tube **272**, and thus **272a** and **272b**, the first expandable balloon **900** and the second expandable balloon **910** are inflated (as illustrated in **FIG. 22**). In the embodiment illustrated in

FIG. 21 and **FIG. 22**, when the balloons **900** and **910** are inflated, the balloons **900** and **910** expand from an outer boundary of the aperture **170** towards the middle of the aperture **170** until they meet to substantially cover the aperture **170** to prevent medical gas from escaping. In an embodiment, the first expandable balloon **900** and the second expandable balloon **910** are low volume high pressure members. In an embodiment, the first expandable balloon **900** and the second expandable balloon **910** are high volume low pressure members. Although not illustrated in **FIG. 21** and **FIG. 22**, in an embodiment, pilot tubes **272a** and **272b** each separately run longitudinally through the wall **110** of the tube so that each of the balloons **900** and **910** can independently be expanded or deflated.

FIG. 23 in conjunction with **FIG. 24** shows cutaway side views of a mechanism adapted to control the amount of medical gas passing through the aperture **170**. The components of the mechanism are positioned within the wall **110** of the tube **100** such that the components are adapted to move in a frontal plane parallel to the central longitudinal axis of the tube **100** to cover the aperture **170** when required. As illustrated in **FIG. 23**, the mechanism includes a first expandable balloon **1000** and a second expandable balloon **1010** both in fluid communication with the pilot tube **272** via tubes **272a** and **272b**, respectively. By pushing fluid (such as air) through pilot tube **272**, and thus **272a** and **272b**, the first expandable balloon **1000** and the second expandable balloon **1010** are inflated (as illustrated in **FIG. 24**). In the embodiment illustrated in **FIG. 23** and **FIG. 24**, when the balloons **1000** and **1010** are inflated, the balloons **1000** and **1010** expand from an outer boundary of the aperture **170** towards the middle of the aperture **170** until they meet to substantially cover the aperture **170** to prevent medical gas from escaping. In an embodiment, the first expandable balloon **1000** and the second expandable balloon **1010** are low volume high pressure members. In an embodiment, the first expandable balloon **1000** and the second expandable balloon **1010** are high volume low pressure members. Although not illustrated in **FIG. 23** and **FIG. 24**, in an embodiment, pilot tubes **272a** and **272b** each separately run longitudinally through the wall **110** of the tube so that each of the balloons **1000** and **1010** can independently be expanded or deflated.

FIG. 25 in conjunction with **FIG. 26** shows cutaway side views of a mechanism adapted to control the amount of medical gas passing through the aperture **170**. The components of the mechanism are positioned within the wall **110** of the tube **100** such that the components are adapted to move in a frontal plane parallel to the central longitudinal axis of the tube **100** to

cover the aperture **170** when required. As illustrated in **FIG. 25**, the mechanism includes an expandable balloon **1100** in fluid communication with the pilot tube **272**. By pushing fluid (such as air) through pilot tube **272** the expandable balloon **1100** is inflated (as illustrated in **FIG. 26**). In the embodiment illustrated in **FIG. 25** and **FIG. 26**, when the balloon **1100** is inflated, the balloon **1100** expands from a first outer boundary of the aperture **170** towards a second outer boundary of the aperture **170** to substantially cover the aperture **170** to prevent medical gas from escaping. In an embodiment, the expandable balloon **1100** is a low volume high pressure member. In an embodiment, the expandable balloon **1100** is a high volume low pressure member. Although the embodiments illustrated in **FIG. 25** and **FIG. 26** show the balloon **1100** positioned on the left outer boundary of the aperture **170**, it should be understood that the balloon **1100** can be positioned on the right outer boundary of the aperture **170**, the top outer boundary of the aperture **170** or on the bottom outer boundary of the aperture **170** and still be within the scope and spirit of the present disclosure.

Referring to **FIG. 27**, the single lumen endobronchial tube **100** is positioned within a patient to facilitate artificial ventilation of the respiratory system. The single lumen endobronchial tube **100** has been placed within a mouth of the patient and positioned such that the tracheal portion **130** resides within the trachea **1320** and the bronchial portion **150** resides within the left main stem bronchi **1330**. The tube **100** may be sufficiently designed such that the bronchial portion **150** curves for ease of placement beyond the carina **1340** into the left main stem bronchi **1330**. In this placement, ventilation of the left lung or the right lung can be accomplished without having to move the single lumen endobronchial tube. Placement of the single lumen endobronchial tube **100** can be performed with or without fiberoptic visualization. Although **FIG. 27** shows the single lumen endobronchial tube **100** being inserted through the mouth of the patient, it should be understood that the single lumen endobronchial tube **100** can also be inserted through the nasal passages into the airway passage. For one-lung ventilation of the right lung **1400**, the aperture **170** remains open, which sufficiently allows the flow of medical gases through the aperture **170** and into the right lung. Once proper positioning of the single lumen endobronchial tube **100** in the pulmonary airway is determined, the bronchial cuff **152** is inflated to a desired pressure by pushing a fluid such as air or saline through the pilot tube **252** leading to the bronchial cuff **152**. In an embodiment, the bronchial cuff **152** is inflated so that the bronchial cuff pressure (BCP) is in the range of about 15 cm H_2O (about 11 mm Hg) to about 30

cm H_2O (about 22 mm Hg). The tracheal cuff **132** is inflated by pushing a fluid such as air or saline through the pilot tube **232** leading to the tracheal cuff **132**. In an embodiment, the tracheal cuff **132** is inflated so that the cuff pressure is in the range of about 15 cm H_2O (about 11 mm Hg) to about 30 cm H_2O (about 22 mm Hg). The seal formed by the inflated tracheal cuff **132** is adapted to substantially provide a seal between the outside of the single lumen endobronchial tube **100** and the interior of the trachea **1320** in which the single lumen endobronchial tube **100** is inserted. The distal intraluminal balloon blocker **162** is inflated by pushing a fluid such as air or saline through the pilot tube **262** leading to the distal intraluminal balloon blocker **162**. In an embodiment, the distal intraluminal balloon blocker **162** is inflated so that the cuff pressure is in the range of about 20 cm H_2O (about 14.7 mm Hg) to about 95 cm H_2O (about 69 mm Hg). The desired agent(s) are then introduced, for example from an anesthesia machine, through the lumen **160** of the tube **100** to deliver the desired agent(s) to the right lung **1400**. The inflated distal intraluminal balloon blocker seals the lumen **160** of the tube **100** distal to the inflated distal intraluminal balloon blocker **162** such that sufficient blockage of the agents to the left lung **1300** is achieved.

FIG. 28 shows the single lumen endobronchial tube **100** positioned during one-lung ventilation of the left lung **1300**. The single lumen endobronchial tube **100** is placed in the pulmonary airway of a patient such that the tracheal portion **130** resides within the trachea **1320** and the bronchial portion **150** resides within the left main stem bronchi **1330**. The tube **100** may be sufficiently designed such that the bronchial portion **150** curves for ease of placement beyond the carina **1340** into the left main stem bronchi **1330**. Placement of the single lumen endobronchial tube **100** can be performed with or without fiberoptic visualization. For one-lung ventilation of the left lung, the aperture **170** is sealed to sufficiently preclude the flow of medical gases through the aperture **170** and into the right lung. Once proper positioning of the single lumen endobronchial tube **100** in the pulmonary airway is determined, the endobronchial cuff **152** is inflated to a desired pressure by pushing a fluid such as air or saline through the pilot tube **252** leading to the bronchial cuff **152**. In an embodiment, the bronchial cuff **152** is inflated so that the cuff pressure is in the range of about 15 cm H_2O (about 11 mm Hg) to about 30 cm H_2O (about 22 mm Hg). The seal formed by the inflated bronchial cuff **152** is adapted to preclude any medical gas that has been forced into the patient's left lung from escaping through the left main stem bronchi **1330** into the trachea **1320**. The endotracheal cuff **132** is inflated by pushing a fluid

such as air or saline through the pilot tube **232** leading to the tracheal cuff **132**. In an embodiment, the tracheal cuff **132** is inflated so that the bronchial cuff pressure (BCP) is in the range of about 15 cm H_2O (about 11 mm Hg) to about 30 cm H_2O (about 22 mm Hg). The seal formed by the inflated tracheal cuff **132** is adapted to substantially provide a seal between the outside of the single lumen endobronchial tube **100** and the interior of the trachea **1320** in which the single lumen endobronchial tube **100** is inserted. The desired agent(s) are then introduced, for example from an anesthesia machine, through the lumen **160** of the tube **100** to deliver the desired agent(s) to the left lung **1300**.

It is also contemplated that in an alternative embodiment of the single lumen endobronchial tube, the distal intraluminal balloon blocker **162** (as well as the other co-dependent components of the distal intraluminal balloon blocker **162** including the pilot tube **262**, the non-return valve **260** and the pilot balloon **264**) are absent. In such an embodiment, a conventional endobronchial blocker can be used to block ventilation of the left main stem bronchi.

FIG. 29 shows an embodiment of a single lumen endobronchial tube **2100** of the present disclosure. The single lumen endobronchial tube **2100** is a medical tube having a proximal end **2102**, a distal end **2104**, and a primary flow passage or lumen **2160** passing therebetween. The distal end **2104** of the tube **2100** has a bronchial opening **2140**. In an embodiment, the bronchial opening **2140** is smooth and beveled, thus minimizing risk of tracheal intubation airway trauma. The distal end **2104** of the tube **2100** can optionally include a Murphy eye **2142**, which is a distal opening in a wall **2110** and through an outer surface **2101** of the tube **2100** which can allow airflow in the event of the bronchial opening **2140** lying against the tracheal wall or being obstructed in other ways. Located at the proximal end **2102** of the tube **2100** is an opening **2145** sufficiently designed to connect with a mechanical ventilation device, including, but not limited to, an anesthesia machine or a PAP machine, with or without the use of an adaptor. The tube **2100** includes a tracheal portion **2130** and a bronchial portion **2150**. The tube **2100** may be made from a flexible material including, but not limited to, latex, silicone, polyvinyl chloride (PVC), polyurethane (PU), polytetrafluoroethylene or a similar material that has met the American National Standard for Anesthetic Equipment; ANSI Z-79 standard and implant-tested to ensure nontoxicity. In an embodiment, the tube **2100** is made from a non-toxic, clear, PVC material. In an embodiment, the tracheal portion **2130** is adapted to follow the natural contour of a patient's

trachea, and the bronchial portion **2150** is adapted to follow the natural contour of a patient's left main stem bronchi. In an embodiment, to facilitate passage of the bronchial portion **2150** into the left main stem bronchi, the tube **2100** is curved or bent and resembles the shape of a hockey stick. In an embodiment, the angle of the bend is about 45°. The lumen **2160** of the tube **2100** is sized and dimensioned to allow other instrumentation to pass through the lumen **2160** as required. The removal of mucous, the injection of medication, or the insertion of fiberoptic scopes for viewing within the tube **2100** are examples of the additional instrumentation capability which is afforded by the tube **2100**. In an embodiment, the single lumen endobronchial tube **2100** may be referred to as a left-sided single lumen endobronchial tube.

A first tracheal cuff **2132**, a second tracheal cuff **2172** and a bronchial cuff **2152** are spaced longitudinally along an exterior surface of the tracheal portion **2130** and the bronchial portion **2150**, respectively. In an embodiment, the first tracheal cuff **2132**, the second tracheal cuff **2172** and the bronchial cuff **2152** are thin walled, high volume low pressure (HVLP) balloon-like members sealed from fluid communication with the tube **2100** and adapted not to compromise the blood flow in the tracheal or bronchial wall when inflated. The first tracheal cuff **2132**, the second tracheal cuff **2172**, and the bronchial cuff **2152** are shown in an expanded state in **FIG. 29**. In an embodiment, the balloon-like members are spherical or elliptical in shape, although any desired shape is possible and within the scope and spirit of the present disclosure. In an embodiment, the walls of the first tracheal cuff **2132**, the second tracheal cuff **2172** and the bronchial cuff **2152** are on the order of about 5 μm to about 500 μm, about 5 μm to about 250 μm, about 5 μm to about 100 μm, about 5 μm to about 50 μm, about 5 μm and about 20 μm, about 5 μm and about 15 μm. It is also contemplated that the walls may have a thickness of less than about 5 μm. Additionally, although the thickness of the walls may vary, it is desirable that the thickness of the material remain consistent throughout the cuff. A distal intraluminal balloon blocker **2162** adapted to inflate and deflate is positioned along an inner surface of the tube **2100** and when inflated acts to block flow by blocking ventilation to the left main stem bronchus. In an embodiment, the distal intraluminal balloon blocker **2162** is a low volume high pressure member. In an embodiment, the member is spherical or elliptical in shape, although any desired shape is possible and within the scope and spirit of the present disclosure.

The first tracheal cuff **2132**, the second tracheal cuff **2172**, the bronchial cuff **2152**, and the distal intraluminal balloon blocker **2162** are each remotely and selectively inflatable through pilot tubes **2232**, **2172**, **2252** and **2262**, respectively, running longitudinally through the wall of the tube **2100**. The wall has an internal wall surface, an external wall surface and a thickness therebetween. Each pilot tube **2232**, **2172**, **2252** and **2262** emerges from the outer surface **2101** of the tube **2100** near the proximal end **2102** of the tube **2100**. Attached to a proximal end of each pilot tube **2232**, **2172**, **2252** and **2262** is a non-return valve **2230**, **2270**, **2250** and **2260** which is adapted to receive the nozzle of a syringe (not visible) and a complementary indicator bladder **2234**, **2274**, **2254** and **2264** which enables an anesthesiologist to confirm that each of the first tracheal cuff **2132**, the second tracheal cuff **2172**, the bronchial cuff **2152**, and the distal intraluminal balloon blocker **2162** has been inflated or deflated. The non-return valves **2230**, **2270**, **2250** and **2260** may be attached to a syringe for injecting a predetermined quantity of air. Various materials may be used to form the first tracheal cuff **2132**, the second tracheal cuff **2172**, the bronchial cuff **2152** and the distal intraluminal balloon blocker **2162**. These materials include, but are not limited to, polyurethane (PU), low-density polyethylene (LDPE), polyvinyl chloride (PVC), silicone, neoprene, polyisoprene, polyamid (PA) or polyethylene teraphthalate (PETP). Additionally, copolymer admixtures for modifying the characteristics of the material may be used, for example a low density polyethylene and ethylene-vinylacetate copolymer (LDPE-EVA), or blends of the above mentioned materials (e.g. PU with PVC or PU with PA) would be considered suitable for forming the first tracheal cuff **2132**, the second tracheal cuff **2172**, the bronchial cuff **2152** and the distal intraluminal balloon blocker **2162**.

An aperture **2170** is provided through the wall **2110** of the tube **2100** between the first tracheal balloon cuff **2132** and the second tracheal balloon cuff **2172**. The aperture **2170** can be of any shape or size. In an embodiment, the aperture **2170** is dimensioned so that a fiberoptic scope can pass through the aperture **2170**. In some embodiments, the single lumen endobrochial tube is adapted for use with a PAP machine. In such embodiments, conduits run longitudinally through the wall **2110** of the tube **2100** to deliver gas to a patient at positive pressure in order to hold open alveoli that would normally close at the end of expiration. The tube **2100** can be manufactured to various sizes and adapted to provide mechanical ventilation to an air-breathing animal in need thereof. In an embodiment, the tube **2100** is manufactured for human use and ranges in size from about 1.5 mm to about 11 mm in internal diameter (ID). In an embodiment,

the tube **2100** is manufactured for human use and ranges in size from about 3 mm to about 10 mm in internal diameter (ID). In an embodiment, the tube **2100** is manufactured for non-human use and ranges in size from about 1.5 mm to about 40 mm in internal diameter (ID). In an embodiment, the tube **2100** is manufactured for non-human use and ranges in size from about 6 mm to about 40 mm in internal diameter (ID).

