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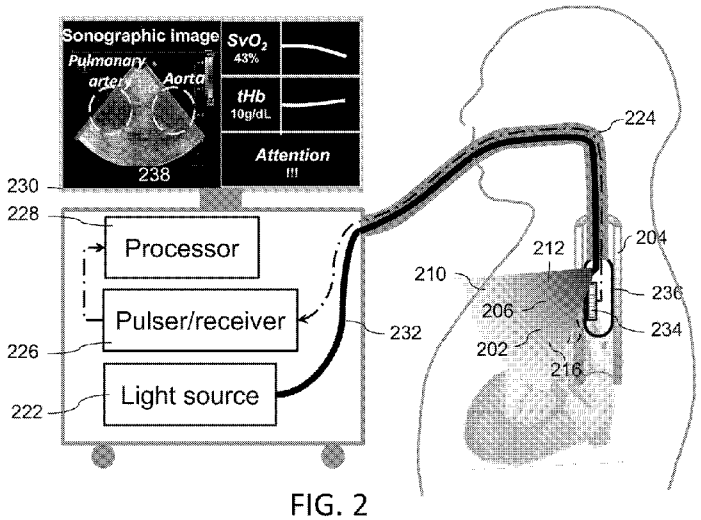

FIG. 2

(57) Abstract: Exemplary system, method and computer accessible medium are provided for determining at least one characteristic of a target object located behind or within a medium. For example, it is possible to identify a reference object that is located behind or within the medium. The target object and the reference object can be irradiated via a surface of the medium using at least one electromagnetic wave. At least one acoustic signal provided from an irradiated tissue volume that is responsive to the electromagnetic wave(s) can be measured. Calibration information can be obtained from the acoustic signal measured from the reference object based on at least one known property of the reference object. Then, the characteristic(s) of the target object can be determined based on the calibration information and the acoustic signal from the target object.

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METHODS AND SYSTEMS FOR CHARACTERIZING AN OBJECT

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] The present application relates to and claims priority from U.S. Provisional Patent Application Serial No. 61/791,713 filed March 15, 2013, the present disclosure of which is incorporated herein by reference in its entirety.

FIELD OF THE DISCLOSURE

[0002] Exemplary embodiments of the present disclosure relate generally to methods and systems for accurately characterizing an object (e.g., a deep object within a tissue), and in particular, to exemplary methods and systems for providing, e.g., a low-risk hemodynamic monitoring in critical care.

BACKGROUND INFORMATION

[0003] Hemodynamic monitoring plays an important role in managing critically ill patients in emergency departments, surgical rooms and intensive care units. Adequate blood oxygen supply to tissue is essential to sustain human life. A lasting deficiency of tissue oxygen could lead to the failure of vital organs, and is ultimately responsible for most deaths from a variety of diseases, such as trauma, burn, heart attack and sepsis. Mixed venous oxygen saturation (SvO_2) is a primary target of hemodynamic monitoring. SvO_2, the oxygen saturation measured from the mixed venous blood in a pulmonary artery, reflects the dynamic balance between the body's global oxygen supply and demand. Normally, SvO_2 is closely maintained between 60~80%. In patients, there are various challenges to the balance of oxygen metabolism. For example, the oxygen demand will increase in case of fever, shivering and seizure, while the oxygen supply could decrease when bleeding. When challenged, stable patients can restore the oxygen equilibrium by increasing the cardiac output, and do not require hemodynamic intervention. But, in high-risk patients, especially those with poor cardiopulmonary reserve, the compensatory increase in cardiac output is limited. As a result, bodies' last

line defense is called upon by extracting more oxygen from blood, that is when SvO_2 starts to decrease. Immediate intervention is indicated, if a >10% deviation of SvO_2 from baseline is seen to last beyond 3 minutes.

[0004] In current practice, SvO_2 can be measured with an indwelling pulmonary artery catheter (PAC), introduced invasively from a peripheral vein. However, the use of PAC was found to be associated with 10% incidence of complications, including hematoma, vessel puncture and cardiac arrest. As a result, the use of PAC has decreased by about 65% between 1993~2004. Modern echocardiography provides a clear view of the cardiac motion and a quantitative evaluation of the cardiac output. But it provides no information about the blood oxygen content.

[0005] Therefore, there is a need to address at least some of such deficiencies and/or issues, and, e.g., to provide a safe device for monitoring SvO_2.

SUMMARY OF EXEMPLARY EMBODIMENTS

[0006] To that end, it may be beneficial to provide exemplary methods and systems for accurately characterizing an object (e.g., a deep object within a tissue), and/or, e.g., facilitating a low-risk hemodynamic monitoring in critical care.

[0007] According to an exemplary embodiment of the present disclosure, method and system can be provided for accurately characterizing a deep target object located behind or inside a medium, which include identifying a reference object, which is located behind and inside said medium, illuminating both the target object and the reference object through a surface of the medium with an electromagnetic wave, measuring acoustic signals emitted from the illuminated tissue volume, obtaining a calibration dataset from the acoustic signal measured from the reference object based on at least one known property of the reference object, and determining at least one property of the target object using the calibration data and the acoustic signal from the target object.

[0008] According to another embodiment, the present disclosure provides a system for monitoring a mixed venous oxygen saturation from a pulmonary artery, having a source generating light with time-varying intensity, a light guide that guides said

light to illuminate a pulmonary artery and an aorta through a wall of an esophagus, at least one acoustic transducer that detects acoustic signals generated from the illuminated tissue volume, and a processing unit, which (i) obtains a calibration data from the acoustic signal measured from the aorta, based on at least one property of the aorta; and (ii) determines at least one property of the pulmonary artery using the calibration data and the acoustic signal from the pulmonary artery.

[0009] According to yet another exemplary embodiment of the present disclosure, exemplary system, method and computer accessible medium are provided for determining at least one characteristic of a target object located behind or within a medium. For example, it is possible to identify a reference object that is located behind or within the medium. The target object and the reference object can be irradiated via a surface of the medium using at least one electromagnetic wave. At least one acoustic signal provided from an irradiated tissue volume that is responsive to the electromagnetic wave(s) can be measured. Calibration information can be obtained from the acoustic signal measured from the reference object based on at least one known property of the reference object. Then, the characteristic(s) of the target object can be determined based on the calibration information and the acoustic signal from the target object.

