US008554298B2

(12) **United States Patent**
Doyle et al.

(10) **Patent No.: US 8,554,298 B2**
(45) **Date of Patent: Oct. 8, 2013**

(54) **MEDICAL VENTILATOR WITH INTEGRATED OXIMETER DATA**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 434 days.

(21) Appl. No.: **12/887,077**

(22) Filed: **Sep. 21, 2010**

(65) **Prior Publication Data**

US 2012/0071729 A1 Mar. 22, 2012

(51) **Int. Cl.**
A61B 5/1455 (2006.01)
A61B 5/00 (2006.01)

(52) **U.S. Cl.**
USPC **600/323**; 600/301; 600/333

(58) **Field of Classification Search**
USPC 600/310, 324, 333, 340, 529, 538, 300, 600/301, 323; 128/203.12–207.18
See application file for complete search history.

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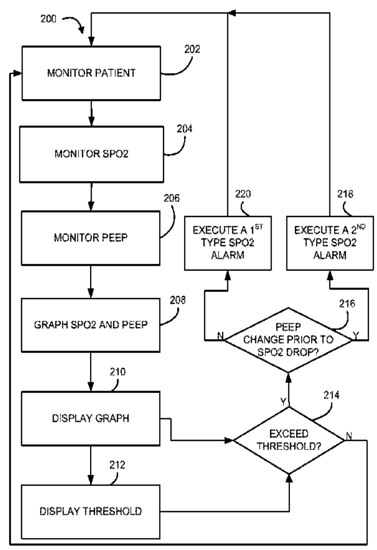
Primary Examiner — Eric Winakur
Assistant Examiner — Chu Chuan (JJ) Liu

(57) **ABSTRACT**

This disclosure describes systems and methods for managing the ventilation of a patient being ventilated by a medical ventilator. The disclosure describes a novel approach of displaying ventilator information integrated with oximeter information. The disclosure further describes a novel approach of alarming based on the integration of ventilator information with oximeter information.

17 Claims, 12 Drawing Sheets



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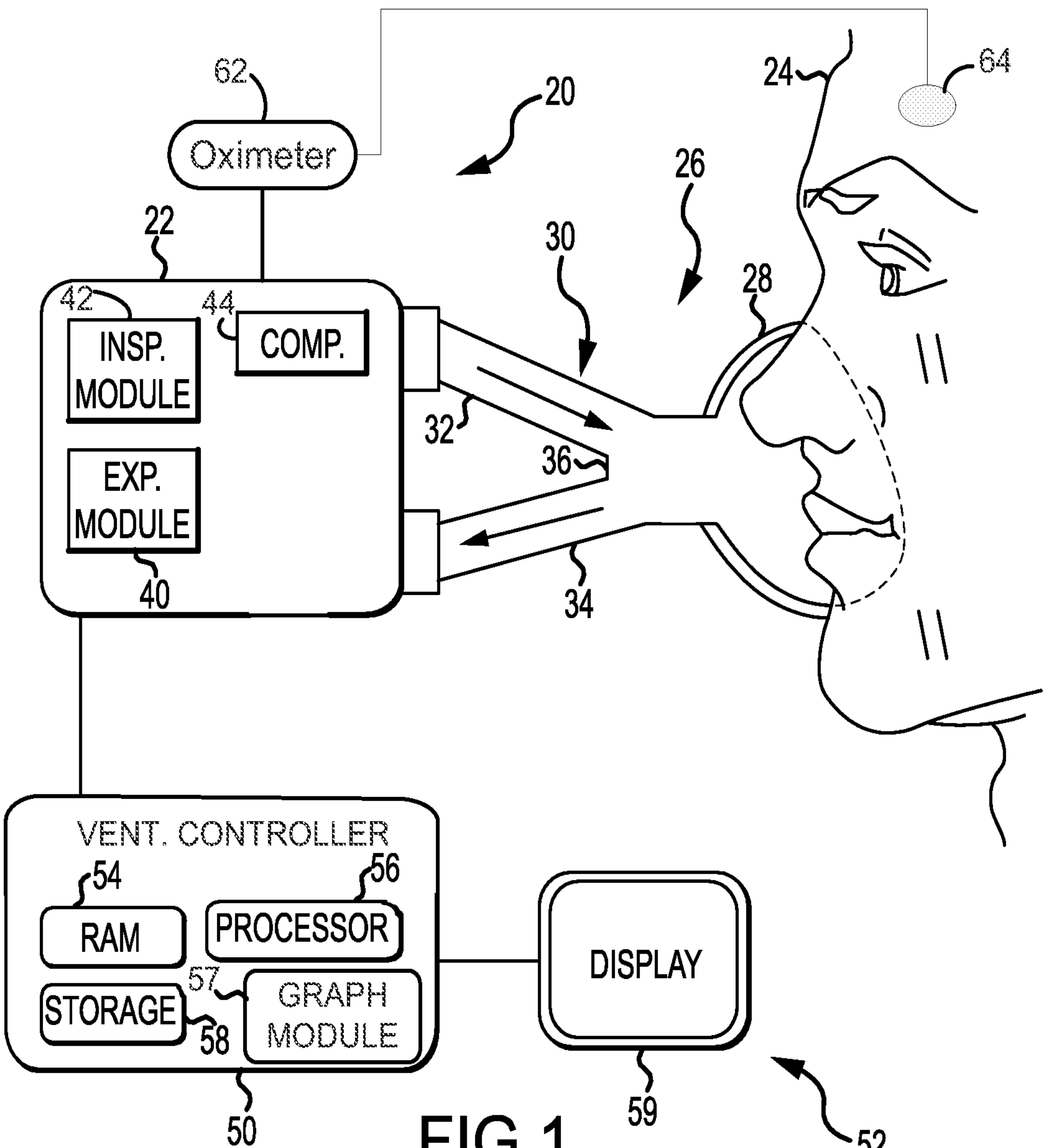
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Oximeter
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EXP.
MODULE
40
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VENT. CONTROLLER
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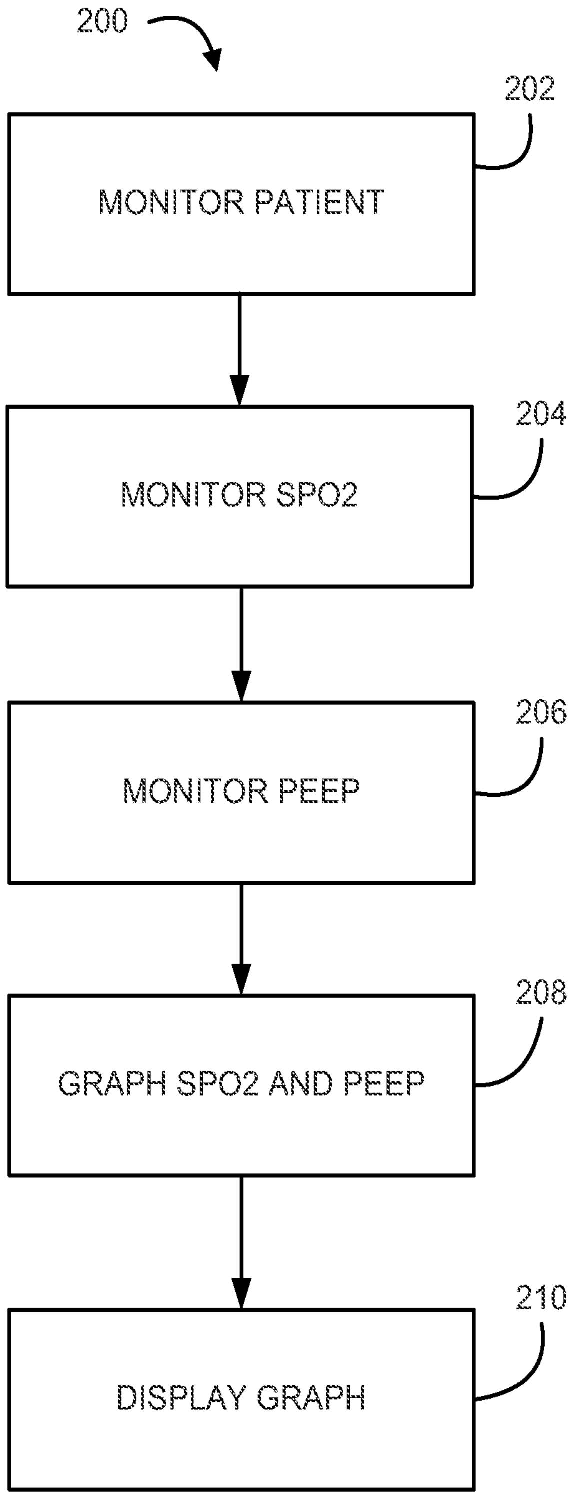
56
RAM
PROCESSOR
57
STORAGE
GRAPH
MODULE
58
DISPLAY
50
59
52

FIG.1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MONITOR PEEP
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GRAPH SPO2 AND PEEP
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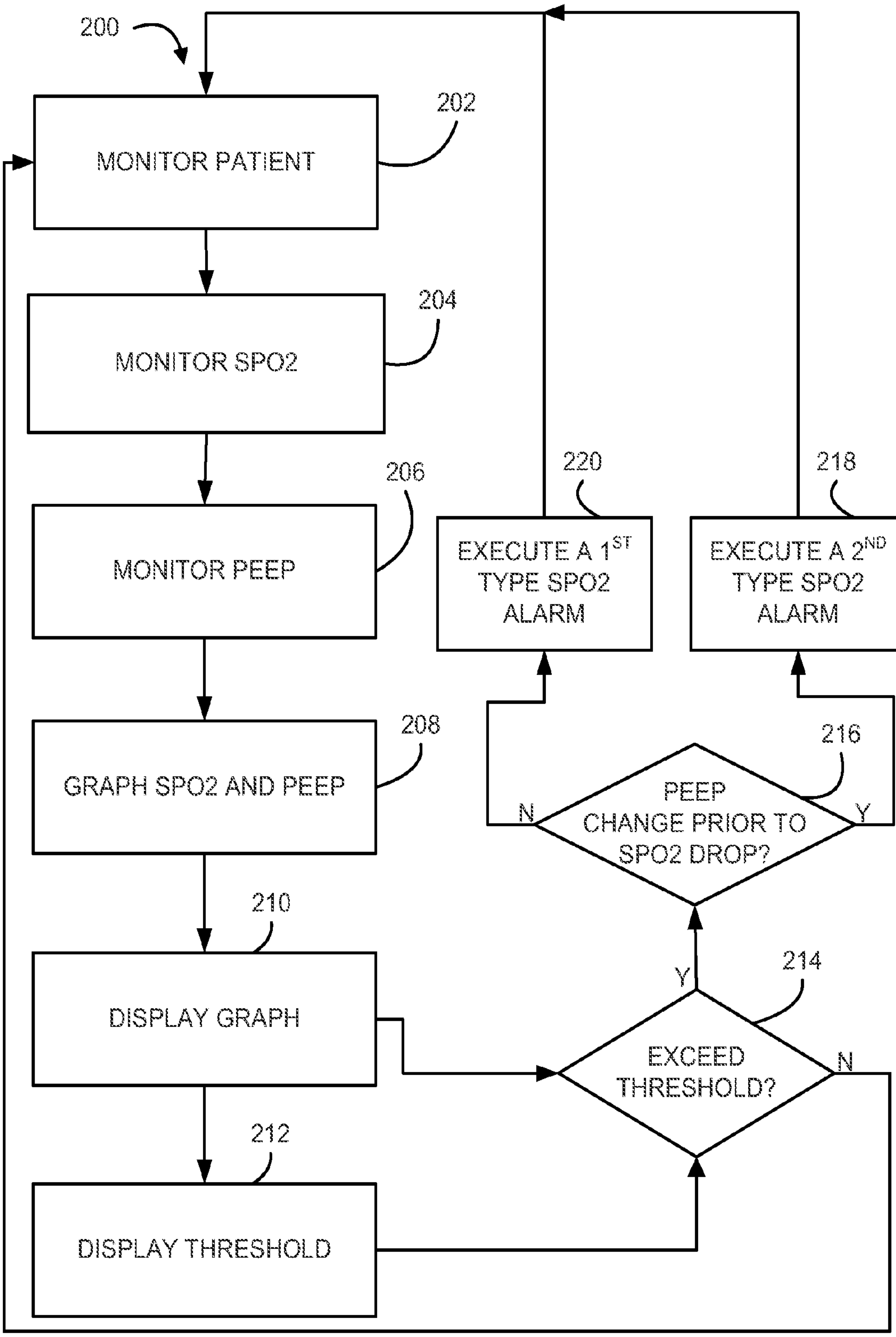
DISPLAY GRAPH