Referring to **FIG. 30**, the single lumen endobronchial tube **2100** is positioned within a patient to facilitate artificial ventilation of the respiratory system. The single lumen endobronchial tube **2100** has been placed within a mouth of the patient and positioned such that the tracheal portion **2130** resides within the trachea **1320** and the bronchial portion **2150** resides within the left main stem bronchi **1330**. The tube **2100** may be sufficiently designed such that the bronchial portion **2150** curves for ease of placement beyond the carina **1340** into the left main stem bronchi **1330**. In this placement, ventilation of the left lung or the right lung can be accomplished without having to move the lumen endobronchial tube. Placement of the lumen endobronchial tube can be performed with or without fiberoptic visualization. Although **FIG. 30** shows the lumen endobronchial tube being inserted through the mouth of the patient, it should be understood that the lumen endobronchial tube can also be inserted through the nasal passages into the airway passage. Once proper positioning of the lumen endobronchial tube in the pulmonary airway is determined, the bronchial cuff **2152** is inflated to a desired pressure by pushing a fluid such as air or saline through the pilot tube **2252** leading to the bronchial cuff **2152**. In an embodiment, the bronchial cuff **2152** is inflated so that the bronchial cuff pressure (BCP) is in the range of about 15 cm H_2O (about 11 mm Hg) to about 30 cm H_2O (about 22 mm Hg). The first tracheal cuff **2132** is inflated by pushing a fluid such as air or saline through the pilot tube **2232** leading to the first tracheal cuff **2132**. The second tracheal cuff **2172** is inflated by pushing a fluid such as air or saline through the pilot tube **2272** leading to the second tracheal cuff **2172**. In an embodiment, the first tracheal cuff **2132** and the second tracheal cuff **2172** are inflated so that the cuff pressure is in the range of about 15 cm H_2O (about 11 mm Hg) to about 30 cm H_2O (about 22 mm Hg). The seal formed by the inflated tracheal cuffs **2132** and **2172** are adapted to substantially provide a seal between the outside of the lumen endobronchial tube and the interior of the trachea **1320** in which the tube **2100** is inserted. The desired agent(s) are then introduced, for example from an anesthesia machine, through the lumen **2160** of the tube **2100** to deliver the desired agent(s) to the left lung **1300**. The closed space between the first tracheal cuff

2132 and the second tracheal cuff **2172** is adapted to block entry of the desired agent(s) to the right lung **1400**. If the desired agent(s) are to be delivered into the right lung **1400** and not the left lung **1300**, the procedure can proceed as follows: the second tracheal cuff **2172** is deflated, and the distal intraluminal balloon blocker **2162** is inflated by pushing a fluid such as air or saline through the pilot tube **2262** leading to the distal intraluminal balloon blocker **2162**. In an embodiment, the distal intraluminal balloon blocker **2162** is inflated so that the cuff pressure is in the range of about 20 cm H_2O (about 14.7 mm Hg) to about 95 cm H_2O (about 69 mm Hg). The inflated distal intraluminal balloon blocker seals the lumen **2160** of the tube **2100** distal to the inflated distal intraluminal balloon blocker **2162** such that sufficient blockage of the agents to the left lung **1300** is achieved.

It is also contemplated that in an alternative embodiment of the single lumen endobronchial tube, the distal intraluminal balloon blocker **2162** (as well as the other co-dependent components of the distal intraluminal balloon blocker **2162** including the pilot tube **2262**, the non-return valve **2260** and the pilot balloon **2264**) are absent. In such an embodiment, a conventional endobronchial blocker can be used to block ventilation of the left main stem bronchi.

FIG. 31 shows an embodiment of a single lumen endobronchial tube **3100** of the present disclosure. The single lumen endobronchial tube **3100** is a medical tube having a proximal end **3102**, a distal end **3104**, and a primary flow passage or lumen **3160** passing therebetween. The distal end **3104** of the tube **3100** has a bronchial opening **3140**. In an embodiment, the bronchial opening **3140** is smooth and beveled, thus minimizing risk of tracheal intubation airway trauma. The distal end **3104** of the tube **3100** can optionally include a Murphy eye **3142**, which is a distal opening in a wall **3110** and through an outer surface **3101** of the tube **3100** which can allow airflow in the event of the bronchial opening **3140** lying against the tracheal wall or being obstructed in other ways. Located at the proximal end **3102** of the tube **3100** is an opening **3145** sufficiently designed to connect with a mechanical ventilation device, including, but not limited to, an anesthesia machine or a PAP machine, with or without the use of an adaptor. The tube **3100** includes a tracheal portion **3130** and a bronchial portion **3150**. The tube **3100** may be made from a flexible material including, but not limited to, latex, silicone, polyvinyl chloride (PVC), polyurethane (PU), polytetrafluoroethylene or a similar material that has met the American National Standard for Anesthetic Equipment; ANSI Z-79 standard and implant-tested to ensure

nontoxicity. In an embodiment, the tube **3100** is made from a non-toxic, clear, PVC material. In an embodiment, the tracheal portion **3130** is adapted to follow the natural contour of a patient's trachea, and the bronchial portion **3150** is adapted to follow the natural contour of a patient's left main stem bronchi. In an embodiment, to facilitate passage of the bronchial portion **150** into the left main stem bronchi, the tube **3100** is curved or bent and resembles the shape of a hockey stick. In an embodiment, the angle of the bend is about 45°. The lumen **3160** of the tube **3100** is sized and dimensioned to allow other instrumentation to pass through the lumen **3160** as required. The removal of mucous, the injection of medication, or the insertion of fiberoptic scopes for viewing within the tube **3100** are examples of the additional instrumentation capability which is afforded by the tube **3100**. In an embodiment, the single lumen endobronchial tube **3100** may be referred to as a left-sided single lumen endobronchial tube.

A tracheal cuff **3132** and a bronchial cuff **3152** are spaced longitudinally along an exterior surface of the tracheal portion **3130** and the bronchial portion **3150**, respectively. In an embodiment, the tracheal cuff **3132** and the bronchial cuff **3152** are thin walled, high volume low pressure (HVLP) balloon-like members sealed from fluid communication with the tube **3100** and adapted not to compromise the blood flow in the tracheal or bronchial wall when inflated. The tracheal cuff **3132** and the bronchial cuff **3152** are shown in an expanded state in **FIG. 31**. In an embodiment, the balloon-like members are spherical or elliptical in shape, although any desired shape is possible and within the scope and spirit of the present disclosure. In an embodiment, the walls of the tracheal cuff **3132** and the bronchial cuff **3152** are on the order of about 5 μm to about 500 μm, about 5 μm to about 250 μm, about 5 μm to about 100 μm, about 5 μm to about 50 μm, about 5 μm and about 20 μm, about 5 μm and about 15 μm. It is also contemplated that the walls may have a thickness of less than about 5 μm. Additionally, although the thickness of the walls may vary, it is desirable that the thickness of the material remain consistent throughout the cuff. A distal intraluminal balloon blocker **3162** adapted to inflate and deflate is positioned along an inner surface of the tube **3100** and when inflated acts to block flow by blocking ventilation to the left main stem bronchus. In an embodiment, the distal intraluminal balloon blocker **3162** is a low volume high pressure member. In an embodiment, the member is spherical or elliptical in shape, although any desired shape is possible and within the scope and spirit of the present disclosure.

The tracheal cuff **3132**, the bronchial cuff **3152**, and the distal intraluminal balloon blocker **3162** are each remotely and selectively inflatable through pilot tubes **3232**, **3252** and **3262**, respectively, running longitudinally through the wall **3110** of the tube **3100**. The wall **3110** has an internal wall surface, an external wall surface and a thickness therebetween. Each pilot tube **3232**, **3252** and **3262** emerges from the outer surface **3101** of the tube **3100** near the proximal end **3102** of the tube **3100**. Attached to a proximal end of each pilot tube **3232**, **3252** and **3262** is a non-return valve **3230**, **3250** and **3260** which is adapted to receive the nozzle of a syringe (not visible) and a complementary indicator bladder **3234**, **3254** and **3264** which enables an anesthesiologist to confirm that each of the tracheal cuff **3132**, the bronchial cuff **3152**, and the distal intraluminal balloon blocker **3162** has been inflated or deflated. The non-return valves **3230**, **3250** and **3260** may be attached to a syringe for injecting a predetermined quantity of air. Various materials may be used to form the tracheal cuff **3132**, the bronchial cuff **3152** and the distal intraluminal balloon blocker **3162**. These materials include, but are not limited to, polyurethane (PU), low-density polyethylene (LDPE), polyvinyl chloride (PVC), silicone, neoprene, polyisoprene, polyamid (PA) or polyethylene teraphthalate (PETP). Additionally, copolymer admixtures for modifying the characteristics of the material may be used, for example a low density polyethylene and ethylene-vinylacetate copolymer (LDPE-EVA), or blends of the above mentioned materials (e.g. PU with PVC or PU with PA) would be considered suitable for forming the tracheal cuff **3132**, the bronchial cuff **3152** and the distal intraluminal balloon blocker **3162**. It is also contemplated that in an alternative embodiment of the single lumen endobronchial tube, the distal intraluminal balloon blocker **3162** (as well as the other co-dependent components of the distal intraluminal balloon blocker **3162** including the pilot tube **3262**, the non-return valve **3260** and the pilot balloon **3264**) are absent. In such an embodiment, a conventional endobronchial blocker can be used to block ventilation of the left main stem bronchi.

An aperture **3170** is provided through the wall **3110** of the tube **3100** between the tracheal balloon cuff **3132** and the bronchial balloon cuff **3152**. The aperture **3170** can be of any shape or size. In an embodiment, the aperture **3170** is dimensioned so that a fiberoptic scope can pass through the aperture **3170**. An expandable balloon **3400** is sufficiently designed to seal the aperture **3170**. The expandable balloon **3400** is adapted to control the amount of medical gas passing through the aperture **3170**. In an embodiment, the expandable balloon **3400** is adapted to

completely close and seal the aperture **3170** such that the amount of medical gas passing through the aperture **3170** from the lumen **3160** is 0%. The expandable balloon **3400** is shown in an expanded state in **FIG. 31**. As illustrated in **FIG. 32**, which is a cross-sectional plan view taken along line 32-32 of **FIG. 31**, when the expandable balloon **3400** is inflated, the expandable balloon **3400** is sufficiently designed to seal up against a trachea and the pressure inside the expandable balloon **3400** keeps the aperture **3170** closed. The expandable balloon **3400** closes the aperture **3170** yet does not herniate into the lumen **3160** of the tube **3100**. If the expandable balloon **3400** inflates from the distal border of the aperture **3170** (as illustrated in **FIG. 34**) conceivably any air leakage from the aperture **3170** would get trapped in a tracheal space formed by the tracheal cuff **3132** and the expandable balloon **3400**. In an embodiment, the expandable balloon **3400** is a thin walled, high volume low pressure (HVLP) member sealed from fluid communication with the tube **3100** and adapted not to compromise the blood flow in the tracheal or bronchial wall when inflated. In an embodiment, the expandable balloon **3400** is spherical or elliptical in shape, although any desired shape is possible and within the scope and spirit of the present disclosure. In an embodiment, the walls of the expandable balloon **3400** are on the order of about 5 μm to about 500 μm, about 5 μm to about 250 μm, about 5 μm to about 100 μm, about 5 μm to about 50 μm, about 5 μm and about 20 μm, about 5 μm and about 15 μm. It is also contemplated that the walls may have a thickness of less than about 5 μm. Additionally, although the thickness of the walls may vary, it is desirable that the thickness of the material remain consistent throughout the cuff. In an embodiment, the expandable balloon **3400** is remotely controlled through a pilot tube **3272** running longitudinally through the wall **3110** of the tube (see **FIG. 32**). The pilot tube **3272** emerges from the outer surface **3101** near the proximal end **3102** of the tube **3100**. Attached to a proximal end of the pilot tube **3272** is a non-return valve **3270** which is adapted to receive the nozzle of a syringe (not visible), and an indicator bladder **3274** which enables an anesthesiologist to confirm that the expandable balloon **3400** has been inflated to close or seal the aperture **3170**. The non-return valve **3270** may be attached to a syringe for injecting a predetermined quantity of air, saline or any other fluid.

In some embodiments, the single lumen endobrochial tube is adapted for use with a PAP machine. In such embodiments, conduits run longitudinally through the wall **3110** of the tube **3100** to deliver gas to a patient at positive pressure in order to hold open alveoli that would normally close at the end of expiration. The tube **3100** can be manufactured to various sizes and

adapted to provide mechanical ventilation to an air-breathing animal in need thereof. In an embodiment, the tube **3100** is manufactured for human use and ranges in size from about 1.5 mm to about 11 mm in internal diameter (ID). In an embodiment, the tube **3100** is manufactured for human use and ranges in size from about 3 mm to about 10 mm in internal diameter (ID). In an embodiment, the tube **3100** is manufactured for non-human use and ranges in size from about 1.5 mm to about 40 mm in internal diameter (ID). In an embodiment, the tube **3100** is manufactured for non-human use and ranges in size from about 6 mm to about 40 mm in internal diameter (ID).

FIG. 33 in conjunction with **FIG. 34** shows cutaway side views of the expandable balloon **3400** adapted to control the amount of medical gas passing through the aperture **3170**. As illustrated in **FIG. 33**, the expandable balloon **3400** is in fluid communication with the pilot tube **3272**. By pushing fluid (such as air) through pilot tube **3272** the expandable balloon **3400** is inflated (as illustrated in **FIG. 34**). When the expandable balloon **3400** is inflated, the expandable balloon **3400** seals up against the trachea and the pressure keeps the aperture **3170** closed. The expandable balloon **3400** closes the aperture **3170** yet does not herniate into the lumen **3160** of the tube **3100**. If the expandable balloon **3400** inflates from the distal border of the aperture **3170** (as illustrated in **FIG. 34**) conceivably any air leakage from the aperture **3170** would get trapped in a tracheal space formed by the tracheal cuff **3132** and the expandable balloon **3400**. Although the embodiments illustrated in **FIG. 33** and **FIG. 34** show the expandable balloon **3400** positioned on the bottom outer boundary of the aperture **3170**, it should be understood that the balloon **3400** can be positioned on the right outer boundary of the aperture **3170**, the top outer boundary of the aperture **3170** or on the left outer boundary of the aperture **3170** and still be within the scope and spirit of the present disclosure.