[0010] In another exemplary embodiment of the present disclosure, a system for determining at least one characteristic of at least one anatomical structure can be provided. For example, a first arrangement can be provided that is configured to forward at least one electromagnetic radiation having a time-varying intensity to the anatomical structure and a further anatomical structure. A second arrangement can be provided which is configured to detect at least one acoustic signal provided from each of the structures in response to the electromagnetic radiation(s) impacting the structures. A processing hardware third arrangement can be provided that is configured to (i) obtain calibration data from the acoustic signal from the further tissue structure, based on at least one property of thereof; and (ii) determine the characteristic(s) of the anatomical structure using the calibration data and the acoustic signal from the at least one anatomical structure.

[0011] The characteristic(s) can include a mixed venous oxygen saturation. The second arrangement can comprise at least one acoustic transducer. The anatomical structure(s) can include a pulmonary artery, and the further anatomical structure can include an aorta. A light guide can be provided which is configured to forward the radiation(s) to the pulmonary artery and the aorta through a wall of an esophagus. The acoustic signal can be obtained from the aorta. The characteristic(s) of the pulmonary artery can be a mixed venous oxygen saturation. The property of the aorta can be an arterial blood oxygen saturation. An oximetric apparatus can be provided for measuring the arterial oxygen saturation, which can include a pulse oximeter. At least a part of the acoustic transducer can be provided and structured to be inside an esophagus. The acoustic transducer can be configured to acquire sonographic images.

[0012] These and other objects, features and advantages of the exemplary embodiments of the present disclosure will become apparent upon reading the following detailed description of the exemplary embodiments of the present disclosure, when taken in conjunction with the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Further objects, features and advantages of the present disclosure will become apparent from the following detailed description taken in conjunction with the accompanying figures showing illustrative embodiments of the present disclosure, in which:

[0014] Fig. 1a is a diagram illustrating a procedure/method for characterizing a deep tissue according to an exemplary embodiment of the present disclosure;

[0015] Fig. 1b is a flow diagram illustrating the steps taken by the exemplary procedure/method shown in Fig. 1a;

[0016] Fig. 2 is a diagram of a transesophageal photoacoustic endoscopic system for monitoring a mixed venous oxygen saturation, according to an exemplary embodiment of the present disclosure;

[0017] Fig. 3a is an exemplary graph illustrating an exemplary relation between a blood oxygen saturation and acoustic waves measured by an transesophageal endoscopic system according to the exemplary embodiment of the present disclosure;

[0018] Fig. 3b is a flow diagram of an exemplary method for accurately monitoring a mixed venous oxygen saturation using a transesophageal endoscopic system according to an exemplary embodiment of the present disclosure;

[0019] Fig. 4a is a Bland-Altman graph providing a comparison of SvO_2 measured by a transesophageal endoscopic system according to an exemplary embodiment of the present disclosure without a calibration using SaO_2, with SvO_2 measured from venous blood samples by a CO-oximeter; and

[0020] Fig. 4b is a Bland-Altman graph providing a comparison of SvO_2 measured by the transesophageal endoscopic system according to the exemplary embodiment of the present disclosure with calibration using SaO_2, with SvO_2 measured from venous blood samples by a CO-oximeter.

[0021] Throughout the drawings, the same reference numerals and characters, if any and unless otherwise stated, are used to denote like features, elements, components, or portions of the illustrated embodiments. Moreover, while the subject disclosure will now be described in detail with reference to the drawings, it is done so in connection with the illustrative embodiments. It is intended that changes and modifications can be made to the described exemplary embodiments without departing from the true scope and spirit of the subject disclosure.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0022] Fig. 1 illustrates an exemplary method/procedure for characterizing an object of interest 102 (e.g., a deep object) using an acoustic signal 112, 116 generated by at least one electromagnetic irradiation or with a plurality of electromagnetic radiation 110 according to one embodiment of the present disclosure. The targeted object 102 can be located behind or inside a medium 104 (e.g., a biological medium). Because at least

one property of the medium 104 can be unknown or varying with time in an unknown manner, the incident electromagnetic wave/radiation 110 can undergo one or more unknown modifications before reaching the target 102. As a result, it can generally be difficult to accurately characterize the target 102, e.g., without an extensive knowledge regarding the medium 104.

[0023] To address the aforementioned issue, as shown in a flow diagram of Fig. 1b, it is possible to first identify a reference object 106, which can also be located behind or inside the same medium 104 – procedure 150. Such reference object 106 can be preferably located in a proximity of the target 102. For example, at least one property of the reference 106 can be known, or obtained and/or measured by another method/procedure known to those having ordinary skill in the art. In addition, it is possible to select the reference object 106 which can naturally co-exist with the target object 102 and/or may be introduced for a purpose different from characterizing the target object 102 (e.g., intervention, a different measurement, etc.) – procedure 155.

[0024] Next, it is possible to transmit an electromagnetic wave/radiation 110 to illuminate both the target object 102 and the reference object 106 through a surface of the medium 104 – procedure 160. The electromagnetic wave/radiation 110 can be a light, a microwave or an X-ray. Further, the intensity of the electromagnetic wave 110 can be varied with time. After absorbing part of the electromagnetic energy, the target object 102 and the reference object 106 can emit propagating acoustic waves 112, 116, respectively, through, e.g., a thermoelastic expansion. Then, it is possible to measure both acoustic waves 112, 116 at a surface of the medium 104 – procedure 165. The measured acoustic waves 112, 116 may be separated in time or space.

[0025] Further, based on at least a physical mechanism or an experiment, it is possible to establish at least one relation between at least one property of the object and at least one feature of the measured acoustic wave emitted from it – procedure 170. Further, based on an established relation, using at least one feature of the measured acoustic wave 116 from the reference 106 and its known property, a calibration dataset can be obtained to reflect the modification done by the medium 104 to the

electromagnetic wave 110 – procedure 175. Finally, based on an established relation, using the calibration dataset and the acoustic wave 112, it is possible to obtain at least one property (e.g. chemical composition, stiffness or temperature) about the target object 102 – procedure 180.

