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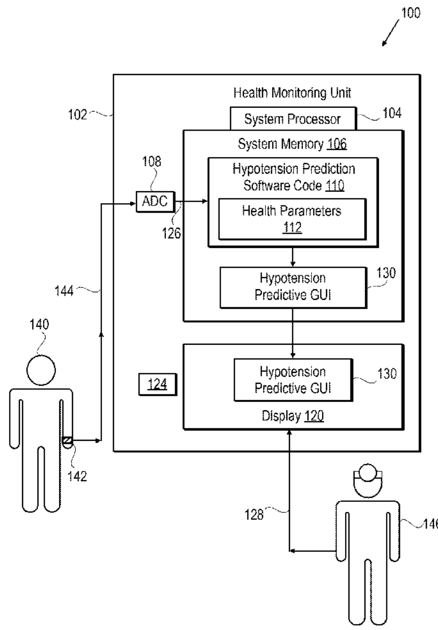

FIG. 1

(57) Abstract: A health monitoring unit includes a hardware processor, a memory, a display, and a graphical user interface (GUI) stored in the memory. The GUI is executed by the processor to provide a selection screen enabling a user to select parameters for viewing on the display from among health parameters of a living subject being tracked by the health monitoring unit. The GUI also presents a main screen showing the parameters selected by the user, the main screen including an icon for communicating a hypotension probability index (HPI) status of the living subject. In addition, the GUI overlays an alarm screen as a pop-up on the display if the HPI of the living subject satisfies a predetermined risk criteria, and enables the user to access an HPI diagnostic screen showing values for a subset of the health parameters identified as predictive of a future hypotension event for the living subject.

WO 2018/022380 A1

HEALTH MONITORING UNIT WITH HYPOTENSION PREDICTIVE GRAPHICAL USER INTERFACE (GUI)

BACKGROUND

Hypotension, or low blood pressure, can be a harbinger of serious medical complications, and even mortality, for patients undergoing surgery and those acutely or critically ill patients receiving treatment in an intensive care unit (ICU). The dangers associated with the occurrence of hypotension in a patient are due both to the potential injury caused by the hypotension itself and to the many serious underlying medical disorders that the occurrence of hypotension may signify.

In and of itself, hypotension in surgical patients or critically ill patients is a serious medical condition. For example, in the operating room (OR) setting, hypotension during surgery is associated with increased mortality and organ injury. Even short durations of extreme hypotension during surgery are associated with acute kidney injury and myocardial injury. Among critically ill patients, in-hospital mortality may be nearly doubled for patients experiencing hypotension after emergency intubation. For surgical patients and seriously ill patients alike, hypotension, if not corrected, can impair organ perfusion, resulting in irreversible ischemic damage, neurological deficit, cardiomyopathy, and renal impairment.

In addition to posing serious risks to surgical patients and critically ill patients in its own right, hypotension can be a symptom of one or more other serious underlying medical conditions. Examples of underlying conditions for which hypotension may serve as an acute symptom include sepsis, myocardial infarction, cardiac arrhythmia, pulmonary embolism, hemorrhage, dehydration, anaphylaxis, acute reaction to medication, hypovolemia, insufficient cardiac output, and vasodilatory shock. Due to its association with such a variety of serious medical conditions, hypotension is relatively common, and is often seen as one of the first signs of patient deterioration in the OR and ICU. For instance, hypotension is seen in up to approximately thirty-three percent of surgeries overall, and up to eighty-five percent in high risk surgeries. Among ICU patients, hypotension occurs in from approximately twenty-four percent to approximately eighty-five percent of all patients, with the eighty-five percent occurrence being seen among critically ill patients.

Conventional patient monitoring for hypotension in the OR and ICU settings can include continuous or periodic blood pressure measurement. However, such monitoring, whether continuous or periodic, typically provides no more than a real-time assessment. As a result, hypotension in a surgical patient or critically ill patient is usually detected only after it begins to occur, so that remedial measures and interventions cannot be initiated until the patient has entered a hypotensive state. Although, as noted above, extreme hypotension can have potentially devastating medical consequences quite quickly, even relatively mild levels of hypotension can herald or precipitate cardiac arrest in patients with limited cardiac reserve.

In view of the frequency with which hypotension is observed to occur in the OR and ICU settings, and due to the serious and sometimes immediate medical consequences that can result when it does occurs, a solution enabling prediction of a future hypotension event, before its occurrence, is highly desirable.

SUMMARY

There are provided exemplary implementations of a health monitoring unit with a hypotension predictive graphical user interface (GUI), and methods for use by such a health monitoring unit, substantially as shown in and/or described in connection with at least one of the figures, and as set forth more completely in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a diagram of an exemplary health monitoring unit with a hypotension predictive graphical user interface (GUI), according to one implementation;

Figure 2A shows a more detailed exemplary implementation of the hypotension predictive GUI shown in Figure 1;

Figure 2B shows a trace of an arterial pressure waveform including exemplary indicia corresponding to the probability of future hypotension in a living subject;

Figure 3 is a flowchart presenting an exemplary method for use by a health monitoring unit with a hypotension predictive GUI;

Figure 4A shows an exemplary selection screen of a hypotension predictive GUI provided on a display of a health monitoring unit, according to one implementation;

Figure 4B shows an exemplary main screen of a hypotension predictive GUI presented on a display of a health monitoring unit, according to one implementation;

Figure 4C shows an exemplary alarm screen of a hypotension predictive GUI overlaid as a pop-up on a display of a health monitoring unit, according to one implementation;

Figure 4D shows an exemplary hypotension probability index (HPI) diagnostic screen of a hypotension predictive GUI provided on a display of a health monitoring unit, according to one implementation;

Figure 5A shows an exemplary selection screen of a hypotension predictive GUI provided on a display of a health monitoring unit, according to another implementation; and

Figure 5B shows an exemplary main screen of a hypotension predictive GUI presented on a display of a health monitoring unit, according to another implementation.

DETAILED DESCRIPTION

The following description contains specific information pertaining to implementations in the present disclosure. One skilled in the art will recognize that the present disclosure may be implemented in a manner different from that specifically discussed herein. The drawings in the present application and their accompanying detailed description are directed to merely exemplary implementations. Unless noted otherwise, like or corresponding elements among the figures may be indicated by like or corresponding reference numerals. Moreover, the drawings and illustrations in the present application are generally not to scale, and are not intended to correspond to actual relative dimensions.

The present application discloses a health monitoring unit with a hypotension predictive graphical user interface (GUI). The health monitoring unit converts data received from a hemodynamic sensor to digital hemodynamic data of a living subject and obtains health parameters that are often highly predictive of future hypotension for the living subject from the digital hemodynamic data. The health monitoring unit utilizes some or all of the health parameters to determine a risk score or hypotension probability index (hereinafter "HPI") corresponding to the probability of a future hypotension event for the living subject.

The hypotension predictive GUI of the health monitoring unit provides a health care worker such as a doctor or nurse (hereinafter "user") with powerful options for monitoring and evaluating the probability of a future hypotension event for the living subject. By providing a selection screen on a display of the health monitoring unit, the hypotension predictive GUI disclosed by the present application enables the user to select parameters for viewing on the display from among the health parameters of the living subject being tracked by the health monitoring unit. By presenting a main screen on the display that includes an icon for communicating the HPI status of the living subject regardless of the parameters selected by the user, the hypotension predictive GUI disclosed by the present application renders the HPI status of the living subject continuously observable by the user.

In addition, by overlaying an alarm screen as a pop-up on the health monitoring unit display if the HPI of the living subject satisfies a predetermined risk criteria, the hypotension predictive GUI disclosed by the present application ensures that a timely warning of a future hypotension event is provided to the user. Moreover, by enabling the user to access an HPI diagnostic screen showing values for a subset of the health parameters identified as predictive of the future hypotension event, the hypotension predictive GUI disclosed by the present application provides detailed diagnostic information allowing the user to identify a most probable cause of the future hypotension event as well as possible medical interventions for its prevention.

Figure 1 shows a diagram of an exemplary system for performing health monitoring. System 100 includes health monitoring unit 102, which may be an integrated health monitoring unit, for example, and hemodynamic sensor 142 coupled to health monitoring unit 102. As shown in Figure 1, health monitoring unit 102 includes system processor 104, implemented as a hardware processor, system memory 106, analog-to-digital converter (ADC) 108, display 120, and sensory alarm 124. As further shown in Figure 1, system memory 106 of health monitoring unit 102 stores hypotension predictive GUI 130 and hypotension prediction software code 110 including health parameters 112.

It is noted that hypotension predictive GUI 130 is shown in Figure 1 as being provided on display 120, as well as being stored in system memory 106 to indicate that hypotension predictive GUI 130 is executed by hardware processor 104 to provide an interactive user interface via display 120 of health monitoring unit 102. Also shown in Figure 1 is digital hemodynamic data 126 generated by ADC 108 from signal 144 received from hemodynamic sensor 142.

Health monitoring unit 102 may be implemented within a patient care environment such as an intensive care unit (ICU) or operating room (OR), for example. As shown in Figure 1, in addition to health monitoring unit 102 and hemodynamic sensor 142, the patient care environment includes patient 140 (hereinafter “living subject 140”), and healthcare worker 146 (hereinafter “user 146”) trained to utilize health monitoring unit 102. As will be discussed in greater detail below, hypotension predictive GUI 130 is configured to receive inputs 128 from user 146, and to invoke sensory alarm 124 if the HPI for living subject 140 satisfies a predetermined risk criteria.

Hemodynamic sensor 142 is shown in an exemplary implementation in Figure 1, and is attached to living subject 140. It is noted that hemodynamic sensor 142 may be a non-invasive or minimally invasive sensor attached to living subject 140. In one implementation, as represented in Figure 1, hemodynamic sensor 142 may be attached non-invasively at an extremity of living subject 140, such as a wrist or finger of living subject 140. Although not explicitly shown in Figure 1, in other implementations, hemodynamic sensor 142 may be attached non-invasively at an ankle or toe of living subject 140. Signal 144 received by health monitoring unit 102 from hemodynamic sensor 142 may include signals corresponding to the arterial pressure of living subject 140. Health monitoring unit 102 and hemodynamic sensor 142 may be configured such that signal 144 may be received by health monitoring unit 102 wirelessly, or via a wired connection with hemodynamic sensor 142.