Referring to **FIG. 35**, the single lumen endobronchial tube **3100** is positioned within a patient to facilitate artificial ventilation of the respiratory system. The single lumen endobronchial tube **3100** has been placed within a mouth of the patient and positioned such that the tracheal portion **3130** resides within the trachea **1320** and the bronchial portion **3150** resides within the left main stem bronchi **1330**. The tube **3100** may be sufficiently designed such that the bronchial portion **3150** curves for ease of placement beyond the carina **1340** into the left main stem bronchi **1330**. In this placement, ventilation of the left lung or the right lung can be accomplished without having to move the tube **3100**. Placement of the single lumen

endobronchial tube **3100** can be performed with or without fiberoptic visualization. Although **FIG. 35** shows the single lumen endobronchial tube **3100** being inserted through the mouth of the patient, it should be understood that the single lumen endobronchial tube **3100** can also be inserted through the nasal passages into the airway passage. Once proper positioning of the single lumen endobronchial tube **3100** in the pulmonary airway is determined, the bronchial cuff **3152** is inflated to a desired pressure by pushing a fluid such as air or saline through the pilot tube **3252** leading to the bronchial cuff **3152**. In an embodiment, the bronchial cuff **3152** is inflated so that the bronchial cuff pressure (BCP) is in the range of about 15 cm H_2O (about 11 mm Hg) to about 30 cm H_2O (about 22 mm Hg). The tracheal cuff **3132** is inflated by pushing a fluid such as air or saline through the pilot tube **3232** leading to the tracheal cuff **3132**. In an embodiment, the tracheal cuff **3132** is inflated so that the cuff pressure is in the range of about 15 cm H_2O (about 11 mm Hg) to about 30 cm H_2O (about 22 mm Hg). The seal formed by the inflated tracheal cuff **3132** is adapted to substantially provide a seal between the outside of the tube **3100** and the interior of the trachea **1320** in which the tube **3100** is inserted. The expandable balloon **3400** is inflated by pushing a fluid such as air or saline through the pilot tube **3272** leading to the expandable balloon **3400**. When the expandable balloon **3400** is inflated, the expandable balloon **3400** seals up against the trachea **1320** and the pressure keeps the aperture **3170** closed. In an embodiment, the expandable balloon **3400** closes the aperture **3170** without herniating into the lumen **3160** of the tube **3100**. When the expandable balloon **3400** inflates from the distal border of the aperture **3170** (as illustrated in **FIG. 34**) any air that may leak from the aperture **3170** would get trapped in a tracheal space formed by the tracheal cuff **3132** and the expandable balloon **3400**. The desired agent(s) are then introduced, for example from an anesthesia machine, through the lumen **3160** of the tube **3100** to deliver the desired agent(s) to the left lung **1300**. The closed space between the tracheal cuff **3132** and the expandable balloon **3400** is adapted to block entry of the desired agent(s) to the right lung **1400**. If the desired agent(s) are to be delivered into the right lung **1400** and not the left lung **1300**, the procedure can proceed as follows: the expandable balloon **3400** is deflated, and the distal intraluminal balloon blocker **3162** is inflated by pushing a fluid such as air or saline through the pilot tube **3262** leading to the distal intraluminal balloon blocker **3162**. In an embodiment, the distal intraluminal balloon blocker **3162** is inflated so that the cuff pressure is in the range of about 20 cm H_2O (about 14.7 mm Hg) to about 95 cm H_2O (about 69 mm Hg). The inflated distal intraluminal

balloon blocker seals the lumen **3160** of the tube **3100** distal to the inflated distal intraluminal balloon blocker **3162** such that sufficient blockage of the agents to the left lung **1300** is achieved.

Endobronchial tube displacement may result in life-threatening complications and continuous direct vision of the position of the endobronchial tube may enable safer management. In an embodiment, any of the single lumen endobronchial tubes disclosed herein may further include a built-in video camera having an optional built-in light source. The video camera is connected to a monitor via a cable that runs longitudinally through the wall of the tube. The video camera and cable are embedded within the common tube wall. In an embodiment, the view from the video camera appears continuously on the monitor in the anaesthetist's vicinity. In an embodiment, the video camera terminates at a location that is distal to the aperture that is provided through the wall of the tube between the tracheal balloon cuff and the bronchial balloon cuff. The placement of the video camera at this location may provide for a better view of the carina of the trachea, the cartilaginous ridge within the trachea that runs anteroposteriorly between the two primary bronchi at the site of the tracheal bifurcation at the lower end of the trachea. This may help ensure that the bronchial portion of the single lumen endobronchial tube is positioned below the carina. In embodiments where the single lumen endobronchial tube includes a built-in video camera, it may not be necessary to use a fiberoptic scope during placement, use, or removal of the tube.

FIG. 36 in conjunction with **FIG. 37** shows an embodiment of a single lumen endobronchial tube **4100** of the present disclosure. The single lumen endobronchial tube **4100** is a medical tube that includes a built-in video camera **4300** having an optional built-in light source. The video camera **4300** is connected to a monitor **4350** via a cable **4332** that runs longitudinally through the wall **4110** of the tube **4100**. The video camera **4300** and cable **4332** are embedded within the common tube wall **4110**. In an embodiment, the view from the video camera **4300** appears continuously on the monitor **4350** in the anaesthetist's vicinity. The single lumen endobronchial tube **4100** has a proximal end **4102**, a distal end **4104**, and a primary flow passage or lumen **4160** passing therebetween. The distal end **4104** of the tube **4100** has a bronchial opening **4140**. In an embodiment, the bronchial opening **4140** is smooth and beveled, thus minimizing risk of tracheal intubation airway trauma. The distal end **4104** of the tube **4100** can optionally include a Murphy eye **4142**, which is a distal opening in a wall **4110** and through an outer surface **4101** of the tube **4100** which can allow airflow in the event of the bronchial

opening **4140** lying against the tracheal wall or being obstructed in other ways. Located at the proximal end **4102** of the tube **4100** is an opening **4145** sufficiently designed to connect with a mechanical ventilation device, including, but not limited to, an anesthesia machine or a PAP machine, with or without the use of an adaptor. The tube **4100** includes a tracheal portion **4130** and a bronchial portion **4150**. The tube **4100** may be made from a flexible material including, but not limited to, latex, silicone, polyvinyl chloride (PVC), polyurethane (PU), polytetrafluoroethylene or a similar material that has met the American National Standard for Anesthetic Equipment; ANSI Z-79 standard and implant-tested to ensure nontoxicity. In an embodiment, the tube **4100** is made from a non-toxic, clear, PVC material. In an embodiment, the tracheal portion **4130** is adapted to follow the natural contour of a patient's trachea, and the bronchial portion **4150** is adapted to follow the natural contour of a patient's left main stem bronchi. In an embodiment, to facilitate passage of the bronchial portion **4150** into the left main stem bronchi, the tube **4100** is curved or bent and resembles the shape of a hockey stick. In an embodiment, the angle of the bend is about 45°. The lumen **4160** of the tube **4100** is sized and dimensioned to allow other instrumentation to pass through the lumen **4160** as required. The removal of mucous, the injection of medication, or the insertion of fiberoptic scopes for viewing within the tube **4100** are examples of the additional instrumentation capability which is afforded by the tube **4100**. In an embodiment, the single lumen endobronchial tube **4100** may be referred to as a left-sided single lumen endobronchial tube.

A tracheal cuff **4132** and a bronchial cuff **4152** are spaced longitudinally along an exterior surface of the tracheal portion **4130** and the bronchial portion **4150**, respectively. In an embodiment, the tracheal cuff **4132** and the bronchial cuff **4152** are thin walled, high volume low pressure (HVLP) balloon-like members sealed from fluid communication with the tube **4100** and adapted not to compromise the blood flow in the tracheal or bronchial wall when inflated. The tracheal cuff **4132** and the bronchial cuff **4152** are shown in an expanded state in **FIG. 36**. In an embodiment, the balloon-like members are spherical or elliptical in shape, although any desired shape is possible and within the scope and spirit of the present disclosure. In an embodiment, the walls of the tracheal cuff **4132** and the bronchial cuff **4152** are on the order of about 5 μm to about 500 μm, about 5 μm to about 250 μm, about 5 μm to about 100 μm, about 5 μm to about 50 μm, about 5 μm and about 20 μm, about 5 μm and about 15 μm. It is also contemplated that the walls may have a thickness of less than about 5 μm. Additionally, although

the thickness of the walls may vary, it is desirable that the thickness of the material remain consistent throughout the cuff. A distal intraluminal balloon blocker **4162** adapted to inflate and deflate is positioned along an inner surface of the tube **4100** and when inflated acts to block flow by blocking ventilation to the left main stem bronchus. In an embodiment, the distal intraluminal balloon blocker **4162** is a low volume high pressure member. In an embodiment, the member is spherical or elliptical in shape, although any desired shape is possible and within the scope and spirit of the present disclosure.

The tracheal cuff **4132**, the bronchial cuff **4152**, and the distal intraluminal balloon blocker **4162** are each remotely and selectively inflatable through pilot tubes **4232**, **4252** and **2624**, respectively, running longitudinally through the wall **4110** of the tube **4100** as shown in **FIG. 37**. The wall **4110** has an internal wall surface, an external wall surface and a thickness therebetween. Each pilot tube **4232**, **4252** and **4262** emerges from the outer surface **4101** of the tube **4100** near the proximal end **4102** of the tube **4100**. The cable **4232** also emerges from the outer surface **4101** of the tube **4100** near the proximal end **4102** of the tube **4100**. Attached to a proximal end of each pilot tube **4232**, **4252** and **4262** is a non-return valve **4230**, **4250** and **4260** which is adapted to receive the nozzle of a syringe (not visible) and a complementary indicator bladder **4234**, **4254** and **4264** which enables an anesthesiologist to confirm that each of the tracheal cuff **4132**, the bronchial cuff **4152**, and the distal intraluminal balloon blocker **4162** has been inflated or deflated. The non-return valves **4230**, **4250** and **4260** may be attached to a syringe for injecting a predetermined quantity of air. Various materials may be used to form the tracheal cuff **4132**, the bronchial cuff **4152** and the distal intraluminal balloon blocker **4162**. These materials include, but are not limited to, polyurethane (PU), low-density polyethylene (LDPE), polyvinyl chloride (PVC), silicone, neoprene, polyisoprene, polyamid (PA) or polyethylene teraphthalate (PETP). Additionally, copolymer admixtures for modifying the characteristics of the material may be used, for example a low density polyethylene and ethylene-vinylacetate copolymer (LDPE-EVA), or blends of the above mentioned materials (e.g. PU with PVC or PU with PA) would be considered suitable for forming the tracheal cuff **4132**, the bronchial cuff **4152** and the distal intraluminal balloon blocker **4162**. It is also contemplated that in an alternative embodiment of the single lumen endobronchial tube, the distal intraluminal balloon blocker **4162** (as well as the other co-dependent components of the distal intraluminal balloon blocker **4162** including the pilot tube **4262**, the non-return valve **4260** and the pilot

balloon **4264**) are absent. In such an embodiment, a conventional endobronchial blocker can be used to block ventilation of the left main stem bronchi.

An aperture **4170** is provided through the wall **4110** of the tube **4100** between the tracheal balloon cuff **4132** and the bronchial balloon cuff **4152**, as best illustrated in **FIG. 36**. The aperture **4170** can be of any shape or size. In an embodiment, the aperture **4170** is dimensioned so that a fiberoptic scope can pass through the aperture **170**. The amount of medical gas passing through the aperture **4170** can be controlled using any of the mechanisms described above with reference to **FIGS. 4-26**. In an embodiment, the components of the mechanism are adapted to completely close and seal the aperture **4170** such that the amount of medical gas passing through the aperture **4170** from the lumen **4160** is 0%. In an embodiment, the components of the mechanism are adapted to partially close the aperture **4170** such that the amount of medical gas passing through the aperture **4170** from the lumen **4160** is greater than 0% but less than 100%.

In some embodiments, the single lumen endobronchial tube **4100** is adapted for use with a PAP machine. In such embodiments, conduits **4282** and **4292** (see **FIG. 36**) run longitudinally through the wall **4110** of the tube **4100** to deliver gas to a patient at positive pressure in order to hold open alveoli that would normally close at the end of expiration. The tube **4100** can be manufactured to various sizes and adapted to provide mechanical ventilation to an air-breathing animal in need thereof. In an embodiment, the tube **4100** is manufactured for human use and ranges in size from about 1.5 mm to about 11 mm in internal diameter (ID). In an embodiment, the tube **4100** is manufactured for human use and ranges in size from about 3 mm to about 10 mm in internal diameter (ID). In an embodiment, the tube **4100** is manufactured for non-human use and ranges in size from about 1.5 mm to about 40 mm in internal diameter (ID). In an embodiment, the tube **4100** is manufactured for non-human use and ranges in size from about 6 mm to about 40 mm in internal diameter (ID).

Referring to **FIG. 38**, the single lumen endobronchial tube **4100** is positioned within a patient to facilitate artificial ventilation of the respiratory system. The single lumen endobronchial tube **4100** has been placed within a mouth of the patient and positioned such that the tracheal portion **4130** resides within the trachea **1320** and the bronchial portion **4150** resides within the left main stem bronchi **1330**. The tube **4100** may be sufficiently designed such that the

bronchial portion **4150** curves for ease of placement beyond the carina **1340** into the left main stem bronchi **1330**. In this placement, ventilation of the left lung or the right lung can be accomplished without having to move the tube **4100**. Placement of the single lumen endobronchial tube **4100** can be performed with the aid of the video camera **4300** and monitor **4350**. Although **FIG. 38** shows the single lumen endobronchial tube **4100** being inserted through the mouth of the patient, it should be understood that the single lumen endobronchial tube **4100** can also be inserted through the nasal passages into the airway passage. For one-lung ventilation of the right lung **1400**, the aperture **4170** remains open, which sufficiently allows the flow of medical gases through the aperture **4170** and into the right lung. Once proper positioning of the single lumen endobronchial tube **4100** in the pulmonary airway is determined, the bronchial cuff **4152** is inflated to a desired pressure by pushing a fluid such as air or saline through the pilot tube **4252** leading to the bronchial cuff **4152**. In an embodiment, the bronchial cuff **4152** is inflated so that the bronchial cuff pressure (BCP) is in the range of about 15 cm H_2O (about 11 mm Hg) to about 30 cm H_2O (about 22 mm Hg). The tracheal cuff **4132** is inflated by pushing a fluid such as air or saline through the pilot tube **4232** leading to the tracheal cuff **4132**. In an embodiment, the tracheal cuff **4132** is inflated so that the cuff pressure is in the range of about 15 cm H_2O (about 11 mm Hg) to about 30 cm H_2O (about 22 mm Hg). The seal formed by the inflated tracheal cuff **4132** is adapted to substantially provide a seal between the outside of the tube **4100** and the interior of the trachea **1320** in which the single lumen endobronchial tube **4100** is inserted. The distal intraluminal balloon blocker **4162** is inflated by pushing a fluid such as air or saline through the pilot tube **4262** leading to the distal intraluminal balloon blocker **4162**. In an embodiment, the distal intraluminal balloon blocker **4162** is inflated so that the cuff pressure is in the range of about 20 cm H_2O (about 14.7 mm Hg) to about 95 cm H_2O (about 69 mm Hg). The desired agent(s) are then introduced, for example from an anesthesia machine, through the lumen **4160** of the tube **4100** to deliver the desired agent(s) to the right lung **1400**. The inflated distal intraluminal balloon blocker seals the lumen **4160** of the tube **4100** distal to the inflated distal intraluminal balloon blocker **4162** such that sufficient blockage of the agents to the left lung **1300** is achieved.

For one-lung ventilation of the left lung **1300,** the single lumen endobronchial tube **4100** is placed in the pulmonary airway of a patient such that the tracheal portion **4130** resides within the trachea **1320** and the bronchial portion **4150** resides within the left main stem bronchi **1330**.