[0026] For example, an object (102 or 106) can contain N major constituents. ε_i and C_i are the molar extinction coefficient and concentration of the i-th constituent, respectively. Physics laws indicates that the peak-to-peak pressure of the emitted acoustic wave (112 or 116) P can be related to a chemical composition of the object (e.g., object 102 or object 106), e.g., $\{C_1 \cdots C_N\}$, by a group of equations

$$\{P(\lambda_j) = kF(\lambda_j)\sum_{i=1}^{N}[\varepsilon_i(\lambda_j)C_i(\lambda_j)]\}_{j=1,2,\cdots M} \quad \text{(Equation 1)}$$

where k is a system constant, F is the fluence of the electromagnetic irradiation reaching the object (102 or 106), and λ_j is one of the M electromagnetic wavelengths used to excite an acoustic emission. Because of missing knowledge about the medium 104, the dependence of F on λ is unknown. According to one embodiment of the present disclosure, using knowledge about the composition (i.e. $\{C_1 \cdots C_N\}$) of the reference object 106 and the corresponding measured acoustic wave 116, $kF(\lambda_j)_{j=1,\cdots,M}$ can be calculated based on Equation 1. Finally, based on Equation 1, using $kF(\lambda_j)_{j=1,\cdots,M}$ and the measured acoustic wave 112, it is possible to obtain the chemical composition (i.e. $\{C_1 \cdots C_N\}$) of the target object 102.

[0027] Fig. 2 illustrates a transesophageal endoscopic system according to another exemplary embodiment of the present disclosure. The exemplary system can be used to safely monitor mixed venous oxygen saturation (SvO_2) from a mixed venous blood in a pulmonary artery 202 through a wall of an esophagus 204 using an arterial blood in an aorta 206 as a reference. The exemplary system can comprise a light source 222 (or an optical source, or another source of electromagnetic radiation), a transesophageal probe 224, an acoustic pulser/receiver 226, a processor 228 and a graphic user interface 230. The source 222 can generate a light or another electromagnetic radiation with a time-varying intensity. The radiation and/or light can have a wavelength

between 600 and 1200 nm. For example, the source 222 can be a pulsed laser, such as a Q-switched Nd:YAG laser, a fiber laser, a dye laser, a Ti-sapphire laser, an optical parametric oscillator (OPO) laser, or a pulsed diode laser. The pulse duration can be on the order of nanoseconds. The source 222 can also be an intensity-modulated continuous-wave light source, such as, e.g., a laser diode, a LED or a solid-state laser. It is possible that measurements be made with light/radiation at a plurality of wavelengths to estimate a blood oxygen saturation. The source 222 can be tuned to generate a plurality of light and/or other radiation with different wavelength. In addition, the exemplary source 222 can be or include a combination of a plurality of optical sources that operate at distinct wavelengths.

[0028] The transesophageal probe 224 can further comprise a light guide 232 and an acoustic transducer 234. The light guide 232 can be configured to collect the light and/or other radiation from the source 222, e.g., at a proximal end and emit light 210 (and/or other radiation) to illuminate the tissue at a distal end. Examples of the light guide 232 can include, but are not limited to a glass fiber bundle, a silica fiber bundle, a photonic crystal fiber, or an articulated arm with mirrors or prisms. Examples of the acoustic transducer 234 can include, but are not limited to a microphone, a hydrophone, a piezoelectric transducer, a polyvinylidene fluoride film transducer, a capacitor micro-machined transducer, an optical acoustic sensor based on an optical set-up or configuration (e.g ,an interferometry, a resonator, etc.). The acoustic transducer 234 can also be and/or include a combination of a plurality of the described acoustic detectors, such as, e.g., a phased array acoustic probe. The central wavelength of the acoustic detector can be in the range of about 0.5 ~ 10 MHz.

[0029] The distal end of the light guide 232 and the acoustic transducer 234 can be assembled into a capsule 236. The capsule 236 is preferred to have a diameter smaller than 2 cm, thus can be introduced into the esophagus 204 through a mouth or a nose. Said capsule 236 is preferred to be able to be navigated to characterize different tissue through the esophageal wall by advancing, rotating or flexing the probe 224. Also, the acoustic transducer 234 is preferred to be able to be rotated inside the pill to look at tissue in a view plane of interest. For monitoring SvO_2, as shown in Fig. 2, it is possible to place the

capsule 236 at a height between an arch of the aorta 206 and the pulmonary artery 202, rotate the capsule 236 to ensure acoustic transducer 234 facing both vessels, then rotate the acoustic transducer 234 to look at both vessels in a sagittal plane. The aforementioned deployment of the capsule 236 is termed as the modified upper-esophagus aortic arch short-axis view.

[0030] Following the illumination by light 210 or other radiation, the acoustic waves 212 and 216 generated respectively from the pulmonary artery 202 and the aorta 206 can be detected by the acoustic transducer 234, amplified and digitized by the pulser/receiver 226, analyzed by the processor 228 to calculate SvO_2, and display the results on the graphic interface 230. The pulser/receiver 226 can also be configured to energize the acoustic transducer 234 to emit an acoustic wave (not shown). By detecting the reflected acoustic waves (not shown) from the tissue, real-time sonogrphic images 238 showing tissue anatomy can be obtained to guide and/or deploy the capsule 236, e.g., at a desired view location. Under many physiological conditions, arterial blood can remain completely oxygenated, e.g., the blood oxygenation in aorta, SaO_2, can be close to 100%. The exemplary transesophageal endoscopic system could further include an oximeter (not shown) to measure SaO_2 in real time. Examples of the oximeter include, but are not limited to a pulse oximeter, a CO-oximeter or an oximetric peripheral arterial catheter.