FIG. 2A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MONITOR SPO2
204
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206
GRAPH SPO2 AND PEEP
208
DISPLAY GRAPH
210
DISPLAY THRESHOLD
212
EXCEED THRESHOLD?
214
Y
N
PEEP CHANGE PRIOR TO SPO2 DROP?
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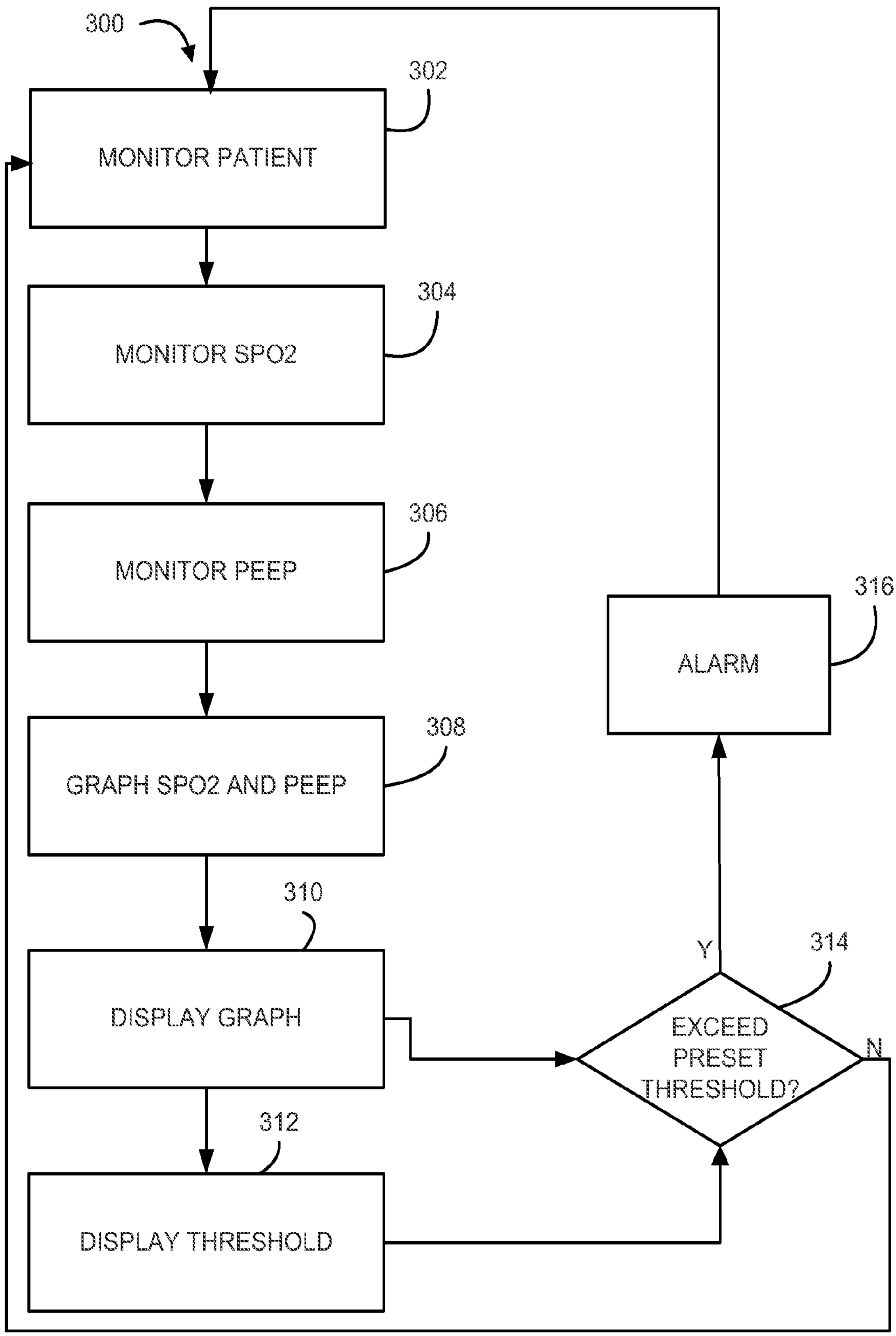
220
EXECUTE A 2ND TYPE SPO2 ALARM
218

FIG. 2B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308
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DISPLAY GRAPH
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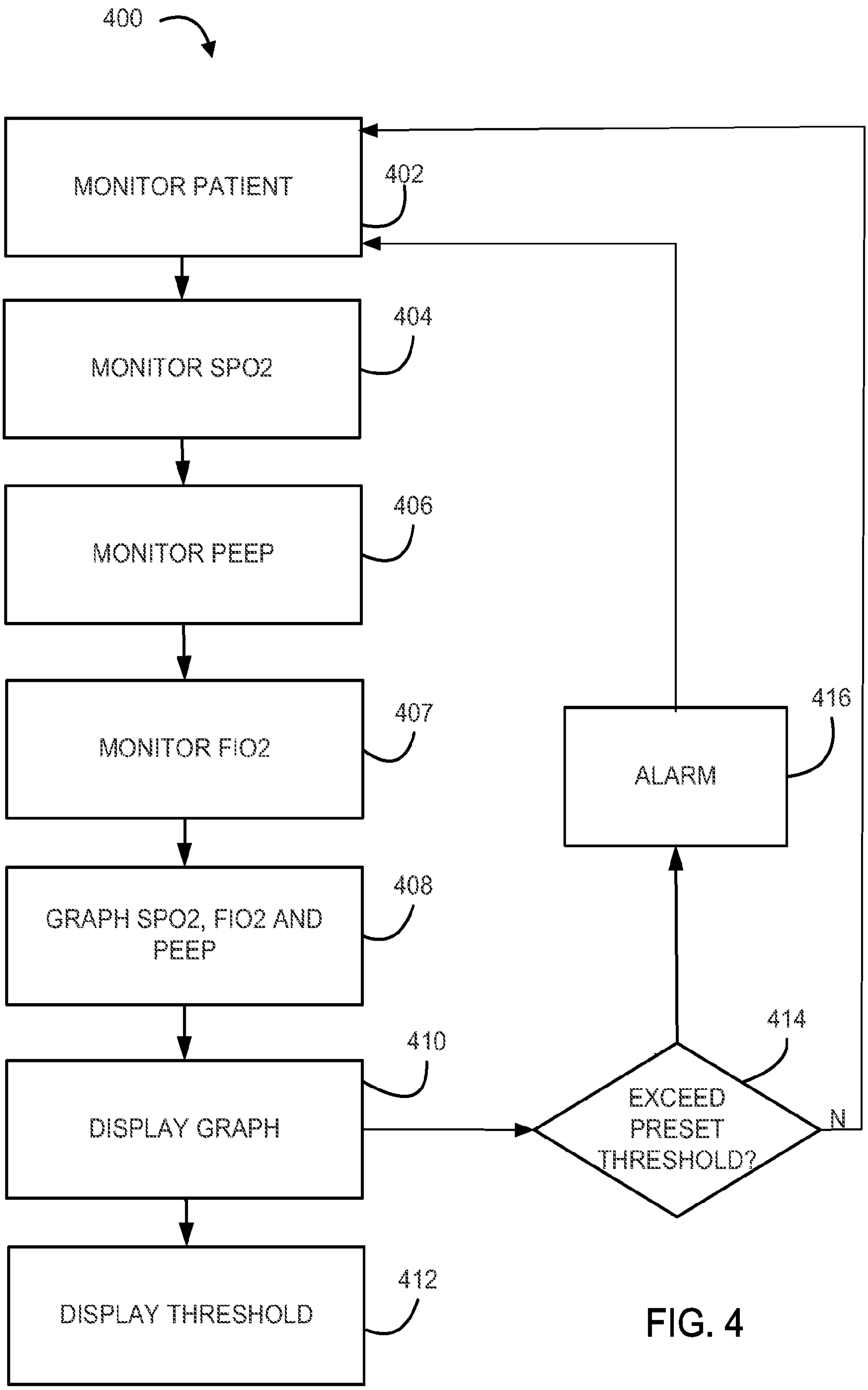
DISPLAY THRESHOLD
316
ALARM
Y
314
EXCEED PRESET THRESHOLD?
N

FIG. 3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MONITOR SPO2
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MONITOR PEEP
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DISPLAY THRESHOLD
412
EXCEED PRESET THRESHOLD?
414
N
ALARM
416