According to the exemplary implementation shown in Figure 1, system processor 104 is configured to utilize ADC 108 to convert signal 144 to digital hemodynamic data 126. System processor 104 is further configured to execute hypotension prediction software code 110 to transform digital hemodynamic data 126 to health parameters 112. System processor 104 is further configured to execute hypotension prediction software code 110 to determine the HPI for living subject 140 based on health parameters 112. In addition, system processor 104 is configured to execute hypotension predictive GUI 130 to invoke sensory alarm 124 if the HPI satisfies a predetermined risk criteria.

For example, system processor 104 may be configured to execute hypotension predictive GUI 130 to overlay an alarm screen as a pop-up on display 120 if the HPI of living subject 140 satisfies a predetermined risk criteria. In such an implementation, overlaying the alarm screen as a pop-up on display 120 may cause sensory alarm 124 to be invoked. Thus, hypotension predictive GUI 130 and/or sensory alarm 124 may be used by health monitoring unit 102 to warn of a hypotension event for living subject 140 predicted to occur approximately one to five minutes in the future, or up to approximately thirty minutes in the future.

In various implementations, sensory alarm 124 may be implemented as one or more of a visual alarm, an audible alarm, and a haptic alarm. For example, when implemented to provide a visual alarm, sensory alarm 124 may be invoked as flashing and/or colored graphics shown by hypotension predictive GUI 130 on display 120, and/or may include displaying the HPI via hypotension predictive GUI 130 on display 120. When implemented to provide an audible alarm, sensory alarm 124 may be invoked as any suitable warning sound, such as a siren or repeated tone. Moreover, when implemented to provide a haptic alarm, sensory alarm 124 may cause health monitoring unit 102 to vibrate or otherwise deliver a physical impulse perceptible to user 146.

It is noted that the HPI for living subject 140 is determined based on health parameters 112, which in turn are derived from signal 144 of living subject 140 received from hemodynamic sensor 142. Consequently, according to the inventive concepts disclosed by the present application, system processor 104 of health monitoring unit 102 is configured to execute hypotension prediction software code 110 to determine the HPI for living subject 140 without comparison with data corresponding to hypotension in other living subjects. In other words, hypotension prediction software code 110 determines the HPI for living subject 140 based on health parameters 112, without reference to a hypotension patient database storing information regarding hypotension in patients other than living subject 140.

Referring to Figure 2A, Figure 2A shows a more detailed exemplary implementation of hypotension predictive GUI 130, in Figure 1. In other words, hypotension predictive GUI 230, in Figure 2A corresponds in general to hypotension predictive GUI 130, in Figure 1, and each of hypotension predictive GUI 130 and hypotension predictive GUI 230 may share any of the characteristics attributed to either of hypotension predictive GUI 130 and hypotension predictive GUI 230 in the present application.

As shown in Figure 2A, hypotension predictive GUI 230 includes several modules for facilitating interaction by a user, such as user 146, in Figure 1, with hypotension predictive GUI 230. Among the modules included in hypotension predictive GUI 230 are selection module 232, presentation module 234, overlay module 236, and user access module 238. It is noted that the functionality of selection module 232, presentation module 234, overlay module 236, and user access module 238 will be described below with reference to flowchart 360, in Figure 3.

Continuing to Figure 2B, diagram 200 in Figure 2B shows a trace of arterial pressure waveform 250 including exemplary indicia for determining the HPI for living subject 140. Arterial pressure waveform 250, which may be a central arterial pressure waveform of living subject 140, for example, may correspond to digital hemodynamic data 126, converted by ADC 108 of health monitoring unit 102 from signal 144 received from hemodynamic sensor 142.

As shown in Figure 2B, arterial pressure waveform 250 includes exemplary indicia 252, 254, 256, and 258, corresponding respectively to the start of a heartbeat, the maximum systolic pressure marking the end of systolic rise, the presence of the dicrotic notch marking the end of systolic decay, and the diastole of the heartbeat of living subject 140. Also shown by diagram 200 is exemplary slope 248 of arterial pressure waveform 250. The indicia extracted from arterial pressure waveform 250, such as exemplary slope 248 and exemplary indicia 252, 254, 256, and 258, may be transformed by hypotension prediction software code 110 to health parameters 112.

In addition to the indicia 252, 254, 256, and 258 of arterial pressure waveform 250 per se, the behavior of arterial pressure waveform 250 during the intervals between those indicia may also be used as indicia for determining the HPI for living subject 140. For example, the interval between the start of the heartbeat at indicia 252 and the maximum systolic pressure at indicia 254 marks the duration of the systolic rise (hereinafter "systolic rise 252-254"). The systolic decay of arterial pressure waveform 250 is marked by the interval between the maximum systolic pressure at indicia 254 and the dicrotic notch at indicia 256 (hereinafter "systolic decay 254-256"). Together, systolic rise 252-254 and systolic decay 254-256 mark the entire systolic phase (hereinafter "systolic phase

252-256”), while the interval between the dicrotic notch at indicia 256 and the diastole at indicia 258 mark the diastolic phase of arterial pressure waveform 250 (hereinafter “diastolic phase 256-258”).

Also of potential diagnostic interest is the behavior of arterial pressure waveform 250 in the interval from the maximum systolic pressure at indicia 254 to the diastole at indicia 258 (hereinafter “interval 254-258”), as well as the behavior of arterial pressure waveform 250 from the start of the heartbeat at indicia 252 to the diastole at indicia 258 (hereinafter “heartbeat interval 252-258”). The behavior of arterial pressure waveform 250 during intervals: 1) systolic rise 252-254, 2) systolic decay 254-256, 3) systolic phase 252-256, 4) diastolic phase 256-258, 5) interval 254-258, and 6) heartbeat interval 252-258 may be determined by measuring the area under the curve of arterial pressure waveform 250 and the standard deviation of arterial pressure waveform 250 in each of those intervals, for example. The respective areas and standard deviations measured for intervals 1, 2, 3, 4, 5, and 6 above may serve as additional indicia for determining the HPI for living subject 140.

Example implementations of the present inventive concepts will be further described below with reference to Figure 3, Figures 4A, 4B, 4C, and 4D (hereinafter “Figures 4A-4D”), and Figures 5A and 5B. Figure 3 presents flowchart 360 outlining an exemplary method for use by health monitoring unit 102 including hypotension predictive GUI 130/230. Figures 4A-4D show user interaction screens provided by hypotension predictive GUI 130/230, executed by system processor 104, through use of respective selection module 232, presentation module 234, overlay module 236, and user access module 238, according to one implementation. Figures 5A and 5B show user interaction screens provided by hypotension predictive GUI 130/230, executed by system processor 104, through use of respective selection module 232, presentation module 234, overlay module 236, and user access module 238, according to another implementation.

It is noted that the various user interaction screens shown by Figures 4A-4D are depicted as being provided by hypotension predictive GUI 430 via display 420, while the user interaction screens shown by Figures 5A and 5B are depicted as being provided by hypotension predictive GUI 530 via display 520. Hypotension predictive GUI 430/530, in Figures 4A-4D, 5A, and 5B corresponds in general to hypotension predictive GUI 130/230, in Figure 1/2B. That is to say, each of hypotension predictive GUI 130/230/430/530 may share any of the characteristics attributed to any other hypotension predictive GUI 130/230/430/530 in the present application.

In addition, display 420/520, in Figures 4A-4D, 5A, and 5B corresponds in general to display 120, in Figure 1. Thus, each of display 120/420/520 may share any of the characteristics attributed to any other display 120/420/520 in the present application. Display 120/420/520 may take the form of a liquid crystal display (LCD), a light-emitting diode (LED) display, an organic light-emitting diode (OLED) display, or another suitable display screen that performs a physical transformation of signals to light.

Referring to Figures 1, 2A, 3, and 4A in combination, flowchart 360 begins with providing selection screen 462 enabling user 146 to select parameters 472 and 484 for viewing on display 120/420 from among health parameters 112/412 of living subject 140 being tracked by health monitoring unit 102 (action 362). Selection screen 462 is provided on display 120/420 of health monitoring unit 102 by hypotension predictive GUI 130/230/430, executed by system processor 104, and through use of selection module 232.

As shown by Figure 4A, selection screen 462 of hypotension predictive GUI 130/230/430 enables user 146 to select from among health parameters 112/412 including cardiac output (CO) 472, stroke volume (SV) 474, stroke volume variation (SVV) 476, diastolic pressure (DIA) 477, pulse rate (PR) 478, stroke volume index (SVI) 480, systemic vascular resistance (SVR) 482, mean arterial pressure (MAP) 414, and HPI 484. In addition, health parameters 112/412 being tracked by health monitoring unit 102 include systemic vascular resistance index (SVRI), cardiac index (CI), and systolic pressure (SYS). It is noted that health parameters 112/412 being tracked by health monitoring unit 102 may further include additional parameters not represented on selection screen 462.

Also shown in Figure 4A is exit button 486 enabling user 146 to close selection screen 462 of hypotension predictive GUI 130/230/430.

According to the exemplary implementation shown by Figure 4A, hypotension predictive GUI 130/230/430 is implemented as a touch screen user interface. However, in other implementations, hypotension predictive GUI 130/230/430 may be configured to receive inputs 128 from user 146 via a keyboard, via another type of input device, such as a mouse or pressure pad, or as voice commands spoken by user 146, for example.

As shown by the shadowing of parameters 476, 480, and 484, user 146 has selected CO 472 and HPI 484 for viewing on display 120/420 of health monitoring unit 102 from among health parameters 112/412 being tracked by health monitoring unit 102.

Referring to Figure 4B in combination with Figures 1, 2A, and 3, flowchart 360 continues with presenting main screen 464 of hypotension predictive GUI 130/230/430 showing parameters CO 472 and HPI 484 selected by user 146 from selection screen 462 (action 364). It is noted that HPI 484 is depicted visually on interactive screens of hypotension predictive GUI 130/230/330 other than selection screen 462 as "P(↓BP)" and is shown on main screen 464 as P(↓BP) 484. It is further noted that the acronym HPI and its symbolic representation as P(↓BP) may be used interchangeably hereinafter. Main screen 464 is provided on display 120/420 of health monitoring unit 102 by hypotension predictive GUI

130/230/430, executed by system processor 104, and through use of presentation module 234.