[0031] For example, relations can be established to link a property of the pulmonary artery 202 (e.g. SvO_2) to at least one feature of the measured acoustic waves 212 and 216. Examples of such exemplary feature can include, but is not limited to, a peak-to-peak pressure, a slope, a peak amplitude or a spectrum of the acoustic wave, a ratio between peak-to-peak pressure of the acoustic wave measured at a different pair of wavelengths, a function of peak-to-peak pressure of the acoustic wave measured at more than two wavelengths. Fig. 3a illustrates a plot providing an exemplary relation between a blood oxygen saturation and acoustic waves measured by the transesophageal endoscopic system according to an exemplary embodiment of the present disclosure. Using the exemplary system shown in Fig. 2, acoustic waves can be generated from a group of blood samples with known oxygen saturation (SO_2) with light at two

wavelengths (830 nm and 760 nm). Notations P(830) and P(760) denote the peak-to-peak pressure of the acoustic waves measured from a blood sample using, e.g., approximately 830-nm and 760-nm light, respectively. Notations F(830) and F(760) represent the optical fluence at a surface of a blood sample at, e.g., about 830 nm and 760 nm, respectively. And $Pr = P(830)/P(760)$ and $Fr = F(830)/F(760)$. From experiments, it was found that the SO_2 and Pr/Fr can be fitted by a polynomial curve $M(SO_2, Pr/Fr)$ shown as a solid curve in Fig. 3a.

[0032] Fig. 3b is a flow diagram representing an exemplary method for accurately monitoring a mixed venous oxygen saturation using a transesophageal endoscopic system according to an exemplary embodiment of the present disclosure. At procedure 350, a physician use real-time sonographic images 238 as a guidance, introduce the capsule 236 into a patient through his/her mouth or nose, and place it in the modified upper-esophagus aortic arch short-axis view. Then, at procedure 352, the exemplary system can activate and/or control the source 222 at least once at about 830 nm, measure the peak-to-peak pressure of the acoustic wave 212 - $P_{pa}(830)$ from the pulmonary artery and the acoustic wave 216 - $P_{ao}(830)$ from the aorta. Further, at procedure 354, the exemplary system can activate/control the source 222 at least once at, e.g., about 760 nm, measure $P_{pa}(760)$ from the pulmonary artery and $P_{ao}(760)$ from the aorta. Procedures 354 and 356 can be reversed, and/or performed at a different optical wavelength. Next, at procedure 356, the exemplary system can calculate $Pr_{pa} = P_{pa}(830)/P_{pa}(760)$ and $Pr_{ao} = P_{ao}(830)/P_{ao}(760)$. Further, at procedure 358, the exemplary system can either assume a typical value for the aortic oxygen saturation SaO_2 (e.g. 100%) or measure such exemplary value with a pulse oximeter from a finger or toe, an earlobe or a piece of esophageal wall. Based on $M(SO_2, Pr/Fr)$ shown in Fig. 3a, using Pr_{ao} and SaO_2, the exemplary system can calculate the calibration dataset Fr. Finally, at procedure 360, based on $M(SO_2, Pr/Fr)$ shown in Fig. 3a, using Pr_{pa} and Fr, the exemplary system can calculate and display SvO_2. The procedures 358 and 360 can be simplified into the follow equation:

$$SvO_2 = M\left\{\frac{\mathrm{Pr}_{pa}}{\mathrm{Pr}_{ao}} M^{-1}\{SaO_2\}\right\}$$

[0033] Figs. 4a and 4b shows exemplary graphs which illustrate a comparison of the bias and precision in SvO_2 measurements made by a transesophageal endoscopic system with and without a calibration step using SaO_2 (see procedure 358 of Figure 3b). Both measurements can be analyzed using a standard Bland-Altman method against the actual SvO_2 measured from venous blood samples by a gold-standard CO-oximeter. The use of the calibration step utilizing SaO_2 (see procedure 358 of Figure 3b) according to an exemplary embodiment of the present disclosure can significantly reduce the bias (from about 6.4% to about 0.4%), and also can improve precision (from about 3.3% to about 2.4%) in measurement of SvO_2.

[0034] The foregoing merely illustrates the principles of the disclosure. Various modifications and alterations to the described embodiments will be apparent to those skilled in the art in view of the teachings herein. The arrangements, systems and methods according to the exemplary embodiments of the present disclosure can be used measure a venous blood oxygen saturation from any vein (e.g. a jugular vein) by using a nearby artery (e.g. a carotid artery) as a reference. Indeed, the arrangements, systems and methods according to the exemplary embodiments of the present disclosure can be used with and/or implement any OCT system, OFDI system, SD-OCT system or other imaging systems, and for example with those described in International Patent Application PCT/US2004/029148, filed September 8, 2004 which published as International Patent Publication No. WO 2005/047813 on May 26, 2005, U.S. Patent Application No. 11/266,779, filed November 2, 2005 which published as U.S. Patent Publication No. 2006/0093276 on May 4, 2006, and U.S. Patent Application No. 10/501,276, filed July 9, 2004 which published as U.S. Patent Publication No. 2005/0018201 on January 27, 2005, and U.S. Patent Publication No. 2002/0122246, published on May 9, 2002, the disclosures of which are incorporated by reference herein in their entireties. It will thus be appreciated that those skilled in the art will be able to devise numerous systems, arrangements and methods which, although not explicitly shown or described herein, embody the principles of the disclosure and are thus within the spirit and scope of the present disclosure. It should be understood that the exemplary procedures described herein can be stored on any computer accessible medium, including a hard drive, RAM,

ROM, removable disks, CD-ROM, memory sticks, etc., and executed by a processing arrangement and/or computing arrangement which can be and/or include a hardware processors, microprocessor, mini, macro, mainframe, etc., including a plurality and/or combination thereof. In addition, certain terms used in the present disclosure, including the specification, drawings and claims thereof, can be used synonymously in certain instances, including, but not limited to, e.g., data and information. It should be understood that, while these words, and/or other words that can be synonymous to one another, can be used synonymously herein, that there can be instances when such words can be intended to not be used synonymously. Further, to the extent that the prior art knowledge has not been explicitly incorporated by reference herein above, it can be explicitly incorporated herein in its entirety. All publications referenced herein can be incorporated herein by reference in their entireties.