FIG. 4

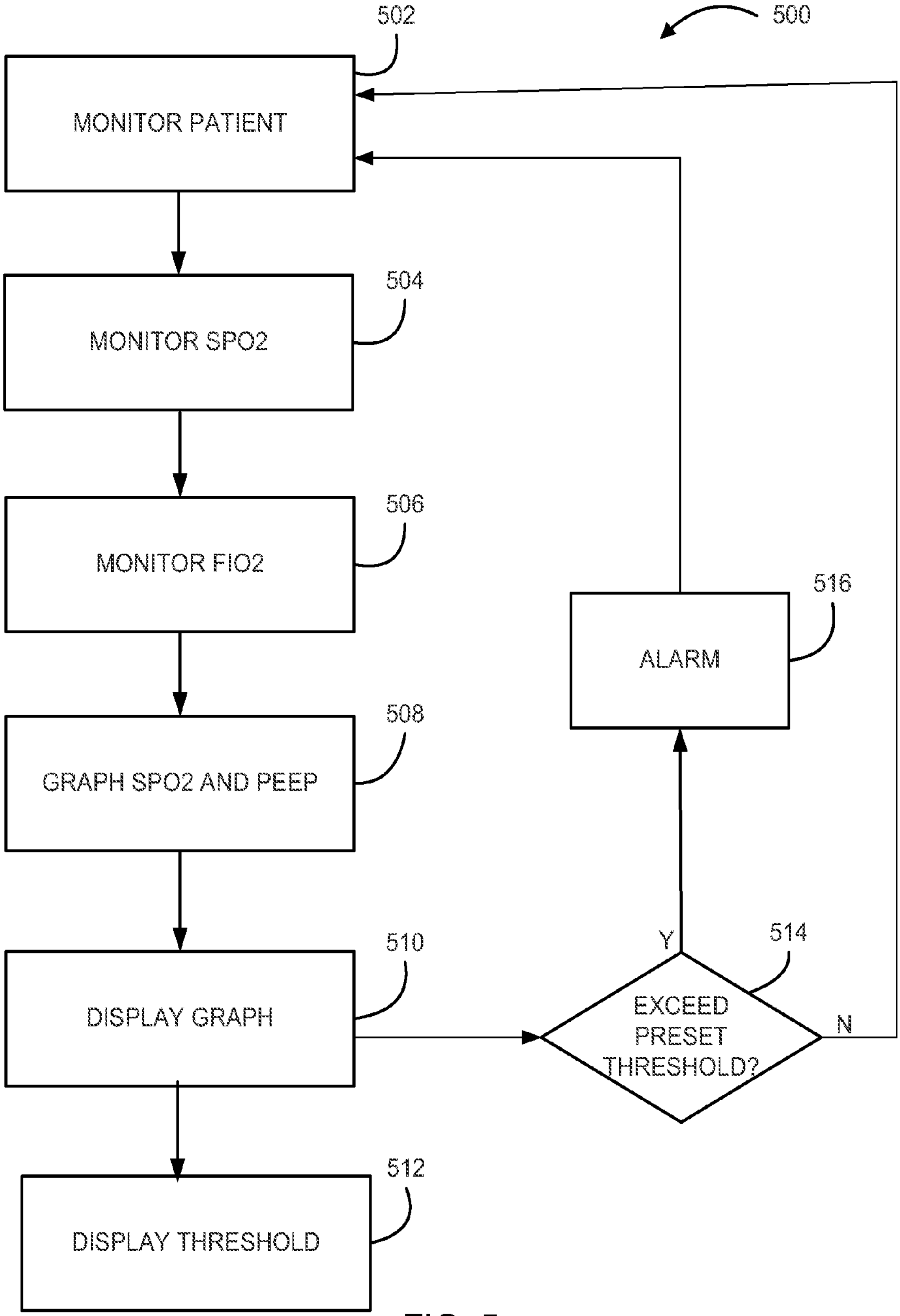
500
502
MONITOR PATIENT
504
MONITOR SPO2
506
MONITOR FIO2
508
GRAPH SPO2 AND PEEP
510
DISPLAY GRAPH
512
DISPLAY THRESHOLD
514
EXCEED PRESET THRESHOLD?
Y
N
516
ALARM

FIG. 5

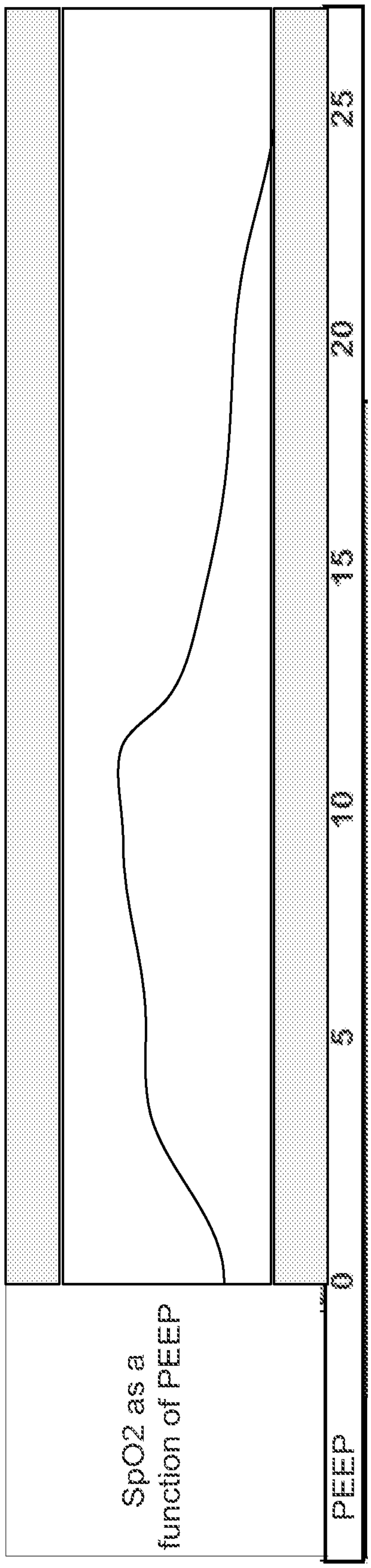

FIG. 6

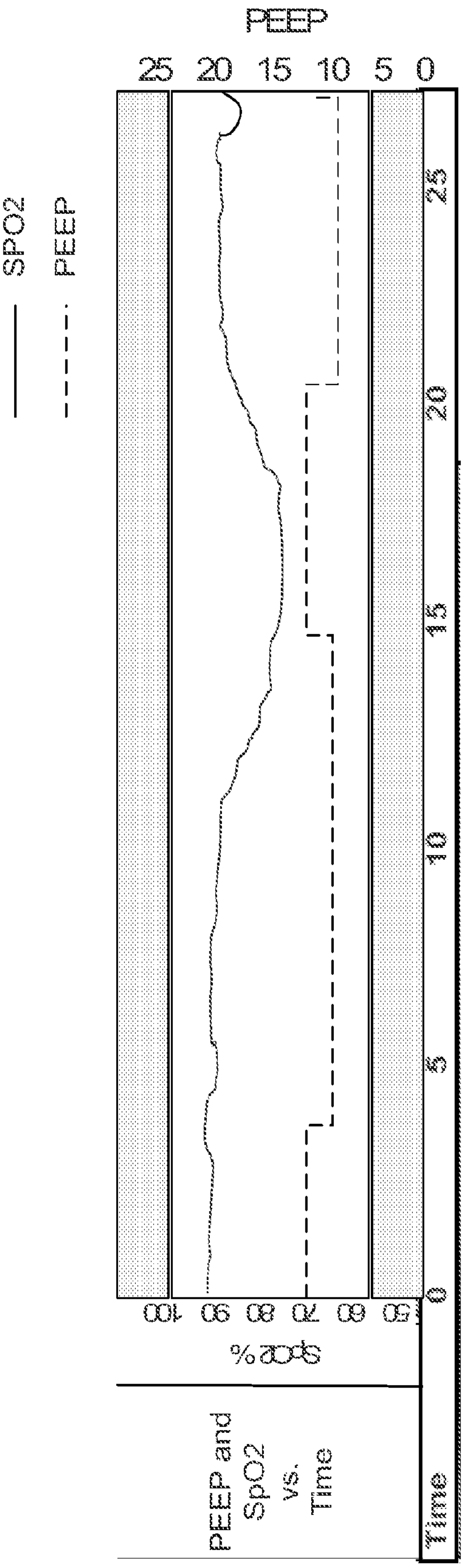
SPO2
PEEP
PEEP
25 20 15 10 5 0
0 5 10 15 20 25
100 90 80 70 60 50
SpO2 %
PEEP and SpO2 vs. Time
Time

FIG. 7

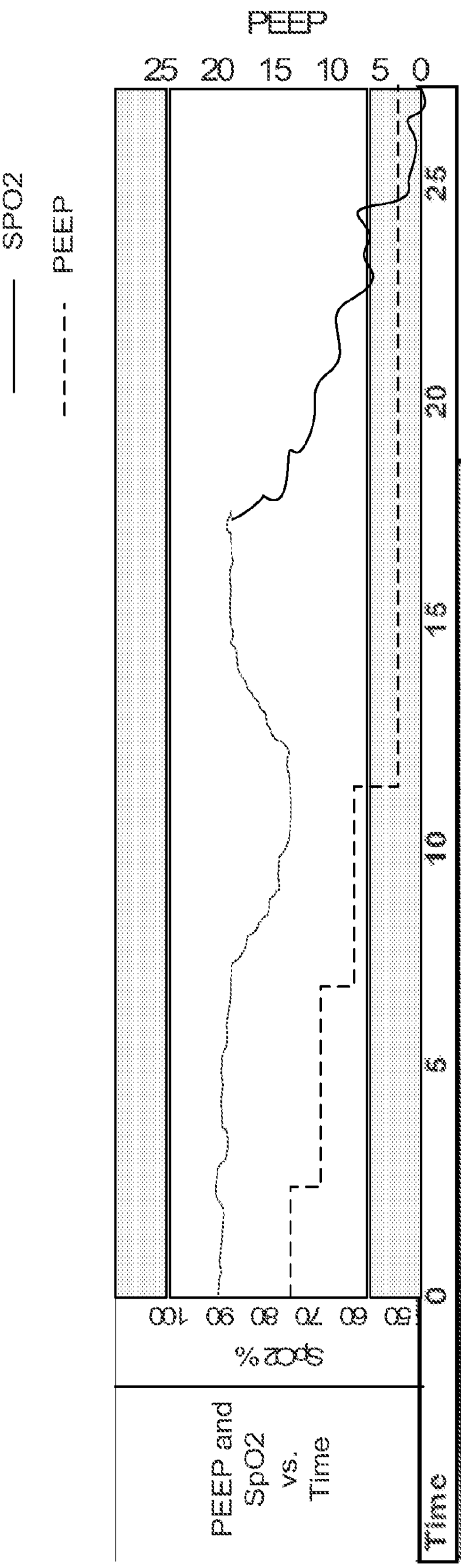
SPO2
PEEP
PEEP
25 20 15 10 5 0
0 5 10 15 20 25
100 90 80 70 60 50
SpO2 %
PEEP and SpO2 vs. Time
Time