As shown by Figure 4B, main screen 464 of hypotension predictive GUI 130/230/430 shows P(↓BP) 484 numerically and as a trace displayed as a function of time. The trace as a function of time and numerical value shown for each of CO 472 and P(↓BP) 484, as well as for blood pressure (BP) 488, which may be included as a default parameter from among health parameters 112/412, may be shown continuously on main screen 464, and may be updated periodically, such as every approximately twenty seconds, for example.

According to the implementation shown by Figure 4B, P(↓BP) 484 is shown as a number between zero and one hundred (0-100) corresponding to the probability that living subject 140 will experience a hypotension event. That is to say, a P(↓BP) near zero indicates that a hypotension event is highly unlikely, while a P(↓BP) near 100 indicates a high probability of an impending hypotension event. The trace and numerical value of P(↓BP) 484 may exhibit a color corresponding in general to the probability of a future hypotension event for living subject 140. For example, a relatively low P(↓BP), such as a P(↓BP) of less than or equal to 50 may cause the trace and/or numerical value of P(↓BP) 484 to appear green on main screen 464. However, a higher P(↓BP), such as a P(↓BP) between 50 and 85, for example, may cause the trace and/or numerical value of

P(↓BP) 484 to appear yellow, while a high P(↓BP), such as a P(↓BP) over 85, may cause the trace and/or numerical value of P(↓BP) 484 to turn red.

In addition to the features described above, main screen 464 of hypotension predictive GUI 130/230/430 provides shortcut button 490 enabling user 146 direct access to an HPI diagnostic screen, described below, including additional data for evaluating the probability and likely cause of a future hypotension event for living subject 140.

Referring to Figure 4C in combination with Figures 1, 2A, and 3, flowchart 360 continues with overlaying alarm screen 466 as a pop-up on display 120/420 of health monitoring unit 102 if P(↓BP) 484 of living subject 140 satisfies a predetermined risk criteria (action 366). Overlay of alarm screen 466 on display 120/420 of health monitoring unit 102 is performed by hypotension predictive GUI 130/230/430, executed by system processor 104, and through use of overlay module 236.

The predetermined risk criteria may be based on the value of P(↓BP) 484, on the trend of P(↓BP) 484 over a time interval, or both. For example, having P(↓BP) 484 exceed a threshold of 85, for instance, may cause alarm screen 466 to pop-up substantially immediately. Alternatively, or in addition, a lower risk score may cause alarm screen 466 to pop-up if it exceeds a predetermined threshold over the entirety of a predetermined time period.

Thus, for example, while having P(↓BP) 484 equal to 85 or more may cause alarm screen 466 to pop-up substantially immediately, having P(↓BP) 484 at or above 80 may cause alarm screen 466 to pop-up after several seconds at that level, such as ten to thirty seconds in which P(↓BP) 484 is continuously between 80 and 85, for example. By analogy, a still lower value of P(↓BP) 484 may cause alarm screen 466 to pop-up if that P(↓BP) value is maintained continuously for one or more minutes. In yet another implementation, P(↓BP) 484 may cause alarm screen 466 to pop-up if it meets or exceeds a predetermined value a predetermined number of times over a predetermined time period. For example, having P(↓BP) 484 exceed 75 three times over a five minute interval may cause alarm screen 466 to pop-up.

Once alarm screen 466 does pop-up, alarm screen 466 overlays display 120/420 persistently until an acknowledgement input is received from user 146 via hypotension predictive GUI 130/230/430. For example, user 146 may either simply acknowledge the alarm by selecting acknowledge bar 416, or may request more information by selecting more information bar 418. Selection of acknowledge bar 416 by user 146 may cause alarm screen 466 to disappear, while selection of more information bar 418 may provide user 146 with direct access to the HPI diagnostic screen, described below, which includes additional data for evaluating the probability and likely cause of a future hypotension event for living subject 140. Thus, it is noted that the HPI diagnostic screen described below is accessible to user 146 from main screen 464 via shortcut button 490, as well as from alarm screen 466 via more information bar 418.

In some implementations, overlaying alarm screen 466 as a pop-up on display 120/420 causes sensory alarm 124/424 to be invoked. As noted above by reference to Figure 1, sensory alarm 124/424 may be implemented as one or more of a visual alarm, an audible alarm, and a haptic alarm. For example, when implemented to provide a visual alarm, sensory alarm 124/424 may be invoked as flashing and/or colored graphics shown by hypotension predictive GUI 130/230/430 on display 120/420, and/or may include displaying P(↓BP) 484 via hypotension predictive GUI 130/230/430 on display 120/420. When implemented to provide an audible alarm, sensory alarm 124/424 may be invoked as any suitable warning sound, such as a siren or repeated tone. Moreover, when implemented to provide a haptic alarm, sensory alarm 124/424 may cause health monitoring unit 102 to vibrate or otherwise deliver a physical impulse perceptible to user 146.

Referring to Figure 4D in combination with Figures 1, 2A, and 3, flowchart 360 can conclude with enabling user 146 to access HPI diagnostic screen 468 showing a subset of health parameters 112/412 identified as hypotension risk indicators predictive of a future hypotension event for living subject 140 (action 368). Access to HPI diagnostic screen 468 is enabled by hypotension predictive

GUI 130/230/430, executed by system processor 104, and through use of user access module 238.

As shown in Figure 4D, in addition to the numerical values for CO 472 and P(↓BP) 484 shown on main screen 464 of hypotension predictive GUI 130/230/430, HPI diagnostic screen 468 of hypotension predictive GUI 130/230/430 shows numerical values and variations for hypotension risk indicators identified as predictive of a future hypotension event. According to the exemplary implementation shown by Figure 4D, the hypotension risk indicators include MAP 114/414, DIA 477, SVR 482, SV 474, PR 478, SVV 476, arterial elastance (E_a) 494, and left ventricle contractility (dP/dt) 496.

The hypotension risk indicators shown as predictive health parameters on HPI diagnostic screen 468 can enable user 146 to identify a most probable cause of the future hypotension event for living subject 140. For example, HPI diagnostic screen 468 provided by hypotension predictive GUI 130/230/430 may enable user 146 to identify one or more of poor vascular tone, low blood volume, or reduced cardiac contractility, to name a few exemplary causes, as a most probable cause of a predicted future hypotension event.

Furthermore, in some implementations, the predictive health parameters shown on HPI diagnostic screen 468 can enable user 146 to determine a medical intervention for preventing the future hypotension event for living subject 140. For example, values and variations for MAP 414, CO 472, SVV 476, and SV 474 are highlighted in green on HPI diagnostic screen 468, indicating that those health parameters are low risk with respect to the probability of a hypotension event for living subject 140. Values and variations for PR 478 and SVR 482 are highlighted in yellow on HPI diagnostic screen 468, indicating that those health parameters are moderate risk with respect to the probability of a hypotension event for living subject 140.

It is noted that the predictive health parameters shown on HPI diagnostic screen 468 are drawn on HPI diagnostic screen 468 as a tree with MAP 414 at the top, and CO 472 and SVR 482 being linked to one another below MAP 414 by a branched connection coming from MAP 414. PR 478 and SV 474 are similarly linked to one another below CO 472 by a branched connection coming from CO 472. In addition, SVV 476, dP/dt 496, and E_a 494 are linked to one another below SV 474 by a branched connection coming from SV 474. Based on the information shown by HPI diagnostic screen 468, i.e., P(↓BP) 484 at a relatively safe level of 35, a hypotension event is not imminent for living subject 140.

Moving to Figures 5A and 5B, Figures 5A and 5B show an implementation of hypotension predictive GUI 130/230/530 in which the main screen of hypotension predictive GUI 130/230/530 displays health parameters 112 using a speedometer type display format. As shown by Figure 5A, selection screen 562 of hypotension predictive GUI 130/230/530 enables user 146 to select from among the same health parameters 112/412 shown in Figure 4A, i.e., CO 572, SV

574, SVV 576, DIA 577, PR 578, SVI 580, SVR 582, MAP 514, and HPI 584, as well as SVRI, CI, and SYS. Thus health parameters 512 correspond respectively to health parameters 112/412 and may share any of the characteristics attributed to those corresponding features above. Also shown in Figure 5A is exit button 586 enabling user 546 to close selection screen 562 of hypotension predictive GUI 130/230/530.

According to the exemplary implementation shown by Figure 5A, hypotension predictive GUI 130/230/530 is implemented as a touch screen user interface. However, in other implementations, hypotension predictive GUI 130/230/530 may be configured to receive inputs 128 from user 146 via a keyboard, via another type of input device, such as a mouse or pressure pad, or as voice commands spoken by user 146, for example. As shown by the shadowing of parameters 576, 578, and 580, user 146 has selected SVV 576, MAP 514, and HPI 584 for viewing on display 120/520 of health monitoring unit 102 from among health parameters 112/412/512 being tracked by health monitoring unit 102.

Referring to Figure 5B, Figure 5B shows main screen 564 of hypotension predictive GUI 130/230/530 displaying parameters SVV 576, MAP 514, and P(↓BP) 584 selected by user 146 from selection screen 562. As shown by Figure 5B, main screen 564 of hypotension predictive GUI 130/230/430/530 also provides shortcut button 590 enabling user 146 direct access to an HPI diagnostic screen corresponding to HP diagnostic screen 468, in Figure 4D, and including additional data for evaluating the probability and likely cause of a future hypotension event for living subject 140.

As further shown by Figure 5B, the health parameters shown on main screen 564 of hypotension predictive GUI 130/230/530 are displayed by reference to color coded risk zones. For example, in the value reported for P(↓BP) 584 is shown to fall in a relatively safe green zone. The value for MAP 514 is shown to fall in a yellow zone, indicating that the value of MAP 514 presents moderate risk with respect to the probability of a hypotension event for living subject 140. By contrast to health parameters highlighted in green or yellow, the value of SVV 576 is shown to have increased into a red zone, indicating that SVV 25 is a high risk health parameter with respect to the probability of a hypotension event for living subject 140.

In the event that P(↓BP) 584 or one or more others of health parameters 112/412/512 satisfies a predetermined risk criteria, as described above by reference to Figure 4C, alarm screen 466 may overlay 120/420/520 as a pop-up. Overlay of alarm screen 466 on display 120/420/520 of health monitoring unit 102 is performed by hypotension predictive GUI 130/230/430, executed by system processor 104, and through use of overlay module 236.

