iii) at least two successive updated end-tidal concentration values are substantially equal; and

f) after e), estimating a functional residual capacity (FRC) of the patient.

[0008] In an aspect, there is provided a system for estimating an efficiency of lungs of a patient receiving respiratory care, comprising:

at least one gas source;

a blender having a primary input port adapted to receive a first gas to be delivered to the patient and at least one secondary input port adapted to receive a second gas from a corresponding one of the at least one gas source, the blender further having a patient-side port adapted for delivery of the first gas and of the second gas from the at least one gas source toward the patient;

a gas composition sensor adapted to measure a fraction of the first gas;

a gas flow sensor adapted to measure a flow of the first gas; and

a controller operatively connected to the at least one gas source, to the gas composition sensor and to the gas flow sensor, the controller being adapted to:

sequentially deliver the first and second gases to the patient, and

estimate a functional residual capacity (FRC) of the patient based on measurements from the gas composition sensor and from the gas flow sensor.

[0008a] In another aspect, there is provided a system for estimating an efficiency of lungs of a patient receiving respiratory care, comprising:

at least one gas source;

a blender having a primary input port adapted to receive a first gas to be delivered to the patient and at least one secondary input port adapted to receive a second gas from a corresponding one of the at least one gas source, the blender further having a patient-side port adapted for delivery of the first gas and of the second gas from the at least one gas source toward the patient;

a gas composition sensor adapted to measure a fraction of the first gas;

a gas flow sensor adapted to measure a flow of the first gas; and

a controller operatively connected to the at least one gas source, to the gas composition sensor and to the gas flow sensor, the controller being adapted to:

sequentially deliver the first and second gases to the patient, and

estimate a cardiac output (CO) of the patient based on measurements from the gas composition sensor and from the gas flow sensor.

[0008b] In yet another aspect, there is provided a system for estimating an efficiency of lungs of a patient receiving respiratory care, comprising:

at least one gas source;

a blender having a primary input port adapted to receive a first gas to be delivered to the patient and at least one secondary input port adapted to receive a second gas from a corresponding one of the at least one gas source, the blender further having a patient-side port adapted for delivery of the first gas and of the second gas from the at least one gas source toward the patient;

a gas composition sensor adapted to measure a fraction of the first gas;

a gas flow sensor adapted to measure a flow of the first gas; and

a controller operatively connected to the at least one gas source, to the gas composition sensor and to the gas flow sensor, the controller being adapted to:

sequentially deliver the first and second gases to the patient, and

estimate a mixed venous gas content of the patient based on measurements from the gas composition sensor and from the gas flow sensor.

[0009] The present disclosure further provides a method for estimating an efficiency of lungs of a patient receiving respiratory care, comprising:

end-tidal concentration of the patient between a preceding breath and a current breath;

d) determining an updated end-tidal concentration of the patient based on measurements obtained during exhalation after c);

e) repeating c) and d) until at least one of:

i) a predetermined time duration after a) elapses,

ii) a predetermined number of breaths have passed after a), and

iii) at least two successive updated end-tidal concentration values are substantially equal; and

f) after e), estimating a mixed venous gas content of the patient.

[0011] The foregoing and other features will become more apparent upon reading of the following non-restrictive description of illustrative examples thereof, given by way of example only with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Embodiments of the disclosure will be described by way of example only with reference to the accompanying drawings, in which:

[0013] Figure 1 shows a schematic diagram of a system implementing a titration method according to an embodiment;

[0014] Figure 2 shows additional details of the system of Figure 1;

[0015] Figure 3a shows an exploded view of a first example of a blender being part of the system of Figure 1;

[0016] Figure 3b shows an exploded view of a second example of a blender being part of the system of Figure 1;

WHAT IS CLAIMED IS:

1. A system for estimating an efficiency of lungs of a patient receiving respiratory care, comprising:

at least one gas source;

a blender having a primary input port adapted to receive a first gas to be delivered to the patient and at least one secondary input port adapted to receive a second gas from a corresponding one of the at least one gas source, the blender further having a patient-side port adapted for delivery of the first gas and of the second gas from the at least one gas source toward the patient;

a gas composition sensor adapted to measure a fraction of the first gas;

a gas flow sensor adapted to measure a flow of the first gas; and

a controller operatively connected to the at least one gas source, to the gas composition sensor and to the gas flow sensor, the controller being adapted to:

sequentially deliver the first and second gases to the patient, and

estimate a functional residual capacity (FRC) of the patient based on measurements from the gas composition sensor and from the gas flow sensor.