FIG. 8

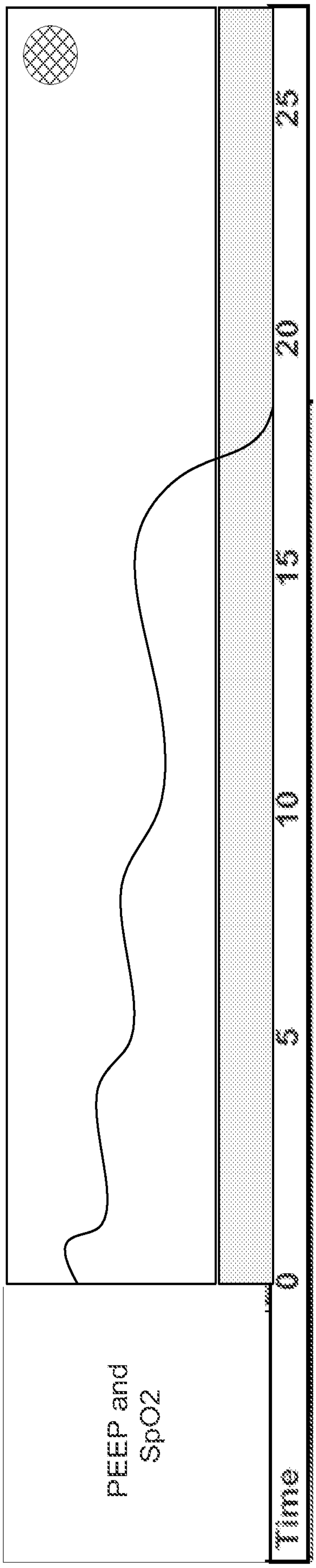
PEEP and SpO2
Time
0
5
10
15
20
25

FIG. 9

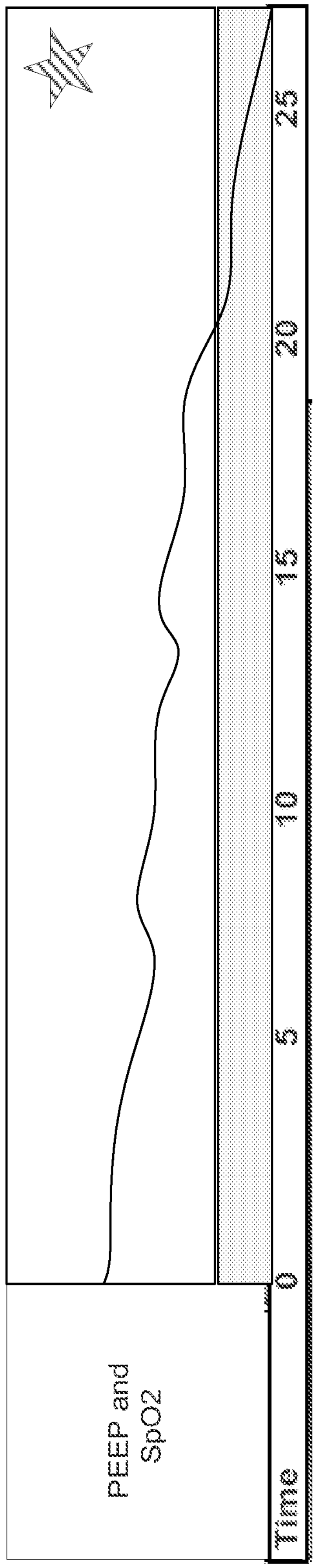
PEEP and SpO2
Time
0
5
10
15
20
25

FIG. 10

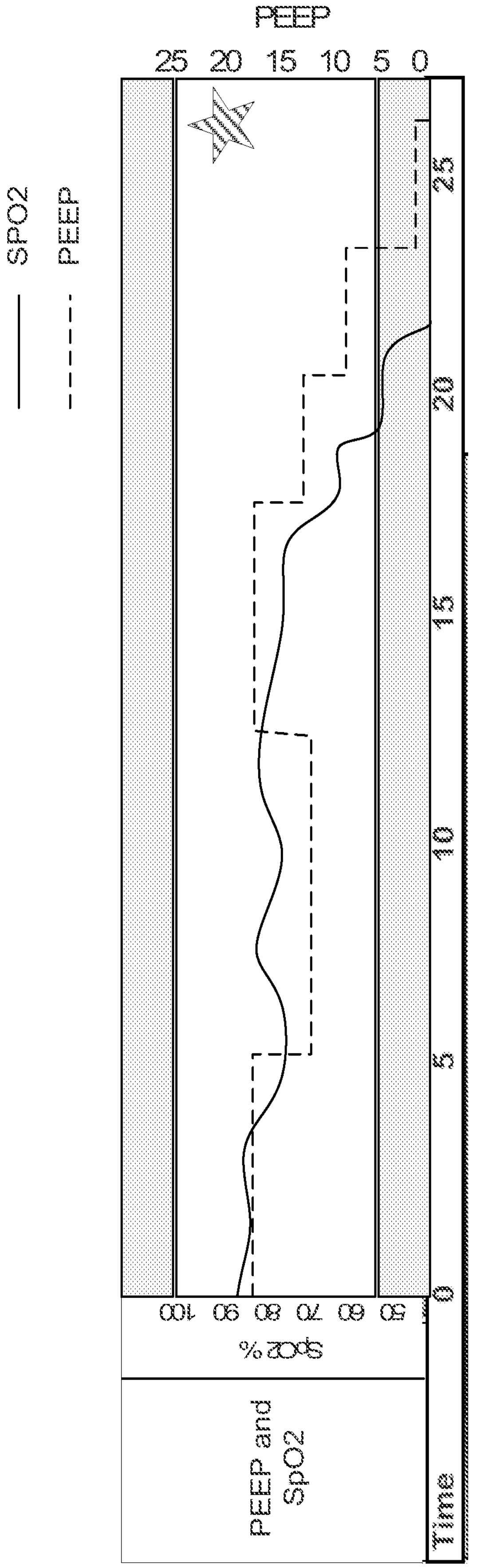
PEEP
25 20 15 10 5 0
SPO2
PEEP
0 5 10 15 20 25
100 90 80 70 60 50
SpO2 %
PEEP and SpO2
Time

FIG. 11

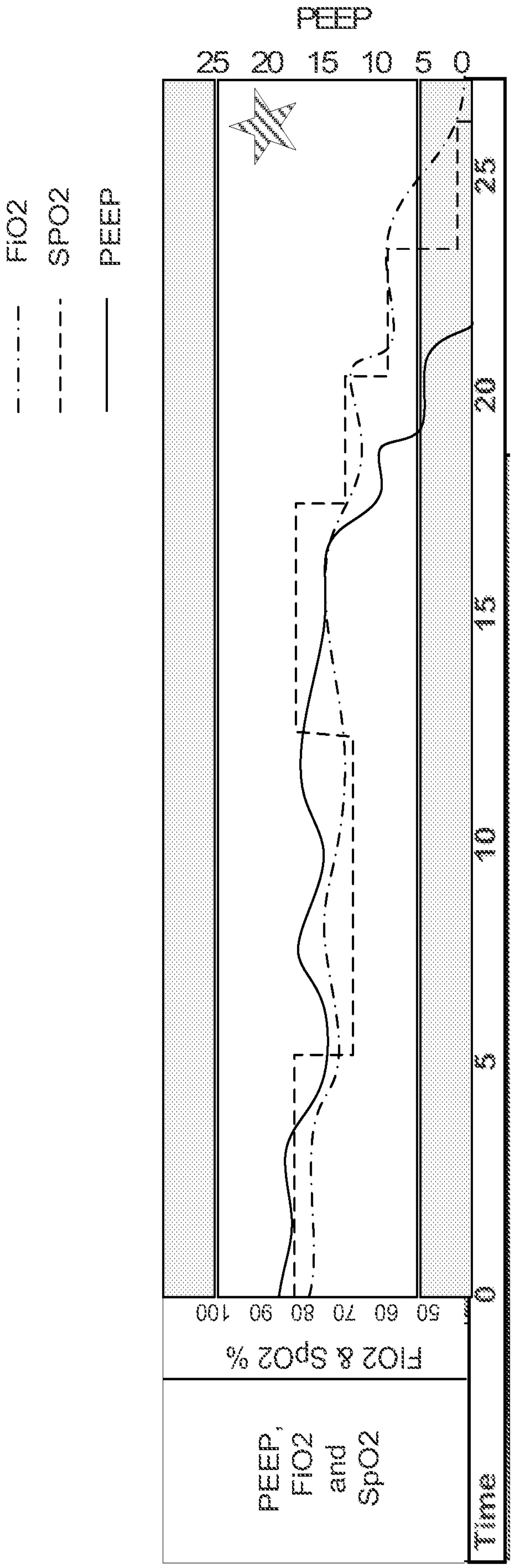
PEEP
25 20 15 10 5 0
FiO2
SPO2
PEEP
0 5 10 15 20 25
Time
100 90 80 70 60 50
FIO2 & SpO2 %
PEEP, FiO2 and SpO2

FIG. 12

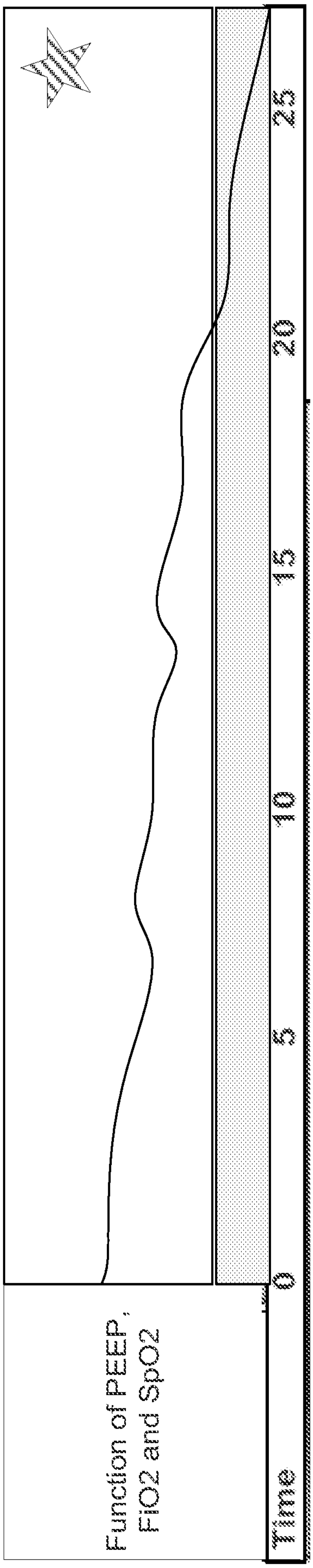

FIG. 13

MEDICAL VENTILATOR WITH INTEGRATED OXIMETER DATA

BACKGROUND

Medical ventilator systems have been long used to provide supplemental oxygen support to patients. These ventilators typically comprise a source of pressurized oxygen which is fluidly connected to the patient through a conduit. Some ventilator systems monitor the patient during ventilation. In some systems, the pulse arterial oxygen saturation (SpO_2) is monitored via a pulse oximeter attached to the patient.

A pulse oximeter includes a light sensor that is placed at a site on a patient, usually a fingertip, toe, forehead or earlobe, or in the case of a neonate, across a foot. Light, which may be produced by a light source integrated into the pulse oximeter, containing both red and infrared wavelengths is directed onto the skin of the patient and the light that passes through the skin is detected by the sensor. The intensity of light in each wavelength is measured by the sensor over time. The graph of light intensity versus time is referred to as the photoplethysmogram (PPG) or, more commonly, simply as the "pleth." From the waveform of the PPG, it is possible to identify the pulse rate of the patient and when each individual pulse occurs. In addition, by comparing the intensities of two wavelengths when a pulse occurs, it is possible to determine blood oxygen saturation of hemoglobin in arterial blood. This relies on the observation that highly oxygenated blood will relatively absorb more red light and less infrared light than blood with a lower oxygen saturation.

Some of previously known medical ventilators attempt to automate the adjustment of fractional inspired oxygen (FiO_2) as a function of the patient's SpO_2. While these previously known automated ventilation systems utilize the oximeter readings for improving ventilation, patient care could be improved by further coordinating the operation of the two devices, particularly by integrating the analysis, storage and display of particular aspects of oximeter data and respiratory data.

SUMMARY

This disclosure describes systems and methods for managing the ventilation of a patient being ventilated by a medical ventilator. The disclosure describes a novel approach of displaying ventilator information integrated with oximeter information. The disclosure further describes a novel approach of alarming based on the integration of ventilator information with oximeter information.

In part, this disclosure describes a method for managing the ventilation of a patient being ventilated by a medical ventilator. The method includes:

a) monitoring a patient during ventilation with an oximeter;

b) monitoring an oxygen saturation level of blood in the patient during ventilation;

c) monitoring a PEEP level of the patient;

d) graphing the oxygen saturation level of the blood in the patient as a function of the PEEP level versus time; and

e) displaying a graph of the function versus time.