As discussed above, once alarm screen 466 does pop-up, alarm screen 466 overlays display 120/420/520 persistently until an acknowledgement input is received from user 146 via hypotension predictive GUI 130/230/430/530. For example, user 146 may either simply acknowledge the alarm by selecting acknowledge bar 416, or may request more information by selecting more information bar 418. Selection of acknowledge bar 416 by user 146 may cause alarm screen 466 to disappear, while selection of more information bar 418 may provide user 146 with direct access to HPI diagnostic screen 468, described above.

Thus, the hypotension predictive GUI of the health monitoring unit disclosed by the present application provides a user with powerful options for monitoring and evaluating the probability of a future hypotension event for a living subject. By providing a selection screen on a display of the health monitoring unit, the hypotension predictive GUI disclosed by the present application enables the user to select parameters for viewing on the display from among the health parameters of the living subject being tracked by the health monitoring unit. By presenting a main screen on the display that includes an icon for communicating the HPI status of the living subject regardless of the parameters selected by the user, the hypotension predictive GUI disclosed by the present application renders the HPI status of the living subject continuously observable by the user.

In addition, by overlaying an alarm screen as a pop-up on the health monitoring unit display if the HPI of the living subject satisfies a predetermined risk criteria, the hypotension predictive GUI disclosed by the present application ensures that a timely warning of a future hypotension event is provided to the user. Moreover, by enabling the user to access an HPI diagnostic screen showing values for a subset of the health parameters identified as predictive of the future hypotension event, the hypotension predictive GUI disclosed by the present application provides detailed diagnostic information allowing the user to identify a most probable cause of the future hypotension event as well as possible medical interventions for its prevention.

From the above description it is manifest that various techniques can be used for implementing the concepts described in the present application without departing from the scope of those concepts. Moreover, while the concepts have been described with specific reference to certain implementations, a person of ordinary skill in the art would recognize that changes can be made in form and detail without departing from the scope of those concepts. As such, the described implementations are to be considered in all respects as illustrative and not restrictive. It should also be understood that the present application is not limited to the particular implementations described herein, but many rearrangements, modifications, and substitutions are possible without departing from the scope of the present disclosure.

CLAIMS

What is claimed is:

1. A health monitoring unit comprising:

a hardware processor;

a memory;

a display; and

a graphical user interface (GUI) stored in the memory and executed by the hardware processor to:

provide a selection screen on the display enabling a user to select a plurality of parameters for viewing on the display from among another plurality of health parameters of a living subject being tracked by the health monitoring unit and being stored in the memory;

present a main screen on the display showing the plurality of parameters selected by the user from the selection screen, the main screen including an icon for communicating a hypotension probability index (HPI) status of the living subject;

overlay an alarm screen as a pop-up on the display if the HPI of the living subject satisfies a predetermined risk criteria; and

enable the user to access an HPI diagnostic screen showing values for a subset of the health parameters identified as predictive of a future hypotension event for the living subject.

2. The health monitoring unit of claim 1, further comprising a sensory alarm, and wherein overlaying the alarm screen as a pop-up on the display causes the sensory alarm to be invoked.

3. The health monitoring unit of claim 1, wherein the alarm screen is persistently displayed until an acknowledgement input is received from the user via the GUI.

4. The health monitoring unit of claim 1, wherein the main screen is configured to show the HPI as a function of time.

5. The health monitoring unit of claim 1, wherein the HPI diagnostic screen is accessible to the user from the main screen and the alarm screen.

6. The health monitoring unit of claim 1, wherein the HPI diagnostic screen enables at least one of identification, by the user, of a most probable cause of the future hypotension event, and determination, by the user, of a medical intervention for preventing the future hypotension event.

7. The health monitoring unit of claim 1, wherein a plurality of predictive health parameters including mean arterial pressure (MAP), cardiac output (CO), systemic vascular resistance (SVR), pulse rate (PR), stroke volume (SV), stroke volume variation (SVV), left ventricle contractility (dP/dt), and arterial elastance (E_a) are drawn on the HPI diagnostic screen as a tree with MAP at the top, with CO and SVR linked to one another below MAP by a branched connection coming from MAP, with PR and SV linked to one another below CO by a branched connection coming from CO, and with SVV, dP/dt, and E_a linked to one another below SV by a branched connection coming from SV.

8. A graphical user interface (GUI) of a health monitoring unit having a hardware processor, a display and a memory storing the GUI for execution by the hardware processor, to the GUI comprising:

a selection module providing a selection screen on the display enabling a user to select a plurality of parameters for viewing on the display from among another plurality of health parameters of a living subject being tracked by the health monitoring unit and being stored in the memory;

a presentation module presenting a main screen on the display showing the plurality of parameters selected by the user from the selection screen, the main screen including an icon for communicating a hypotension probability index (HPI) status of the living subject;

an overlay module overlaying an alarm screen as a pop-up on the display if the HPI of the living subject satisfies a predetermined risk criteria; and

a user access module enabling the user to access an HPI diagnostic screen showing values for a subset of the health parameters identified as predictive of a future hypotension event for the living subject.

9. The GUI of claim 8, wherein the health monitoring unit further comprises a sensory alarm, and wherein overlaying the alarm screen as a pop-up on the display causes the sensory alarm to be invoked.

10. The GUI of claim 8, wherein the alarm screen is persistently displayed until an acknowledgement input is received from the user via the GUI.

11. The GUI of claim 8, wherein the main screen is configured to show the HPI as a function of time.

12. The GUI of claim 8, wherein the HPI diagnostic screen is accessible to the user from the main screen and the alarm screen.

13. The GUI of claim 8, wherein the HPI diagnostic screen enables at least one of identification, by the user, of a most probable cause of the future

hypotension event, and determination, by the user, of a medical intervention for preventing the future hypotension event.

14. The GUI of claim 8, wherein a plurality of predictive health parameters including mean arterial pressure (MAP), cardiac output (CO), systemic vascular resistance (SVR), pulse rate (PR), stroke volume (SV), stroke volume variation (SVV), left ventricle contractility (dP/dt), and arterial elastance (E_a) are drawn on the HPI diagnostic screen as a tree with MAP at the top, with CO and SVR linked to one another below MAP by a branched connection coming from MAP, with PR and SV linked to one another below CO by a branched connection coming from CO, and with SVV, dP/dt, and E_a linked to one another below SV by a branched connection coming from SV.

15. A method of presenting a graphical user interface (GUI) on a display of a health monitoring unit having a memory storing the GUI and a hardware processor executing the GUI from the memory, the method comprising:

providing, using the hardware processor, a selection screen on the display enabling a user to select a plurality of parameters for viewing on the display from among another plurality of health parameters of a living subject being tracked by the health monitoring unit and being stored in the memory;

presenting, using the hardware processor, a main screen on the display showing the plurality of parameters selected by the user from the selection screen, the main screen including an icon for communicating a hypotension probability index (HPI) status of the living subject;

overlaying, using the hardware processor, an alarm screen as a pop-up on the display if the HPI of the living subject satisfies a predetermined risk criteria; and

enabling, using the hardware processor, the user to access an HPI diagnostic screen showing values for a subset of the health parameters identified as predictive of a future hypotension event for the living subject.

16. The method of claim 15, wherein the health monitoring unit further comprises a sensory alarm, and wherein overlaying the alarm screen as a pop-up on the display causes the sensory alarm to be invoked.

17. The method of claim 15, wherein the main screen is configured to show the HPI as a function of time.

18. The method of claim 15, wherein the HPI diagnostic screen is accessible to the user from the main screen and the alarm screen.

19. The method of claim 15, wherein the HPI diagnostic screen enables at least one of identification, by the user, of a most probable cause of the future hypotension event, and determination, by the user, of a medical intervention for preventing the future hypotension event.

20. The method of claim 15, further comprising drawing a plurality of predictive health parameters including mean arterial pressure (MAP), cardiac output (CO), systemic vascular resistance (SVR), pulse rate (PR), stroke volume (SV), stroke volume variation (SVV), left ventricle contractility (dP/dt), and arterial elastance (E_a) on the HPI diagnostic screen as a tree with MAP at the top, with CO and SVR linked to one another below MAP by a branched connection coming from MAP, with PR and SV linked to one another below CO by a branched connection coming from CO, and with SVV, dP/dt, and E_a linked to one another below SV by a branched connection coming from SV.

