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(54) Title: ADAPTIVE NON-INVASIVE BLOOD PRESSURE ALGORITHM

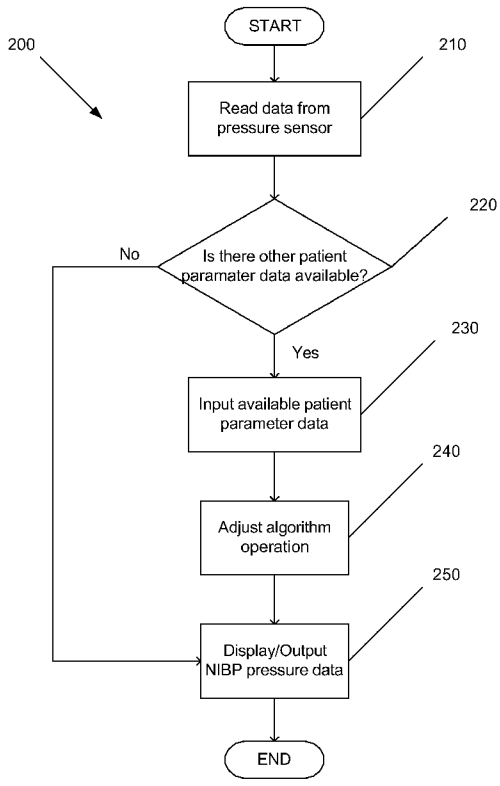


Fig. 2

(57) Abstract: A system and method for receiving pressure measurements corresponding to arterial pressure of a patient during a measurement process, receiving an additional patient parameter and determining a blood pressure of the patient based on the pressure measurements and the additional patient parameter. In addition, a system having a pressure sensor detecting arterial pressure of a patient and a control element receiving the arterial pressures from the pressure sensor and an additional patient parameter,the control element determining a blood pressure of the patient based on the arterial pressures and the additional patient parameter.

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# Adaptive Non-Invasive Blood Pressure Algorithm

## Field of Invention

The present application generally relates to systems and methods for a non-invasive blood pressure (NIBP) patient monitor. Specifically, the system and methods may allow a user of the NIBP monitor to attain accurate blood pressure readings using data from other patient parameters.

## Background

Blood pressure is generally assessed by systolic and diastolic arterial pressure. Systolic arterial pressure is the peak pressure in the arteries, which occurs near the beginning of a cardiac cycle. Diastolic arterial pressure is the lowest pressure and occurs at the resting stage. Non-invasive blood pressure (NIBP) monitors generally use an oscillometric method in order to determine arterial pressure. The oscillometric method entails measuring a mean arterial pressure to estimate the systolic and diastolic pressures. NIBP monitors are fitted with an electronic pressure sensor to detect blood flow. An air-filled cuff is wrapped around the patient's arm and is inflated to a pressure usually in excess of the systolic arterial pressure, and then reduced to below a diastolic pressure over a period. As the cuff is allowed to deflate, pressure data is recorded by the device. Over time, the pressure data looks like a waveform. The point of maximum amplitude is considered the mean arterial pressure.

NIBP monitoring techniques are generally preferred over other blood pressure measuring techniques because they simpler, quicker, require less expertise, have virtually no complication, and are less unpleasant and painful for the

patient. However, because it estimates systolic and diastolic pressure from the mean arterial pressure, an erroneous mean arterial pressure will produce inaccurate results. Some NIBP devices use computer-assisted analysis of the arterial pressure wave form to determine systolic, mean and diastolic arterial points. However, even these NIBP devices may produce measurements of limited accuracy.

## Summary Of The Invention

A method for receiving pressure measurements corresponding to arterial pressure of a patient during a measurement process, receiving an additional patient parameter and determining a blood pressure of the patient based on the pressure measurements and the additional patient parameter.

In addition, a system having a pressure sensor detecting arterial pressure of a patient and a control element receiving the arterial pressures from the pressure sensor and an additional patient parameter, the control element determining a blood pressure of the patient based on the arterial pressures and the additional patient parameter.

## Brief Description Of The Drawings

Fig. 1 shows a schematic of an exemplary embodiment of the present invention.

Fig. 2 shows a flow diagram of an exemplary method of the present invention.