The tube **4100** may be sufficiently designed such that the bronchial portion **4150** curves for ease of placement beyond the carina **1340** into the left main stem bronchi **1330**. Placement of the single lumen endobronchial tube **4100** can be performed with the aid of the video camera **4300** and monitor **4350**. For one-lung ventilation of the left lung, the aperture **4170** is sealed to sufficiently preclude the flow of medical gases through the aperture **4170** and into the right lung. Once proper positioning of the single lumen endobronchial tube **4100** in the pulmonary airway is determined, the endobronchial cuff **4152** is inflated to a desired pressure by pushing a fluid such as air or saline through the pilot tube **4252** leading to the bronchial cuff **4152**. In an embodiment, the bronchial cuff **4152** is inflated so that the cuff pressure is in the range of about 15 cm H_2O (about 11 mm Hg) to about 30 cm H_2O (about 22 mm Hg). The seal formed by the inflated bronchial cuff **4152** is adapted to preclude any medical gas that has been forced into the patient's left lung from escaping through the left main stem bronchi **1330** into the trachea **1320**. The endotracheal cuff **4132** is inflated by pushing a fluid such as air or saline through the pilot tube **4232** leading to the tracheal cuff **4132**. In an embodiment, the tracheal cuff **4132** is inflated so that the bronchial cuff pressure (BCP) is in the range of about 15 cm H_2O (about 11 mm Hg) to about 30 cm H_2O (about 22 mm Hg). The seal formed by the inflated tracheal cuff **4132** is adapted to substantially provide a seal between the outside of the tube **4100** and the interior of the trachea **1320** in which the single lumen endobronchial tube **4100** is inserted. The desired agent(s) are then introduced, for example from an anesthesia machine, through the lumen **4160** of the tube **4100** to deliver the desired agent(s) to the left lung **1300**.

In an embodiment, a single lumen endobronchial tube of the present disclosure can be used in general anesthesia, intensive care, and emergency medicine for airway management and mechanical ventilation. In an embodiment, a single lumen endobronchial tube of the present disclosure can be used during any procedure where lung separation is necessary to isolate and selectively ventilate a single lung, including, but not limited to, thoracic surgical procedures, lung abscess surgical procedures, and pulmonary hemorrhage surgical procedures. In some embodiments, a single lumen endobronchial tube of the present disclosure is used with a BiPAP machine. In some embodiments, a single lumen endobronchial tube of the present disclosure is used with a CPAP machine. In such embodiments, the proximal end of the medical tube is connected to the PAP machine such that compressed air is delivered directly to the pulmonary airway of a patient. Use of a single lumen endobronchial tube of the present disclosure in

conjunction with a CPAP machine may be useful in treating or preventing various conditions in patients, including, but not limited to, obstructive sleep apnea and respiratory failure.

In some embodiments, a single lumen endobronchial tube of the present disclosure is used with an anesthesia machine. In such embodiments, the proximal end of the medical tube is connected to the anesthesia machine such that medical gases are delivered to the pulmonary airway of an air-breathing animal. Use of a single lumen endobronchial tube of the present disclosure in conjunction with an anesthesia machine may be useful to support the administration of anesthesia to the animal.

A method of selective left lung bronchial occlusion for right lung ventilation of a patient includes inserting a single lumen endobronchial tube into the pulmonary airway of a patient, the tube having: a lumen extending throughout the tube's entire length with an opening at each of opposed distal and proximal ends of the tube, the opening at the proximal end of the tube being adapted for connection to an external mechanical ventilation device, and the opening at the distal end of the tube being adapted for delivery of a medical gas; a wall extending throughout the tube's entire length having an internal wall surface, an external wall surface and a thickness therebetween, a portion of the wall having an aperture and a shaft adapted to house a mechanism for sealing the aperture; a distal bronchial cuff positioned along the external wall surface and adapted to expand radially outward; a proximal tracheal cuff positioned along the external wall surface and adapted to expand radially outward; and a distal intraluminal balloon blocker at a respective distal location relative to the aperture; positioning the tube in the pulmonary airway such that the distal bronchial cuff is in the left main stem bronchus, and the proximal tracheal cuff is in the trachea; inflating the distal bronchial cuff radially outwardly to seal against the surrounding bronchus of the left lung; inflating the proximal tracheal cuff radially outwardly to seal against the surrounding trachea of the patient; inflating the distal intraluminal balloon blocker radially outwardly to occlude the lumen of the tube and thereby effectively occlude the left lung, whereby an airway from the ventilation device to the patient's right lung is maintained via the aperture.

A method of selective right lung bronchial occlusion for left lung ventilation of a patient includes inserting a single lumen endobronchial tube into the pulmonary airway of a patient, the tube having: a lumen extending throughout the tube's entire length with an opening at each of

opposed distal and proximal ends of the tube, the opening at the proximal end of the tube being adapted for connection to an external mechanical ventilation device, and the opening at the distal end of the tube being adapted for delivery of a medical gas; a wall extending throughout the tube's entire length having an internal wall surface, an external wall surface and a thickness therebetween, a portion of the wall having an aperture and a shaft adapted to house a mechanism for sealing the aperture; a distal bronchial cuff positioned along the external wall surface and adapted to expand radially outward; a proximal tracheal cuff positioned along the external wall surface and adapted to expand radially outward; and a distal intraluminal balloon blocker at a respective distal location relative to the aperture; positioning the tube in the pulmonary airway such that the distal bronchial cuff is in the left main stem bronchus, and the proximal tracheal cuff is in the trachea; inflating the distal bronchial cuff radially outwardly to seal against the surrounding bronchus of the left lung; inflating the proximal tracheal cuff radially outwardly to seal against the surrounding trachea of the patient; and sealing the aperture by activating the mechanism housed in the shaft of the wall of the tube to block the aperture and thereby effectively occlude the right lung, whereby an airway from the ventilation device to the patient's left lung is maintained via the opening at the distal end of the tube.

A method for one-lung ventilation of a lung of an air-breathing animal includes providing a single lumen endobronchial tube, the single lumen endobronchial tube comprising a medical tube having a single lumen with an opening at each of opposed distal and proximal ends of the tube, the opening at the proximal end of the tube being adapted for connection to an external mechanical ventilation device, and the opening at the distal end of the tube being adapted for delivery of a medical gas; a wall extending throughout the tube's entire length having an internal wall surface, an external wall surface and a thickness therebetween, a portion of the wall having an aperture and a shaft adapted to house a mechanism for sealing the aperture; a distal bronchial cuff positioned along the external wall surface and adapted to expand radially outward; at least a first proximal tracheal cuff positioned along the external wall surface and adapted to expand radially outward; and a distal intraluminal balloon blocker at a respective distal location relative to the aperture; positioning the single lumen endobronchial tube in the pulmonary airway of the animal such that the distal bronchial cuff is in the left main stem bronchus, and the first proximal tracheal cuff is in the trachea, wherein a distal end of the medical tube is positioned beyond the carina of the animal; connecting the proximal end of the medical tube to the external mechanical

ventilation device; inflating the distal bronchial cuff radially outwardly to seal against the surrounding bronchus of the left lung; inflating the proximal tracheal cuff radially outwardly to seal against the surrounding trachea of the animal; and performing a step selected from one of inflating the distal intraluminal balloon blocker radially outwardly to occlude the lumen of the tube and thereby effectively occlude the left lung, whereby an airway from the ventilation device to the animal's right lung is maintained via the aperture or sealing the aperture by activating the mechanism housed in the shaft of the wall of the tube to block the aperture and thereby effectively occlude the right lung, whereby an airway from the ventilation device to the anima's left lung is maintained via the opening at the distal end of the tube.

All patents, patent applications, and published references cited herein are hereby incorporated by reference in their entirety. It will be appreciated that various of the above-disclosed and other features and functions, or alternatives thereof, may be desirably combined into many other different systems or applications. Various presently unforeseen or unanticipated alternatives, modifications, variations, or improvements therein may be subsequently made by those skilled in the art which are also intended to be encompassed by the following claims.

CLAIMS

What is claimed is:

1. A single lumen endobronchial tube adapted for isolating a first lung of a patient and ventilating a second lung of the patient comprising:

a medical tube comprising a tracheal portion and a bronchial portion having a common single lumen and a common tube wall thickness, wherein a proximal end of the tracheal portion includes an opening adapted for connection to an external mechanical ventilation device, and wherein a distal end of the bronchial portion includes an opening adapted for delivery of a medical gas;

at least a first tracheal inflatable cuff positioned around an external surface of the tracheal portion and adapted to expand radially outward sealing against the trachea of the patient;

a bronchial inflatable cuff positioned around an external surface of the bronchial portion and adapted to expand radially outward against the left main stem bronchi of the patient;

an aperture positioned between the tracheal portion and the bronchial portion and adapted to deliver an amount of medical gas to the secondlung of the patient; and

a mechanism positioned within the wall of the tube, the mechanism adapted to control the amount of medical gas passing through the aperture.

2. The endobronchial tube of claim 1 wherein the mechanism is positioned within a shaft of the common tube wall and includes a door portion moveable over the aperture to control the amount of medical gas passing through the aperture.

3. The endobronchial tube of claim 1 wherein the mechanism is positioned within a shaft of the common tube wall and includes a balloon expandable over the aperture to control the amount of medical gas passing through the aperture.

4. The endobronchial tube of claim 1 further comprising a distal intraluminal balloon blocker adapted to expand radially outward sealing the common single lumen.

5. The endobronchial tube of claim 4 wherein the distal intraluminal balloon blocker is a low volume high pressure member.

6. The endobronchial tube of claim 4 wherein the tracheal inflatable cuff, the bronchial inflatable cuff and the distal intraluminal balloon blocker are each remotely and selectively inflatable.

7. The endobronchial tube of claim 1 further comprising a second tracheal inflatable cuff positioned around an external surface of the tracheal portion and adapted to expand radially outward at a respective distal location relative to the aperture.

8. The endobronchial tube of claim 1 further comprising a built-in video camera embedded within the common tube wall.

9. A single lumen endobronchial tube comprising:

a medical tube comprising a single lumen with an opening at each of opposed distal and proximal ends of the tube, the opening at the proximal end of the tube being adapted for connection to an external mechanical ventilation device, and the opening at the distal end of the tube being adapted for delivery of a medical gas;

a wall extending throughout the tube's entire length having an internal wall surface, an external wall surface and a thickness therebetween, a portion of the wall having an aperture and a shaft adapted to house a mechanism for sealing the aperture;

a distal bronchial cuff positioned along the external wall surface and adapted to expand radially outward; and

at least a first proximal tracheal cuff positioned along the external wall surface and adapted to expand radially outward.

10. The endobronchial tube of claim 9 wherein the mechanism includes a door portion moveable over the aperture to control the amount of medical gas passing through the aperture.

11. The endobronchial tube of claim 9 wherein the mechanism includes a balloon expandable over the aperture to control the amount of medical gas passing through the aperture.

12. The endobronchial tube of claim 9 further comprising a distal intraluminal balloon blocker adapted to expand radially outward sealing the lumen.

13. The endobronchial tube of claim 12 wherein the tracheal inflatable cuff, the bronchial inflatable cuff and the distal intraluminal balloon blocker are each remotely and selectively inflatable.

14. The endobronchial tube of claim 9 further comprising a second tracheal inflatable cuff positioned around an external surface of the tracheal portion and adapted to expand radially outward at a respective distal location relative to the aperture.

15. The endobronchial tube of claim 9 further comprising a built-in video camera embedded within the common tube wall.

16. A method for one-lung ventilation of a lung of an air-breathing animal comprising:

providing a single lumen endobronchial tube, the single lumen endobronchial tube comprising:

a medical tube having a single lumen with an opening at each of opposed distal and proximal ends of the tube, the opening at the proximal end of the tube being adapted for connection to an external mechanical ventilation device, and the opening at the distal end of the tube being adapted for delivery of a medical gas;

a wall extending throughout the tube's entire length having an internal wall surface, an external wall surface and a thickness therebetween, a portion of the wall having an aperture and a shaft adapted to house a mechanism for sealing the aperture;

a distal bronchial cuff positioned along the external wall surface and adapted to expand radially outward;

at least a first proximal tracheal cuff positioned along the external wall surface and adapted to expand radially outward; and

a distal intraluminal balloon blocker at a respective distal location relative to the aperture;

positioning the single lumen endobronchial tube in the pulmonary airway of the animal such that the distal bronchial cuff is in the left main stem bronchus, and the first proximal

tracheal cuff is in the trachea, wherein a distal end of the medical tube is positioned beyond the carina of the animal;

connecting the proximal end of the medical tube to the external mechanical ventilation device;

inflating the distal bronchial cuff radially outwardly to seal against the surrounding bronchus of the left lung;

inflating the proximal tracheal cuff radially outwardly to seal against the surrounding trachea of the animal; and performing a step selected from one of

inflating the distal intraluminal balloon blocker radially outwardly to occlude the lumen of the tube and thereby effectively occlude the left lung, whereby an airway from the ventilation device to the animal's right lung is maintained via the aperture, or

sealing the aperture by activating the mechanism housed in the shaft of the wall of the tube to block the aperture and thereby effectively occlude the right lung, whereby an airway from the ventilation device to the anima's left lung is maintained via the opening at the distal end of the tube.

17. The method of claim 16 wherein the air-breathing animal is a human and the medical tube has an internal diameter ranging from about 1.5 mm to about 11.0 mm.

18. The method of claim 16 wherein the air-breathing animal is a non-human and the medical tube has an internal diameter ranging from about 1.5 mm to about 40.0 mm.

19. The method of claim 16 wherein the single lumen endobronchial tube further comprises a built-in video camera embedded within the tube wall for real-time visualization of the method.

