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(54) PATIENT MONITOR AND METHOD WITH NON-INVASIVE CARDIAC OUTPUT MONITORING

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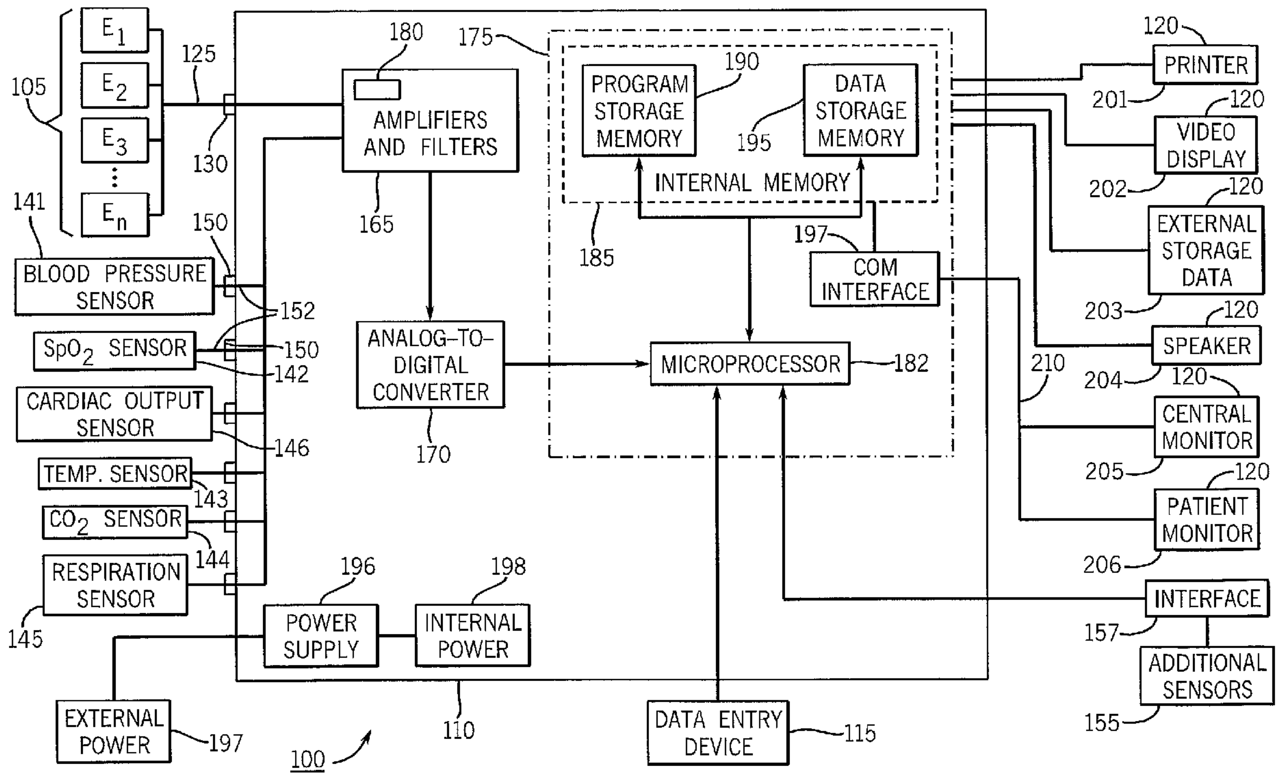
(52) U.S. Cl. 600/513

(57) ABSTRACT

A patient monitoring system comprises a non-invasive cardiac output sensor and a patient monitor console. The non-invasive cardiac output sensor is capable of acquiring a signal from a patient indicative of blood flow through a heart of the patient. The patient monitor console includes an analysis module and a display. The analysis module is coupled to the non-invasive cardiac output sensor and processes the signal from the patient indicative of blood flow to produce a value pertaining to cardiac output. The display is coupled to the analysis module and displays the value pertaining to cardiac output.



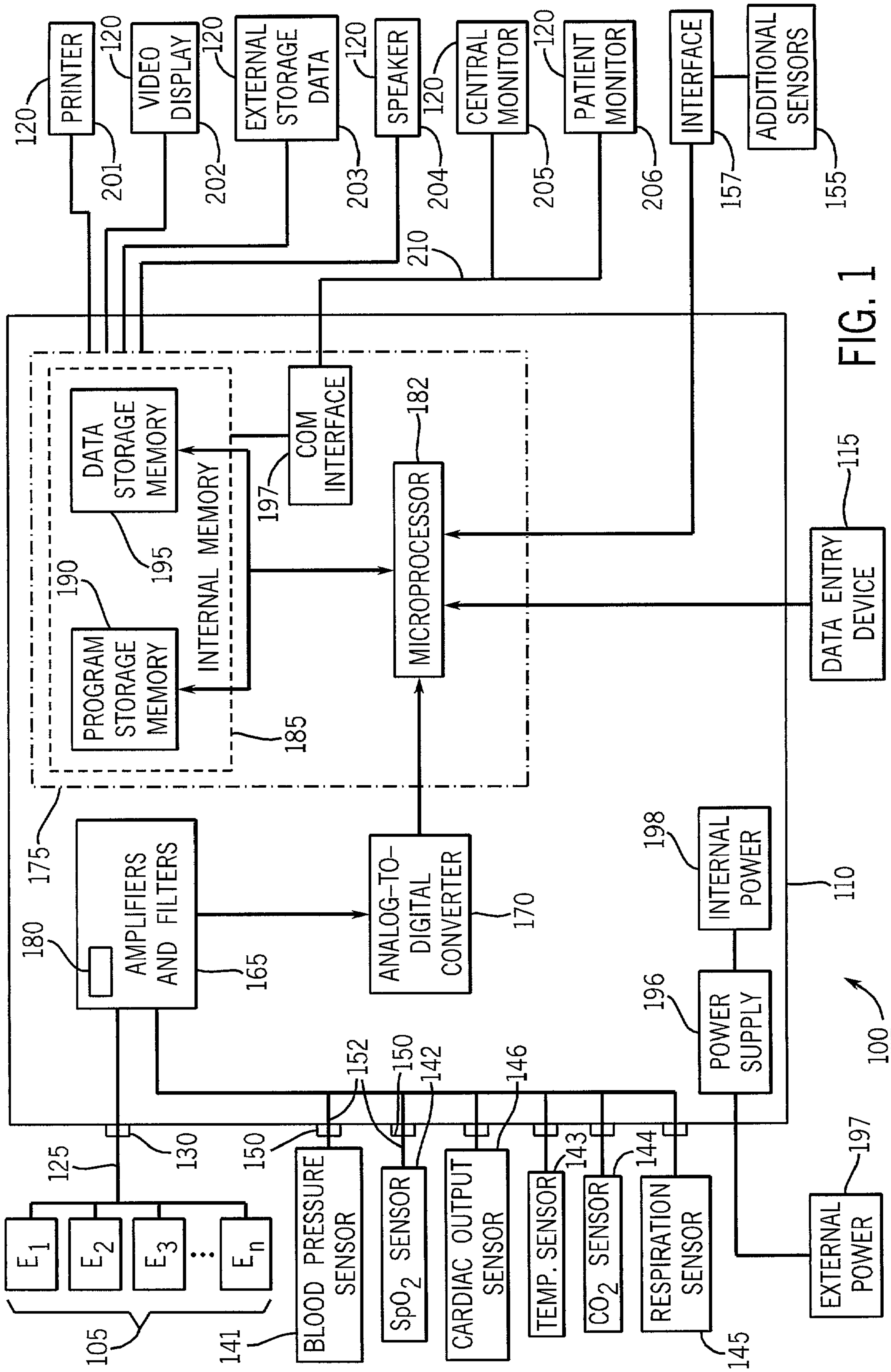
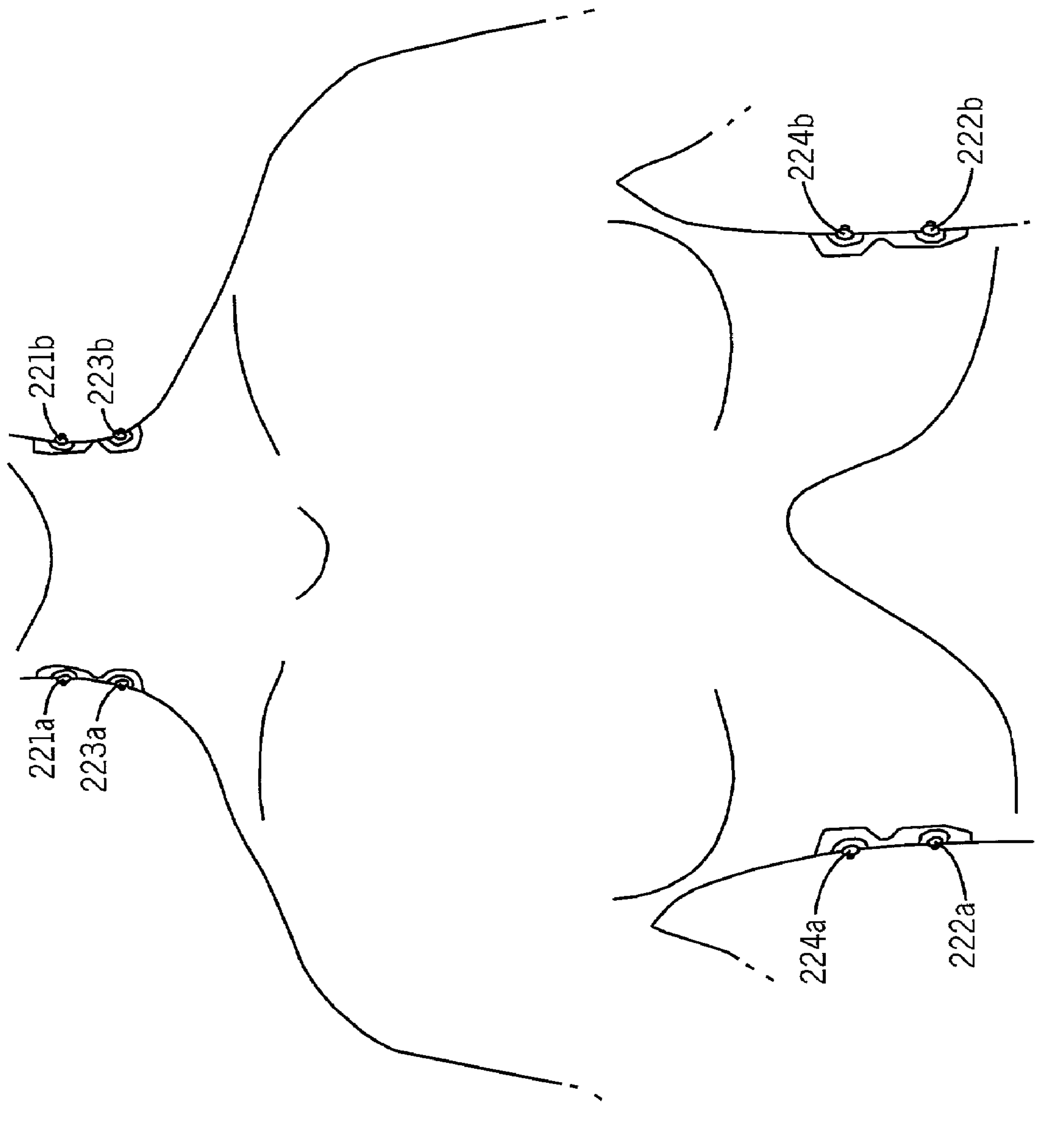