The disclosure also describes another method for managing the ventilation of a patient being ventilated by a medical ventilator. The method includes:

a) monitoring a patient during ventilation with an oximeter;

b) monitoring an oxygen saturation level of blood in the patient during ventilation based on readings from the oximeter;

c) monitoring a PEEP level of the patient;

d) graphing the oxygen saturation level of the blood in the patient versus time;

e) graphing the PEEP level of the patient versus time; and

f) displaying both the oxygen saturation level of the blood in the patient versus time and the PEEP level of the patient versus time on one graph,

The disclosure further describes another method for managing the ventilation of a patient being ventilated by a medical ventilator. The method includes:

a) monitoring a patient during ventilation with an oximeter;

b) monitoring an oxygen saturation level of blood in the patient during ventilation based on readings from the oximeter;

c) monitoring the PEEP of the patient;

d) monitoring the fractional inspired oxygen level of the patient;

e) graphing the oxygen saturation level of the blood in the patient versus time;

f) graphing the PEEP level of the patient versus time;

g) graphing the fractional inspired oxygen level of the patient versus time; and

h) displaying the oxygen saturation level of the blood in the patient versus time, the fractional inspired oxygen level of the patient versus time, and the PEEP level of the patient versus time on one graph.

Additionally, the disclosure also describes a computer-readable medium having computer-executable instructions for performing a method for managing the ventilation of a patient being ventilated by a medical ventilator. The method includes:

a) repeatedly monitoring a patient with an oximeter during ventilation;

b) repeatedly monitoring an oxygen saturation level of blood in the patient during ventilation;

c) repeatedly monitoring a PEEP level of the patient;

d) repeatedly graphing the oxygen saturation level of the blood in the patient in a mathematical relation to the PEEP level versus time; and

e) repeatedly displaying a graph of the mathematical relationship versus time.

Further, the disclosure also describes a medical ventilator system. The medical ventilator system includes means for repeatedly monitoring a patient during ventilation with an oximeter, means for repeatedly monitoring an oxygen saturation level of blood in the patient during ventilation, means for repeatedly monitoring a PEEP level of the patient, means for repeatedly graphing the oxygen saturation level of the blood in the patient in a mathematical relation to the PEEP level versus time, and means for repeatedly displaying a graph of the mathematical relationship versus time.

These and various other features as well as advantages which characterize the systems and methods described herein will be apparent from a reading of the following detailed description and a review of the associated drawings. Additional features are set forth in the description which follows, and in part will be apparent from the description, or may be learned by practice of the technology. The benefits and features of the technology will be realized and attained by the structure particularly pointed out in the written description and claims hereof as well as the appended drawings.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

The following drawing figures, which form a part of this application, are illustrative of embodiment systems and methods described below and are not meant to limit the scope of the invention in any manner, which scope shall be based on the claims appended hereto.

FIG. **1** illustrates an embodiment of a ventilator and oximeter connected to a human patient.

FIG. **2**A illustrates an embodiment of a method for managing the ventilation of a patient being ventilated by a medical ventilator.

FIG. **2**B illustrates an embodiment of a method for managing the ventilation of a patient being ventilated by a medical ventilator.

FIG. **3** illustrates an embodiment of a method for managing the ventilation of a patient being ventilated by a medical ventilator.

FIG. **4** illustrates an embodiment of a method for managing the ventilation of a patient being ventilated by a medical ventilator.

FIG. **5** illustrates an embodiment of a method for managing the ventilation of a patient being ventilated by a medical ventilator.

FIG. **6** illustrates an embodiment of a graph of SpO_2 as a function of PEEP as displayed on a display screen.

FIG. **7** illustrates an embodiment of a graph of SpO_2 and PEEP of a patient on a medical ventilator versus time as displayed on a display screen.

FIG. **8** illustrates an embodiment of a graph of SpO_2 and PEEP of a patient on a medical ventilator versus time as displayed on a display screen.

FIG. **9** illustrates an embodiment of a graph of a function of SpO_2 and PEEP of a patient on a medical ventilator versus time as displayed on a display screen.

FIG. **10** illustrates an embodiment of a graph of a function of SpO_2 and PEEP of a patient on a medical ventilator versus time as displayed on a display screen.

FIG. **11** illustrates an embodiment of a graph of a function of SpO_2 and PEEP of a patient on a medical ventilator versus time as displayed on a display screen.

FIG. **12** illustrates an embodiment of a graph of a SpO_2, FiO_2, and PEEP of a patient on a medical ventilator versus time as displayed on a display screen.

FIG. **13** illustrates an embodiment of a graph of a function of SpO_2, FiO_2, and PEEP of a patient on a medical ventilator versus time as displayed on a display screen.

DETAILED DESCRIPTION

Although the techniques introduced above and discussed in detail below may be implemented for a variety of medical devices, the present disclosure will discuss the implementation of these techniques in the context of a medical ventilator and oximeter for use in providing ventilation support to a human patient. The reader will understand that the technology described in the context of a medical ventilator and oximeter for human patients could be adapted for use with other systems and purposes, such as treating non-human patients.

Medical ventilators are used to provide a breathing gas to a patient who may otherwise be unable to breathe sufficiently. In modern medical facilities, pressurized air and oxygen sources are often available from wall outlets. However, ventilators may also provide pressure regulating valves (or regulators) connected to localized sources of pressurized air and pressurized oxygen. Internal to the ventilator are regulating valves that function to regulate flow so that respiratory gas having a desired concentration of oxygen is supplied to the patient at desired pressures and rates. Ventilators capable of operating independently of external sources of pressurized air are also available.

While operating a ventilator, it is desirable to control the percentage of oxygen in the gas supplied by the ventilator to the patient. Further, it is desirable to monitor the oxygen saturation level of blood (SpO_2 level) of a patient. Accordingly, medical care facilities typically have oximeters for non-invasively determining the SpO_2 level of a patient.

Although ventilators and oximeters are often used on the same patient, ventilators typically display data based solely on respiratory data monitored by the ventilator. Further, oximeters typically display data based solely on the oximeter readings. However, it is desirable to display information that incorporates oximeter data with ventilator data for the patient, ventilator operator, and/or medical caregiver.

The present disclosure describes trended SpO_2 data that is graphically depicted on a display as a function of a Positive End-Expiratory Pressure (PEEP) and/or other respiratory parameters such as FiO_2. PEEP is the pressure exerted at the end of expiration to oppose passive emptying of the lung and to keep the airway pressure above the atmospheric pressure. By displaying the combination of SpO_2 and PEEP, a significantly clearer picture of the time-based cause and effect of PEEP on SpO_2 can be better inferred. This clearer picture allows a clinician to more appropriately adjust PEEP and/or oxygen levels.

Those skilled in the art will recognize that the methods and systems of the present disclosure may be implemented in many ways and as such are not to be limited by the foregoing exemplary embodiments and examples. In other words, functional elements being performed by a single or multiple components, in various combinations of hardware and software or firmware, and individual functions, can be distributed among software applications at either the client or server level or both. In this regard, any number of the features of the different embodiments described herein may be combined into single or multiple embodiments, and alternate embodiments having fewer than or more than all of the features herein described are possible. Functionality may also be, in whole or in part, distributed among multiple components, in manners now known or to become known. Thus, myriad software/hardware/firmware combinations are possible in achieving the functions, features, interfaces and preferences described herein. Moreover, the scope of the present disclosure covers conventionally known ways for carrying out the described features and functions and interfaces, and those variations and modifications that may be made to the hardware or software or firmware components described herein as would be understood by those skilled in the art now and hereafter.

FIG. **1** illustrates an embodiment of a ventilator **20** connected to a human patient **24**. Ventilator **20** includes a pneumatic system **22** (also referred to as a pressure generating system **22**) for circulating breathing gases to and from patient **24** via the ventilation tubing system **26**, which couples the patient **24** to the pneumatic system **22** via physical patient interface **28** and ventilator circuit **30**. Ventilator **20** also includes an oximeter **62** for determining the SpO_2 of patient **24**, which is operatively coupled to the ventilator **20** during ventilation.

Ventilator circuit **30** could be a two-limb or one-limb circuit **30** for carrying gas to and from the patient **24**. In a two-limb embodiment as shown, a wye fitting **36** may be provided as shown to couple the patient interface **28** to the inspiratory limb **32** and the expiratory limb **34** of the circuit **30**.

The present description contemplates that the patient interface **28** may be invasive or non-invasive, and of any configuration suitable for communicating a flow of breathing gas from the patient circuit **30** to an airway of the patient **24**. Examples of suitable patient interface **28** devices include a nasal mask, nasal/oral mask (which is shown in FIG. **1**), nasal prong, full-face mask, tracheal tube, endotracheal tube, nasal pillow, etc.

Pneumatic system **22** may be configured in a variety of ways. In the present example, system **22** includes an expiratory module **40** coupled with an expiratory limb **34** and an inspiratory module **42** coupled with an inspiratory limb **32**. Compressor **44** or another source or sources of pressurized gas (e.g., pressured air and/or oxygen) is controlled through the use of one or more gas regulators. The pneumatic system **22** may include a variety of other components, including sources for pressurized air and/or oxygen, mixing modules, valves, sensors, tubing, filters, etc.

The oximeter **62** is connected to a patient oximeter sensor **64**. As illustrated, in an embodiment, the oximeter **62** is a completely separate and independent component from the ventilator **20**. In an alternative embodiment, the oximeter **62** is part of the ventilator system or the pneumatic system **22**.

The oximeter **62** determines an oxygen gas saturation level of blood in the patient based on the patient readings taken by the pulse oximeter sensor **64** during ventilation of patient **24** by the ventilator **20**. The oximeter sends the measured oxygen saturation level of the blood of patient **24** to a controller **50**. The controller **50** may be any individual controller or combination of controllers within ventilator **20** or operatively coupled to ventilator **20**. In one embodiment, the controller **50** includes a SpO_2 controller, PEEP controller and/or FiO_2 controller. Controller **50** monitors the PEEP of patient **24**. In one embodiment, controller **50** sends a graph plotting the SpO_2 and PEEP of patient **24** in two separate lines versus time on the same graph to display **59**. In another embodiment, controller **50** sends the necessary data to the display **59** for displaying a graph plotting a function of SpO_2 and PEEP versus time.

In an additional embodiment, controller **50** monitors the fractional inspired oxygen (FiO_2) delivered to patient **24**. In one embodiment, controller **50** sends the necessary data to display **59** for displaying a graph plotting SpO_2, FiO_2 and PEEP of patient **24** in three separate lines versus time on the same graph. In another embodiment, controller **50** sends the necessary data to display **59** for displaying a graph plotting a function of FiO_2, SpO_2 and PEEP versus time on a graph.

In this embodiment, the function of SpO_2 and PEEP or FiO_2, SpO_2 and PEEP may be the multiplication, addition, subtraction, ratio and/or any other mathematical relationship between the separate readings. This function is then plotted on a graph versus time. In an embodiment, controller **50** sends the necessary data to the display **59** for displaying a graph plotting the blood gas oxygen saturation level along with the fractional inspired oxygen concentration and PEEP to graphically depict the relationship between FiO_2, SpO_2 and PEEP.

In one embodiment, the graph is displayed on an oximeter display. In another embodiment, the graph is displayed on a ventilator display **59**.

In another embodiment, the graph may display upper and/or lower preset thresholds for the plotted line or lines. As used herein, the term "preset" refers to any parameter that is calculated by the operator, entered by the operator, set during configuration, or selected by the operator. In this embodiment, the graph may designate with lines, colors, and/or shapes a preset threshold for the plotted line or lines. The preset threshold marker provides the patient, ventilator operator, and/or medical caregiver with a quick and easy way to check the status of the patient. Further, the patient, ventilator operator, and/or medical caregiver can determine with one glance the severity of a preset threshold breach. The severity of the breach is determined by the amount by which the parameter exceeds the preset threshold, the magnitude of the breach and the duration of the breach, which are fully visible in this embodiment to the patient, ventilator operator, and/or medical caregiver on the displayed graph. Further, the graph illustrates the relationship between SpO_2 and PEEP or SpO_2 and FiO_2 at a glance providing the operator with additional useful information for operating the ventilator. In another embodiment, the graph illustrates the relationship between SpO_2, FiO_2, and PEEP at a glance providing the operator with additional useful information for managing the ventilator.