WHAT IS CLAIMED IS:

1. A system for determining at least one characteristic of at least one anatomical structure, comprising:

a first arrangement configured to forward at least one electromagnetic radiation having a time-varying intensity to the at least one anatomical structure and a further anatomical structure;

a detector second arrangement configured to detect at least one acoustic signal provided from each of the at least one anatomical structure and the further anatomical structure in response to the at least one electromagnetic radiation impacting the structures; and

a processing hardware third arrangement configured to (i) obtain calibration data from the acoustic signal from the further anatomical structure, based on at least one property of thereof; and (ii) determine the at least one characteristic of the at least one anatomical structure using the calibration data and the acoustic signal from the at least one anatomical structure.

2. The system according to claim 1, wherein the at least one characteristic includes a blood oxygen saturation.

3. The system according to claim 1, wherein the second arrangement comprises at least one acoustic transducer.

4. The system according to claim 1, wherein the at least one anatomical structure includes a pulmonary artery, and the further anatomical structure includes an aorta.

5. The system according to claim 1, wherein the at least one anatomical structure includes a vein, and the further anatomical structure includes an artery.

6. The system according to claim 5, further comprising a light guide which is configured to forward the at least one radiation to the pulmonary artery and the aorta

through a wall of an esophagus.

7. The system according to claim 5, wherein the acoustic signal is obtained from the aorta.

8. The system according to claim 5, wherein the at least one characteristic of the pulmonary artery is a mixed venous oxygen saturation.

9. The system according to claim 5, wherein the at least one property of the aorta is an arterial blood oxygen saturation.

10. The system according to claim 2, further compriseingan oximetric apparatus configured to measure the arterial oxygen saturation.

11. The system according to claim 10, wherein the oximeteric apparatus is a pulse oximeter.

12. The system according to claim 3, wherein at least a part of the acoustic transducer is provided and structured to be inside an esophagus.

13. The system according to claim 3, wherein the acoustic transducer is configured to acquire sonographic images.

14. A non-transitory computer-accessible medium which includes computer executable instructions for determining at least one characteristic of a target object located behind or within a medium, wherein, when a hardware processing arrangement executes the instructions, the processing arrangement is configured to execute procedures comprising:

identifying a reference object that is located behind or within the medium;

causing an irradiation on the target object and the reference object via a surface of the medium using at least one electromagnetic wave;

measuring at least one acoustic signal provided from an irradiated tissue volume that is responsive to the at least one electromagnetic wave;

obtaining a calibration information from the acoustic signal measured from the reference object based on at least one known property of the reference object; and

determining the at least one characteristic of the target object based on the calibration information and the acoustic signal from the target object.

15. The computer-accessible medium according to claim 14, wherein the at least one characteristic includes a blood oxygen saturation.

16. The computer-accessible medium according to claim 14, wherein the at least one anatomical structure includes a pulmonary artery, and the further anatomical structure includes an aorta.

17. The computer-accessible medium according to claim 14, wherein the at least one anatomical structure includes a vein, and the further anatomical structure includes an artery.

18. The computer-accessible medium according to claim 17, whereing the processing arrangement is configured to cause the at least one radiation to the pulmonary artery and the aorta using alight guide to be provided through a wall of an esophagus.

19. The computer-accessible medium according to claim 17, wherein the acoustic signal is obtained from the aorta.

20. The computer-accessible medium according to claim 17, wherein the at least one characteristic of the pulmonary artery is a mixed venous oxygen saturation.

21. The computer-accessible medium according to claim 17, wherein the at least one property of the aorta is an arterial blood oxygen saturation.

22. The computer-accessible medium according to claim 16, wherein at least a part of the acoustic transducer is provided and structured to be inside an esophagus.

23. The computer-accessible medium according to claim 16, wherein the acoustic transducer is configured to acquire sonographic images.

24. A method for determining at least one characteristic of a target object located behind or within a medium, comprising:

identifying a reference object that is located behind or within the medium;

irradiating the target object and the reference object via a surface of the medium using at least one electromagnetic wave;

measuring acoustic signals provided from an irradiated tissue volume of the target and reference objects responsive to the at least one electromagnetic wave;

obtaining a calibration information from at least one of the acoustic signals measured from the reference object based on at least one known property of the reference object; and

determining the at least one characteristic of the target object based on the calibration information and the acoustic signal from the target object.