PRINTER
VIDEO DISPLAY
EXTERNAL STORAGE DATA
SPEAKER
CENTRAL MONITOR
PATIENT MONITOR
INTERFACE
ADDITIONAL SENSORS
DATA STORAGE MEMORY
PROGRAM STORAGE MEMORY
INTERNAL MEMORY
COM INTERFACE
MICROPROCESSOR
DATA ENTRY DEVICE
AMPLIFIERS AND FILTERS
ANALOG-TO-DIGITAL CONVERTER
INTERNAL POWER
POWER SUPPLY
EXTERNAL POWER
E_1
E_2
E_3
E_n
BLOOD PRESSURE SENSOR
SpO_2 SENSOR
CARDIAC OUTPUT SENSOR
TEMP. SENSOR
CO_2 SENSOR
RESPIRATION SENSOR
100
105
110
115
120
125
130
141
142
143
144
145
146
150
152
155
157
165
170
175
180
182
185
190
195
196
197
198
201
202
203
204
205
206
210

FIG. 1

FIG. 2



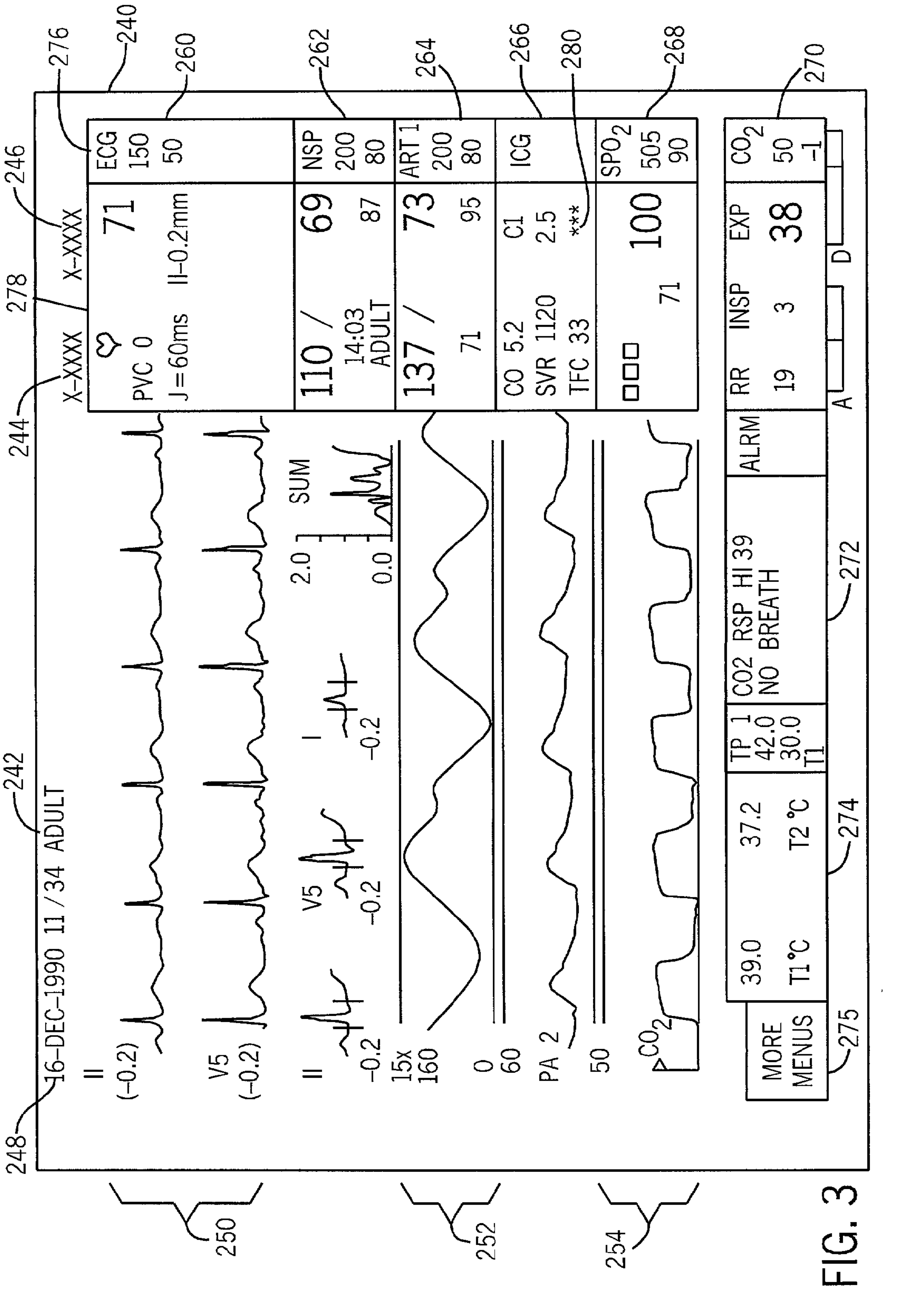

16-DEC-1990 11/34 ADULT
X-XXXX
X-XXXX
ECG 150 50
71
PVC 0
J=60ms
II-0.2mm
NSP 200 80
110 / 69
14:03
ADULT
87
ART 1 200 80
137 / 73
71
95
ICG
CO 5.2
SVR 1120
TFC 33
CI 2.5
***
SPO2 505 90
100
71
CO2 50 -1
RR 19
INSP 3
EXP 38
A
D
ALRM
CO2 RSP HI 39
NO BREATH
TP 1 42.0 30.0 T1
39.0 T1°C
37.2 T2°C
MORE MENUS
II (-0.2)
V5 (-0.2)
II -0.2
V5 -0.2
I -0.2
2.0
0.0
SUM
15x 160
0
60
PA 2
50
CO2
240
242
244
246
248
250
252
254
260
262
264
266
268
270
272
274
275
276
278
280