In one embodiment, as illustrated in FIG. **1**, the plotting of the data is performed by a graph module **57** in controller **50**. The graph module **57** interprets the SpO_2, and PEEP data, and/or FiO_2 data and converts this information into the form necessary for graphing the SpO_2 and PEEP and/or FiO_2 or a function of SpO_2 and PEEP versus time and/or a function of SpO_2, FiO_2, and PEEP versus time and for displaying the determined graph on a display screen. In an alternative embodiment, the graph module **57** is part of the oximeter **62**. In another embodiment, the graph module **57** includes a processor and is a separate and independent component from the controller **50**.

In a further embodiment, controller **50** issues an alarm based on the graphed information to notify the operator, patient, and/or medical caregiver that the patient requires assistance or a change in ventilator parameters and/or features is desirable. For example, if the function of SpO_2 and PEEP and/or FiO_2 falls below or above a preset threshold in a patient, the controller **50** may execute an alarm. The alarm may be any visual and/or audio cue supplemental to the graphed information that notifies the patient, operator, and/or medical care giver of a preset threshold breach. In another example, controller **50** determines if the PEEP of patient **24** drops before a drop in SpO_2, such as could occur in response to a clinician lowering PEEP. In this embodiment, if controller **50** determines that PEEP dropped before a drop in SpO_2, controller **50** executes a 2^{nd} type SpO_2 alarm. As used herein, a "2^{nd} type SpO_2 alarm" is any suitable audio and/or visual warning supplemental to the graph information that notifies the patient, operator, and/or medical care giver of a preset threshold breach with a drop in PEEP prior to a drop in SpO_2. As used herein, a "3^{rd} type SpO_2 alarm" is any suitable audio and/or visual warning supplemental to the graph information that notifies the patient, operator, and/or medical care giver of a preset threshold breach with a drop in FiO_2 prior to a drop in SpO_2. In yet another example, the controller **50** determines if SpO_2 drops independently of a change in PEEP and/or FiO_2. If controller **50** determines a drop in SpO_2 independent of a change in PEEP and/or FiO_2, the controller **50** executes a first type oxygen saturation or 1^{st} type SpO_2 alarm. As used herein, a "1^{st} type SpO_2 alarm" is any suitable audio and/or visual warning supplemental to the graph information that notifies the patient, operator, and/or medical care giver of a preset threshold breach with a drop in SpO_2 independent of a change in PEEP and/or FiO_2.

In another embodiment, the ventilator may alarm if the plotted parameter exceeds the preset threshold. The alarm may include a visual cue and/or an audio cue. Further, the alarm may offer different levels or degrees of visual cues and/or audio cues depending upon the severity of the preset threshold breach.

Controller **50** is operatively coupled with pneumatic system **22**, signal measurement and acquisition systems, and an operator interface **52**, which may be provided to enable an operator to interact with the ventilator **20** (e.g., change ventilator settings, select operational modes, view monitored parameters, etc.). In one embodiment, controller **50** is operatively coupled with a SpO_2 controller, PEEP controller, and/or FiO_2 controller. Controller **50** may include memory **54**, one or more processors **56**, storage **58**, and/or other components of the type commonly found in command and control computing devices.

The memory **54** is non-transitory computer-readable storage media that stores software that is executed by the processor **56** and which controls the operation of the ventilator **20**. In an embodiment, the memory **54** comprises one or more solid-state storage devices such as flash memory chips. In an alternative embodiment, the memory **54** may be mass storage connected to the processor **56** through a mass storage controller (not shown) and a communications bus (not shown). Although the description of non-transitory computer-readable media contained herein refers to a solid-state storage, it should be appreciated by those skilled in the art that non-transitory computer-readable storage media can be any available media that can be accessed by the processor **56**. Non-transitory computer-readable storage media includes volatile and non-volatile, removable and non-removable media implemented in any method or technology for storage of information such as computer-readable instructions, data structures, program modules or other data. Non-transitory computer-readable storage media includes, but is not limited to, RAM, ROM, EPROM, EEPROM, flash memory or other solid state memory technology, CD-ROM, DVD, or other optical storage, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store the desired information and which can be accessed by the processor **56**.

The controller **50** issues commands to pneumatic system **22** in order to control the breathing assistance provided to the patient **24** by the ventilator **20**. The specific commands may be based on inputs received from patient **24**, pneumatic system **22** and sensors, operator interface **52** and/or other components of the ventilator **20**.

In the depicted example, operator interface **52** includes a display **59** that is touch-sensitive, enabling the display **59** to serve both as an input user interface and an output device. The display **59** can display any type of ventilation information, such as sensor readings, parameters, commands, alarms, warnings, and smart prompts (i.e., ventilator determined operator suggestions). In this embodiment, display **59** further displays oximeter and ventilator information, such as a graph of SpO_2 in relation to PEEP versus time. In an alternative embodiment, an oximeter display or monitor displays oximeter and ventilator information, such as a graph of SpO_2 in relation to PEEP versus time.

In another embodiment, display **59** further displays oximeter and ventilator information, such as a graph of SpO_2 in relation to PEEP and FiO_2 versus time. In an alternative embodiment, an oximeter display or monitor displays oximeter and ventilator information, such as a graph of SpO_2 in relation to PEEP and FiO_2 versus time.

As illustrated in FIGS. **2**A and **2**B, an embodiment of a method **200** for managing the ventilation of a patient being ventilated by a medical ventilator is shown. Method **200** performs a patient monitoring operation **202**. The patient monitoring operation **202** utilizes an oximeter to monitor the status of a patient during ventilation. The oximeter is operatively coupled to the controller of the ventilation system.

Next, method **200** performs a SpO_2 monitoring operation **204**. The SpO_2 monitoring operation **204** determines the SpO_2 of the patient from patient data gathered by patient monitoring operation **202**. The SpO_2 monitoring operation **204** can be performed by the oximeter and/or the ventilator by utilizing oximeter sensor readings to monitor the SpO_2 of the patient.

Further, method **200** performs a PEEP monitoring operation **206**. The PEEP monitoring operation **206** monitors the PEEP of the patient during ventilation. The PEEP monitoring operation **206** may monitor the PEEP of the patient with one or more flow and/or pressure sensors depending on the configuration of the ventilator. The reading from the flow and/or pressure sensors may be utilized to monitor the PEEP of the patient.

Method **200** performs a graphing operation **208**. The graphing operation **208** graphs SpO_2 and PEEP versus time. In one embodiment, graphing operation **208** graphs PEEP and SpO_2 as separate lines on one graph. In an alternative embodiment, graphing operation **208** calculates a function of PEEP and SpO_2 and graphs this number as one line versus time. The function of SpO_2 and PEEP may be the multiplication, addition, subtraction, ratio and/or any other mathematical relationship between of the separate readings.

In one embodiment, the graphing operation **208** is performed by a controller. Further, the controller may include a graphing module for receiving and interpreting the PEEP and SpO_2 data to correctly graph this data versus time. The graphing operation **208** converts the PEEP and SpO_2 data into graphable information and displayable information.

Method **200** also performs a display operation **210**. Display operation **210** displays the graph created by graphing operation **208**. The displaying operation **210** may display the graph on a display in the oximeter and/or ventilator. As illustrated in FIGS. **6** through **11**, an embodiment of a graph of a function of SpO_2 and PEEP or separate SpO_2 and PEEP readings of a patient on a medical ventilator as displayed on a display screen is shown.

In one embodiment, as illustrated in FIG. **2**B, method **200** further performs a preset threshold display operation **212**. The preset threshold display operation **212** displays at least one preset threshold on the graph displayed by display operation **210**. The preset threshold provides the patient, operator, and/or medical care giver with a quick reference point to determine the status of the patient during ventilation. In an embodiment, preset threshold display operation **212** displays an upper and a lower preset threshold limit on the graphed function of SpO_2 and PEEP or each reading individually. Preset threshold display operation **212** may depict a preset threshold with color, symbols, lines, light, and/or text. The preset threshold may be preset by the operator, configured into the ventilator based on the ventilator settings, and/or selected by the operator.

As illustrated in FIG. **2**B, method **200** may further perform a preset threshold determination operation **214**. The preset threshold determination operation **214** determines if PEEP, SpO_2, and/or a function of PEEP and SpO_2 exceeds a preset threshold. If preset threshold determination operation **214** determines that PEEP, SpO_2, and/or a function of PEEP and SpO_2 exceeds a preset threshold, preset threshold determination operation **214** has method **200** perform PEEP determination operation **216**. If preset threshold determination operation **214** determines that PEEP, SpO_2, and/or a function of PEEP and SpO_2 do not exceed a preset threshold, preset threshold determination operation **214** has method **200** perform patient monitoring operation **202** again.

As illustrated in FIG. **2**B, method **200** may further perform a PEEP determination operation **216**. The PEEP determination operation **216** determines if PEEP changes prior to a SpO_2 drop after preset threshold determination operation **214** determines that a preset threshold had been exceeded. If PEEP determination operation **216** determines that PEEP changed prior to a SpO_2 drop, PEEP determination operation **216** has method **200** perform a 2^{nd} type SpO_2 alarm operation **218**. If PEEP determination operation **216** determines that SpO_2 dropped independently of a change in PEEP, PEEP determination operation **216** has method **200** perform a 1^{st} type SpO_2 alarm operation **220**.

As illustrated in FIG. **2**B, method **200** may perform a 2^{nd} type SpO_2 alarm operation **218**. Second type SpO_2 alarm operation **218** executes a specific alarm that notifies the operator that a preset threshold was exceeded during which PEEP changed prior to a drop in SpO_2. The 2^{nd} type SpO_2 alarm may be any visual and/or audio cue.

As illustrated in FIG. **2**B, method **200** may perform 1^{st} type SpO_2 alarm operation **220**. First type SpO_2 alarm operation **220** executes a specific alarm that notifies the operator that a preset threshold was exceeded during which PEEP did not change prior to a drop in SpO_2. The 1^{st} type SpO_2 alarm may be any visual and/or audio cue.

After performing the 2^{nd} type SpO_2 alarm operation **218** or the 1^{st} type SpO_2 alarm operation **220**, method **200** performs patient monitoring operation **202** again.

In an additional embodiment, method **200** further monitors a FiO_2 level of the patient, graphs the oxygen saturation level of the blood in the patient as a function of the FiO_2 level and PEEP versus time, and then displays in the graph the oxygen saturation level of the blood in the patient as a function of the FiO_2 level and PEEP versus time. Accordingly, method **200** may further determine that either function is outside a preset threshold. If method **200** determines that the FiO_2 of the patient dropped prior to a drop in the oxygen saturation level of the blood in the patient, method **200** executes a 3^{rd} type SpO_2 alarm. Alternatively, if method **200** determines that the PEEP of the patient dropped prior to a drop in the oxygen saturation level of the blood in the patient, method **200** executes a 2^{nd} type SpO_2 alarm. In an another embodiment, if method **200** determines that the oxygen saturation level of the blood in the patient dropped independently of a drop in PEEP and/or FiO_2, then method **200** executes a first type oxygen saturation alarm. Further, the step of graphing the oxygen saturation level of the blood in the patient as a function of the FiO_2 level and PEEP versus time performed by method **200** can include converting PEEP data oxygen saturation level data, and FiO_2 data into a plotted graph and into displayable information.