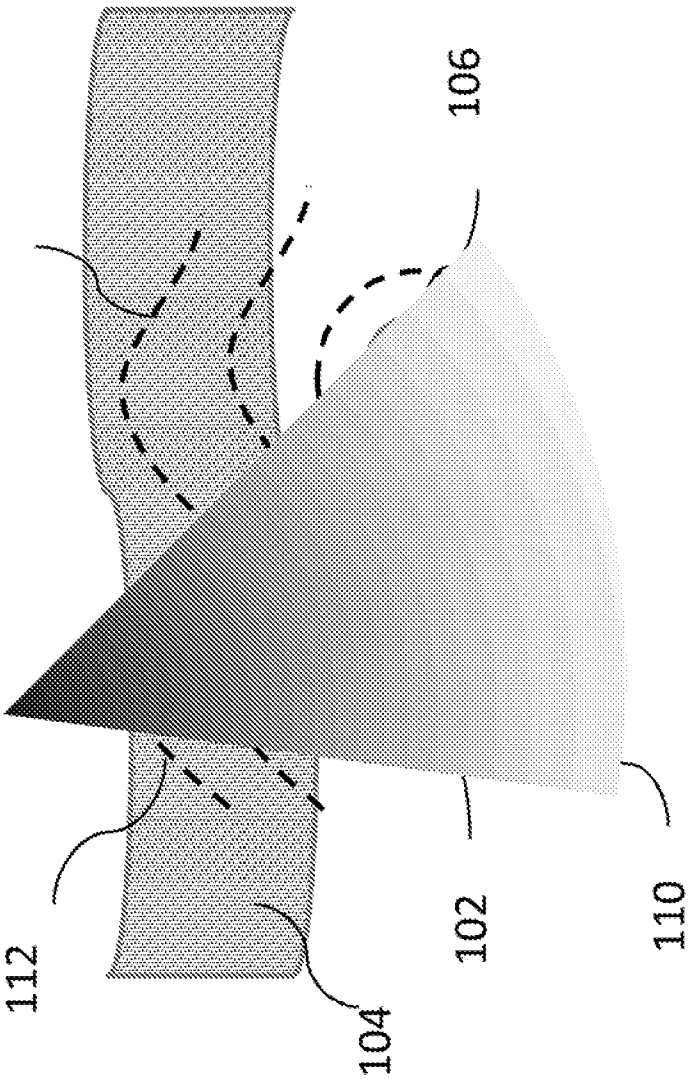


FIG. 1A

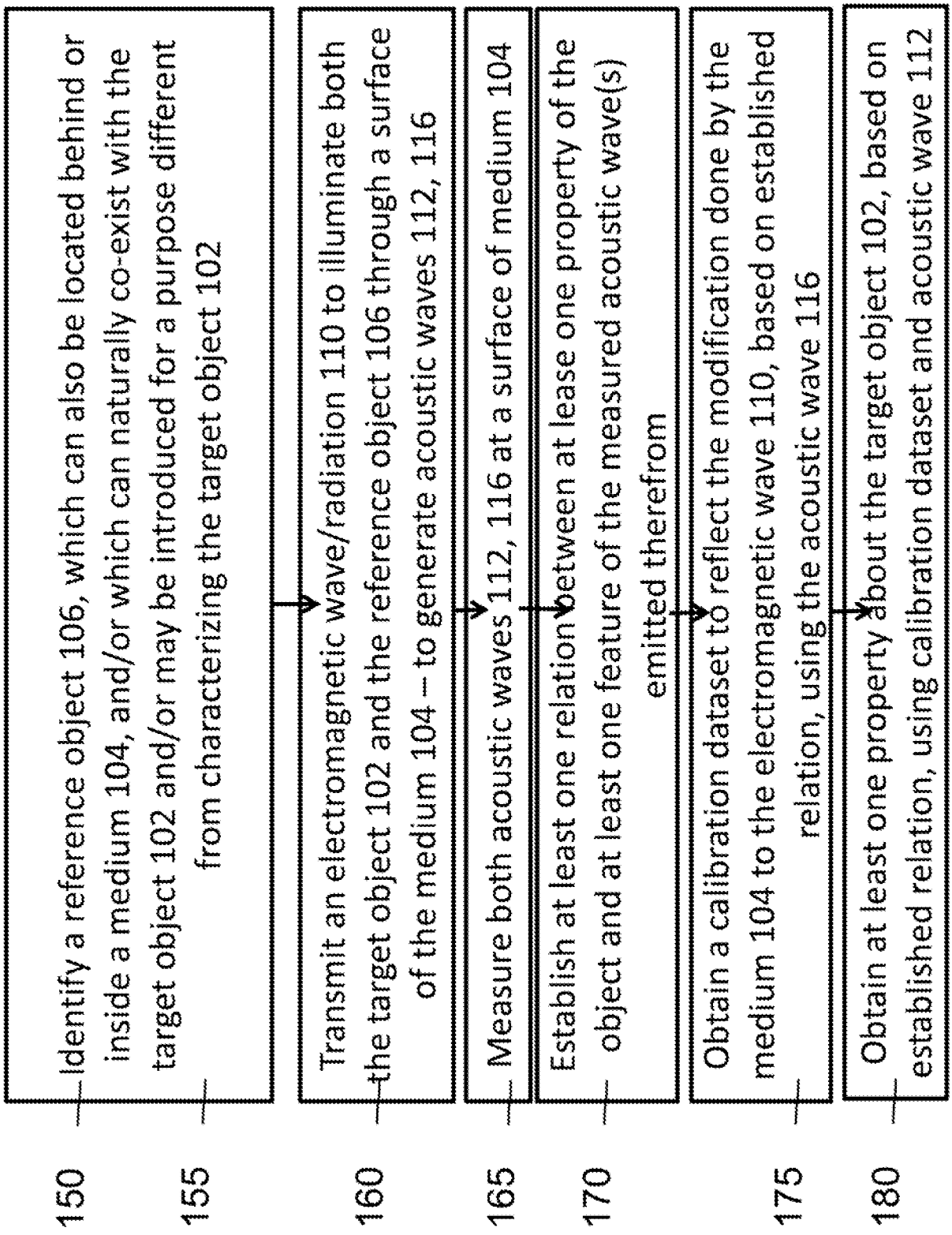

150
Identify a reference object 106, which can also be located behind or inside a medium 104, and/or which can naturally co-exist with the target object 102 and/or may be introduced for a purpose different from characterizing the target object 102
155
160
Transmit an electromagnetic wave/radiation 110 to illuminate both the target object 102 and the reference object 106 through a surface of the medium 104 – to generate acoustic waves 112, 116
165
Measure both acoustic waves 112, 116 at a surface of medium 104
170
Establish at least one relation between at lease one property of the object and at least one feature of the measured acoustic wave(s) emitted therefrom
175
Obtain a calibration dataset to reflect the modification done by the medium 104 to the electromagnetic wave 110, based on established relation, using the acoustic wave 116
180
Obtain at least one property about the target object 102, based on established relation, using calibration dataset and acoustic wave 112