FIG. 3

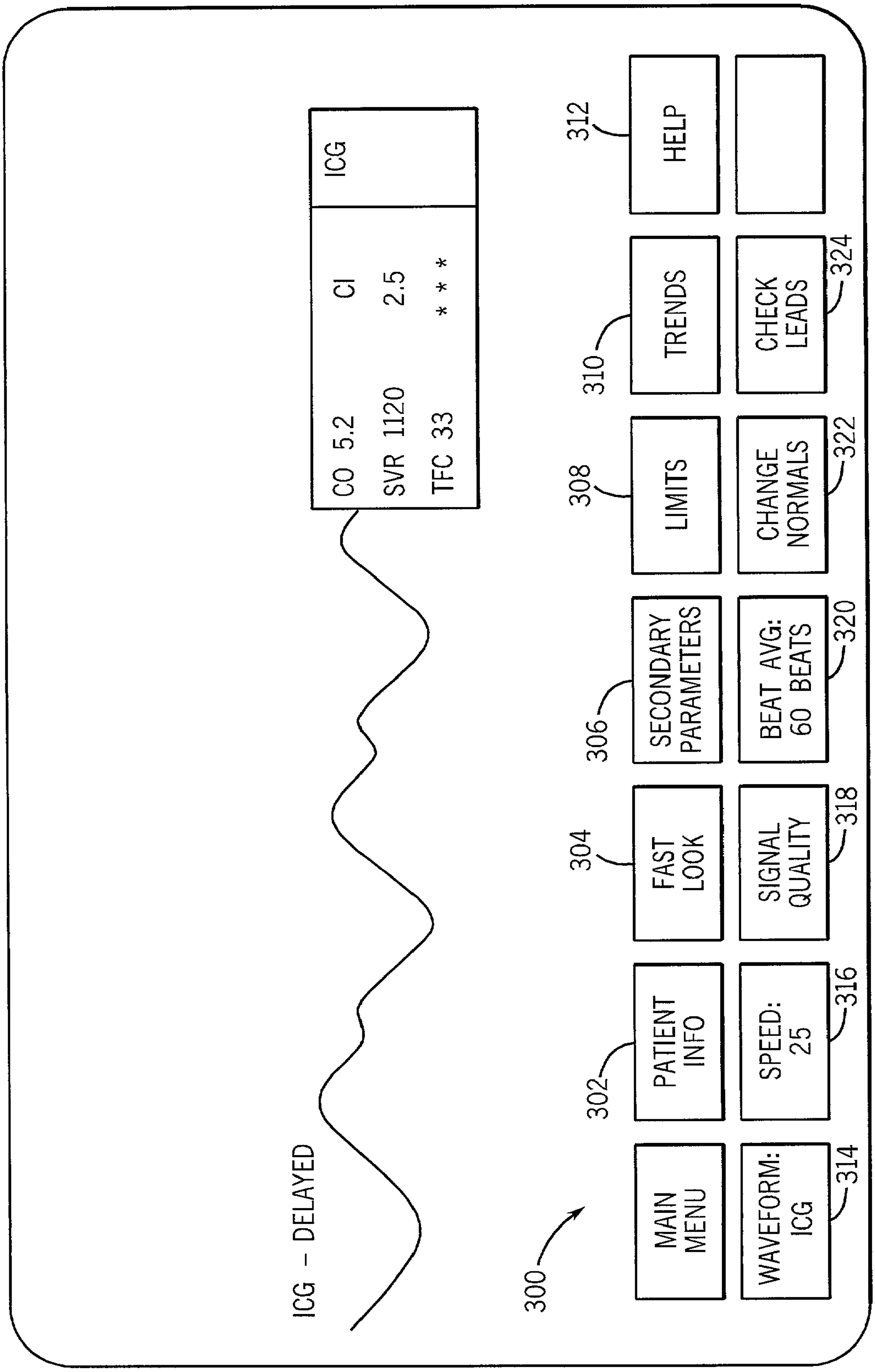
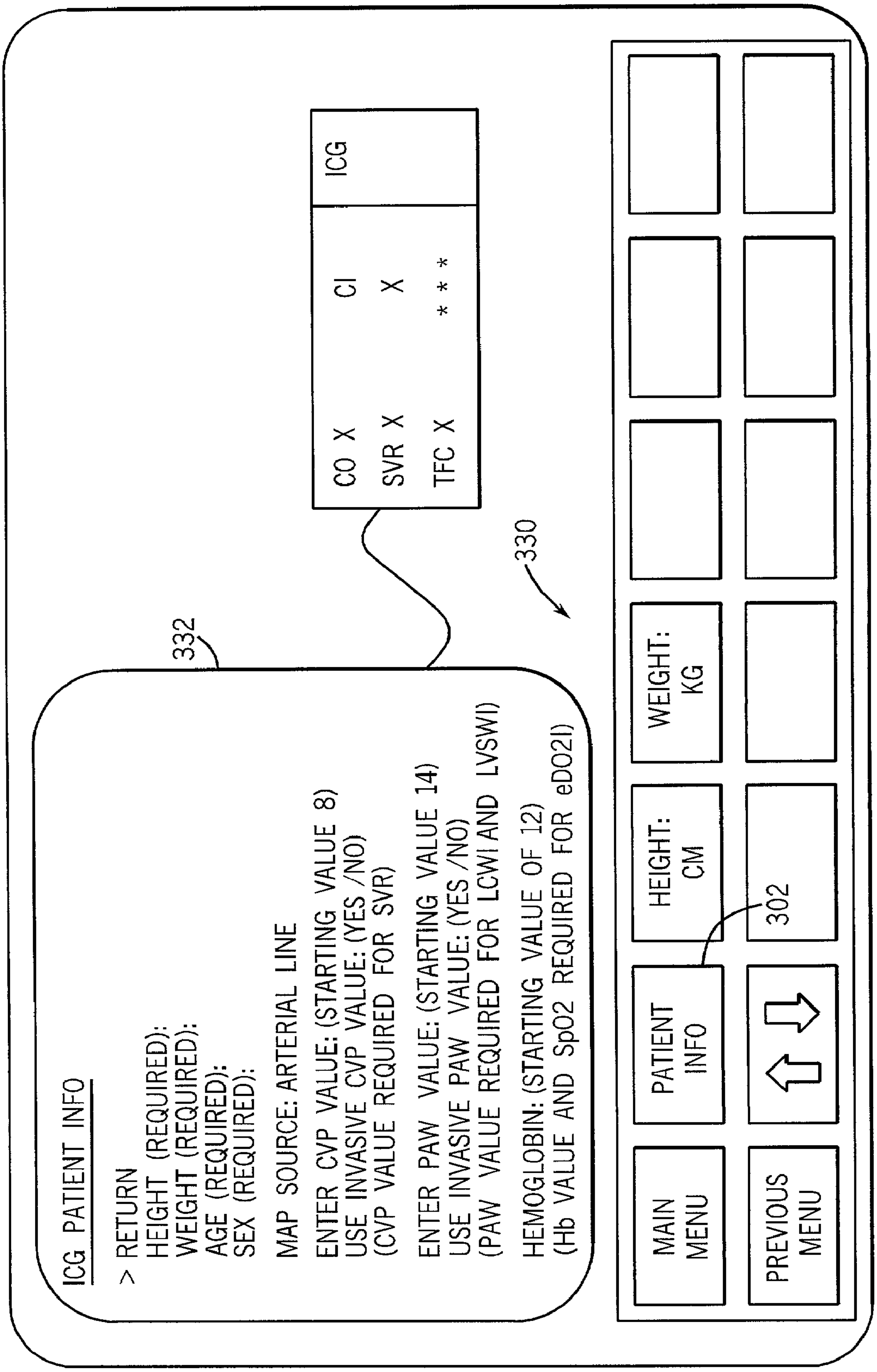

ICG
CO 5.2
CI
SVR 1120
2.5
TFC 33
* * *
ICG - DELAYED
300
MAIN MENU
WAVEFORM: ICG
314
302
PATIENT INFO
SPEED: 25
316
304
FAST LOOK
SIGNAL QUALITY
318
306
SECONDARY PARAMETERS
BEAT AVG: 60 BEATS
320
308
LIMITS
CHANGE NORMALS
322
310
TRENDS
CHECK LEADS
324
312
HELP

FIG. 4

FIG. 5


ICG PATIENT INFO
> RETURN
HEIGHT (REQUIRED):
WEIGHT (REQUIRED):
AGE (REQUIRED):
SEX (REQUIRED):
MAP SOURCE: ARTERIAL LINE
ENTER CVP VALUE: (STARTIING VALUE 8)
USE INVASIVE CVP VALUE: (YES /NO)
(CVP VALUE REQUIRED FOR SVR)
ENTER PAW VALUE: (STARTING VALUE 14)
USE INVASIVE PAW VALUE: (YES /NO)
(PAW VALUE REQUIRED FOR LCWI AND LVSWI)
HEMOGLOBIN: (STARTING VALUE OF 12)
(Hb VALUE AND SpO2 REQUIRED FOR eDO2I)
332
ICG
CO X
SVR X
TFC X
CI
X
* * *
330
MAIN MENU
PATIENT INFO
HEIGHT: CM
WEIGHT: KG
302
PREVIOUS MENU

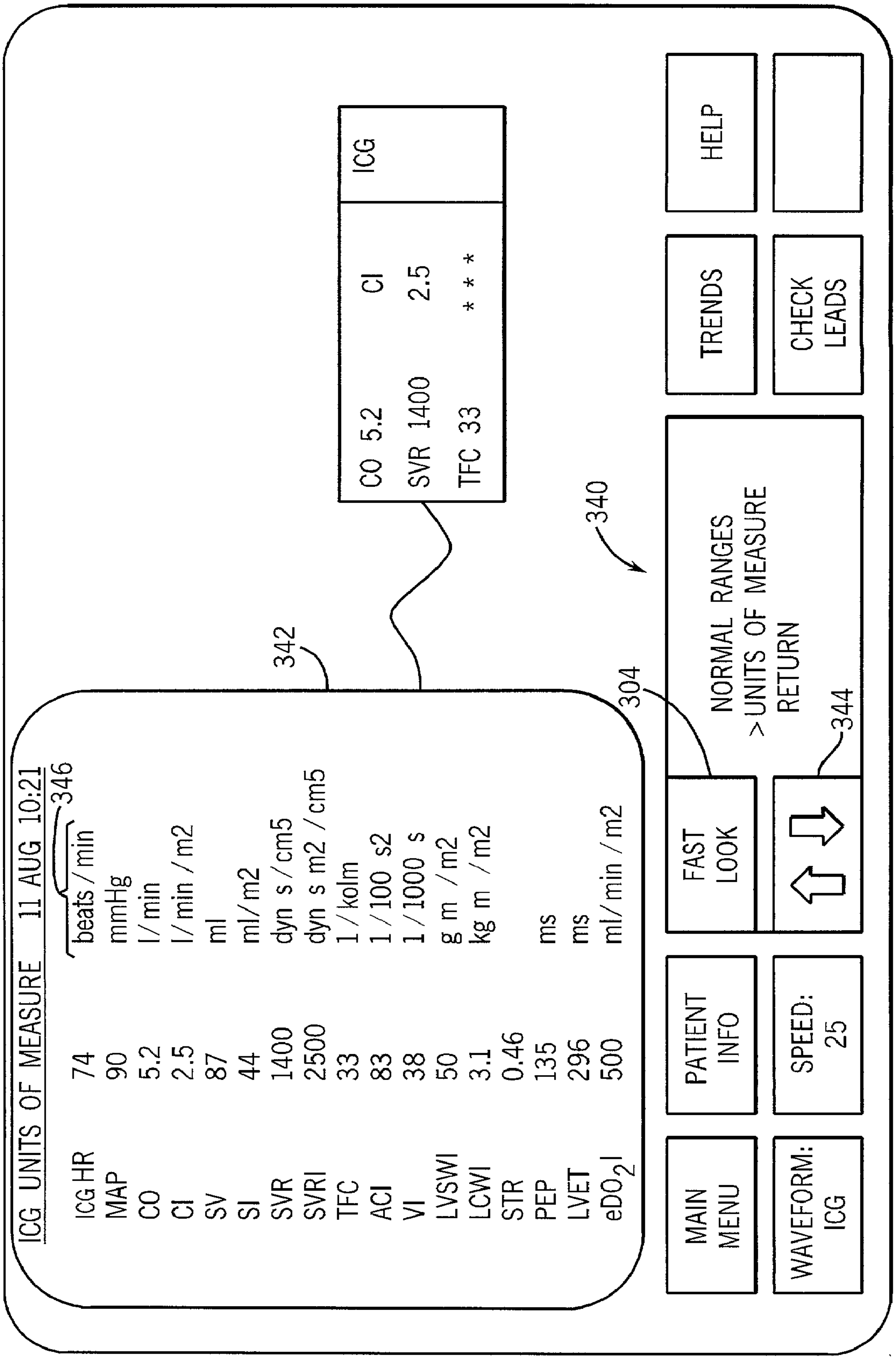
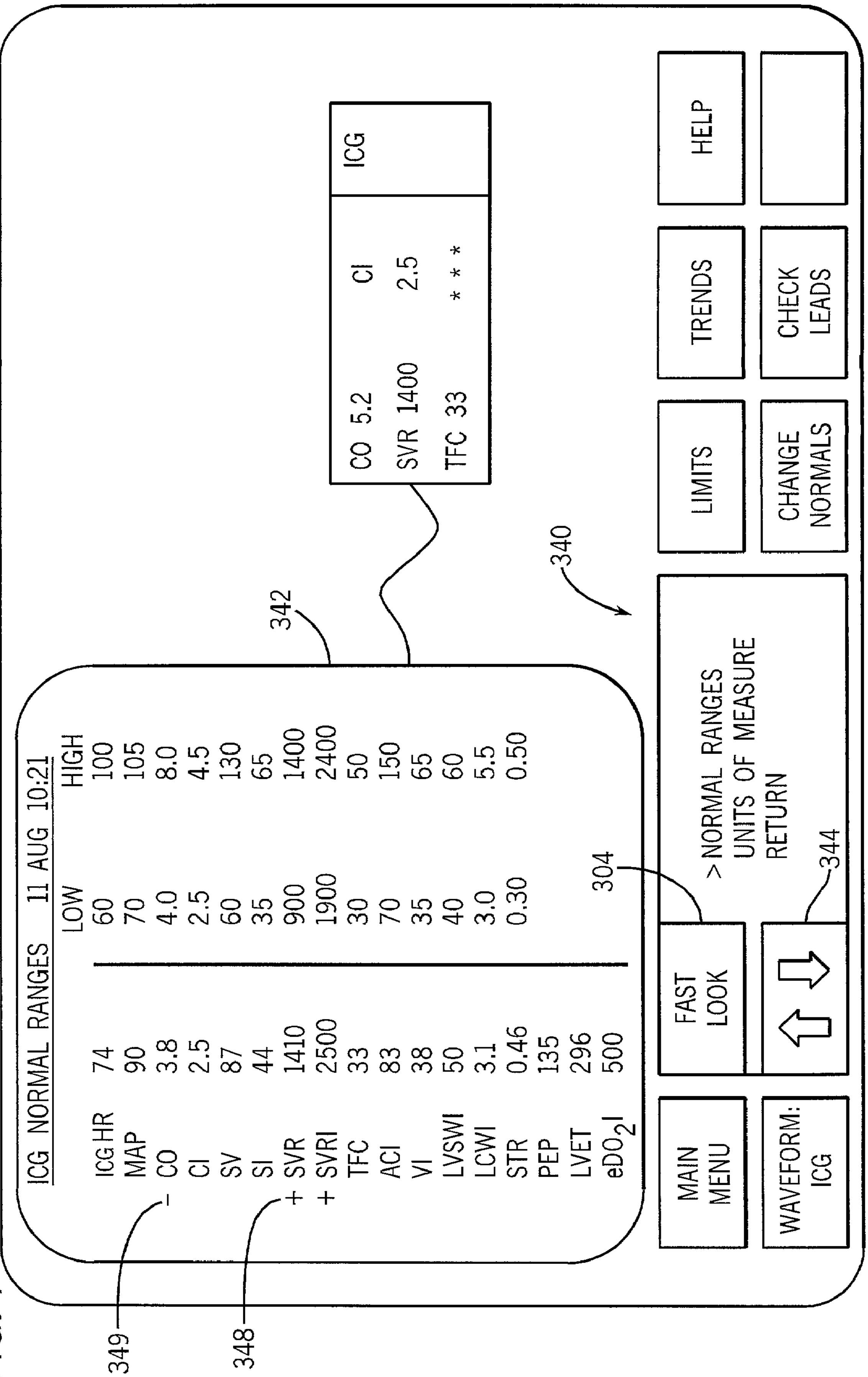