Detailed Description

The present invention may be further understood with reference to the following description of exemplary embodiments and the related appended drawings, wherein like elements are provided with the same reference numerals. The exemplary embodiments of the present invention are related to a system and method for utilizing other available patient parameters, such as electrocardiogram (ECG) and saturation of peripheral oxygen ($SpO_2$) data, when determining a non-invasive blood pressure (NIBP) in order to achieve a more accurate blood pressure reading.

Erroneous arterial pressure values may result for several reasons. For example, if a patient's blood pressure does not remain constant during the measurement, if the patient is experiencing an irregular or abnormal heartbeat, if the patient makes any sort of movement during measurement, or any other heart or circulation problems. A patient's blood pressure may change during measurement for several reasons. The patient may be suffering from cardiac disease, respiratory disease, kidney disease or blood loss, or may be experiencing a changing psychological/emotional state that may lead to changes in heart rate. Changes in blood pressure during blood pressure measurement will lead to distorted amplitudes of pressure pulses and will result in erroneously high or erroneously low readings. Such changes may also result from arrhythmias or abnormal heartbeats, which cause the heart to contract earlier or later than normal. In addition, patient movement may impact blood pressure measurements.

Fig. 1 shows an exemplary embodiment of a NIBP system 100 that utilizes available patient parameters to determine a more accurate NIBP. The NIBP system 100 comprises an NIBP control software 110 that may run on either a local or a host processor. It is noted that throughout the description it is stated that various components (e.g., pump 140, valves 142, etc.) are connected to the NIBP control software 110. Those skilled in the art will understand that the NIBP control software 110 is implemented, for example, as lines of code that are executed by a processor, controller, microcontroller, etc. Thus, the term connected should not be construed to mean there is a physical connection between the NIBP control software 110 and the other components, but merely that data generated by the other components may be received by the NIBP control software 110 and/or data generated by the NIBP control software 110 may be sent to the other components (e.g., via input/output mechanisms of a processor executing the NIBP control software 110).

The NIBP control software 110 is connected to a pump 140, a valve 142, and a pressure sensor 120 that detects blood flow. In addition, the NIBP control software 110 may be coupled to a server (or other device) that contains or measures patient parameter data 130. When a server with patient parameter data 130 is detected by the processor executing the NIBP control software 110, the server inputs the available data while the processor retrieves it. The NIBP system 100 further comprises an input/output display and control center 150. Patient parameter data 130 is used in conjunction with blood flow data from the pressure sensors 120 to calculate an accurate NIBP pressure data 152 that may be displayed on input/output center 150. The display and control center 150 may also show a status

154 of determining the NIBP. The center 150 may also be used to input control information 156.

An inflatable cuff may be used with the NIBP system 100 in order to measure a blood flow using the pressure sensor 120. The cuff may be connected to the NIBP control software 110 as well as the pump 140 and the valve 142. When measuring a blood flow, the valve 142 allows pressurized air from the pump 140 into the cuff. Once the cuff is sufficiently inflated, the pressurized air is slowly released and the cuff is deflated. While the cuff is deflating, the pressure sensor 120 detects the blood flow and inputs this data to the NIBP control software 110, which uses the pressure data to calculate blood pressure. It will be understood by those of ordinary skill in the art that other means of measuring blood flow with a pressure sensor, without using a cuff, may also be used in the NIBP system 100.

At least one cardiac cycle is needed to measure a patient's blood pressure. The frequency of the cardiac cycle is the heartbeat. Systolic arterial pressure is measured at the beginning of the cycle when the heart beats and pumps blood to the arteries creating pressure in them. Diastolic pressure refers to the pressure in the arteries between heartbeats when it is at rest. However, blood pressure readings may be different at different times of the day, or depending upon a person's posture or movement. A physician may take a patient's blood pressure several times before determining whether the patient has high or low blood pressure. A blood pressure monitor will also produce erroneous readings if a person is experiencing irregular heartbeats or other symptoms that result in changes in the cardiac cycle. For example, a normal heartbeat that beats consistently will also produce consistent

pressure regardless of the cardiac cycle that it is measured in. However, the heart of a patient with arrhythmia may beat prematurely or with a slight delay every few cardiac cycles. A premature beat will result in an increased pressure point after the next beat because more blood than normal has been pumped to the heart. A delayed beat will result in a lower pressure than normal after the next heartbeat because pressure was allowed to decrease for a longer period of time and thus dipped below normal. Therefore, the NIBP control software 110 may combine blood flow detected by pressure sensor 120 with other patient parameters 130 to determine a more accurate blood pressure.