2. The system of claim 1, wherein the controller is adapted to implement a sequence to obtain baseline measurements and test measurements, the sequence comprising:

a) causing a delivery of a first gas in a first breath to the patient at a perturbative concentration;

b) after a), determining an end-tidal concentration of the patient based on measurements obtained during exhalation of the first breath of the patient;

c) recalculating a concentration of the first gas for delivery to the patient in a following breath based at least in part on a variation of the end-tidal concentration of the patient between a preceding breath and a current breath;

d) determining an updated end-tidal concentration of the patient based on measurements obtained during exhalation after c);

e) repeating c) and d) at least one of:

i) a predetermined time duration after b) elapses,

ii) a predetermined number of breaths have passed after b), and

iii) at least two successive updated end-tidal concentration values are substantially equal; and

f) after e), estimating the FRC of the patient.

3. The system of claim 2, wherein controller is further adapted to:

before a), determine a baseline end-tidal concentration of the patient while causing delivery of a baseline concentration of the first gas in a first breath of the patient;

determine the baseline and recalculated concentrations of the first gas delivered to the patient based on measurements from the gas composition sensor obtained during an inspiratory phase of the patient;

determine the baseline and updated end-tidal concentrations of the patient based on measurements from the gas composition sensor obtained during an expiratory phase of the patient; and

determine a volume of the first gas delivered to the patient by integrating measurements from the gas flow sensor obtain over the inspiratory phase of the patient.

4. The system of claim 2 or 3, wherein the controller is further adapted to abort the sequence if two successive and substantially equal updated end-tidal concentration values are not obtained after a predetermined time duration after a).

5. The system of any one of claims 1 to 4, wherein the controller is adapted modify the concentration of the first gas by controlling a delivery of the second gas from the at least one gas source to the blender.

6. The system of any one of claims 1 to 5, wherein the controller comprises one of more valves adapted to control delivery of gases from corresponding ones of the at least one gas source toward corresponding ones of the at least one secondary input port of the blender.

7. The system of any one of claims 1 to 6, wherein the blender comprises:

an input side including the primary input port and the one or more secondary input ports; and

an output side fluidly connected to the input side, the output side including a mixing chamber adapted to receive gases from the primary input port and from the one or more secondary input ports and to direct a blend of the received gases to the patient-side port.

8. The system of claim 7, wherein the mixing chamber is sized and configured to minimize dead space added by the blender in a respiratory airway circuit connected to the patient.

9. The system of claim 7 or 8, wherein the gas composition sensor and the gas flow sensor are mounted to the output side of the blender.

10. The system of any one of claims 1 to 6, wherein the blender comprises:

an input side including the primary input port and the one or more secondary input ports; and

an output side including:

a mixing chamber fluidly connected to the input side, the mixing chamber being adapted to receive gases from the primary input port and from the one or more secondary input ports and to direct a blend of the received gases to the patient-side port, and

an exhaust port fluidly connected to the patient-side port and adapted to expel exhale gases received from the patient-side port.

11. The system of any one of claims 1 to 6, wherein:

the gas composition sensor is a first gas composition sensor mounted on an inhale limb of a respiratory airway circuit connected to the patient and adapted to measure a composition of gases delivered to the patient;

the system further comprises a second gas composition sensor mounted on an exhale limb of the respiratory airway circuit and adapted to measure a composition of gases exhaled by the patient;

the gas flow sensor is a first gas flow sensor mounted on the inhale limb of the respiratory airway circuit and adapted to measure a flow of gases delivered to the patient; and

the system further comprises a second gas flow sensor mounted on the exhale limb of the respiratory airway circuit and adapted to measure a flow of the gases exhaled by the patient.

12. The system of any one of claims 1 to 11, wherein the gas flow detector comprises:

a light source;

a one-way valve adapted to block a gas flow in a reverse direction, to flex in a forward direction of the gas flow, and to deflect light emitted by light source when flexed; and

a light detector positioned so that flexing of the one-way valve modifies a detection of the light emitted by the light source.