ICG UNITS OF MEASURE 11 AUG 10:21
346
ICG HR 74 beats / min
MAP 90 mmHg
CO 5.2 l / min
CI 2.5 l / min / m2
SV 87 ml
SI 44 ml / m2
SVR 1400 dyn s / cm5
SVRI 2500 dyn s m2 / cm5
TFC 33 1 / kolm
ACI 83 1 / 100 s2
VI 38 1 / 1000 s
LVSWI 50 g m / m2
LCWI 3.1 kg m / m2
STR 0.46
PEP 135 ms
LVET 296 ms
eDO2I 500 ml / min / m2
342
CO 5.2 CI
SVR 1400 2.5
TFC 33 * * *
ICG
340
304
NORMAL RANGES
>UNITS OF MEASURE
RETURN
344
MAIN MENU
PATIENT INFO
FAST LOOK
TRENDS
HELP
WAVEFORM: ICG
SPEED: 25
CHECK LEADS
FIG. 6

FIG. 7


ICG NORMAL RANGES 11 AUG 10:21
LOW HIGH
ICG HR 74 60 100
MAP 90 70 105
– CO 3.8 4.0 8.0
CI 2.5 2.5 4.5
SV 87 60 130
SI 44 35 65
+ SVR 1410 900 1400
+ SVRI 2500 1900 2400
TFC 33 30 50
ACI 83 70 150
VI 38 35 65
LVSWI 50 40 60
LCWI 3.1 3.0 5.5
STR 0.46 0.30 0.50
PEP 135
LVET 296
eDO2I 500
CO 5.2 CI
SVR 1400 2.5
TFC 33 * * *
ICG
HELP
TRENDS
CHECK LEADS
LIMITS
CHANGE NORMALS
>NORMAL RANGES
UNITS OF MEASURE
RETURN
FAST LOOK
MAIN MENU
WAVEFORM: ICG
349
348
342
340
304
344

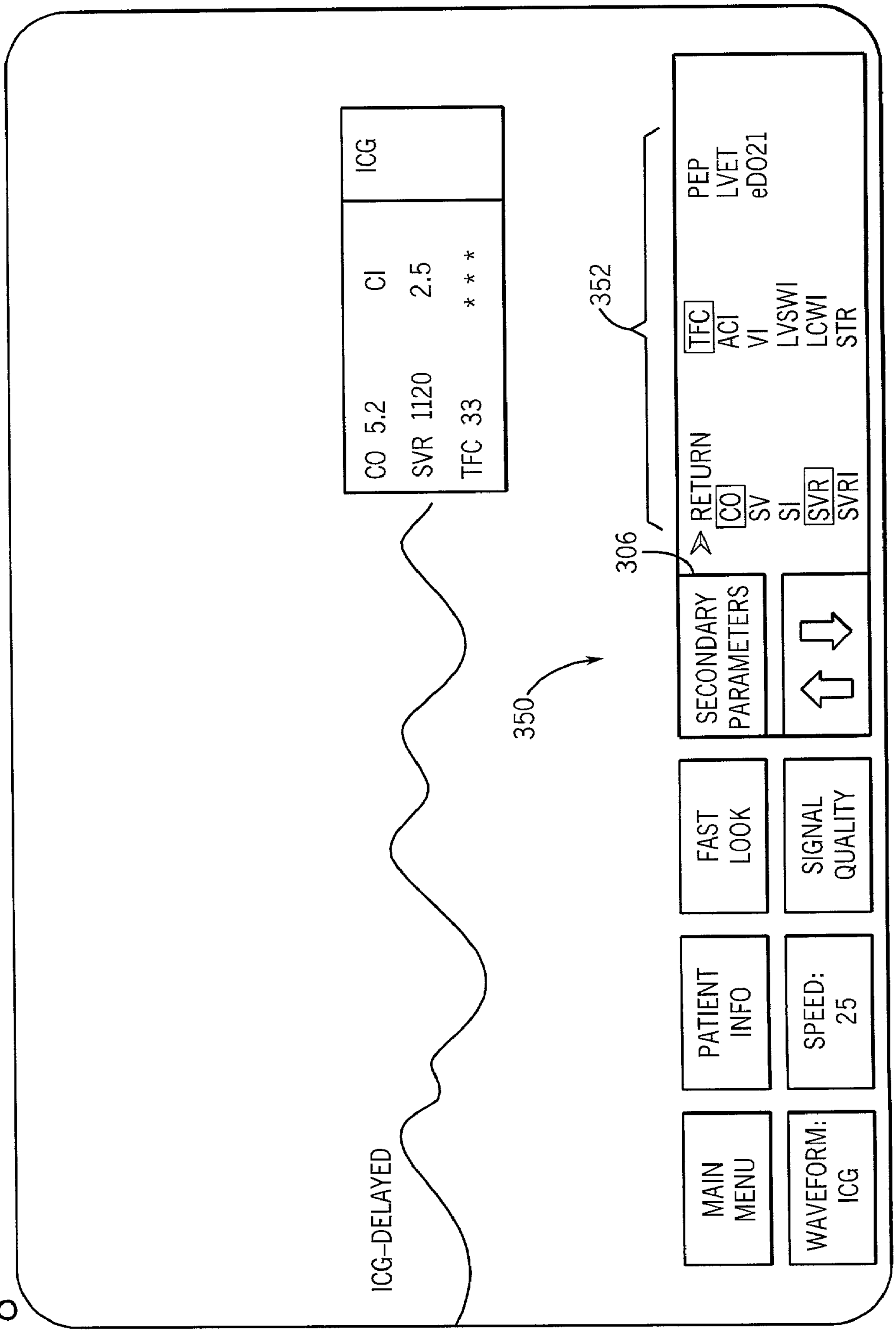
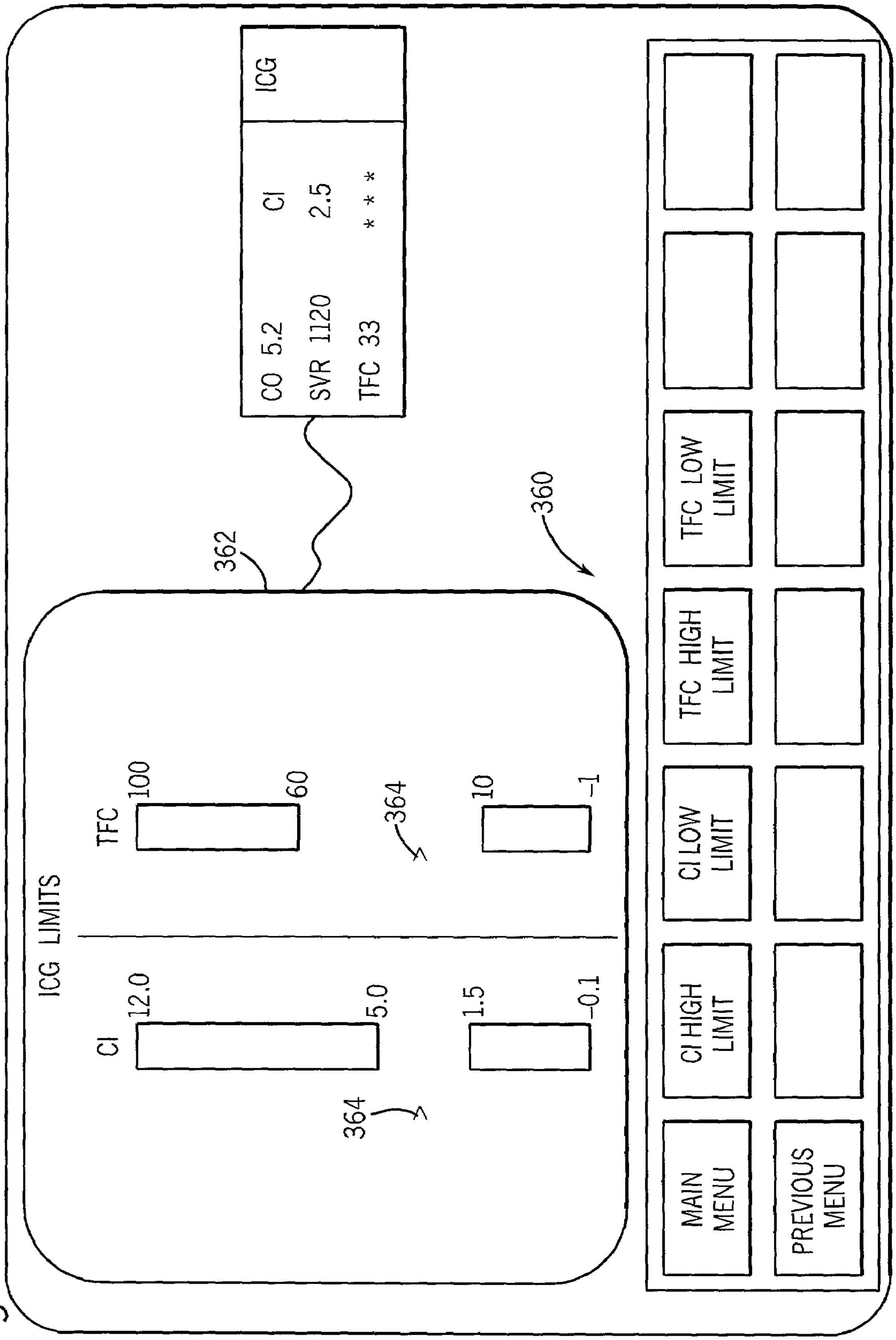