As illustrated in FIG. **3**, an embodiment of a method **300** for managing the ventilation of a patient being ventilated by a medical ventilator is shown. Method **300** performs a patient monitoring operation **302**. The patient monitoring operation **302** utilizes an oximeter to monitor the status of a patient during ventilation. The oximeter is operatively coupled to the controller of the ventilation system.

Next, method **300** performs a SpO_2 monitoring operation **304**. The SpO_2 monitoring operation **304** determines the SpO_2 of the patient based on the results of the patient monitoring operation **302**. The SpO_2 monitoring operation **304** can be performed by the oximeter or the ventilator. The oximeter or the ventilator utilizes oximeter sensor readings to monitor the SpO_2 of the patient.

Further, method **300** performs a PEEP monitoring operation **306**. The PEEP monitoring operation **306** monitors the PEEP of the patient during ventilation. The PEEP monitoring operation **306** may monitor the PEEP of the patient with a flow and/or pressure sensor. The reading from the flow and/or pressure sensor may be utilized to monitor the PEEP of the patient.

Method **300** performs a graphing operation **308**. The graphing operation **308** graphs SpO_2 and PEEP versus time. In one embodiment, graphing operation **308** graphs PEEP and SpO_2 as separate lines on one graph. In an alternative embodiment, graphing operation **308** calculates a function of PEEP and SpO_2 and graphs this number in one line versus time. The function of SpO_2 and PEEP may be the multiplication, addition, subtraction, ratio and/or any other mathematical relationship between the separate readings.

In one embodiment, the graphing operation **308** is performed by a controller. Further, the controller may include a graphing module for receiving and interpreting the PEEP and SpO_2 data to correctly graph this data versus time. The graphing operation **308** converts the PEEP and SpO_2 data into graphable information and displayable information.

Method **300** also performs a display operation **310**. Display operation **310** displays the graph created by graphing step **308**. The displaying operation **310** may display the graph on a display in the oximeter and/or ventilator. As illustrated in FIGS. **6** through **11**, an embodiment of a graph of a function of SpO_2 and PEEP or separate SpO_2 and PEEP readings of a patient on a medical ventilator as displayed on a display screen is shown.

Next, method **300** performs a preset threshold display operation **312**. The preset threshold display operation **312** displays at least one preset threshold on the graph displayed by display operation **310**. The preset threshold provides the patient, operator, and/or medical care giver with a quick reference point to determine the status of the patient during ventilation. In an embodiment, preset threshold display operation **312** displays an upper and a lower preset threshold limit on the graph. Preset threshold display operation **312** may depict a preset threshold with color, symbols, lines, light, and/or text. The preset threshold may be preset by the operator, configured into the ventilator based on the ventilator settings, and/or selected by the operator.

Further, method **300** performs a preset threshold determination operation **314**. The preset threshold determination operation **314** determines if PEEP, SpO_2, and/or a function of PEEP and SpO_2 preset threshold was exceeded. If preset threshold determination operation **314** determines that a preset threshold was exceeded, preset threshold determination operation **314** has method **300** perform an alarm operation **316**. If preset threshold determination operation **314** determines that a preset threshold was not exceeded, preset threshold determination operation **314** has method **300** perform patient monitoring operation **302** again.

Method **300** performs an alarm operation **316**. The alarm operation **316** executes an alarm to notify the operator that a preset threshold has been exceeded. The alarm may be any visual and/or audio cue. After performing alarm operation **316**, method **300** performs patient monitoring operation **302** again.

As illustrated in FIG. **4**, an embodiment of a method **400** for managing the ventilation of a patient being ventilated by a medical ventilator is shown. Method **400** performs a patient monitoring operation **402**. The patient monitoring operation **402** utilizes an oximeter to monitor the status of a patient during ventilation. The oximeter is operatively coupled to the controller of the ventilation system.

Next, method **400** performs a SpO_2 monitoring operation **404**. The SpO_2 monitoring operation **404** determines the SpO_2 of the patient based on the results of the patient monitoring operation **402**. The SpO_2 monitoring operation **404** can be performed by the oximeter and/or the ventilator. The oximeter and/or the ventilator utilize oximeter sensor readings to monitor the SpO_2 of the patient.

Further, method **400** performs a PEEP monitoring operation **406**. The PEEP monitoring operation **406** monitors the PEEP of the patient during ventilation. The PEEP monitoring operation **406** may monitor the PEEP of the patient with a flow and/or pressure sensor. The reading from the flow and/or pressure sensor may be utilized to monitor the PEEP of the patient.

Further, method **400** performs a FiO_2 monitoring operation **407**. The FiO_2 monitoring operation **407** monitors the FiO_2 of the patient during ventilation. The FiO_2 monitoring operation **407** may monitor the FiO_2 of the patient with a gas sensor and/or a flow and/or pressure sensor. The reading from the gas sensor may be utilized to monitor the FiO_2 of the patient.

Method **400** performs a graphing operation **408**. The graphing operation **408** graphs SpO_2, FiO_2, and PEEP versus time. In one embodiment, graphing operation **408** graphs PEEP, FiO_2, and SpO_2 as separate lines on one graph. In an alternative embodiment, graphing operation **408** calculates a function of PEEP, FiO_2, and SpO_2 and graphs this number in one line versus time. The function of FiO_2, SpO_2 and PEEP may be the multiplication, addition, subtraction, ratio and/or any other mathematical relationship between the separate readings.

In one embodiment, the graphing operation **408** is performed by a controller. The controller may be located in the oximeter and/or the ventilator. Further, the controller may include a graphing module for receiving and interpreting the PEEP, FiO_2, and SpO_2 data to correctly graph this data versus time. The graphing operation **408** converts the PEEP, FiO_2, and SpO_2 data into graphable information and displayable information.

Method **400** also performs a display operation **410**. Display operation **410** displays the graph created by graphing step **408**. The displaying operation **410** may display the graph on a display in the oximeter and/or ventilator. As illustrated in FIGS. **12** and **13**, an embodiment of a graph of a function of FiO_2, SpO_2 and PEEP or separate SpO_2, FiO_2, and PEEP readings of a patient on a medical ventilator versus time as displayed on a display screen is shown.

Next, method **400** performs a preset threshold display operation **412**. The preset threshold display operation **412** displays at least one preset threshold on the graph displayed by display operation **408**. The preset threshold provides the patient, operator, and/or medical care giver with a quick reference point to determine the status of the patient during ventilation. In an embodiment, preset threshold display operation **412** displays an upper and a lower preset threshold limit on the graph. Preset threshold display operation **412** may depict a preset threshold with color, symbols, lines, light, and/or text. The preset threshold may be preset by the operator, configured into the ventilator based on the ventilator settings, and/or selected by the operator.

Further, method **400** performs a preset threshold determination operation **414**. The preset threshold determination operation **414** determines if a PEEP, FiO_2, SpO_2, and/or a function of PEEP, FiO_2, and SpO_2 preset threshold was exceeded. If preset threshold determination operation **414** determines that a preset threshold was exceeded, preset threshold determination operation **414** has method **400** perform an alarm operation **416**. If preset threshold determination operation **414** determines that a preset threshold was not exceeded, preset threshold determination operation **414** has method **400** perform patient monitoring operation **402** again.

Method **400** performs an alarm operation **416**. The alarm operation **416** executes an alarm to notify the operator that a preset threshold has been exceeded. The alarm may be any visual and/or audio cue. After performing alarm operation **416**, method **400** performs patient monitoring operation **402** again.

As illustrated in FIG. **5**, an embodiment of a method **500** for managing the ventilation of a patient being ventilated by a medical ventilator is shown. Method **500** performs a patient monitoring operation **502**. The patient monitoring operation **502** utilizes an oximeter to monitor the status of a patient during ventilation. The oximeter is operatively coupled to the controller of the ventilation system.

Next, method **500** performs a SpO_2 monitoring operation **504**. The SpO_2 monitoring operation **504** determines the SpO_2 of the patient based on the data gathered by the patient monitoring operation **502**. The SpO_2 monitoring operation **504** can be performed by the oximeter or the ventilator. The oximeter or the ventilation utilizes oximeter sensor readings to monitor the SpO_2 of the patient.

Further, method **500** performs a FiO_2 monitoring operation **506**. The FiO_2 monitoring operation **506** monitors the FiO_2 of the patient during ventilation. The FiO_2 monitoring operation **506** may monitor the FiO_2 of the patient with a gas sensor and/or a flow and/or pressure sensor. The reading from the gas sensor may be utilized to monitor the FiO_2 of the patient.

Method **500** performs a graphing operation **508**. The graphing operation **508** graphs SpO_2 and FiO_2 versus time. In one embodiment, graphing operation **508** graphs FiO_2 and SpO_2 as separate lines on one graph. In an alternative embodiment, graphing operation **508** calculates a function of FiO_2 and SpO_2 and graphs this number in one line versus time. The function of SpO_2 and FiO_2 may be the multiplication, addition, subtraction, and/or ratio of the separate readings.

In one embodiment, the graphing operation **508** is performed by a controller. The controller may be located in the oximeter and/or the ventilator. Further, the controller may include a graphing module for receiving and interpreting the raw FiO_2 and SpO_2 data to correctly graph this data versus time. The graphing operation **508** converts the raw FiO_2 and SpO_2 data into graphable information and displayable information.

Method **500** also performs a display operation **510**. Display operation **510** displays the graph created by graphing step **508**. The displaying operation **510** may display the graph on a display in the oximeter and/or ventilator.

Next, method **500** performs a preset threshold display operation **512**. The preset threshold display operation **512** displays at least one preset threshold on the graph displayed by display operation **508**. The preset threshold provides the patient, operator, and/or medical care giver with a quick reference point to determine the status of the patient during ventilation. In an embodiment, preset threshold display operation **512** displays an upper and a lower preset threshold limit on the graph. Preset threshold display operation **512** may depict a preset threshold with color, symbols, lines, light, and/or text. The preset threshold may be preset by the operator, configured into the ventilator based on the ventilator settings, and/or selected by the operator.

Further, method **500** performs a preset threshold determination operation **514**. The preset threshold determination operation **514** determines if a FiO_2, SpO_2, and/or a function of FiO_2 and SpO_2 preset threshold was exceeded. If preset threshold determination operation **514** determines that a preset threshold was exceeded, preset threshold determination operation **514** has method **500** perform an alarm operation **516**. If preset threshold determination operation **514** determines that a preset threshold was not exceeded, preset threshold determination operation **514** has method **500** perform patient monitoring operation **502** again.

Method **500** performs an alarm operation **516**. The alarm operation **516** executes an alarm to notify the operator that a preset threshold has been exceeded. The alarm may be any visual and/or audio cue. After performing alarm operation **516**, method **500** performs patient monitoring operation **502** again.

In alternative embodiment, a computer-readable medium having computer-executable instructions for performing a method for managing the ventilation of a patient being ventilated by a medical ventilator is disclosed. The method includes repeatedly performing the steps disclosed in method **200**, method **300**, method **400**, or method **500**.