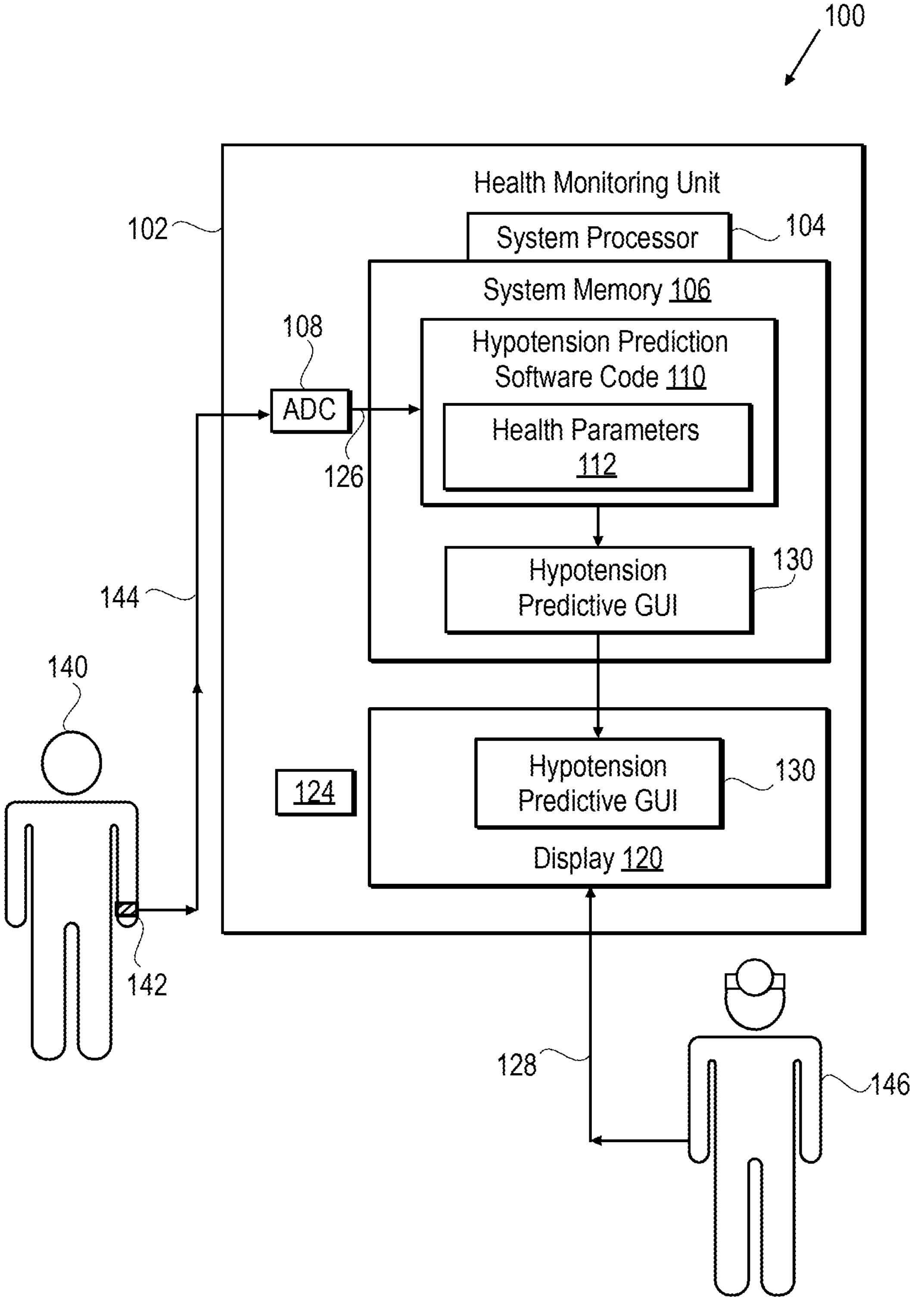
100
102
Health Monitoring Unit
System Processor
104
System Memory 106
108
Hypotension Prediction Software Code 110
ADC
Health Parameters 112
126
144
Hypotension Predictive GUI
130
140
124
Hypotension Predictive GUI
130
Display 120
142
128
146

FIG. 1

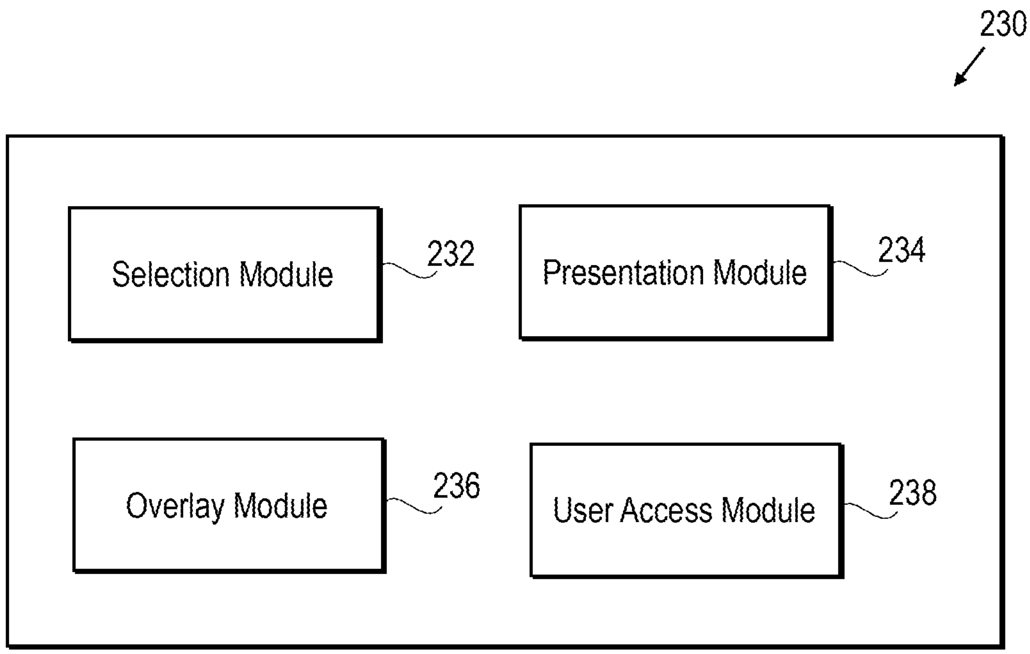
230
Selection Module
232
Presentation Module
234
Overlay Module
236
User Access Module
238

FIG. 2A

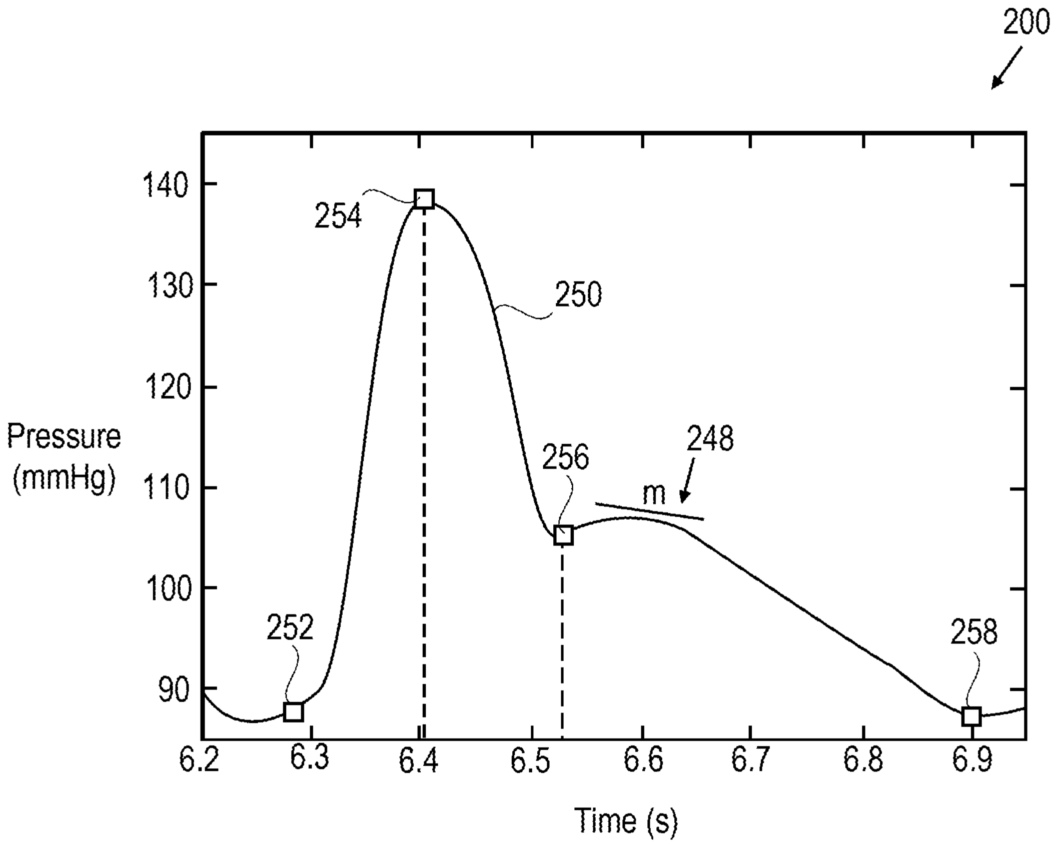
200
140
130
120
110
100
90
Pressure
(mmHg)
254
250
256
248
m
252
258
6.2
6.3
6.4
6.5
6.6
6.7
6.8
6.9
Time (s)

FIG. 2B

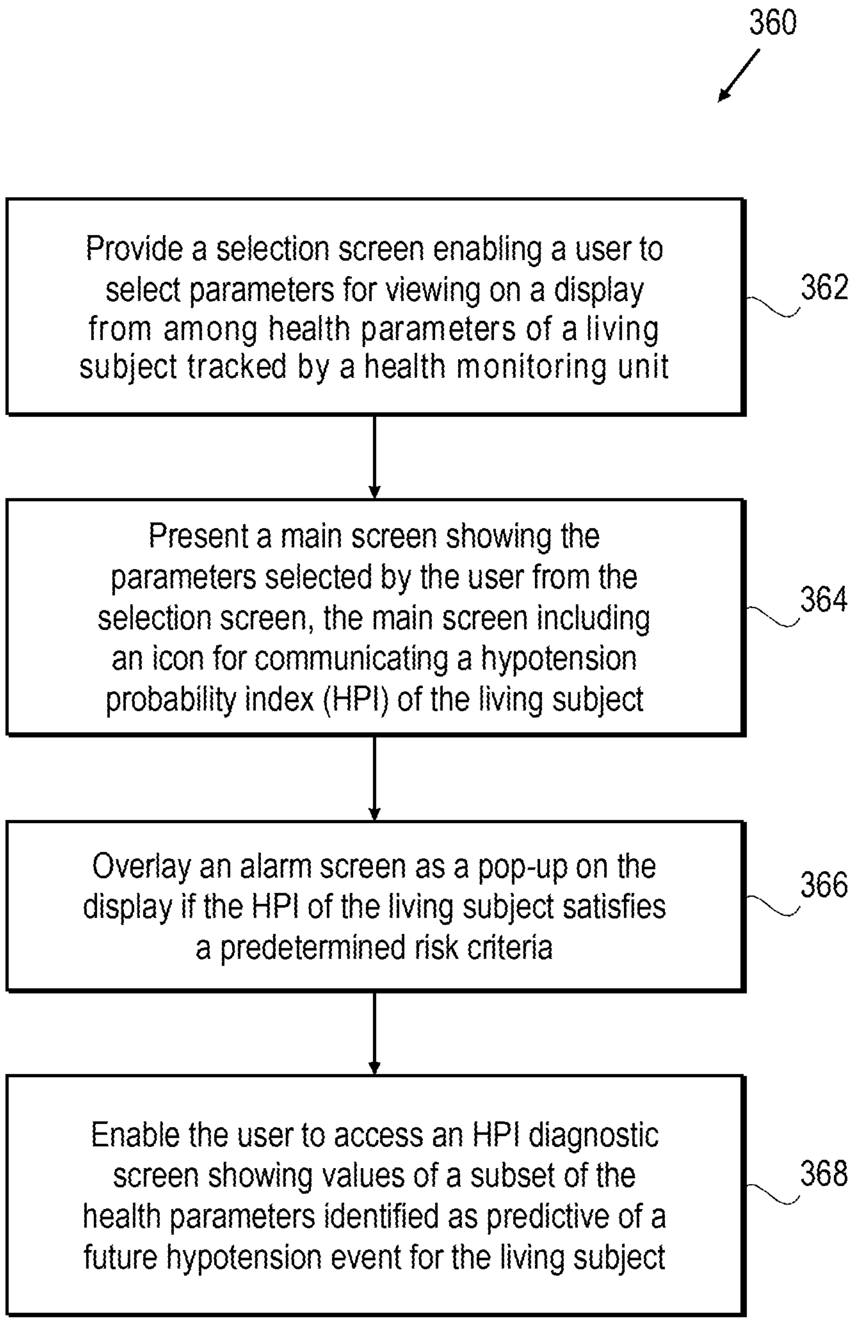
360
Provide a selection screen enabling a user to select parameters for viewing on a display from among health parameters of a living subject tracked by a health monitoring unit
362
Present a main screen showing the parameters selected by the user from the selection screen, the main screen including an icon for communicating a hypotension probability index (HPI) of the living subject
364
Overlay an alarm screen as a pop-up on the display if the HPI of the living subject satisfies a predetermined risk criteria
366
Enable the user to access an HPI diagnostic screen showing values of a subset of the health parameters identified as predictive of a future hypotension event for the living subject
368