ICG–DELAYED
CO 5.2
SVR 1120
TFC 33
CI
2.5
* * *
ICG
352
PEP
LVET
eDO21
TFC
ACI
VI
LVSWI
LCWI
STR
RETURN
CO
SV
SI
SVR
SVRI
306
350
SECONDARY PARAMETERS
FAST LOOK
SIGNAL QUALITY
PATIENT INFO
SPEED: 25
MAIN MENU
WAVEFORM: ICG

FIG. 8

FIG. 9



ICG
CO 5.2
CI
SVR 1120
2.5
TFC 33
* * *
362
360
ICG LIMITS
CI
12.0
5.0
1.5
-0.1
TFC
100
60
10
-1
364
364
MAIN MENU
PREVIOUS MENU
CI HIGH LIMIT
CI LOW LIMIT
TFC HIGH LIMIT
TFC LOW LIMIT

FIG. 10

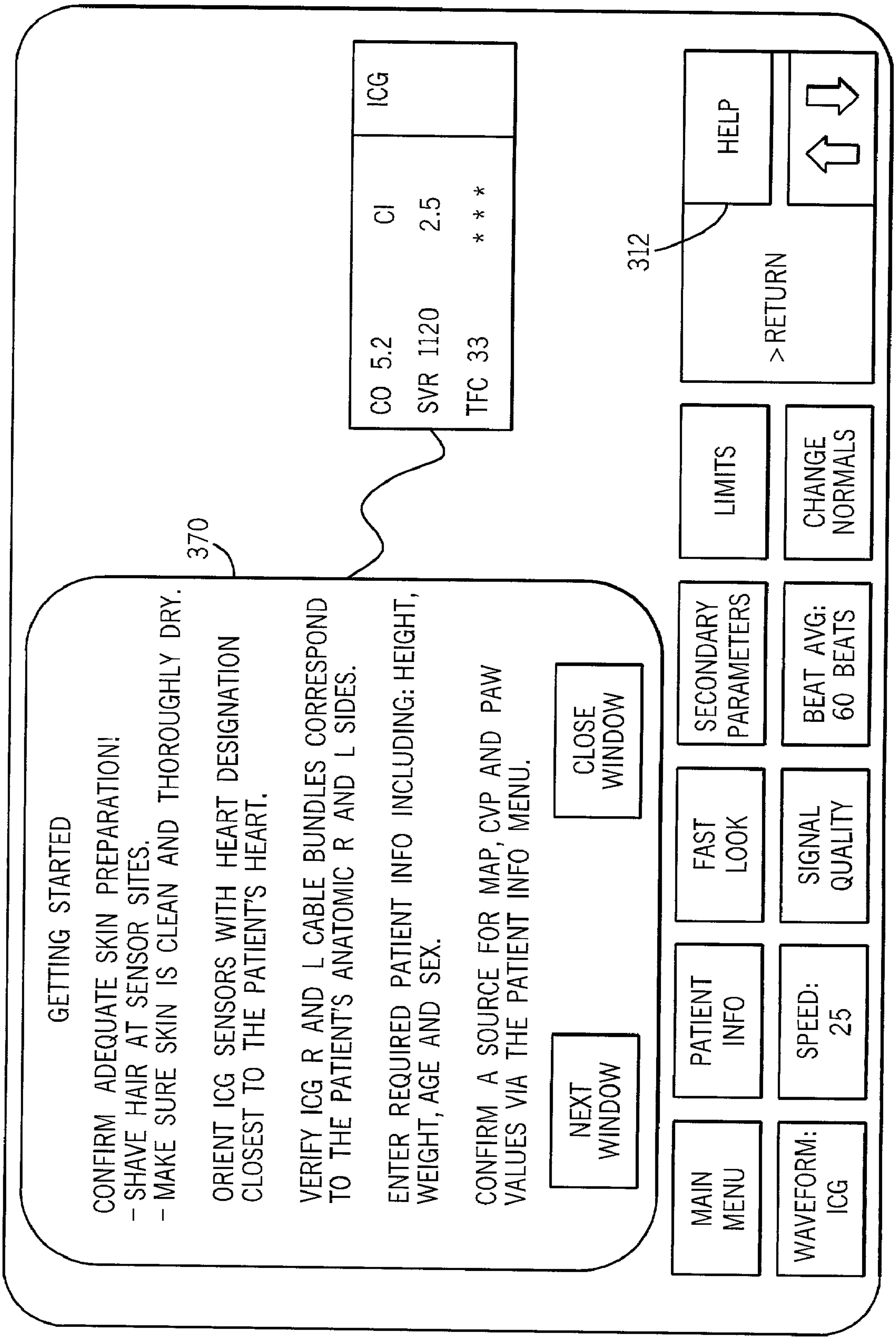
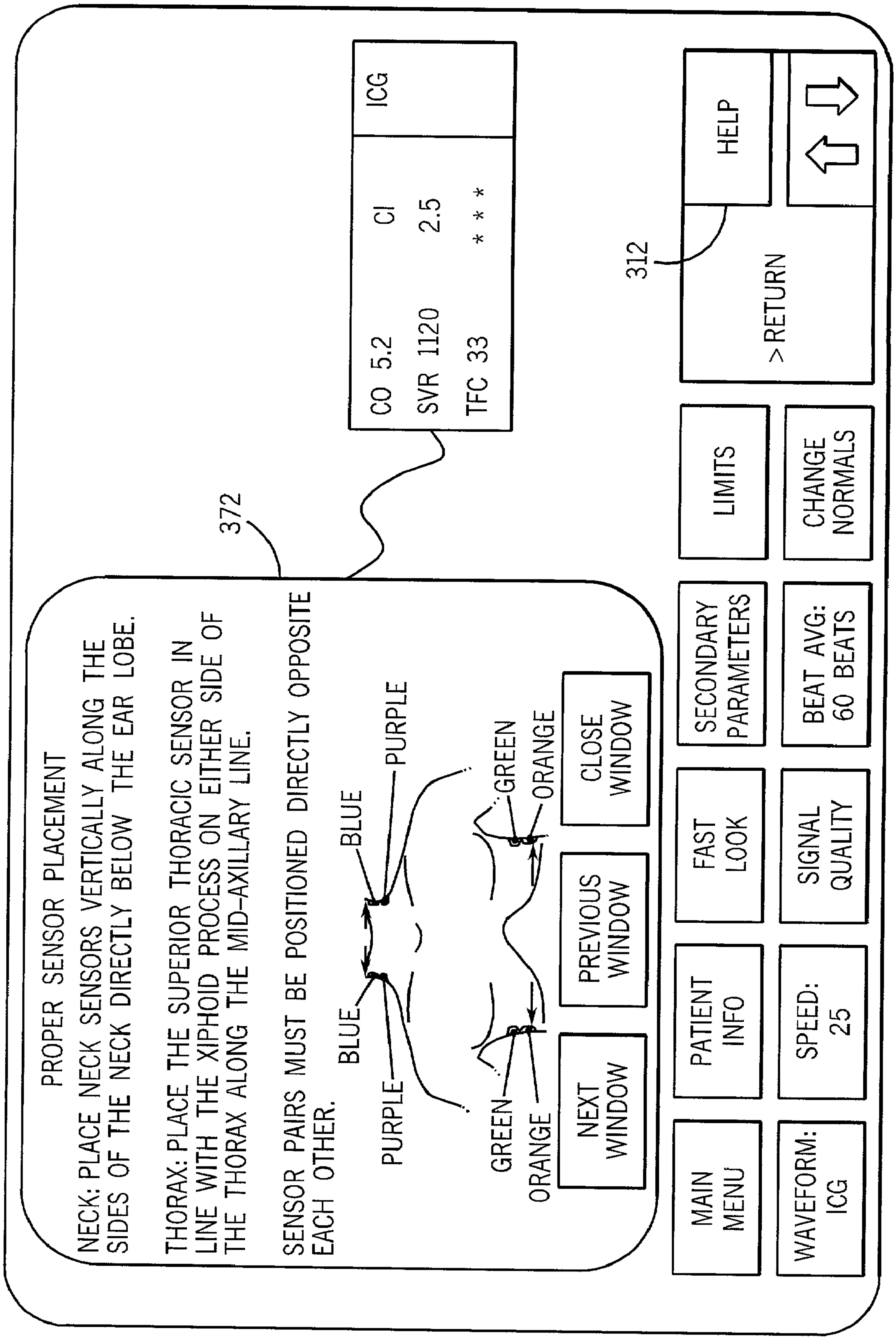