Patient parameter data 130 may include information such as ECG data, $SpO_2$ data, invasive pressure data, $CO_2$ data, etc. An ECG is graphic data that is produced by an electrocardiograph that records the electrical activity of the heart over time. The ECG may be used to determine a patient's heart rhythm and is the accepted standard for being able to detect irregular heartbeats. $SpO_2$ data is an estimation of the oxygen saturation levels in the blood stream and is measured with a pulse oximeter, which also provides continuous information on pulse rate since arterial blood vessels expand and contract with each heartbeat. It will be understood by those of ordinary skill in the art that although patient parameter data 130 is discussed in terms of ECG and $SpO_2$ data, any patient parameters that indicate pulse rate or cardiac activity will be acceptable patient parameter data 130 to be utilized by the NIBP system 100.

Using the additional available patient parameters 130, the NIBP control software 110 will calculate a more accurate blood pressure 152 by correlating the pulse waves from the

patient parameters 130 with the arterial pressure detected by the pressure sensor 120. By doing so, the NIBP control software 110 is also able optimize the timing and operation of the measuring cycles. NIBP control software 110 may utilize one, all, or only some of the available patient parameters 130. Input/output display and control center 150 of the NIBP control system 100 may further comprise a display on which the NIBP pressure data 152 may be outputted upon completion of the correlation and assessment of the various parameters 130 and data from the pressure sensor 120. During the assessment and correlation process, however, the display may show a status 154 indicating whether the process has been completed. Once completed, the display may show a status 154 indicating completion.

Input/output center 150 further comprises a control input means 156 which may include further options such as printing or storing the NIBP pressure data 152. Thus, the server on which the NIBP control software 110 runs may further include memory to store pressure data 152 and may be connected to a printer in order to print pressure data 152. In addition, control 156 may allow a user to input whether there is available patient parameter data 130 and/or what kind of parameters 130 are available or should be used by the NIBP control software 110 to calculate blood pressure. It will be understood by those of ordinary skill in the art that control 156 may include further inputting options that may be utilized by the NIBP system 100.

Fig. 2 shows an exemplary method 200 of the NIBP control software 110. In step 210, data from the pressure sensor 120 is read by the NIBP control software 110. In step 220, the NIBP system 100 determines whether there exist

additional patient parameters 130, such as ECG and $SpO_2$, which may be utilized. If it is determined that there are other available patient parameters 130, the patient parameters 130 are inputted in step 230. This inputted data is used to adjust the NIBP algorithm in step 240. As described herein, this adjustment may include for example, adaptive filtering, adjusting the sampling window (period), measurement timing, noise detection and rejection, etc. The optimized algorithm of the NIBP control software 110 may then determine the NIBP pressure data 152. In step 250, the NIBP pressure data 152 is displayed to the user.

The NIBP system 100 reads data from a pressure sensor in step 210 and determines whether other patient parameter data is available in a step 220. The NIBP system 100 may determine whether other patient parameters 130 exist in several manners. In one embodiment, a processor may be able to determine whether any additional parameters are available by detecting whether there are any connections to the processor. A server with ECG or $SpO_2$ information may be connected to the processor via a port or directly to a local processor. In another embodiment, a user may be able to indicate, via an input means 156, whether such information is available and what kind of information is available, indicating to the processor that the information should be detected. Once the processor determines that the information is available, it will begin to input or read the data, in step 230.

In step 240 of method 200, the NIBP control software 110 adjusts the NIBP algorithm such that the NIBP blood pressure is determined by taking into consideration the cardiac cycle of the patient. Patient parameter data such as ECG and $SpO_2$ allows

the control software to determine when the heart beats and can adjust the blood flow data by accounting for irregular heartbeats or other factors that may cause the blood pressure reading to be erroneously high or erroneously low. Thus, the processor may be able to detect when to take the appropriate reading and/or whether it needs to be adjusted to account for errors. Once the NIBP pressure data 152 has been determined, the data is displayed to the user in step 250.