20. The method of claim 16 wherein the one-lung ventilation is performed during a thoracic procedure.

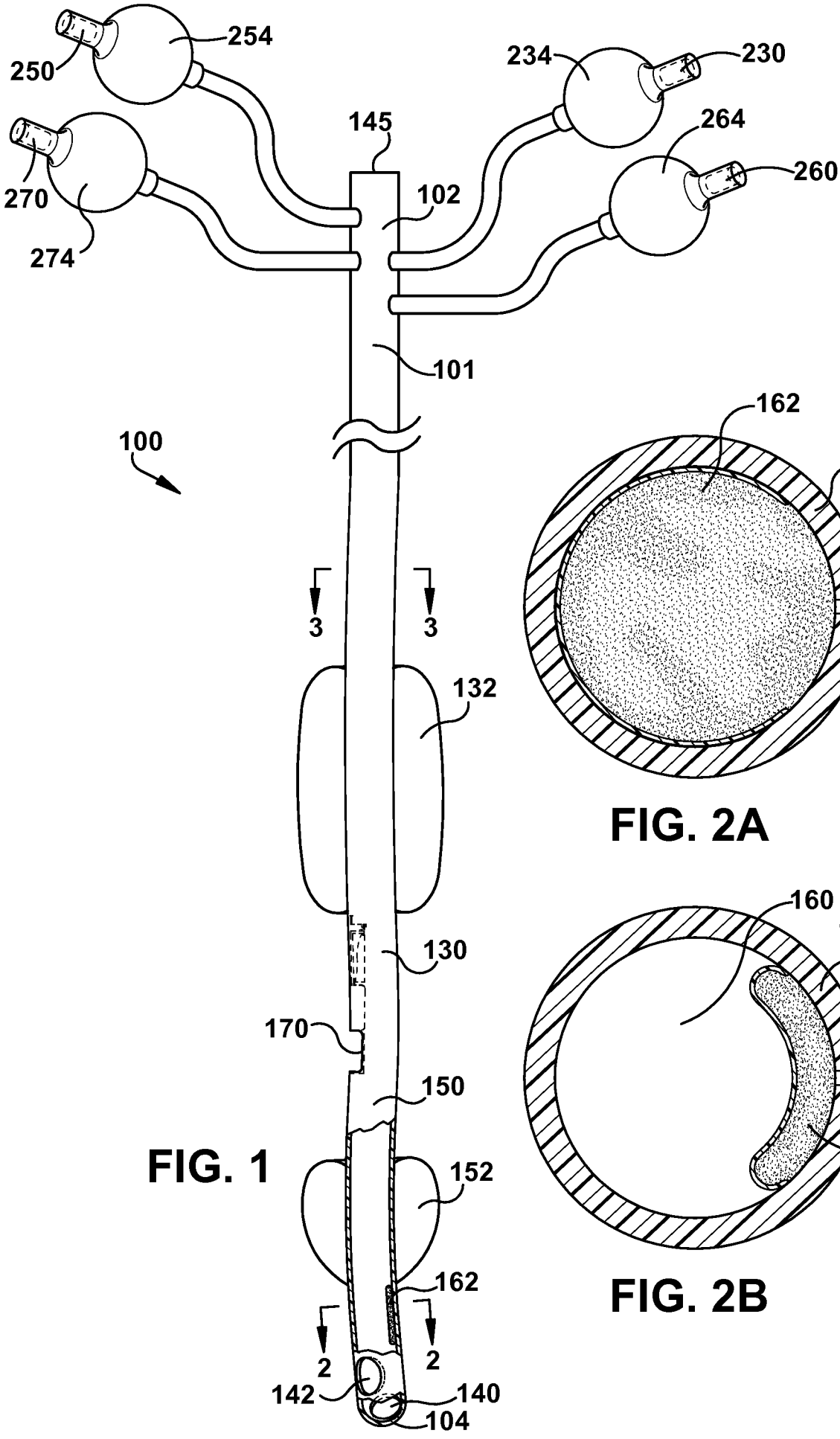

FIG. 1

FIG. 2A

FIG. 2B

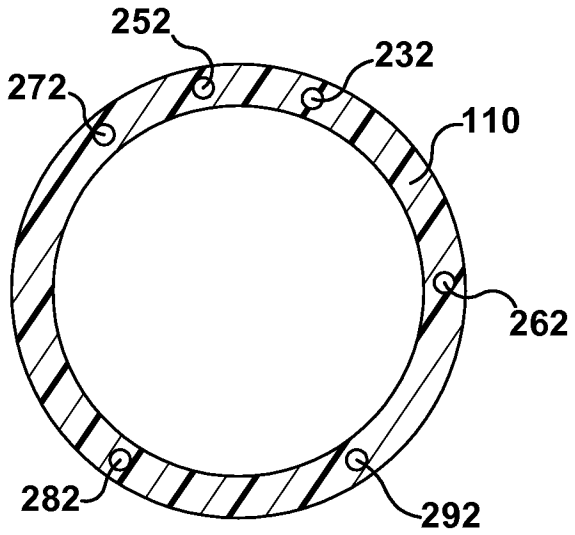

FIG. 3

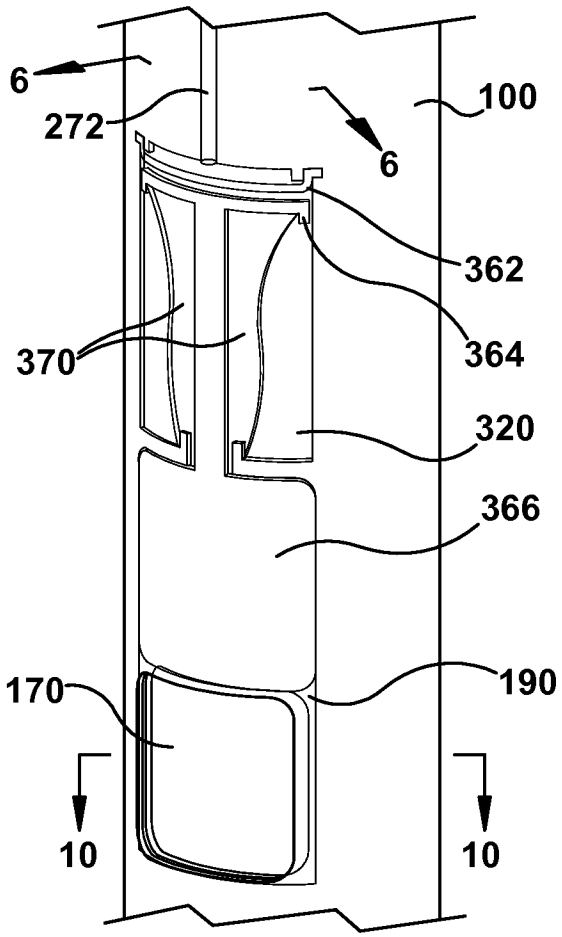

FIG. 4

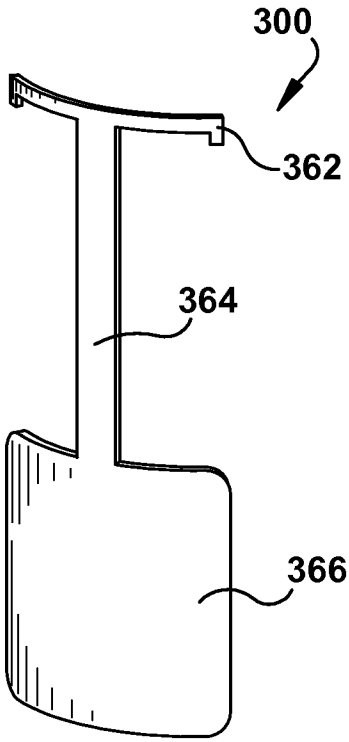

FIG. 5

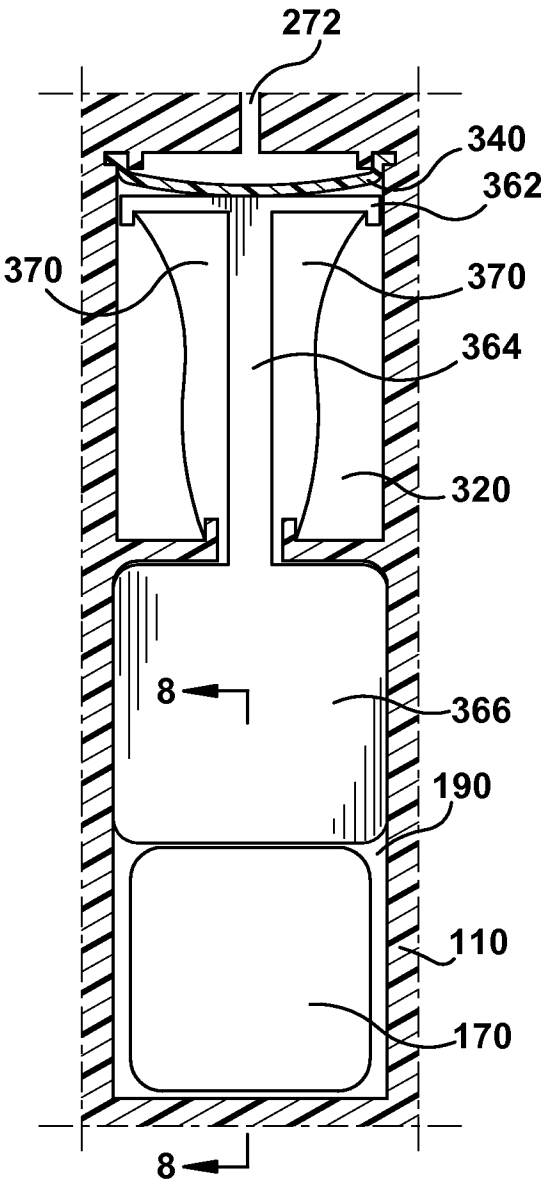
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FIG. 6

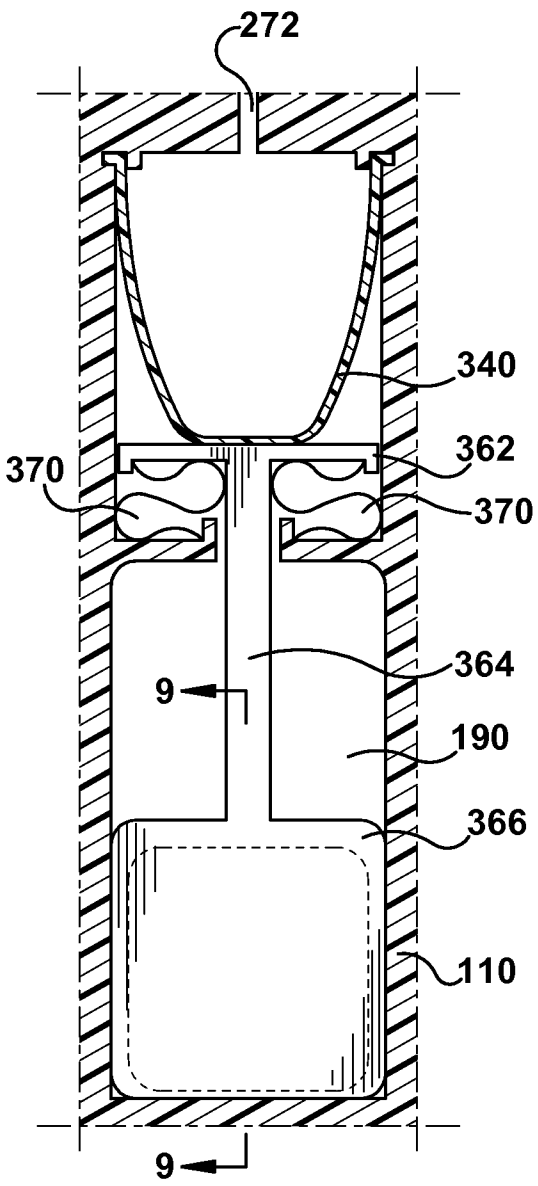
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FIG. 7

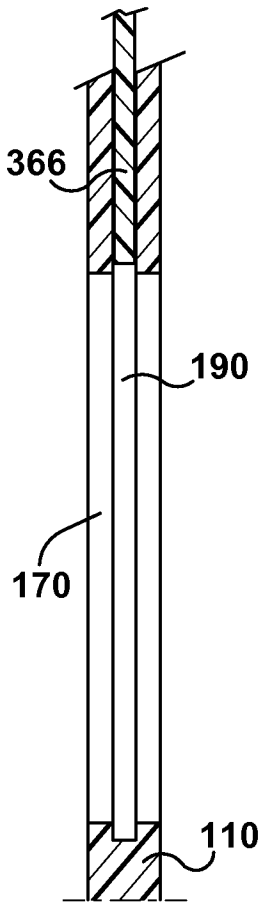

FIG. 8

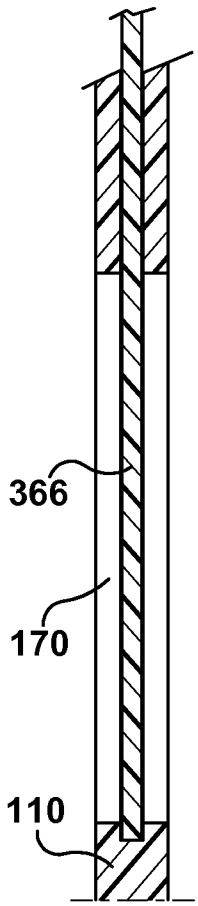

FIG. 9

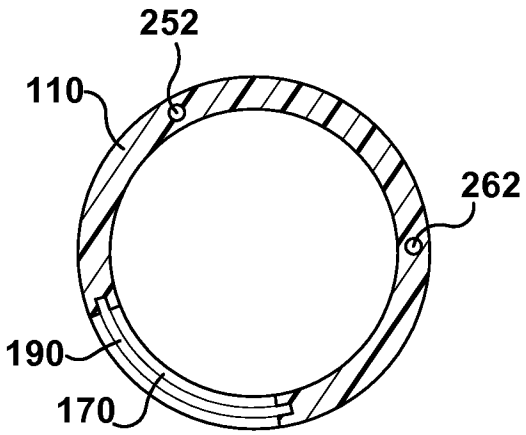

FIG. 10

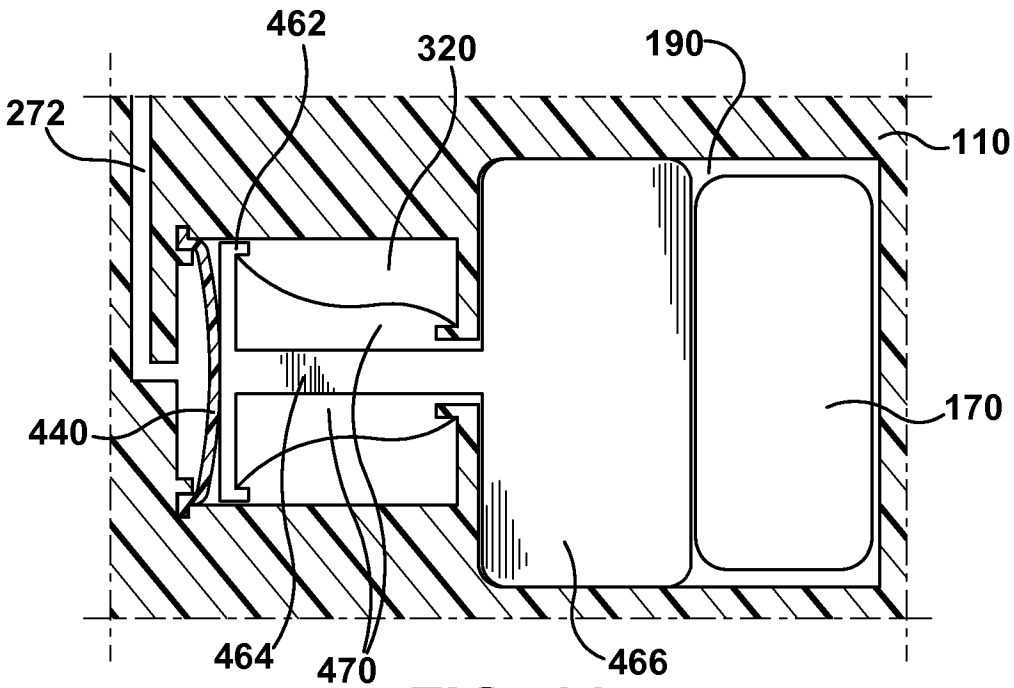

FIG. 11

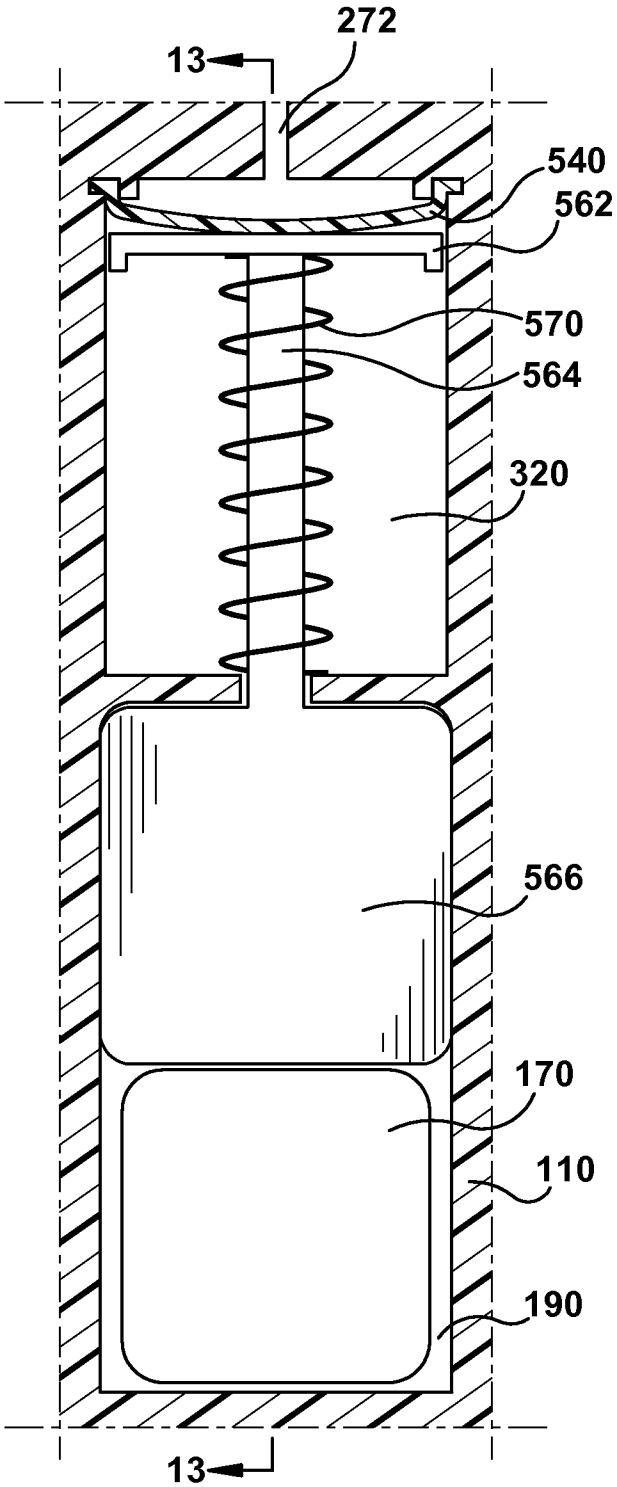
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FIG. 12