GETTING STARTED
CONFIRM ADEQUATE SKIN PREPARATION!
– SHAVE HAIR AT SENSOR SITES.
– MAKE SURE SKIN IS CLEAN AND THOROUGHLY DRY.
ORIENT ICG SENSORS WITH HEART DESIGNATION CLOSEST TO THE PATIENT'S HEART.
VERIFY ICG R AND L CABLE BUNDLES CORRESPOND TO THE PATIENT'S ANATOMIC R AND L SIDES.
ENTER REQUIRED PATIENT INFO INCLUDING: HEIGHT, WEIGHT, AGE AND SEX.
CONFIRM A SOURCE FOR MAP, CVP AND PAW VALUES VIA THE PATIENT INFO MENU.
NEXT WINDOW
CLOSE WINDOW
370
ICG
CO 5.2
CI
SVR 1120
2.5
TFC 33
* * *
312
HELP
>RETURN
MAIN MENU
PATIENT INFO
FAST LOOK
SECONDARY PARAMETERS
LIMITS
WAVEFORM: ICG
SPEED: 25
SIGNAL QUALITY
BEAT AVG: 60 BEATS
CHANGE NORMALS

FIG. 11


PROPER SENSOR PLACEMENT
NECK: PLACE NECK SENSORS VERTICALLY ALONG THE SIDES OF THE NECK DIRECTLY BELOW THE EAR LOBE.
THORAX: PLACE THE SUPERIOR THORACIC SENSOR IN LINE WITH THE XIPHOID PROCESS ON EITHER SIDE OF THE THORAX ALONG THE MID-AXILLARY LINE.
SENSOR PAIRS MUST BE POSITIONED DIRECTLY OPPOSITE EACH OTHER.
BLUE
PURPLE
BLUE
PURPLE
GREEN
ORANGE
GREEN
ORANGE
NEXT WINDOW
PREVIOUS WINDOW
CLOSE WINDOW
372
CO 5.2
CI
ICG
SVR 1120
2.5
TFC 33
* * *
312
>RETURN
HELP
MAIN MENU
PATIENT INFO
FAST LOOK
SECONDARY PARAMETERS
LIMITS
WAVEFORM: ICG
SPEED: 25
SIGNAL QUALITY
BEAT AVG: 60 BEATS
CHANGE NORMALS

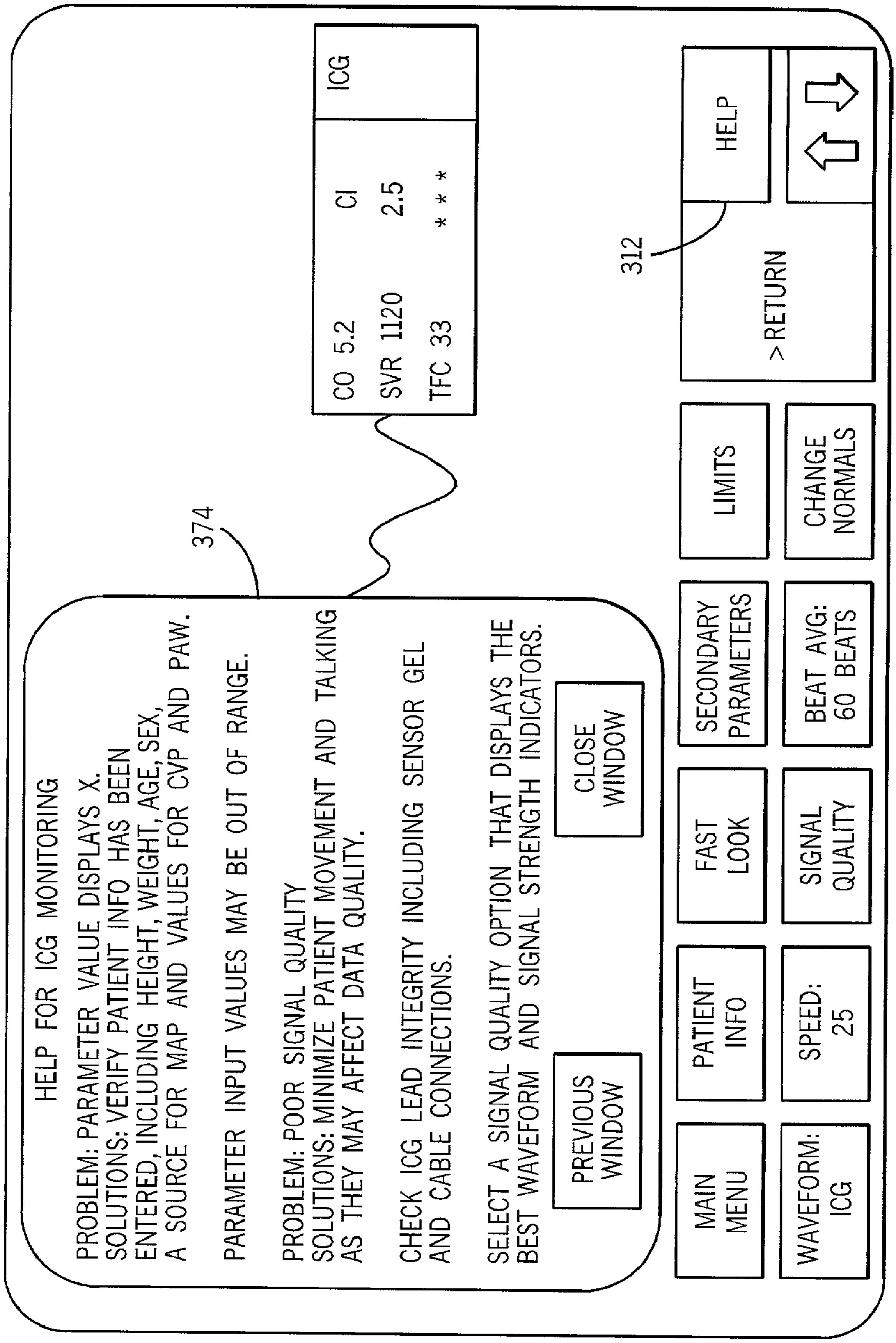

HELP FOR ICG MONITORING
PROBLEM: PARAMETER VALUE DISPLAYS X.
SOLUTIONS: VERIFY PATIENT INFO HAS BEEN ENTERED, INCLUDING HEIGHT, WEIGHT, AGE, SEX, A SOURCE FOR MAP AND VALUES FOR CVP AND PAW.
PARAMETER INPUT VALUES MAY BE OUT OF RANGE.
PROBLEM: POOR SIGNAL QUALITY
SOLUTIONS: MINIMIZE PATIENT MOVEMENT AND TALKING AS THEY MAY AFFECT DATA QUALITY.
CHECK ICG LEAD INTEGRITY INCLUDING SENSOR GEL AND CABLE CONNECTIONS.
SELECT A SIGNAL QUALITY OPTION THAT DISPLAYS THE BEST WAVEFORM AND SIGNAL STRENGTH INDICATORS.
PREVIOUS WINDOW
CLOSE WINDOW
374
CO 5.2
CI
SVR 1120
2.5
TFC 33
* * *
ICG
312
>RETURN
HELP
MAIN MENU
PATIENT INFO
FAST LOOK
SECONDARY PARAMETERS
LIMITS
WAVEFORM: ICG
SPEED: 25
SIGNAL QUALITY
BEAT AVG: 60 BEATS
CHANGE NORMALS