FIG. 1b

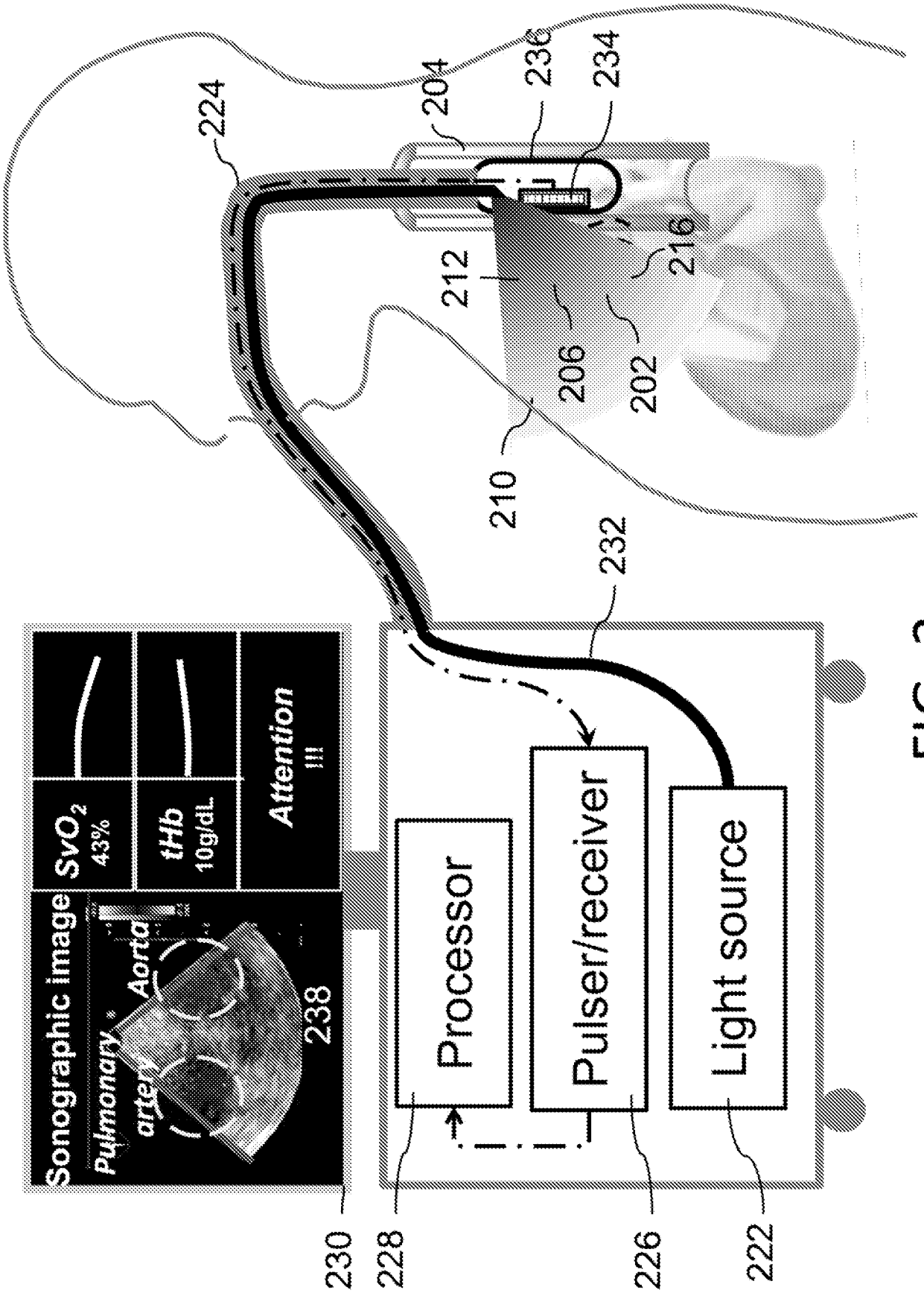
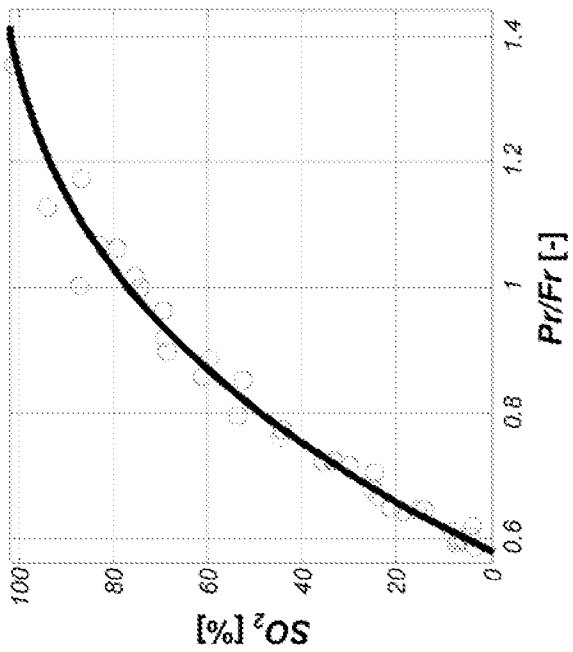

Sonographic image
Pulmonary artery
Aorta
238
SvO2 43%
tHb 10g/dL
Attention
230
Processor
228
Pulser/receiver
226
Light source
222
232
224
204
236
234
212
216
206
202
210