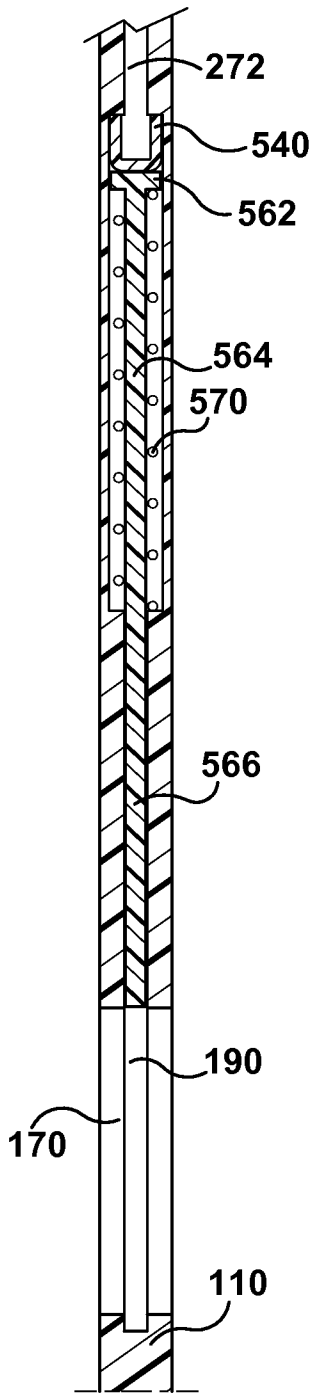
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FIG. 13