FIG. 12

FIG. 13

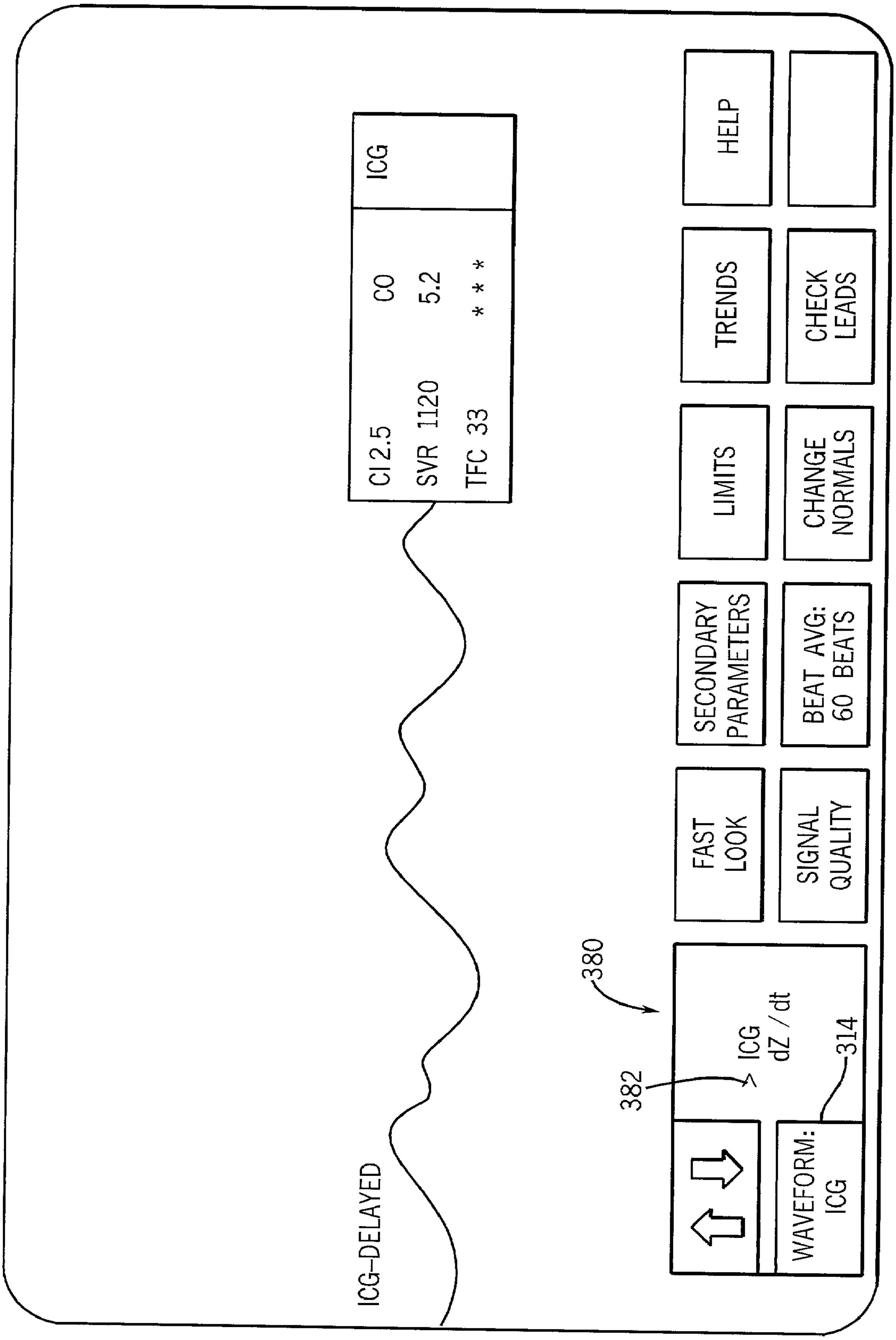
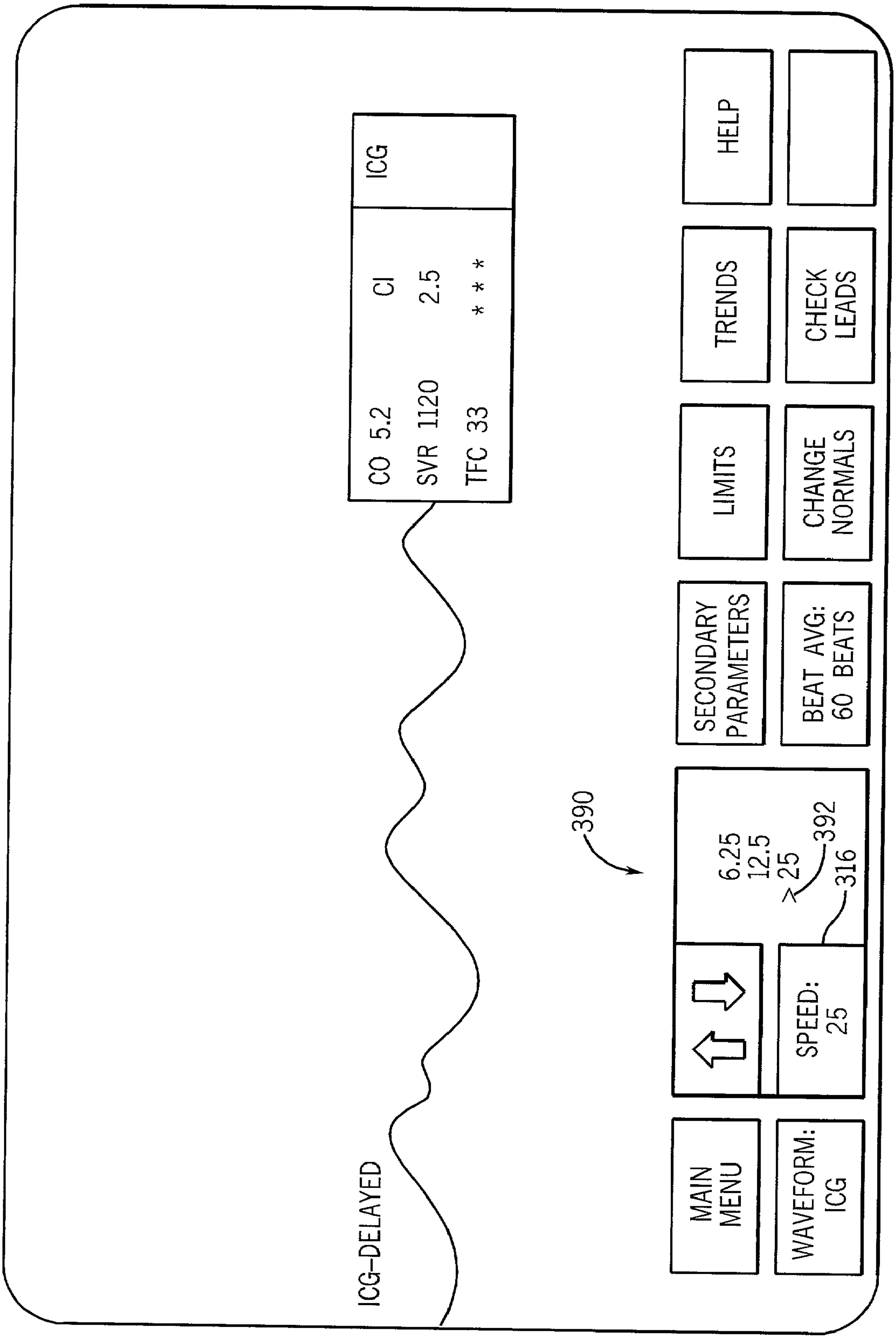

ICG–DELAYED
ICG
CI 2.5
CO
SVR 1120
5.2
TFC 33
* * *
HELP
TRENDS
CHECK LEADS
LIMITS
CHANGE NORMALS
SECONDARY PARAMETERS
BEAT AVG: 60 BEATS
FAST LOOK
SIGNAL QUALITY
380
382
ICG dZ /dt
314
WAVEFORM: ICG

FIG. 14


ICG
CO 5.2
CI
SVR 1120
2.5
TFC 33
* * *
ICG-DELAYED
390
6.25
12.5
> 25
392
316
SPEED: 25
MAIN MENU
WAVEFORM: ICG
SECONDARY PARAMETERS
BEAT AVG: 60 BEATS
LIMITS
CHANGE NORMALS
TRENDS
CHECK LEADS
HELP