It should be noted that the adjustment of the NIBP algorithm in step 240 may include an adjustment to actual pressure data that has been collected and/or an adjustment to the process for collecting the pressure data. For example, if the NIBP control software 110 receives ECG data as patient parameter 130, the NIBP control software 110 may correlate the ECG data (e.g., an arrhythmic heartbeat) to a particular pressure reading and discard that pressure reading because of the arrhythmic issue. In another example, the NIBP control software 110 may determine that the patient's heart rate increased or decreased by a predetermined threshold during the testing and therefore the collected pressure values should be reacquired to account for change in the heart rate. In a further example, the NIBP control software 110 may determine that a patient's heart is being paced at a certain rate by, for example, a pacemaker. The NIBP control software 110 may modify the testing process (e.g., recording of pressure measurements) to coincide with the detected pacing pattern. Those skilled in the art will understand that there may be many types of adjustments that may be made to the data and/or testing process based on the type of patient parameter 130 received by the NIBP control software 110.

In further embodiments additional steps may be taken after the NIBP pressure data 152 has been displayed for the user in step 250. The user may also opt to print or store the data to either an attached printer or a memory. The data may be printed to be added to a patient file or may be stored in order to be retrieved at a later time. The user may input these additional preferences via the control input means 156.

It is also noted that if in step 220 other patient parameter data is not available, the patient's blood pressure will still be taken, but it will be taken and analyzed using a standard NIBP algorithm. That is, in step 250, the patient's blood pressure will be displayed, but the NIBP algorithm for collecting and analyzing the blood pressure will not take other patient parameters into account.

Through the use of the exemplary systems and methods, a more accurate non-invasive blood pressure may be taken as a result of the optimized blood pressure algorithm. The optimized blood pressure algorithm will reduce the amount of time needed to complete a measurement cycle by indicating a proper cardiac cycle to take a reading, so that it will not be necessary for a NIBP device to make several attempts to get an accurate reading. It will also improve accuracy by determining factors that may indicate an erroneously high or erroneously low blood pressure, such as patient movement or an irregular heartbeat, and accounting for these factors. Thus, the NIBP system of the present invention will be able to determine an accurate blood pressure reading in a more efficient manner.

It will be apparent to those skilled in the art that various modifications may be made in the present invention,

without departing from the spirit or the scope of the invention. Thus, it is intended that the present invention cover modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

It is also noted that the claims may include reference signs/numerals in accordance with PCT Rule 6.2(b). However, the present claims should not be considered to be limited to the exemplary embodiments corresponding to the reference signs/numerals.

What is claimed is:

1. A method, comprising:

receiving (210) pressure measurements corresponding to arterial pressure of a patient during a measurement process;

receiving (220, 230) an additional patient parameter; and

determining (240) a blood pressure of the patient based on the pressure measurements and the additional patient parameter.

2. The method of claim 1, further comprising:

outputting (250) the blood pressure to a display device.

3. The method of claim 1, wherein the determining includes:

adjusting (240) at least a portion of the pressure measurements based on the additional patient parameter.

4. The method of claim 1, wherein the determining includes:

adjusting (240) the measurement process for collecting the pressure measurements.

5. The method of claim 1, further comprising:

one of printing and storing the blood pressure.

6. The method of claim 1, wherein the additional patient parameter is one of an electrocardiogram and a saturation of peripheral oxygen measurement.

7. The method of claim 1, further comprising:

outputting (250) control signals to a pump and a valve of a blood pressure cuff applied to the patient.

8. The method of claim 1, further comprising:

receiving a control signal from an input device; and

adjusting the measurement process based on the control signal.

9. The method of claim 1, further comprising:
outputting a status signal corresponding to the measurement process.

10. A system, comprising:
a pressure sensor (120) detecting arterial pressure of a patient; and
a control element (110) receiving the arterial pressures from the pressure sensor (120) and an additional patient parameter, the control element (110) determining a blood pressure of the patient based on the arterial pressures and the additional patient parameter.

11. The system of claim 10, further comprising:
a display device (150) displaying the blood pressure to a user.

12. The system of claim 10, wherein the control element (110) determines the blood pressure by adjusting at least a portion of the arterial pressures based on the additional patient parameter.

13. The system of claim 10, wherein the control element (110) determines the blood pressure by adjusting a measuring process for collecting the arterial pressures.