FIG. 3

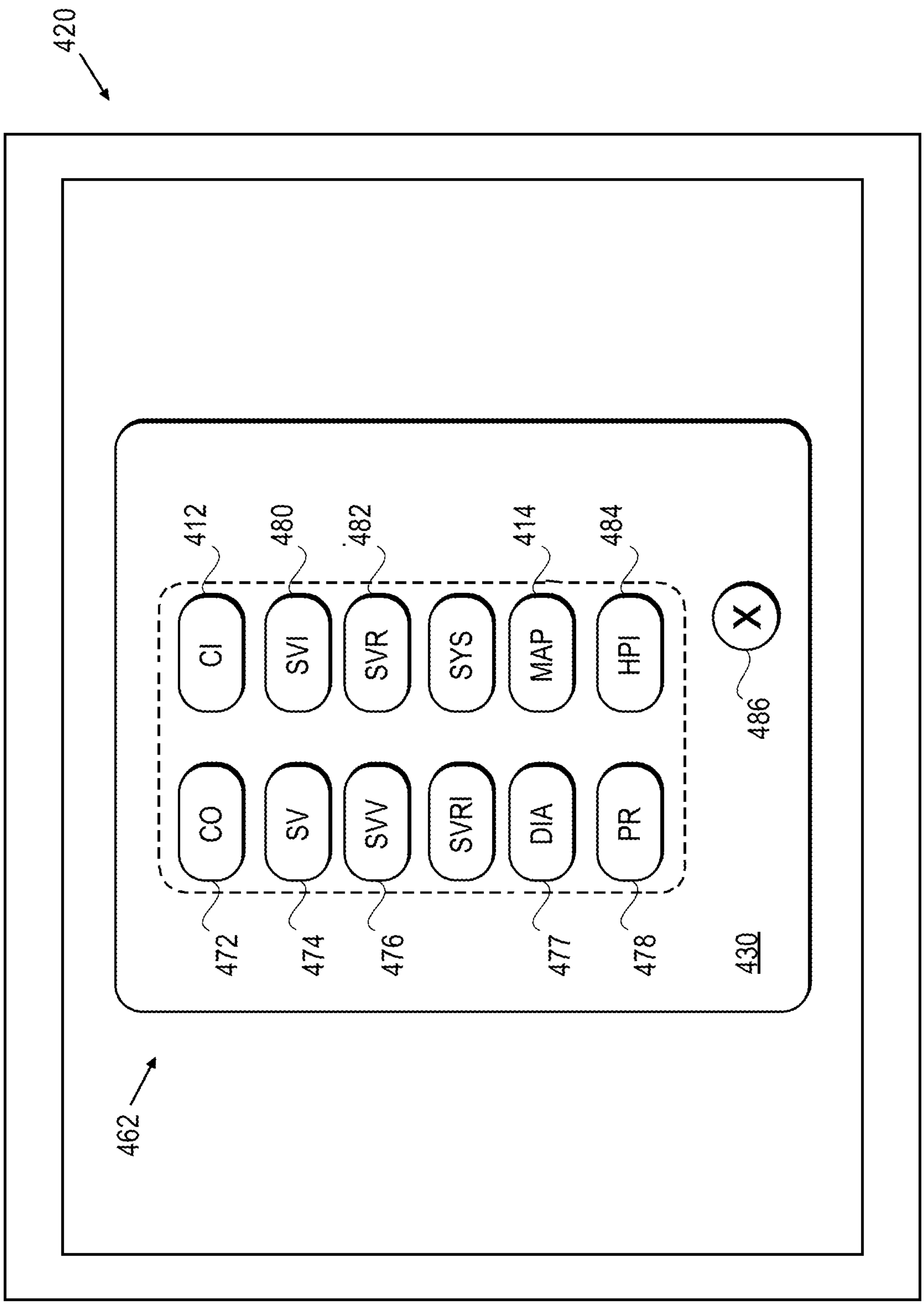
420
CI
SVI
SVR
SYS
MAP
HPI
CO
SV
SVV
SVRI
DIA
PR
412
480
482
414
484
472
474
476
477
478
486
430
462

FIG. 4A

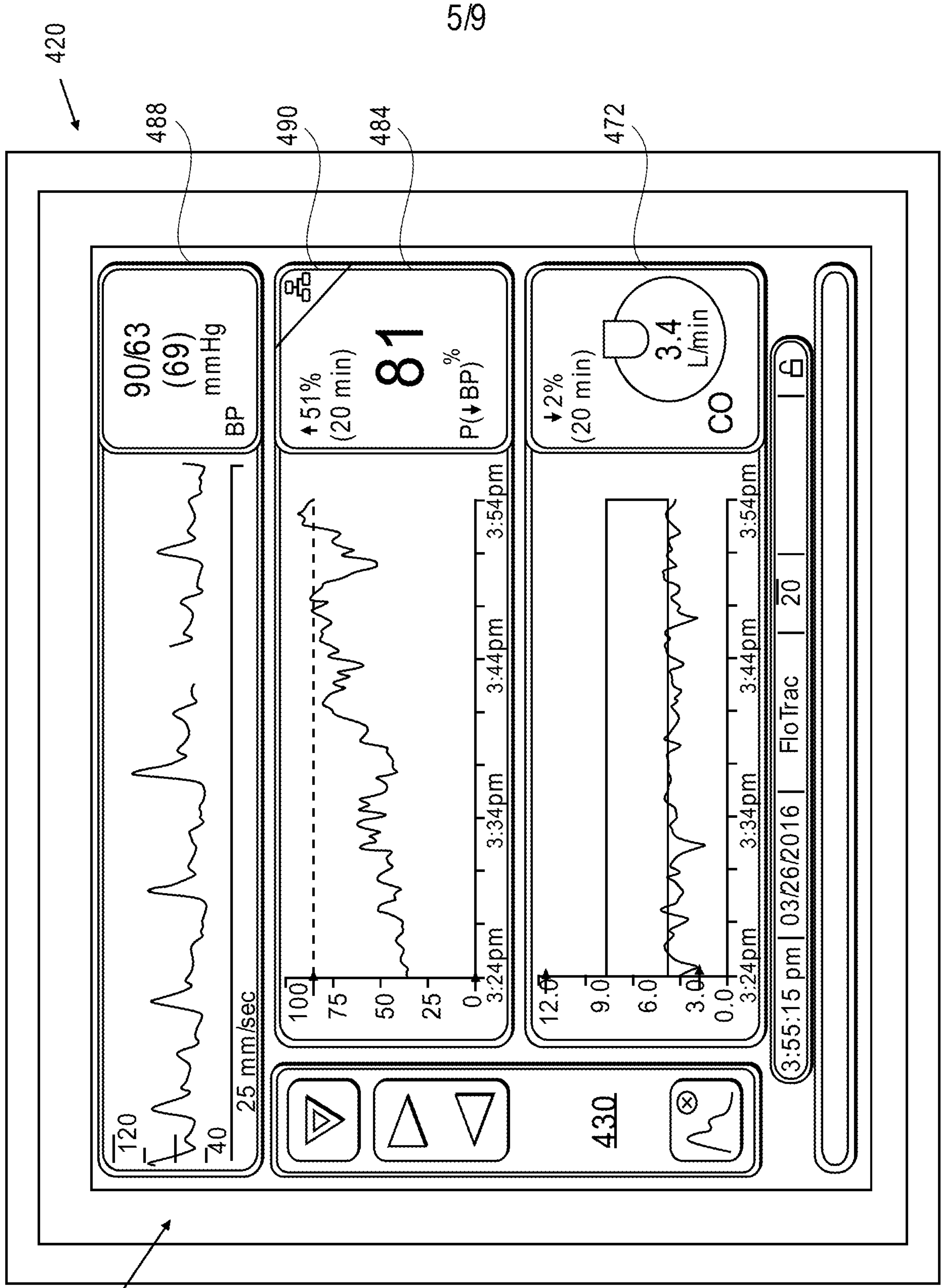
420
488
490
484
472
90/63
(69)
mmHg
BP
↑51%
(20 min)
81
P(↓BP)%
↓2%
(20 min)
3.4
L/min
CO
120
40
25 mm/sec
100
75
50
25
0
3:24pm
3:34pm
3:44pm
3:54pm
12.0
9.0
6.0
3.0
0.0
430
3:55:15 pm
03/26/2016
FloTrac
20
464