In another embodiment, a medical ventilator system is disclosed. The medical ventilator includes means for repeatedly monitoring a patient during ventilation with an oximeter, means for repeatedly monitoring an oxygen saturation level of blood in the patient during ventilation, means for repeatedly monitoring a PEEP level of the patient, means for repeatedly graphing the oxygen saturation level of the blood in the patient as a function of the PEEP level versus time, and means for repeatedly displaying a graph of the function versus time. In one embodiment, the means for the medical ventilator system are all illustrated in FIG. **1** and description above in the description of FIG. **1**. However, the means described above for FIG. **1** and illustrated in FIG. **1** are exemplary only and are not meant to be limiting.

EXAMPLE 1

The following are embodiments of graphs that can be displayed on a display screen of a medical ventilator or an oximeter that graphs PEEP and SpO_2 versus time.

The following are embodiments of graphs that depict PEEP and SpO_2 as separate lines versus time that can be displayed on a display screen. A display may show a graph with an upper and lower preset threshold for two separate lines depicting the patient's SpO_2 and PEEP during ventilation versus time in seconds as illustrated in FIGS. **7**, **8**, and **11**. As shown in FIG. **7**, both PEEP and SpO_2 remain within the upper and lower preset thresholds depicted by the shaded areas. FIG. **8** illustrates a preset threshold that was exceeded first by a drop in PEEP and followed by a drop in SpO_2. The appropriate scales for PEEP and SpO_2 may be displayed in any conventional manner.

FIG. **11** illustrates a preset threshold that was exceeded first by a drop in SpO_2 and then followed by a drop in PEEP. FIG. **11** further illustrates a visual alarm icon that indicates that a preset threshold was exceeded first by a drop in SpO_2 followed by a drop in PEEP. As illustrated in FIG. **11**, the visual alarm cue is a colored star that flashes in the corner of the graph. This alarm is exemplary only and does not limit the disclosure.

The following are embodiments of graphs that depict a function of SpO_2 and PEEP versus time that can be displayed on display screen. The function of SpO_2 and PEEP may be the multiplication, addition, subtraction, ratio, and/or any other mathematical relationship between the parameters. For example, in an embodiment, PEEP and SpO_2 for any given period (e.g., for each monitoring cycle of 5 ms or for a group of monitoring cycles) are multiplied resulting in a graph of P_{PEEP}*O_2% v. time. However, any function of PEEP and SpO_2 of clinical value may be used. A display may show a graph with an upper and lower preset threshold for the function of the patient's SpO_2 and PEEP during ventilation versus time in seconds.

In an alternative example, a display may show a graph with only a lower preset threshold and one line depicting the function of the patient's SpO_2 and PEEP during ventilation versus time in seconds as illustrated in FIGS. **9** and **10**. The lower preset threshold is the shaded area in the graphs illustrated in FIGS. **9** and **10**. FIGS. **9** and **10** further illustrate visual alarm icons that indicate that a preset threshold was exceeded by a drop in SpO_2 independently of a change in PEEP or was exceeded first by a drop in PEEP followed by a drop in SpO_2. As illustrated in FIG. **11**, the visual alarm icon is a colored star that flashes in the corner of the graph when a preset threshold is exceeded by a drop in SpO_2 independently of a change in PEEP. As illustrated in FIG. **9**, the visual alarm icon is a colored circle that flashes in the corner of the graph when the preset threshold was exceeded first by a drop in PEEP followed by a drop in SpO_2. These alarms are exemplary only and do not limit the disclosure.

The following are embodiments of graphs that can be displayed on a display screen of a medical ventilator or an oximeter that graphs PEEP, FiO_2 and SpO_2 versus time.

The following is an embodiment of a graph that depicts PEEP, FiO_2 and SpO_2 as separate lines versus time that can be displayed on a display screen. A display may show a graph with an upper and lower preset threshold for three separate lines depicting the patient's SpO_2, FiO_2, and PEEP during ventilation versus time in seconds as illustrated in FIG. **12**. As shown in FIG. **12** a preset threshold that was exceeded first by a drop in PEEP and followed by a drop in SpO_2. The appropriate scales for PEEP, FiO_2, and SpO_2 may be displayed in any conventional manner.

The following is an embodiment of a graph that depicts a function of SpO_2, PEEP, and FiO_2 versus time that can be displayed on a display screen. The function of SpO_2, PEEP and FiO_2 may be the multiplication, addition, subtraction, ratio, and/or any other mathematical relationship between the parameters. For example, in an embodiment, PEEP, FiO_2, and SpO_2 for any given period (e.g., for each monitoring cycle of 5 ms or for a group of monitoring cycles) are multiplied resulting in a graph of P_{FiO2}*P_{PEEP}*O_2% v. time. However, any function of PEEP, FiO_2, and SpO_2 of clinical value may be used. A display may show a graph with an upper and/or lower preset threshold for the function of the patient's SpO_2, FiO_2, and PEEP during ventilation versus time in seconds. FIG. **13** illustrates a graph displaying a lower preset threshold for the function of the patient's SpO_2, FiO_2, and PEEP during ventilation versus time in seconds. As shown in FIG. **4**, the function of PEEP and SpO_2 exceeds the lower preset threshold depicted by the shaded areas activating an alarm icon (i.e. a colored star icon). The displayed alarm is exemplary only and does not limit the disclosure.

Numerous other changes may be made which will readily suggest themselves to those skilled in the art and which are encompassed in the spirit of the disclosure and as defined in the appended claims. For example, in the embodiments of the methods described herein various operations and steps could be combined into a single operation (e.g., a single monitoring operation) or the operations could be performed in a different order or as parallel operations. While various embodiments have been described for purposes of this disclosure, various changes and modifications may be made which are well within the scope of the present invention. Numerous other changes may be made which will readily suggest themselves to those skilled in the art and which are encompassed in the spirit of the disclosure and as defined in the appended claims.

What is claimed is:

1. A method for managing ventilation of a patient being ventilated by a medical ventilator, the method comprising:
monitoring a patient during ventilation with an oximeter;
monitoring an oxygen saturation level of blood in the patient during ventilation;
monitoring a PEEP level of the patient;
graphing a function of the oxygen saturation level of the blood of and the PEEP level versus time;
displaying a graph of the function versus time; issuing a first alarm if the function is outside of a preset threshold, a drop in the oxygen saturation level of the blood is detected, and the PEEP level does not change; and
issuing a second alarm if the function is outside of the preset threshold and the drop in the oxygen saturation level of the blood occurred after the PEEP level dropped.

2. The method of claim **1**, wherein the graph is displayed by an oximeter display.

3. The method of claim **1**, wherein the graph is displayed by a ventilator display.

4. The method of claim **1**, further comprising displaying at least one preset threshold on the graph.

5. The method of claim **1**, wherein the step of graphing the function comprises converting raw PEEP data and raw oxygen saturation level data into a plotted graph and into displayable information.

6. The method of claim **1**, further comprising:
monitoring a fractional inspired oxygen level of the patient;
graphing a function of the oxygen saturation level of the blood and the fractional inspired oxygen level versus time; and
displaying on the graph the function of the oxygen saturation level of the blood and the fractional inspired oxygen level versus time.

7. The method of claim **1**, wherein the step of issuing the first alarm includes displaying the first alarm.

8. The method of claim **7**, wherein the step of displaying the first alarm includes displaying the first alarm on the graph.

9. The method of claim **7**, wherein the step of displaying the first alarm includes displaying the first alarm as an icon.

10. The method of claim **1**, wherein the step of issuing the first alarm includes issuing an audio notification.

11. The method of claim **4**, wherein the step of displaying the at least one preset threshold on the graph includes displaying the at least one preset threshold as a shaded area on the graph.

12. The method of claim **1**, wherein the function is the oxygen saturation level of blood multiplied by the PEEP level for a given period.

13. The method of claim **1**, further comprising:
issuing a third alarm if the function is outside of the preset threshold and the drop in the oxygen saturation level of the blood occurred before the PEEP level dropped.

14. A non-transitory computer-readable medium having computer-executable instructions for performing a method for managing ventilation of a patient being ventilated by a medical ventilator, the method comprising:
repeatedly monitoring a patient during ventilation with an oximeter;
repeatedly monitoring an oxygen saturation level of blood in the patient during ventilation;
repeatedly monitoring a PEEP level of the patient;
repeatedly graphing a mathematical relationship of the oxygen saturation level of the blood and the PEEP level versus time;
repeatedly displaying a graph of the mathematical relationship versus time;
repeatedly issuing a first alarm if the mathematical relationship is outside of a preset threshold, a drop in the oxygen saturation level of the blood is detected, and the PEEP level does not change; and
repeatedly issuing a second alarm if the mathematical relationship is outside of the preset threshold and the drop in the oxygen saturation level of the blood occurred after a drop in the PEEP level.

15. The method of claim **14**, further comprising:
repeatedly issuing a third alarm if the mathematical relationship is outside of the preset threshold and the drop in the oxygen saturation level of the blood occurred before the drop in the PEEP level.

16. A medical ventilator system, comprising:
means for monitoring a patient during ventilation with an oximeter;
means for monitoring an oxygen saturation level of blood in the patient during ventilation;
means for monitoring a PEEP level of the patient;
means for graphing a mathematical relationship of the oxygen saturation level of the blood and the PEEP level versus time;
means for displaying a graph of the mathematical relationship versus time;
means for determining that the mathematical relationship is outside a preset threshold;
means for determining that the PEEP level of the patient dropped prior to a drop in the oxygen saturation level of the blood in the patient, determining that the oxygen saturation level of the blood in the patient dropped prior to a drop in the PEEP level, and determining the drop in the oxygen saturation level of the blood when the PEEP level does not change;
means for issuing a first alarm if the mathematical relationship is outside of the preset threshold, the drop in the oxygen saturation level of the blood is detected, and the PEEP level does not change; and
means for issuing a second alarm if the mathematical relationship is outside of the preset threshold and the drop in the oxygen saturation level of the blood occurred after the PEEP level dropped.

17. The method of claim **16**, further comprising:
means for issuing a third alarm if the mathematical relationship is outside of the preset threshold and the drop in the oxygen saturation level of the blood occurred before the PEEP level dropped.

* * * * *

patsnap

专利名称(译)	带有集成血氧计数据的医用呼吸机		
公开(公告)号	US8554298	公开(公告)日	2013-10-08
申请号	US12/887077	申请日	2010-09-21
[标]申请(专利权)人(译)	内尔科尔普里坦贝内特公司		
申请(专利权)人(译)	NELLCOR PURITAN BENNETT LLC		
当前申请(专利权)人(译)	COVIDIEN LP		
[标]发明人	DOYLE PETER VANDINE JOSEPH DOUGLAS SANBORN WARREN GRABOI DAN		
发明人	DOYLE, PETER VANDINE, JOSEPH DOUGLAS SANBORN, WARREN GRABOI, DAN		
IPC分类号	A61B5/1455 A61B5/00		
CPC分类号	A61B5/085 A61B5/1455 A61M16/00 A61B5/082 A61M16/0666 A61M16/0465 A61M16/0057 A61M16/0051 A61B5/4836 A61B5/14551 A61M16/0875 A61M2016/0027 A61M2016/1025 A61M2205/18 A61M2205/505 A61M2230/435 A61M2230/205 A61M16/0063 A61M16/024		
其他公开文献	US20120071729A1		
外部链接	Espacenet USPTO		

摘要(译)

本公开描述了用于管理由医疗呼吸机进行通气的患者的通气的系统和方法。本公开描述了一种显示与血氧计信息集成的呼吸机信息的新方法。本公开还描述了一种基于呼吸机信息与血氧计信息的集成的新型警报方法。