14. The system of claim 10, wherein the additional patient parameter is one of an electrocardiogram and a saturation of peripheral oxygen measurement.

15. The system of claim 10, further comprising:

an input device (150) receiving user input, the user input adjusting a measurement process controlled by the control element (110),

wherein the display (150) further displays a status of a measuring process.

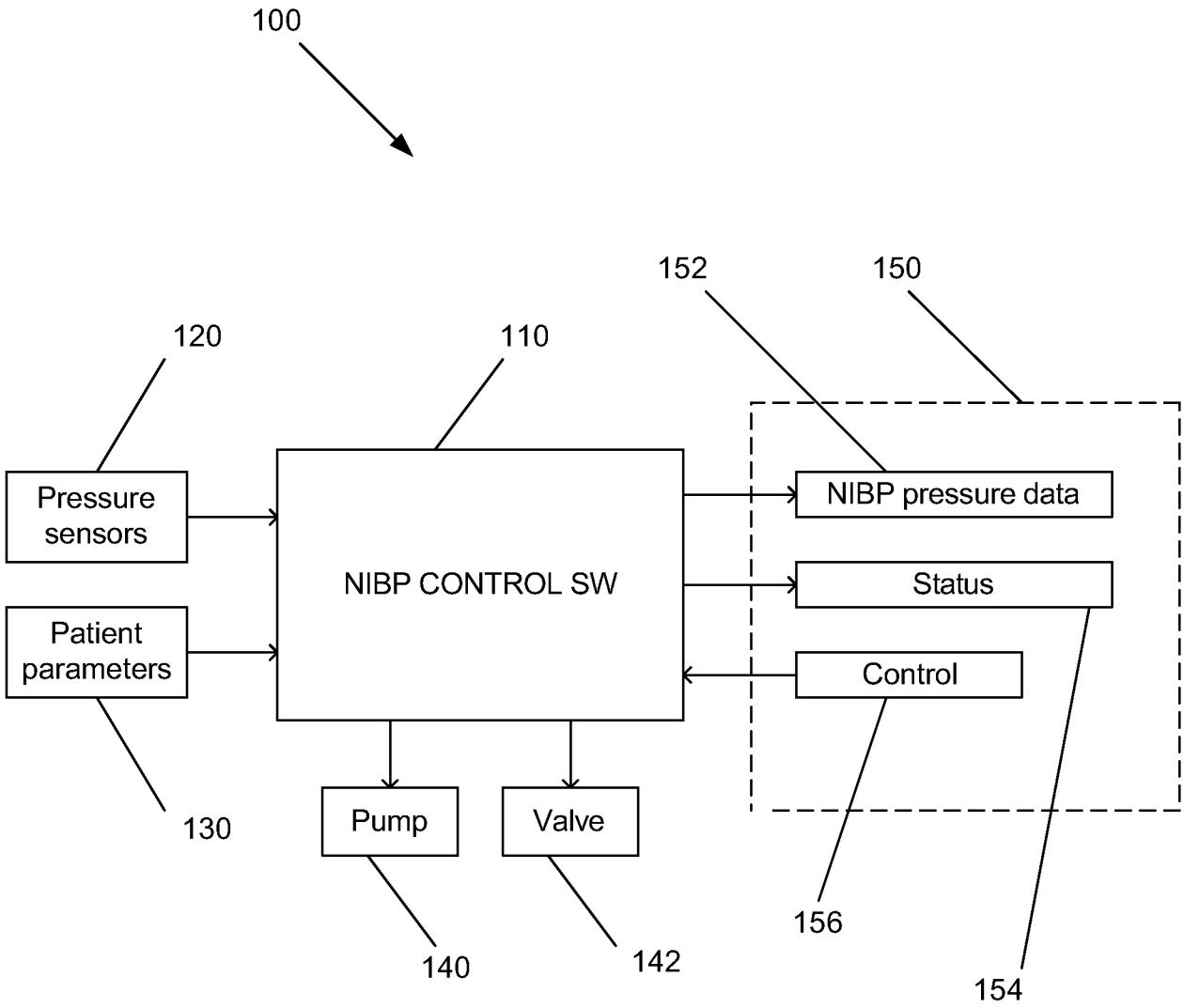
100
152
150
120
110
Pressure sensors
Patient parameters
NIBP CONTROL SW
NIBP pressure data
Status
Control
130
Pump
Valve
140
142
156
154