FIG. 4B

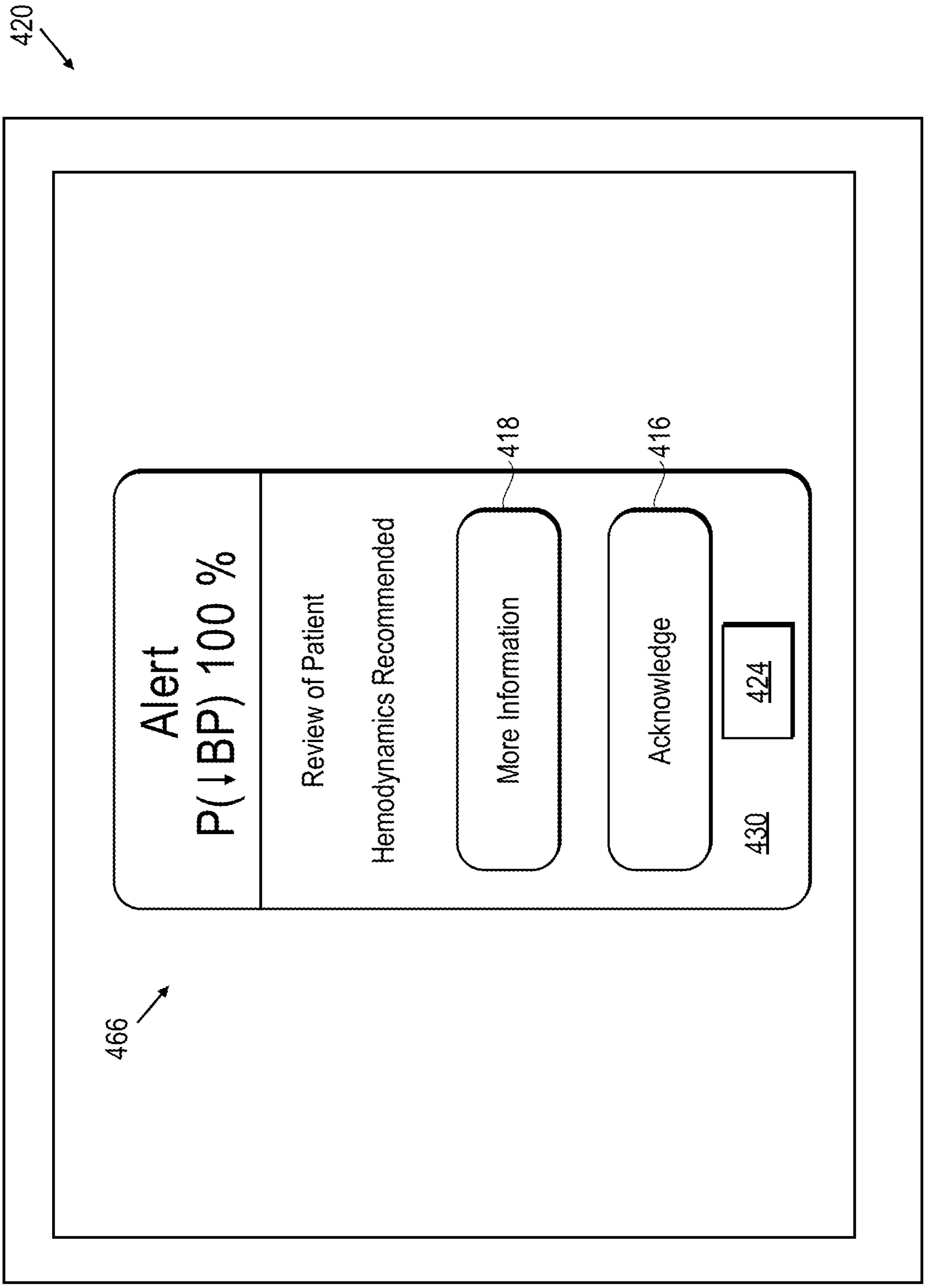
420
Alert
P(↓BP) 100 %
Review of Patient
Hemodynamics Recommended
More Information
Acknowledge
418
416
424
430
466

FIG. 4C

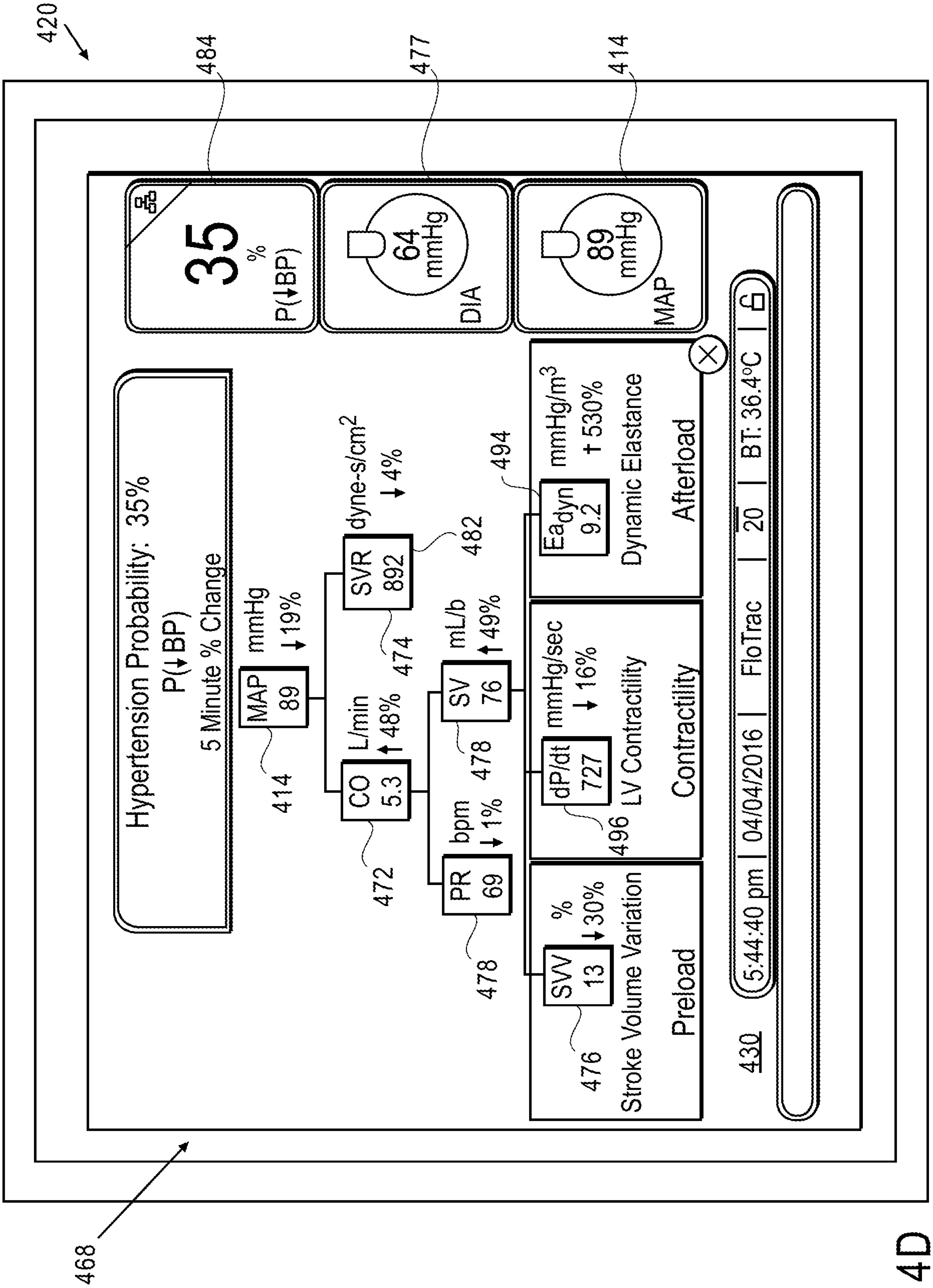
420
484
477
414
35
%
P(↓BP)
64
mmHg
DIA
89
mmHg
MAP
Hypertension Probability: 35%
P(↓BP)
5 Minute % Change
MAP
89
mmHg
↓19%
414
SVR
892
dyne-s/cm2
↓4%
482
474
CO
5.3
L/min
↑48%
472
SV
76
mL/b
↑49%
478
PR
69
bpm
↓1%
478
Eadyn
9.2
mmHg/m3
↑530%
494
Dynamic Elastance
Afterload
dP/dt
727
mmHg/sec
↓16%
496
LV Contractility
Contractility
SVV
13
%
↓30%
476
Stroke Volume Variation
Preload
5:44:40 pm
04/04/2016
FloTrac
20
BT: 36.4°C
430
468