13. The system of any one of claims 1 to 12, wherein the gas composition sensor comprises:

a pair of couplings mounted on the patient-side port of the blender and adapted for attachment of a pair of external optical fibers;

a light source adapted to illuminate a first one of the external optical fibers;

a first lens mounted on a first internal face of the patient-side port of the blender, the first lens being positioned to be illuminated by the first one of the external optical fibers;

a second lens mounted on a second internal face of the patient-side port of the blender, the second lens being positioned opposite from the first lens, light emitted by the first lens passing through a flow formed of the first and second gases before being received at the second lens to illuminate a second one of the external optical fibers; and

a spectroscopic analyzer adapted to receive light from the second one of the external optical fibers and to provide the measure of the fraction of the first gas.

14. The system of any one of claims 1 to 12, wherein the primary input port of the blender is adapted to be connected to a mechanical ventilator for receiving therefrom the first gas to be delivered to the patient.

15. The system of any one of claims 1 to 12, further comprising a mechanical ventilator fluidly connected to the primary input port of the

blender.

16. A system for estimating an efficiency of lungs of a patient receiving respiratory care, comprising:

at least one gas source;

a blender having a primary input port adapted to receive a first gas to be delivered to the patient and at least one secondary input port adapted to receive a second gas from a corresponding one of the at least one gas source, the blender further having a patient-side port adapted for delivery of the first gas and of the second gas from the at least one gas source toward the patient;

a gas composition sensor adapted to measure a fraction of the first gas;

a gas flow sensor adapted to measure a flow of the first gas; and

a controller operatively connected to the at least one gas source, to the gas composition sensor and to the gas flow sensor, the controller being adapted to:

sequentially deliver the first and second gases to the patient, and

estimate a cardiac output (CO) of the patient based on measurements from the gas composition sensor and from the gas flow sensor.

17. The system of claim 16, wherein the controller is adapted to implement a sequence to obtain baseline measurements and test measurements, the sequence comprising:

a) causing a delivery of a first gas in a first breath to the patient at a perturbative concentration;

b) after a), determining an end-tidal concentration of the patient based on measurements obtained during exhalation of the first breath of the patient;

c) recalculating a concentration of the first gas for delivery to the patient in a following breath based at least in part on a variation of the end-tidal concentration of the patient between a preceding breath and a current breath;

d) determining an updated end-tidal concentration of the patient based on measurements obtained during exhalation after c);

e) repeating c) and d) at least one of:

i) a predetermined time duration after b) elapses,

ii) a predetermined number of breaths have passed after b), and

iii) at least two successive updated end-tidal concentration values are substantially equal; and

f) after e), estimating the CO of the patient.

18. A system for estimating an efficiency of lungs of a patient receiving respiratory care, comprising:

at least one gas source;

a blender having a primary input port adapted to receive a first gas to be delivered to the patient and at least one secondary input port adapted to receive a second gas from a corresponding one of the at least one gas source, the blender further having a patient-side port adapted for delivery of the first gas and of the second gas from the at least one gas source toward the patient;

a gas composition sensor adapted to measure a fraction of the first gas;

a gas flow sensor adapted to measure a flow of the first gas; and

a controller operatively connected to the at least one gas source, to the gas composition sensor and to the gas flow sensor, the controller being adapted to:

sequentially deliver the first and second gases to the patient, and

estimate a mixed venous gas content of the patient based on measurements from the gas composition sensor and from the gas flow sensor.

19. The system of claim 18, wherein the controller is adapted to implement a sequence to obtain baseline measurements and test measurements, the sequence comprising:

a) causing a delivery of a first gas in a first breath to the patient at a perturbative concentration;

b) after a), determining an end-tidal concentration of the patient based on measurements obtained during exhalation of the first breath of the patient;

c) recalculating a concentration of the first gas for delivery to the patient in a following breath based at least in part on a variation of the end-tidal concentration of the patient between a preceding breath and a current breath;

d) determining an updated end-tidal concentration of the patient based on measurements obtained during exhalation after c);

e) repeating c) and d) at least one of:

i) a predetermined time duration after b) elapses,

ii) a predetermined number of breaths have passed after b), and

iii) at least two successive updated end-tidal concentration values are substantially equal; and

f) after e), estimating the mixed venous gas content of the patient.