Fig. 1

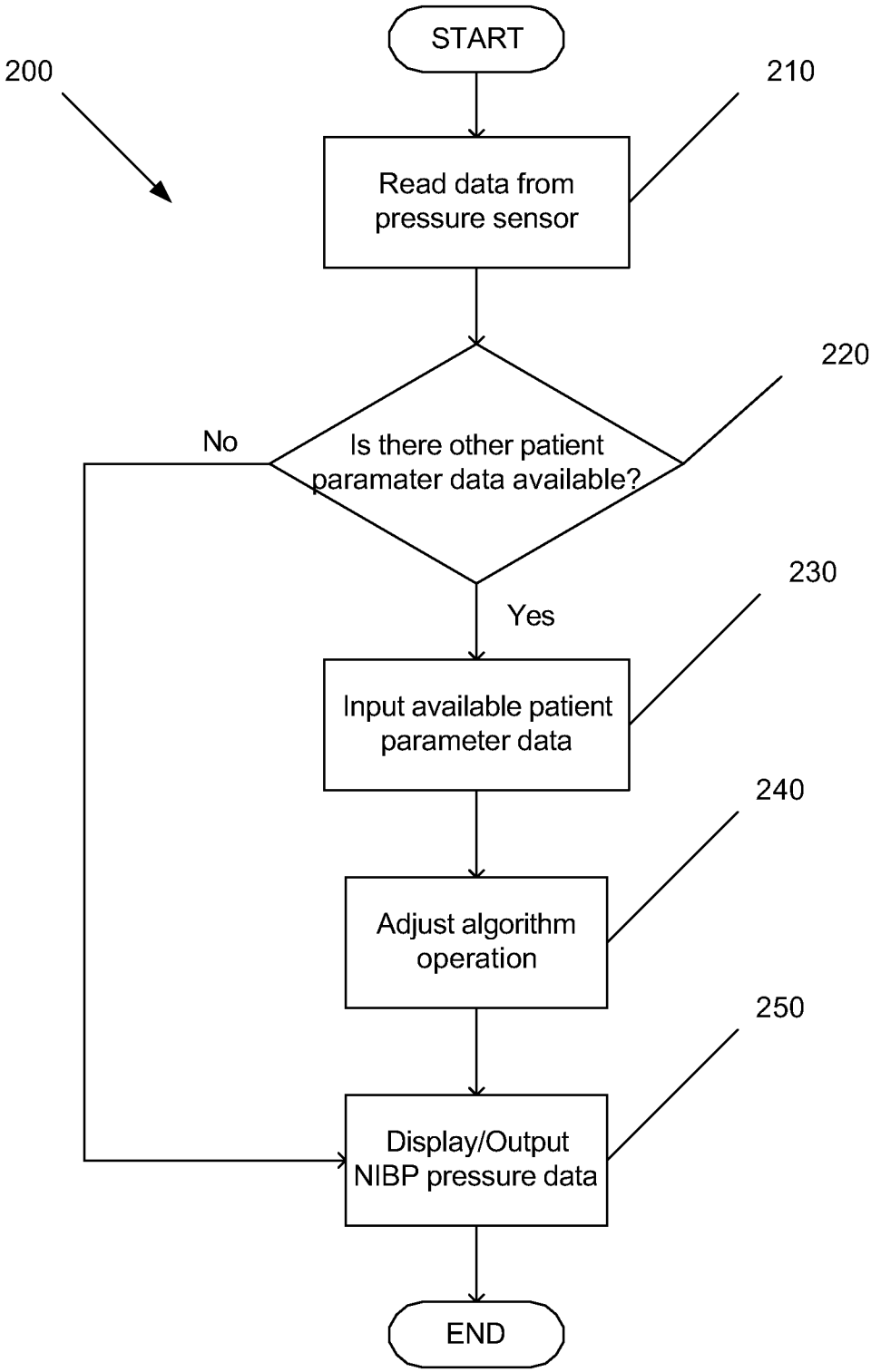
START
200
210
Read data from pressure sensor
220
No
Is there other patient paramater data available?
230
Yes
Input available patient parameter data
240
Adjust algorithm operation
250
Display/Output NIBP pressure data
END

Fig. 2