FIG. 4D

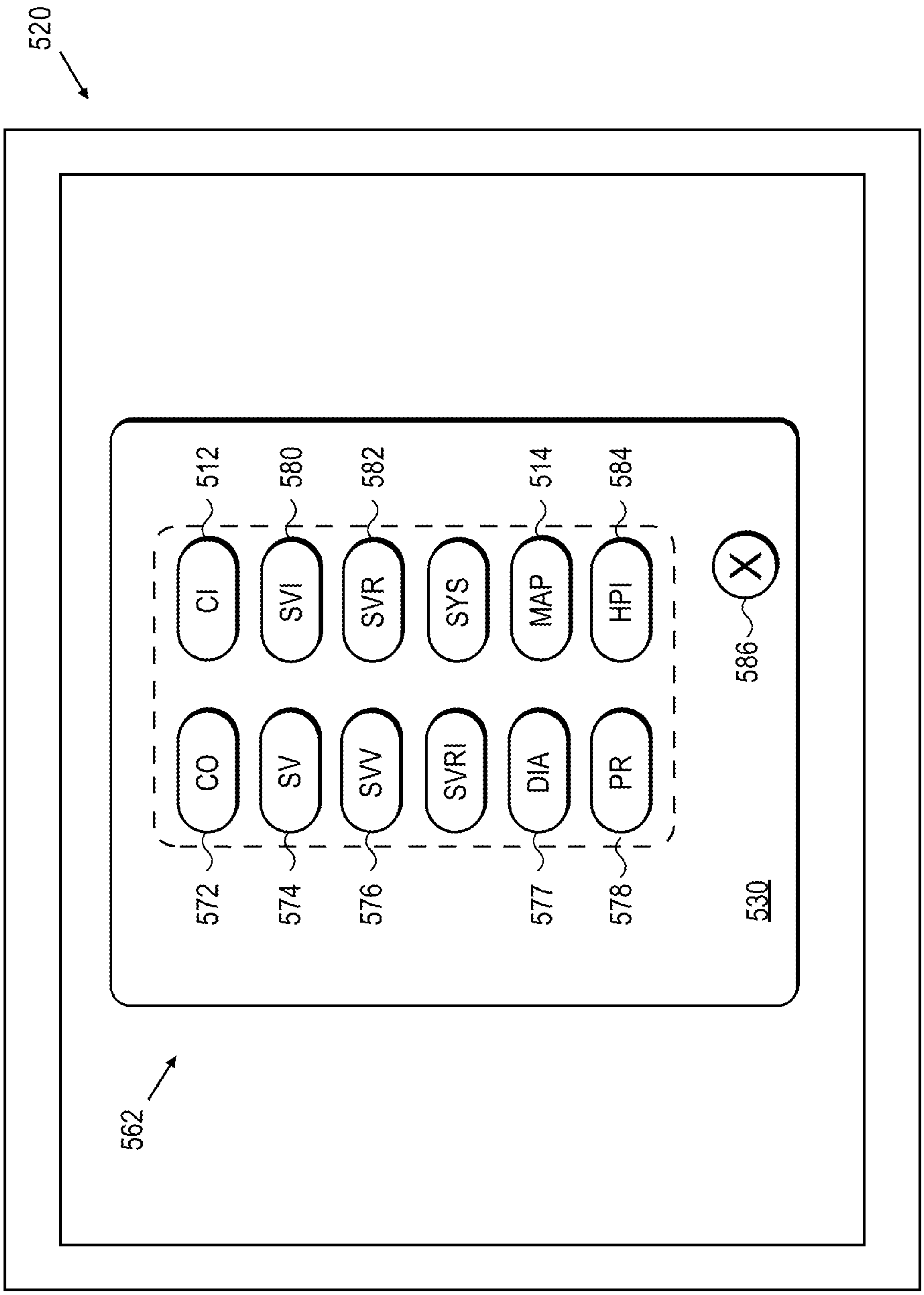
520
562
530
CI
SVI
SVR
SYS
MAP
HPI
CO
SV
SVV
SVRI
DIA
PR
512
580
582
514
584
572
574
576
577
578
586

FIG. 5A

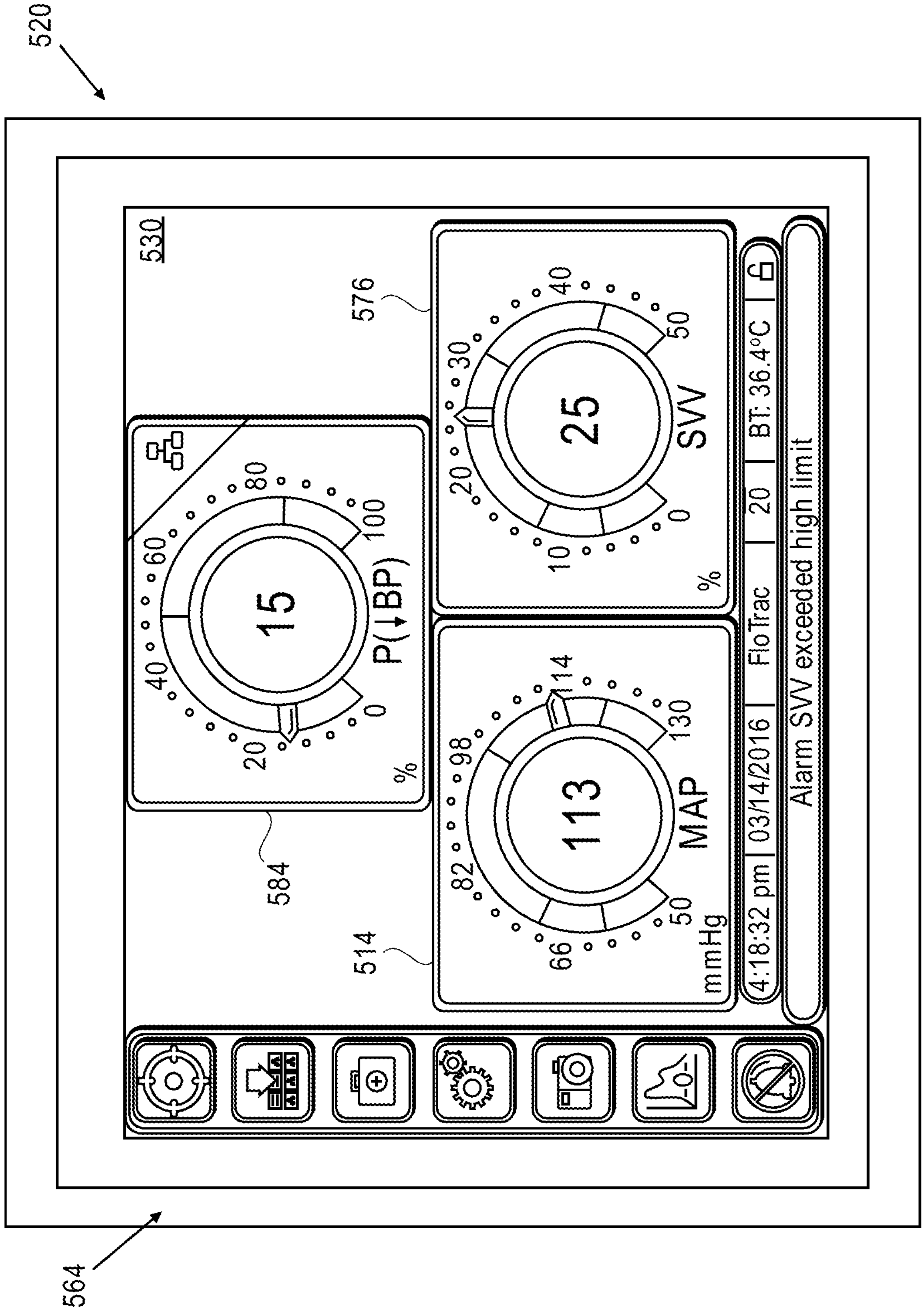
520
530
576
584
514
564
15
P(↓BP)
%
25
SVV
%
113
MAP
mmHg
4:18:32 pm
03/14/2016
FloTrac
20
BT: 36.4°C
Alarm SVV exceeded high limit

FIG. 5B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/042879

A. CLASSIFICATION OF SUBJECT MATTER

A61B 5/00(2006.01)i, A61B 5/021(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61B 5/00; G06F 17/60; G06T 11/20; A61B 5/0402; A61B 5/021

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: health, monitoring, GUI, display, hypotension, probability, HIP, alarm

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2015-0116333 A1 (ABBOTT DIABETES CARE INC.) 30 April 2015 See paragraphs [55]-[76],[279] and claims 13-18.	1-20
Y	WO 2016-022989 A2 (THE GENERAL HOSPITAL CORPORATION) 11 February 2016 See paragraph [114] and figures 20,21.	1-20
A	WO 2004-034898 A2 (PHILIPS INTELLECTUAL PROPERTY & STANDARDS GMBH et al.) 29 April 2004 See claims 1-21 and figure 3.	1-20
A	WO 2015-183689 A1 (ROCHE DIABETES CARE, INC. et al.) 03 December 2015 See claims 1-20 and figure 2.	1-20
A	US 2005-0187796 A1 (ROSENFELD et al.) 25 August 2005 See claims 1-6 and figure 19.	1-20

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 September 2017 (20.09.2017)	**21 September 2017 (21.09.2017)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea
Facsimile No. +82-42-481-8578

Authorized officer
KIM, Yeon Kyung
Telephone No. +82-42-481-3325

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		EP 2473422 A4	17/09/2014
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		US 2006-0025657 A1	02/02/2006

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		US 2006-0071797 A1	06/04/2006
		US 2006-0085227 A1	20/04/2006
		US 2006-0085229 A9	20/04/2006
		US 2006-0122869 A9	08/06/2006
		US 2006-0161459 A9	20/07/2006
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		US 7411509 B2	12/08/2008
		US 7433827 B2	07/10/2008
		US 7454359 B2	18/11/2008
		US 7454360 B2	18/11/2008
		US 7467094 B2	16/12/2008
		US 7475019 B2	06/01/2009
		US 7650291 B2	19/01/2010
		US 7837792 B2	23/11/2010
		US 7991625 B2	02/08/2011
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		US 8175895 B2	08/05/2012
		US 8326649 B2	04/12/2012
		US 8401874 B2	19/03/2013
		WO 00-79466 A2	28/12/2000
		WO 00-79466 A3	19/07/2001

patsnap

专利名称(译)	具有低血压预测图形用户界面（GUI）的健康监测单元		
公开(公告)号	[EP3490437A4](#)	公开(公告)日	2019-08-07
申请号	EP2017834994	申请日	2017-07-19
[标]申请(专利权)人(译)	爱德华兹生命科学公司		
申请(专利权)人(译)	爱德华生命科学公司		
当前申请(专利权)人(译)	爱德华生命科学公司		
[标]发明人	AL HATIB FERAS IFFT PETER JAMES		
发明人	AL HATIB, FERAS IFFT, PETER, JAMES		
IPC分类号	A61B5/00 A61B5/021		
CPC分类号	A61B5/026 A61B5/7275 A61B5/7282 A61B5/742 A61B5/7435 A61B5/746 A61B5/7475 A61B8/06 A61B8/065 G06F19/34 G16H40/40 G16H40/63 G16H50/30		
优先权	62/366953 2016-07-26 US 15/649872 2017-07-14 US		
其他公开文献	EP3490437A1		
外部链接	Espacenet		

摘要(译)

健康监测单元包括硬件处理器，存储器，显示器和存储在存储器中的图形用户界面（GUI）。 GUI由处理器执行以提供选择屏幕，使得用户能够从健康监测单元所跟踪的活体的健康参数中选择用于在显示器上观看的参数。 GUI还呈现显示用户选择的参数的主屏幕，主屏幕包括用于传达活体的低血压概率指数（HPI）状态的图标。此外，如果活体的HPI满足预定的风险标准，则GUI将警报屏幕覆盖为显示器上的弹出窗口，并且使用户能够访问HPI诊断屏幕，该屏幕显示所识别的健康参数的子集的值。预测生命受试者未来的低血压事件。