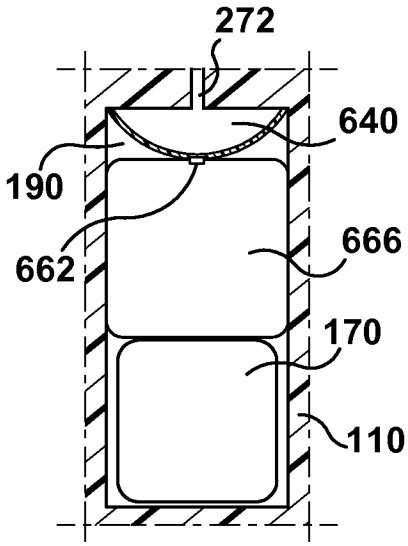


FIG. 14

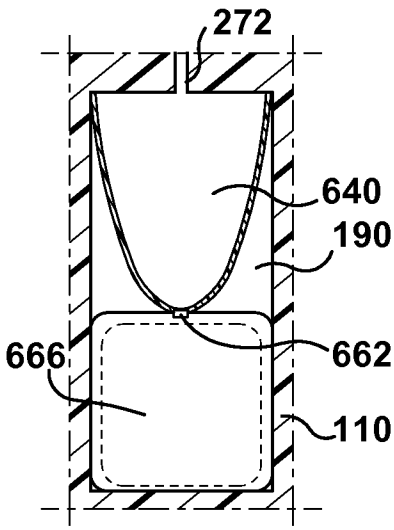


FIG. 15

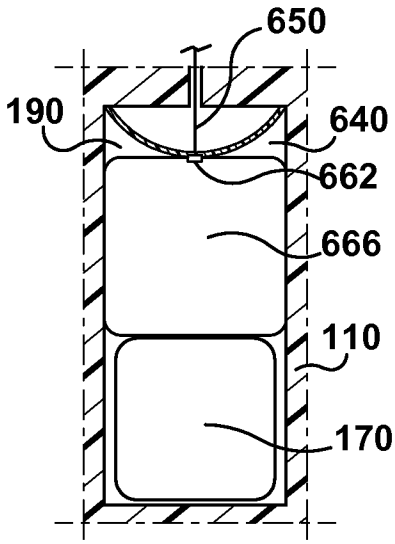


FIG. 16

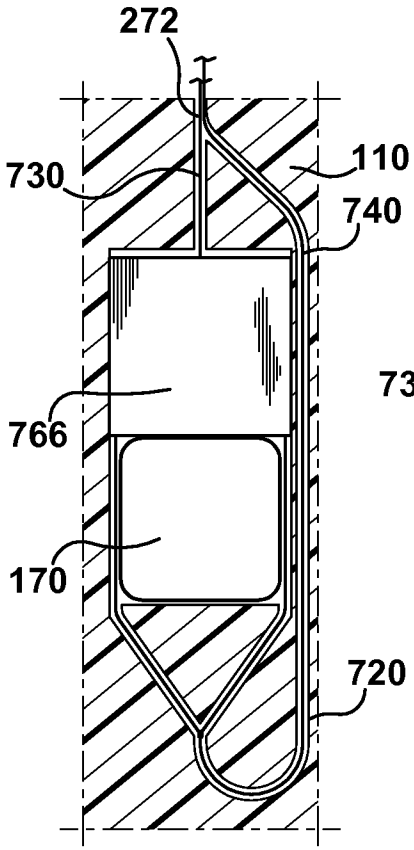


FIG. 17

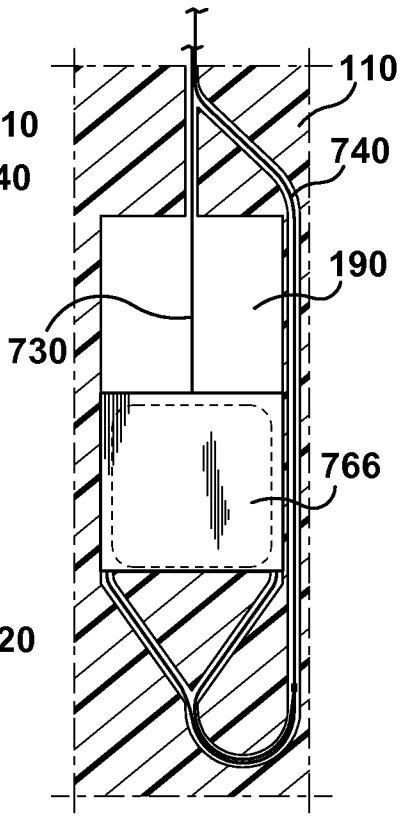


FIG. 18

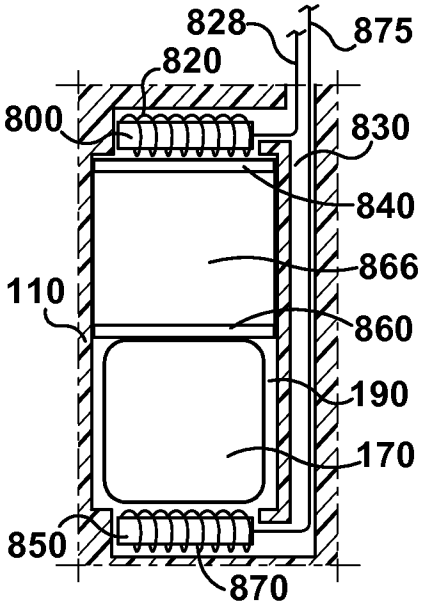


FIG. 19

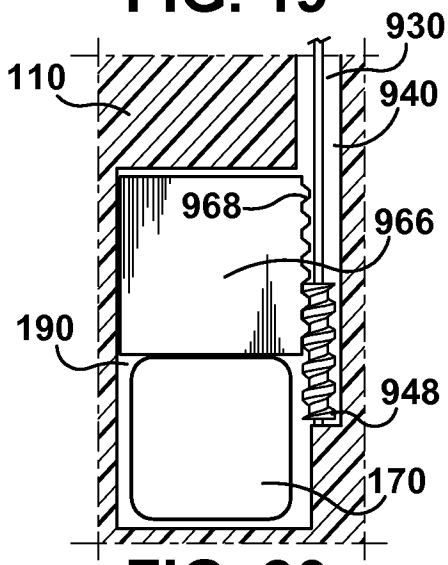


FIG. 20

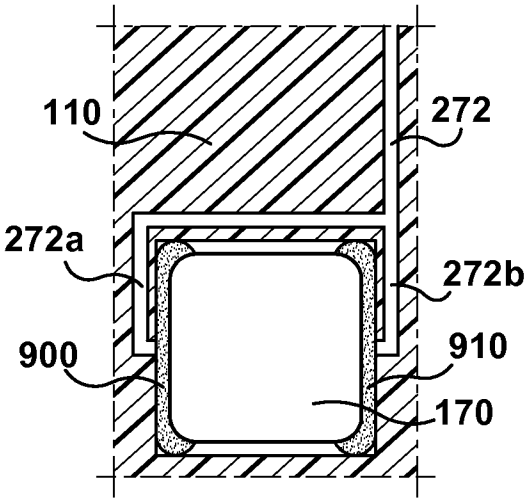


FIG. 21

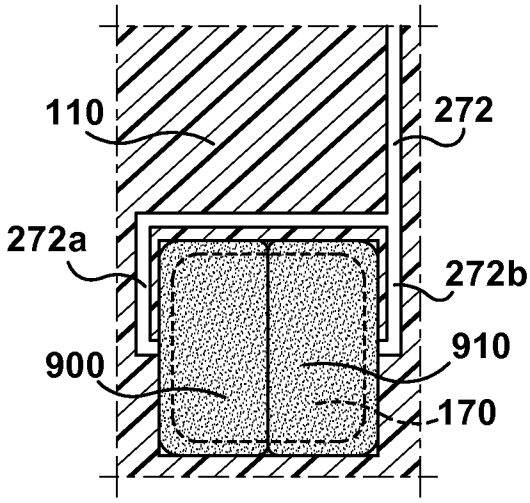


FIG. 22

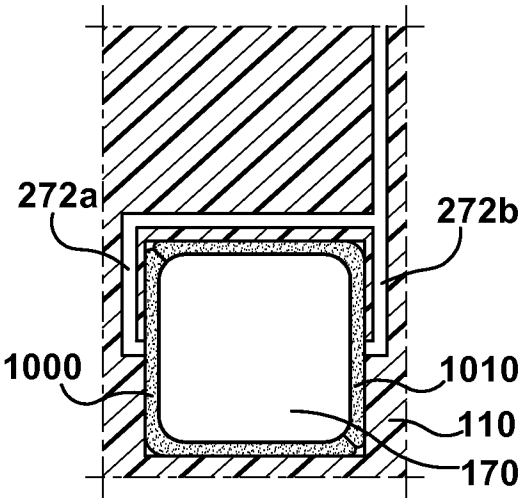


FIG. 23

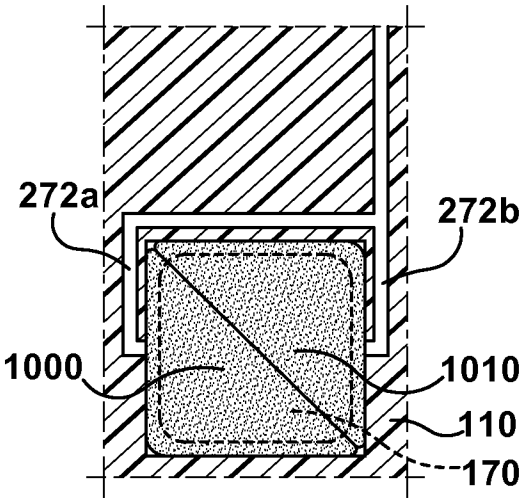


FIG. 24

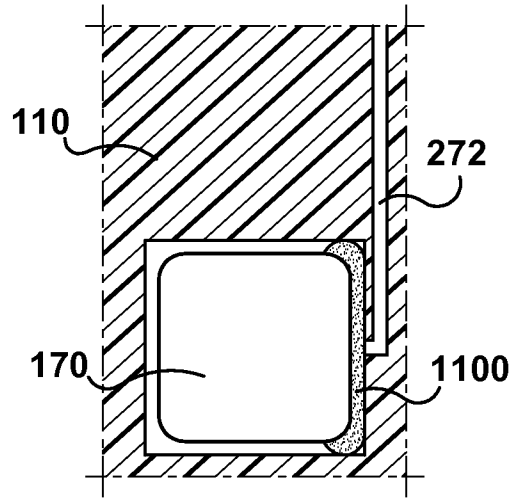


FIG. 25

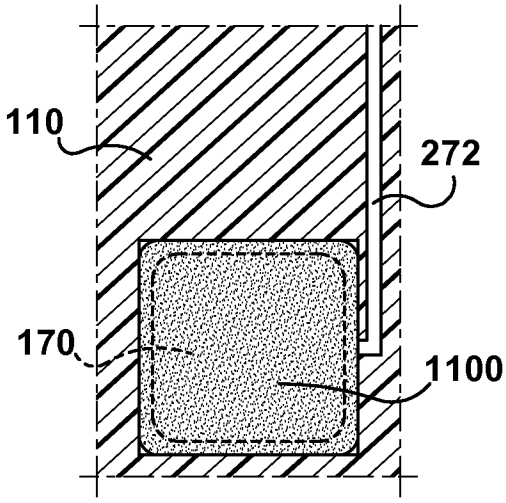


FIG. 26

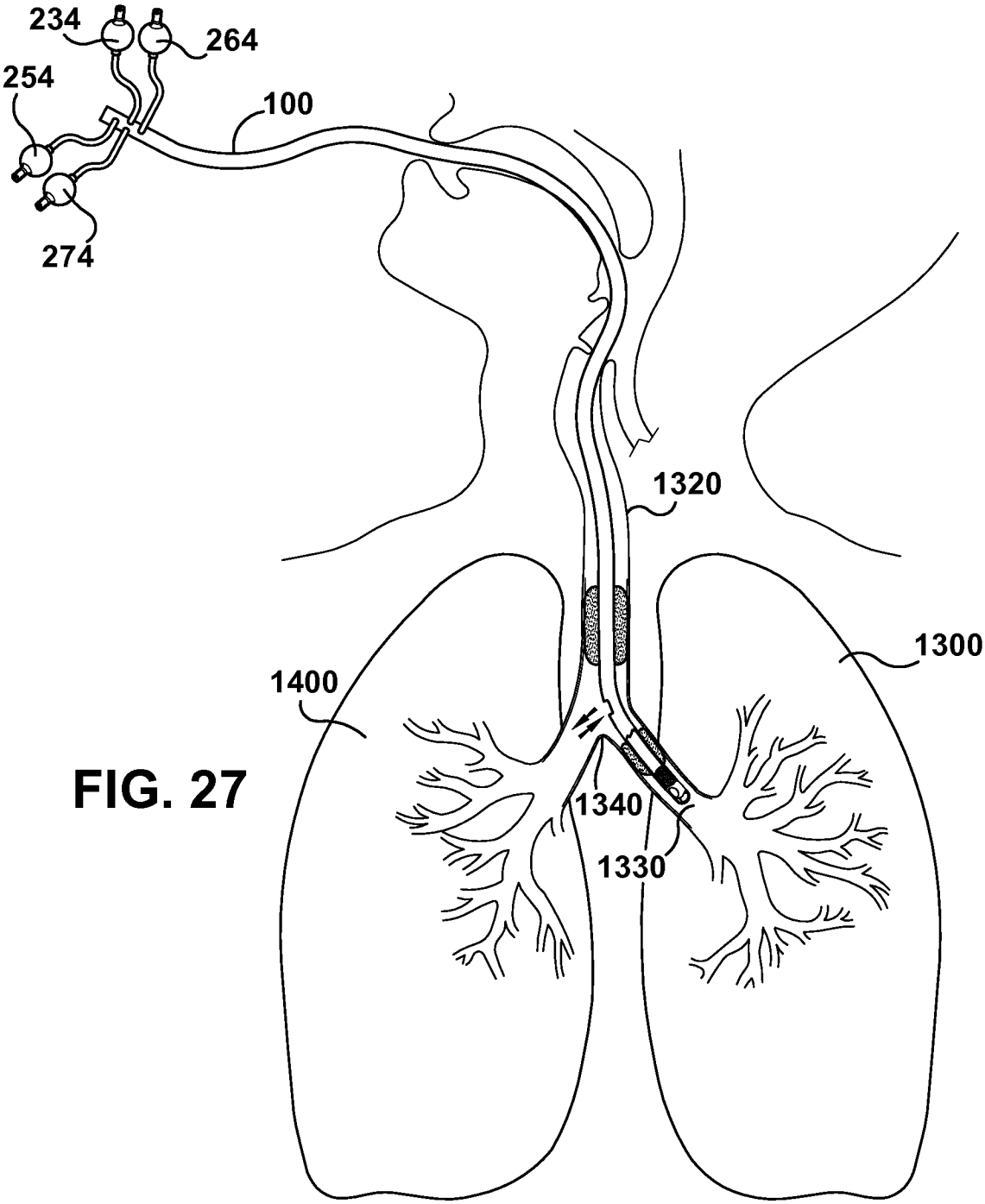


FIG. 27

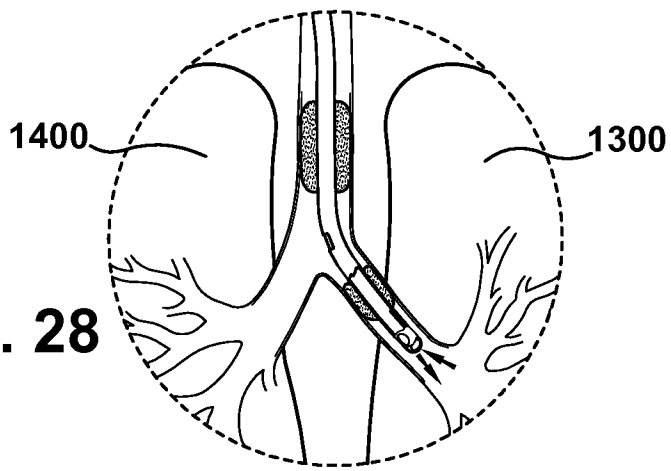


FIG. 28

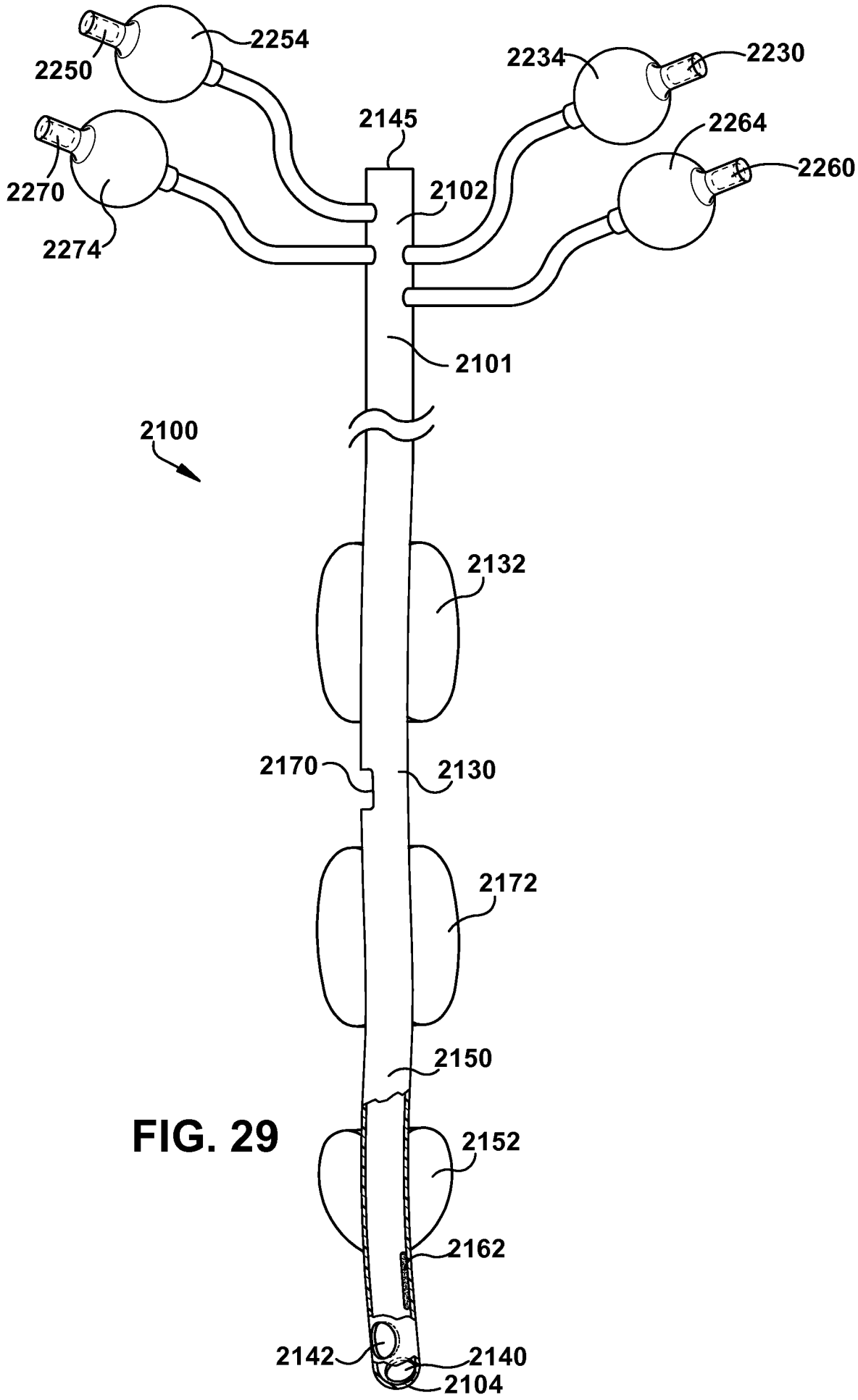

2254
2250
2234
2230
2145
2264
2260
2270
2102
2274
2101
2100
2132
2170
2130
2172
2150
2152
2162
2142
2140
2104

FIG. 29

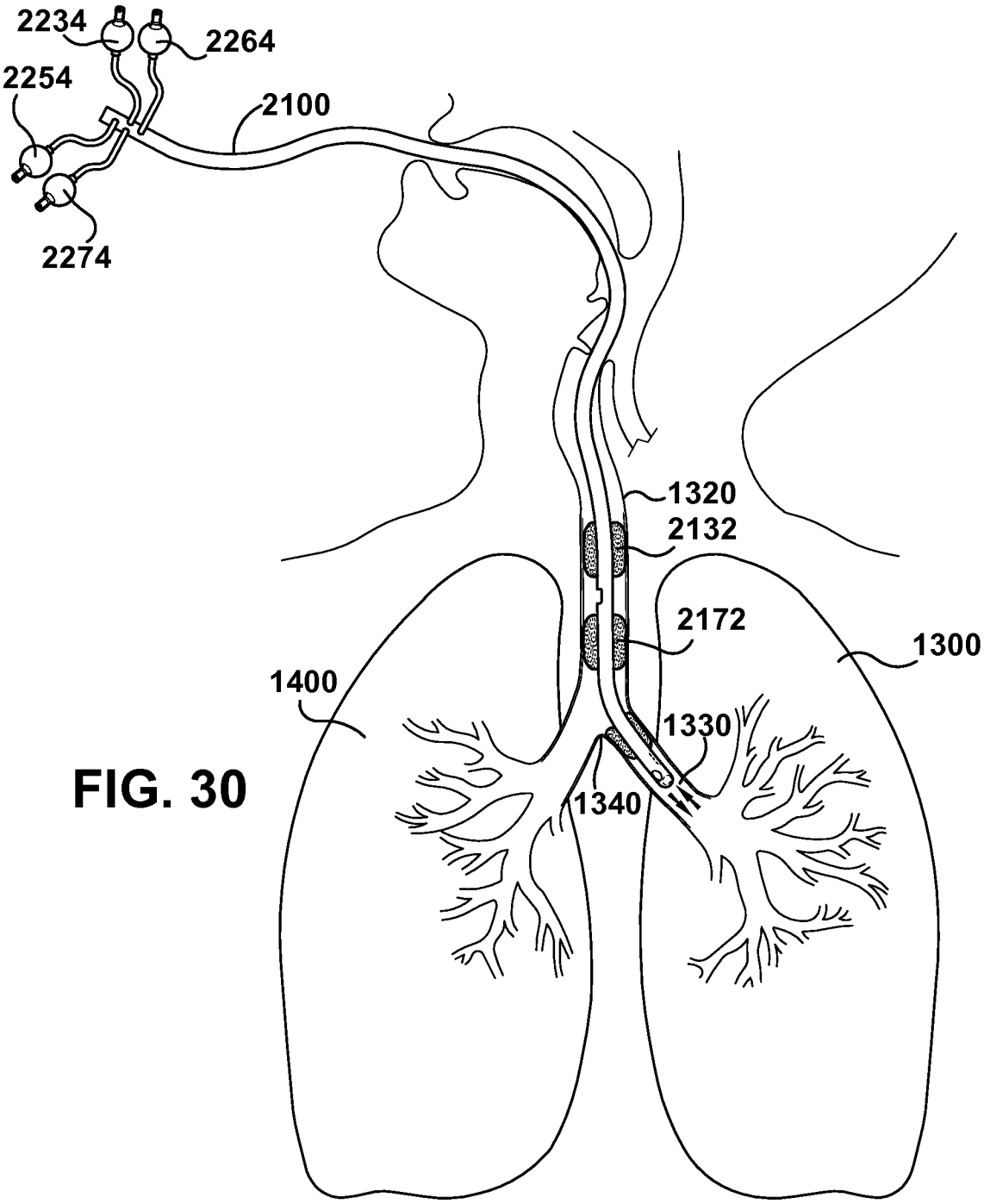
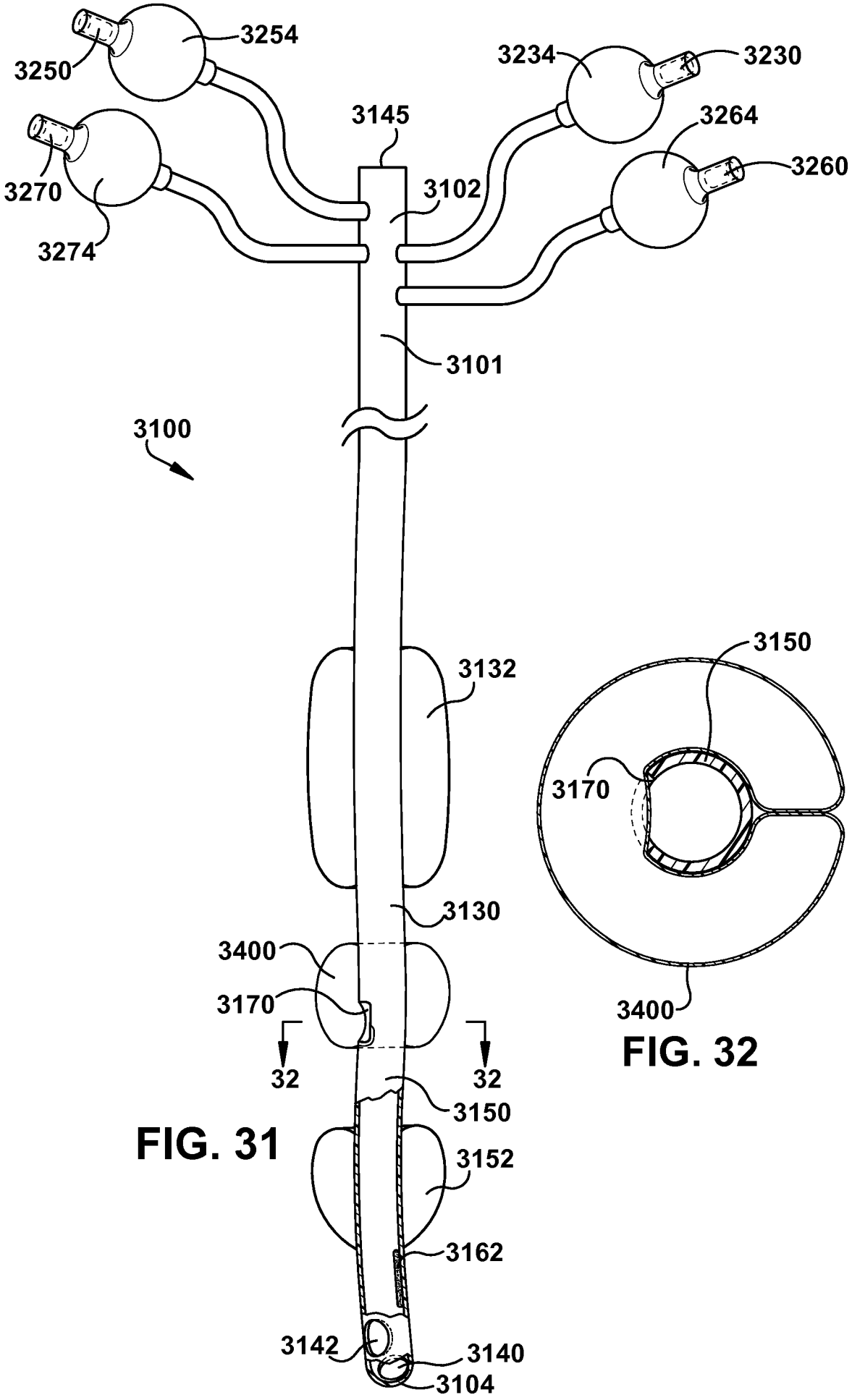