FIG. 2

FIG. 3a



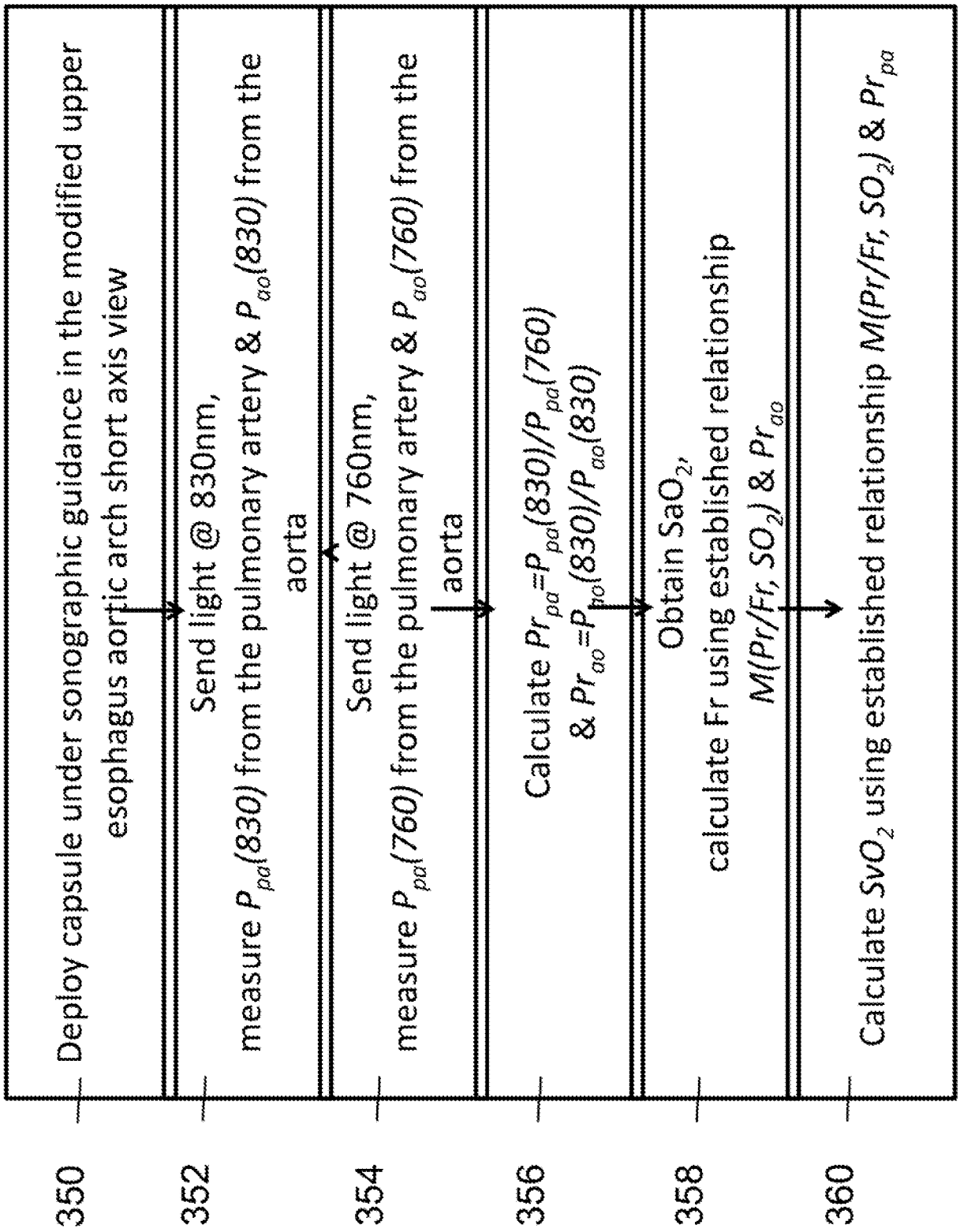

Deploy capsule under sonographic guidance in the modified upper esophagus aortic arch short axis view
350
Send light @ 830nm, measure $P_{pa}(830)$ from the pulmonary artery & $P_{ao}(830)$ from the aorta
352
Send light @ 760nm, measure $P_{pa}(760)$ from the pulmonary artery & $P_{ao}(760)$ from the aorta
354
Calculate $Pr_{pa}=P_{pa}(830)/P_{pa}(760)$ & $Pr_{ao}=P_{ao}(830)/P_{ao}(830)$
356
Obtain SaO_2, calculate Fr using established relationship $M(Pr/Fr, SO_2)$ & Pr_{ao}
358
Calculate SvO_2 using established relationship $M(Pr/Fr, SO_2)$ & Pr_{pa}
360

FIG. 3b

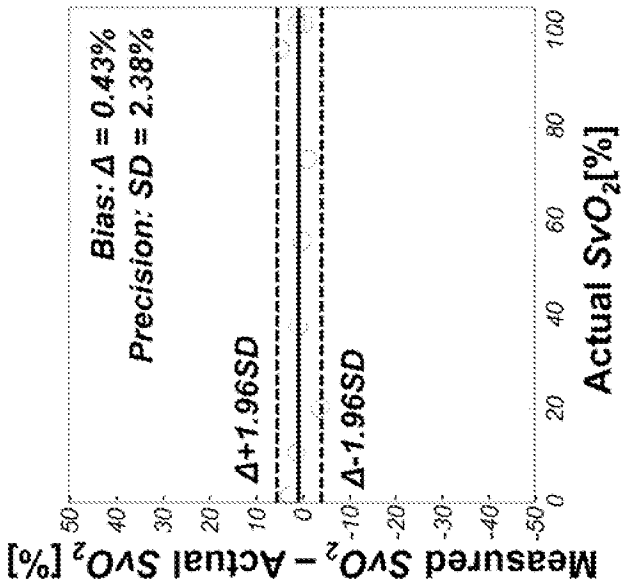

Bias: Δ = 0.43%
Precision: SD = 2.38%
Δ+1.96SD
Δ-1.96SD
Measured SvO2 – Actual SvO2 [%]
Actual SvO2[%]
50
40
30
20
10
0
-10
-20
-30
-40
-50
0
20
40
60
80
100

FIG. 4b

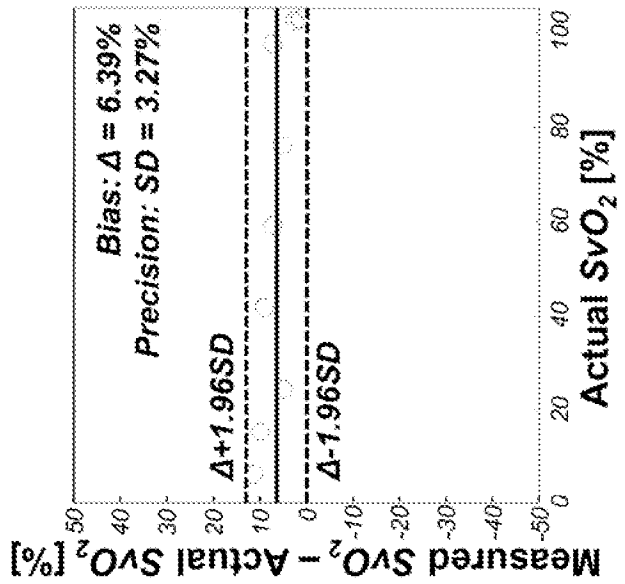

Bias: Δ = 6.39%
Precision: SD = 3.27%
Δ+1.96SD
Δ-1.96SD
Measured SvO2 – Actual SvO2 [%]
Actual SvO2 [%]
50
40
30
20
10
0
-10
-20
-30
-40
-50
0
20
40
60
80
100

FIG. 4a