FIG. 30


3254
3250
3234
3230
3145
3264
3260
3270
3102
3274
3101
3100
3132
3130
3400
3170
32
32
3150
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3162
3142
3140
3104

FIG. 31

3150
3170
3400

FIG. 32

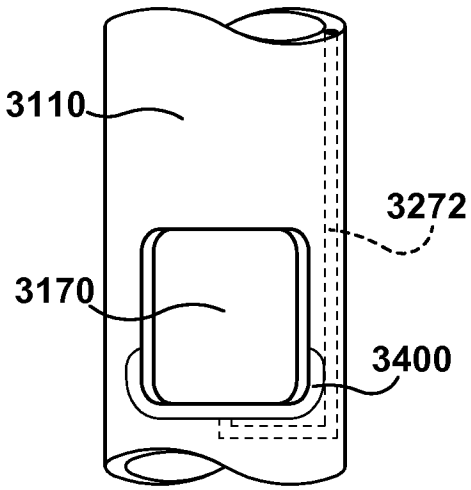


FIG. 33

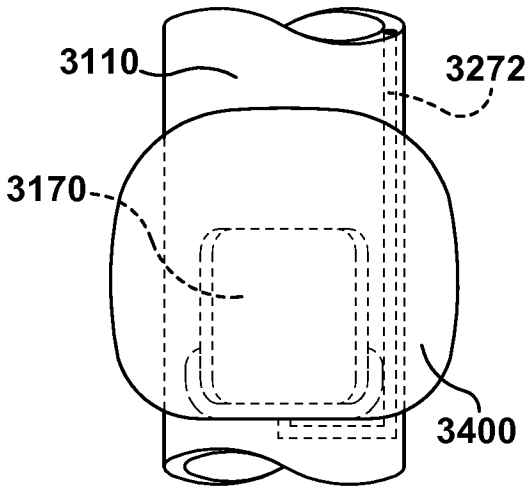


FIG. 34

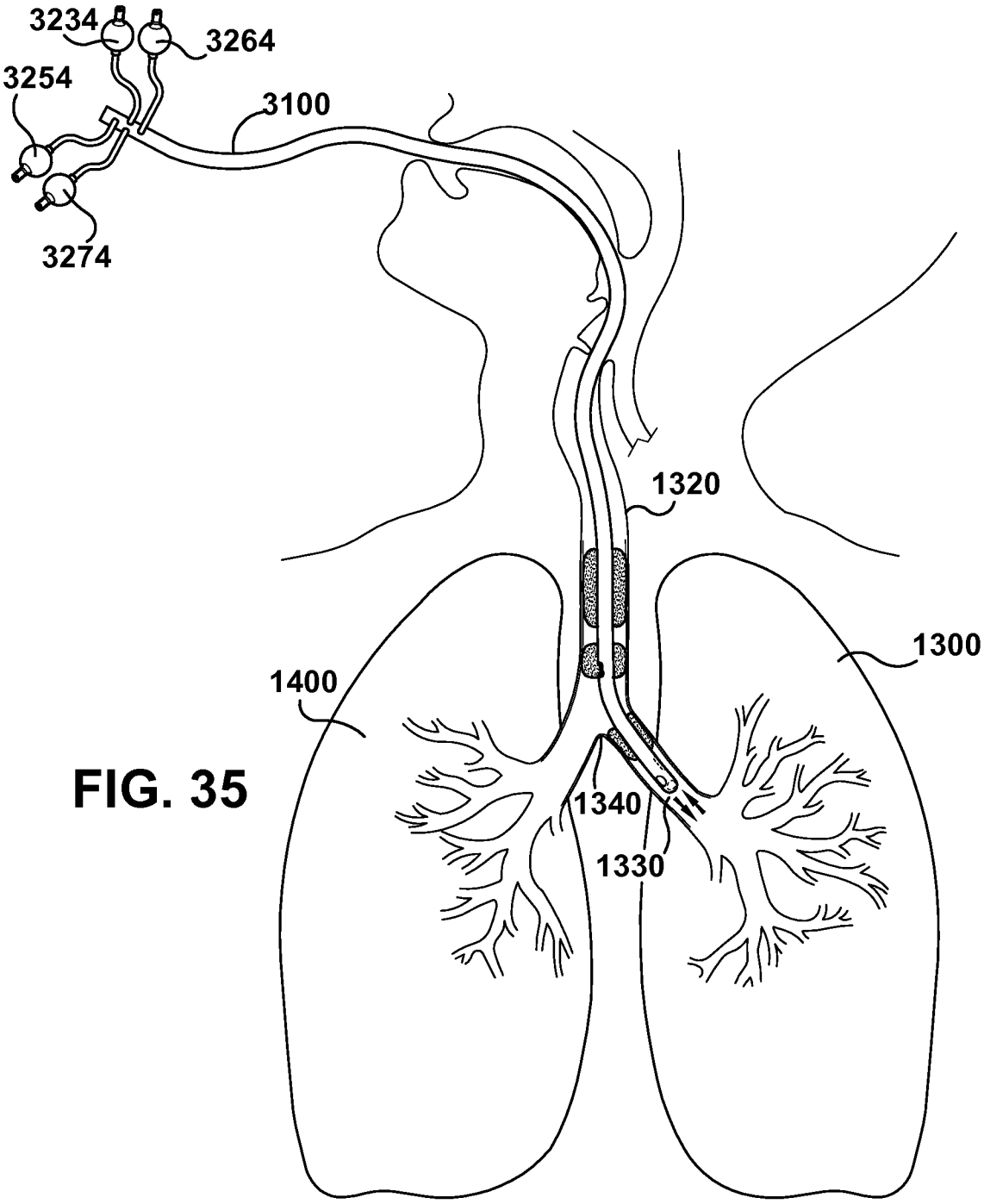
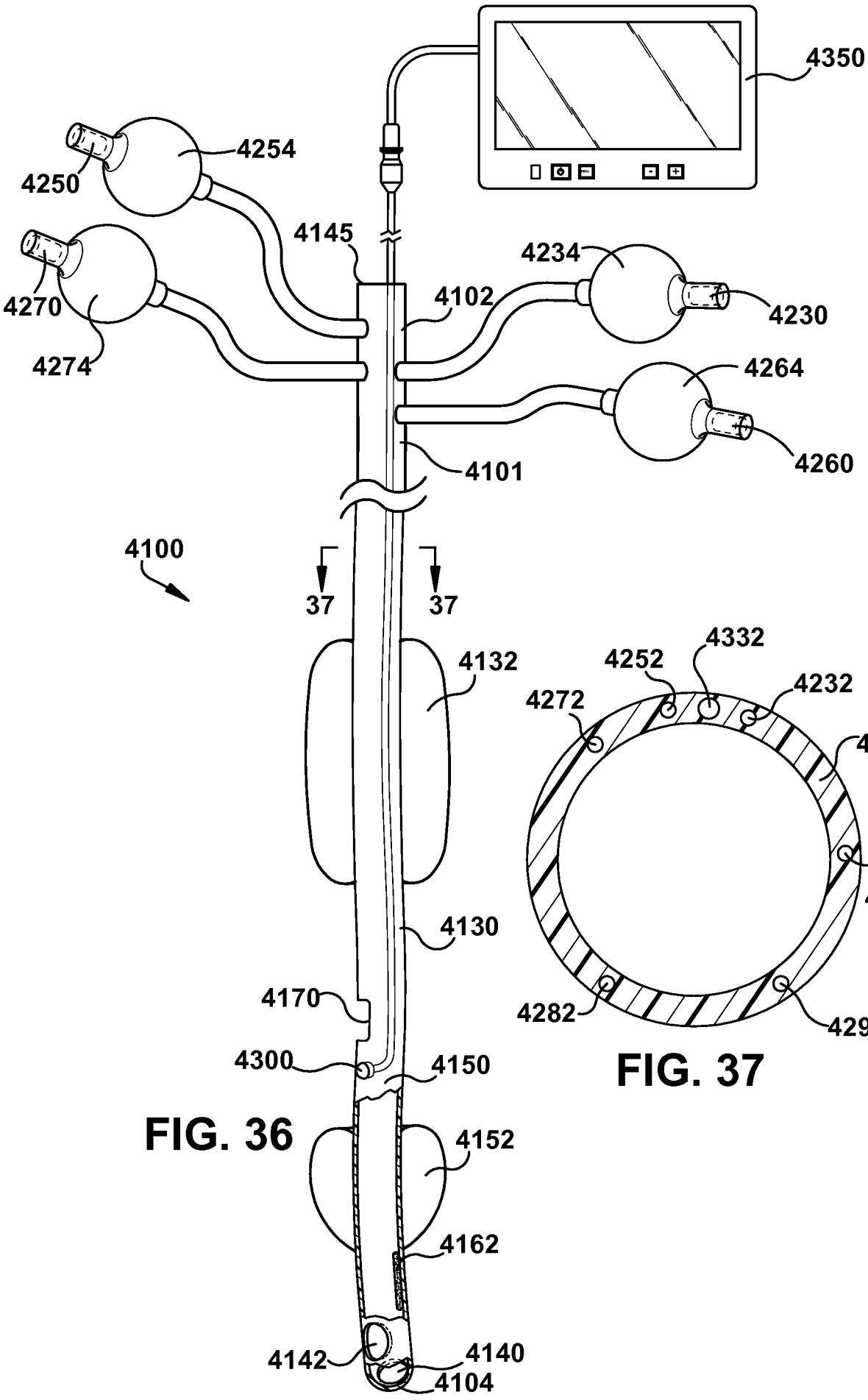


FIG. 35


4350
4254
4250
4145
4234
4270
4102
4230
4274
4264
4260
4101
4100
37
37
4132
4130
4170
4300
4150
4152
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4142
4140
4104

FIG. 36

4332
4252
4232
4272
4110
4262
4282
4292

FIG. 37

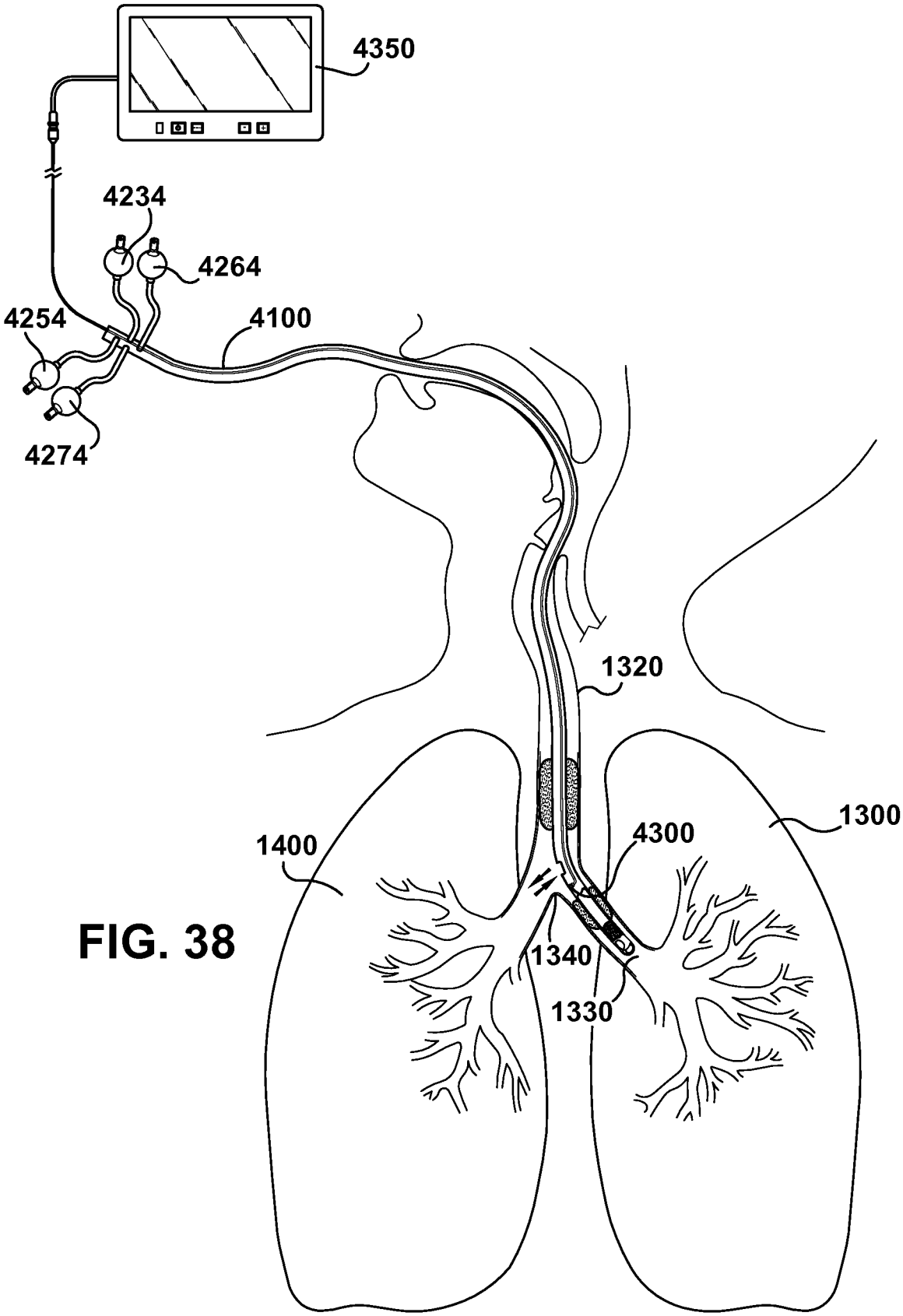

FIG. 38

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2011/023689

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - A61M 16/00 (2011.01)
USPC - 128/207.15
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)
IPC(8) - A61M 16/00, 25/00 (2011.01)
USPC - 128/207.14, 207.15, 207.16; 604/96.01, 101.01, 101.03

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)

MicroPatent, Google Patents
Search terms: endobronchial, endotracheal, cuff, balloon, aperture, opening, hole, vent, low volume, high pressure, inner, internal, diameter, size, occlude, block, isolate, lung, intraluminal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005/0205097 A1 (KYLE, JR.) 22 September 2005 (22.09.2005) entire document	1, 2, 9, 10
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Y		3-8, 11-20
Y	US 6,609,521 B1 (BELANI et al) 26 August 2003 (26.08.2003) entire document	3-6, 11-13, 16-20
Y	WO 2009/044192 A2 (NASIR) 09 April 2009 (09.04.2009) entire document	5
Y	US 5,315,992 A (DALTON) 31 May 1994 (31.05.1994) entire document	7, 14
Y	US 7,297,105 B2 (MACKIN) 20 November 2007 (20.11.2007) entire document	8, 15, 19
A	US 4,248,221 A (WINNARD) 03 February 1981 (03.02.1981) entire document	1-20
A	US 4,233,984 A (WALLING) 18 November 1980 (18.11.1980) entire document	1-20
A	US 2007/0215162 A1 (GLASSENBERG et al) 20 September 2007 (20.09.2007) entire document	1-20

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"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)
"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
"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
"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
"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
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 March 2011	19 APR 2011
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (July 2009)