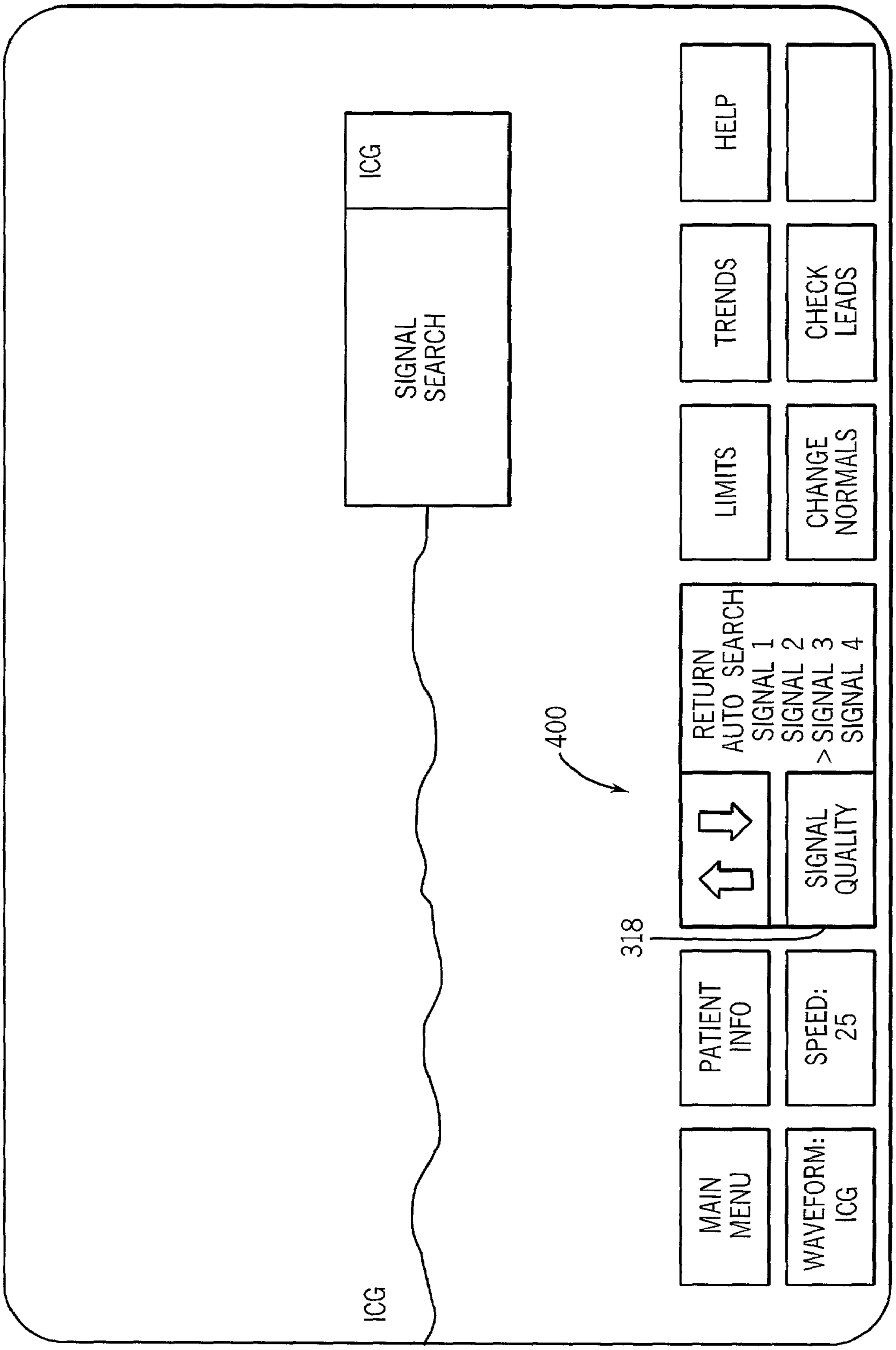
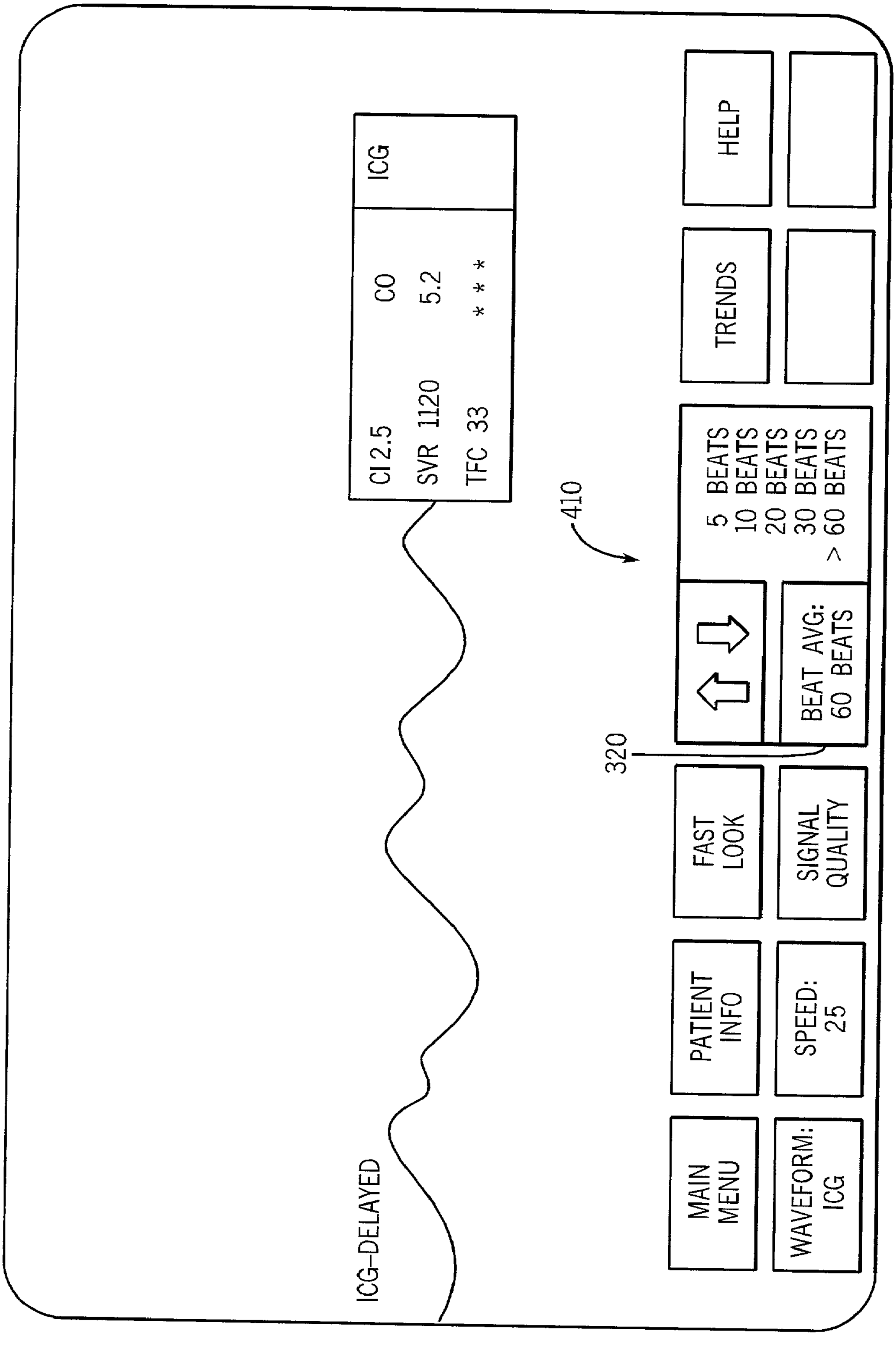

ICG
SIGNAL SEARCH
ICG
HELP
TRENDS
CHECK LEADS
LIMITS
CHANGE NORMALS
RETURN
AUTO SEARCH
SIGNAL 1
SIGNAL 2
> SIGNAL 3
SIGNAL 4
400
SIGNAL QUALITY
318
PATIENT INFO
SPEED: 25
MAIN MENU
WAVEFORM: ICG

FIG. 15

FIG. 16


ICG–DELAYED
CI 2.5
CO
SVR 1120
5.2
TFC 33
* * *
ICG
410
320
5 BEATS
10 BEATS
20 BEATS
30 BEATS
> 60 BEATS
BEAT AVG:
60 BEATS
MAIN MENU
WAVEFORM:
ICG
PATIENT INFO
SPEED:
25
FAST LOOK
SIGNAL QUALITY
TRENDS
HELP

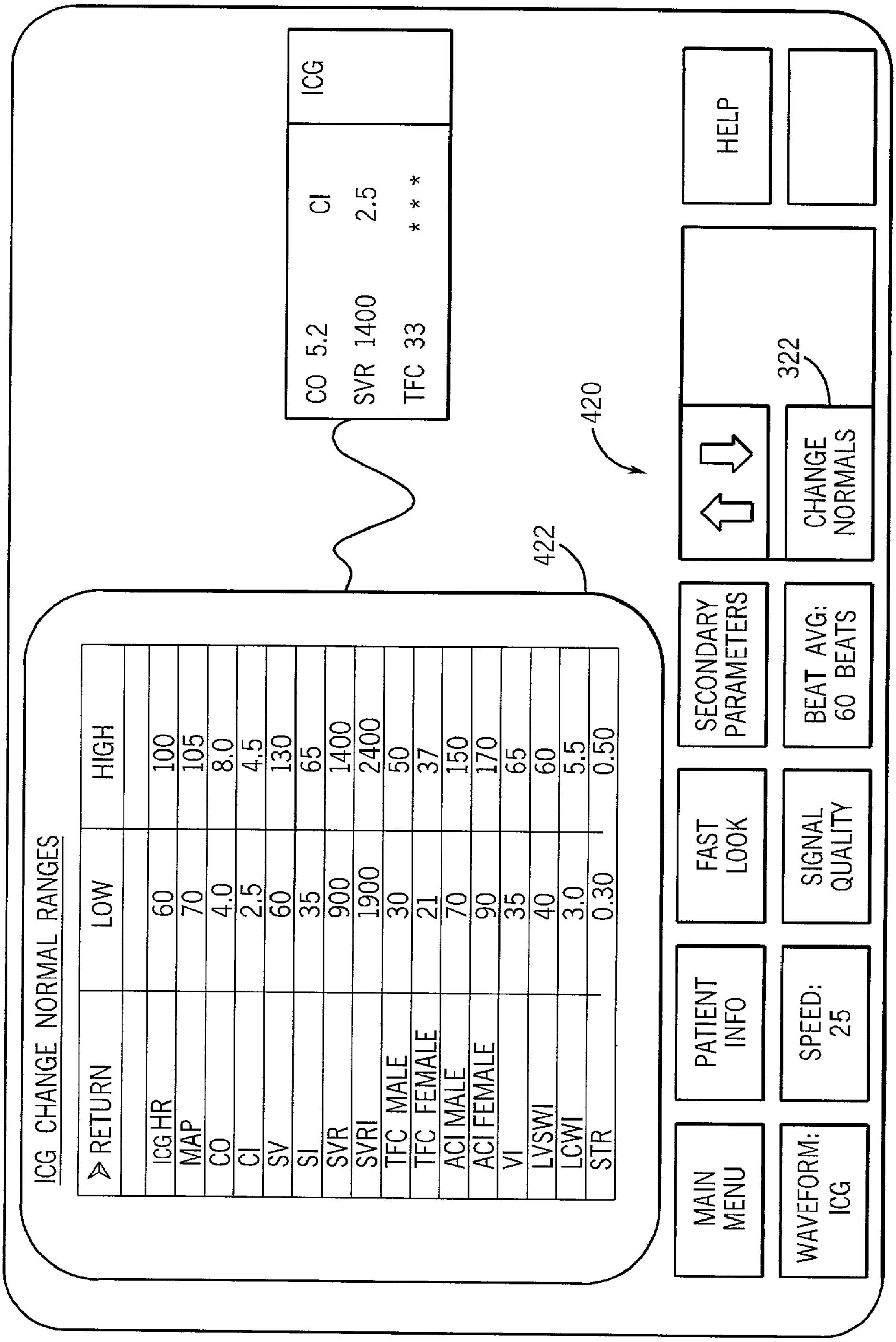

ICG
CO 5.2
CI
SVR 1400
2.5
TFC 33
* * *
HELP
420
422
322
CHANGE NORMALS
ICG CHANGE NORMAL RANGES
RETURN
LOW
HIGH
ICG HR 60 100
MAP 70 105
CO 4.0 8.0
CI 2.5 4.5
SV 60 130
SI 35 65
SVR 900 1400
SVRI 1900 2400
TFC MALE 30 50
TFC FEMALE 21 37
ACI MALE 70 150
ACI FEMALE 90 170
VI 35 65
LVSWI 40 60
LCWI 3.0 5.5
STR 0.30 0.50
SECONDARY PARAMETERS
BEAT AVG: 60 BEATS
FAST LOOK
SIGNAL QUALITY
PATIENT INFO
SPEED: 25
MAIN MENU
WAVEFORM: ICG

FIG. 17

FIG. 18

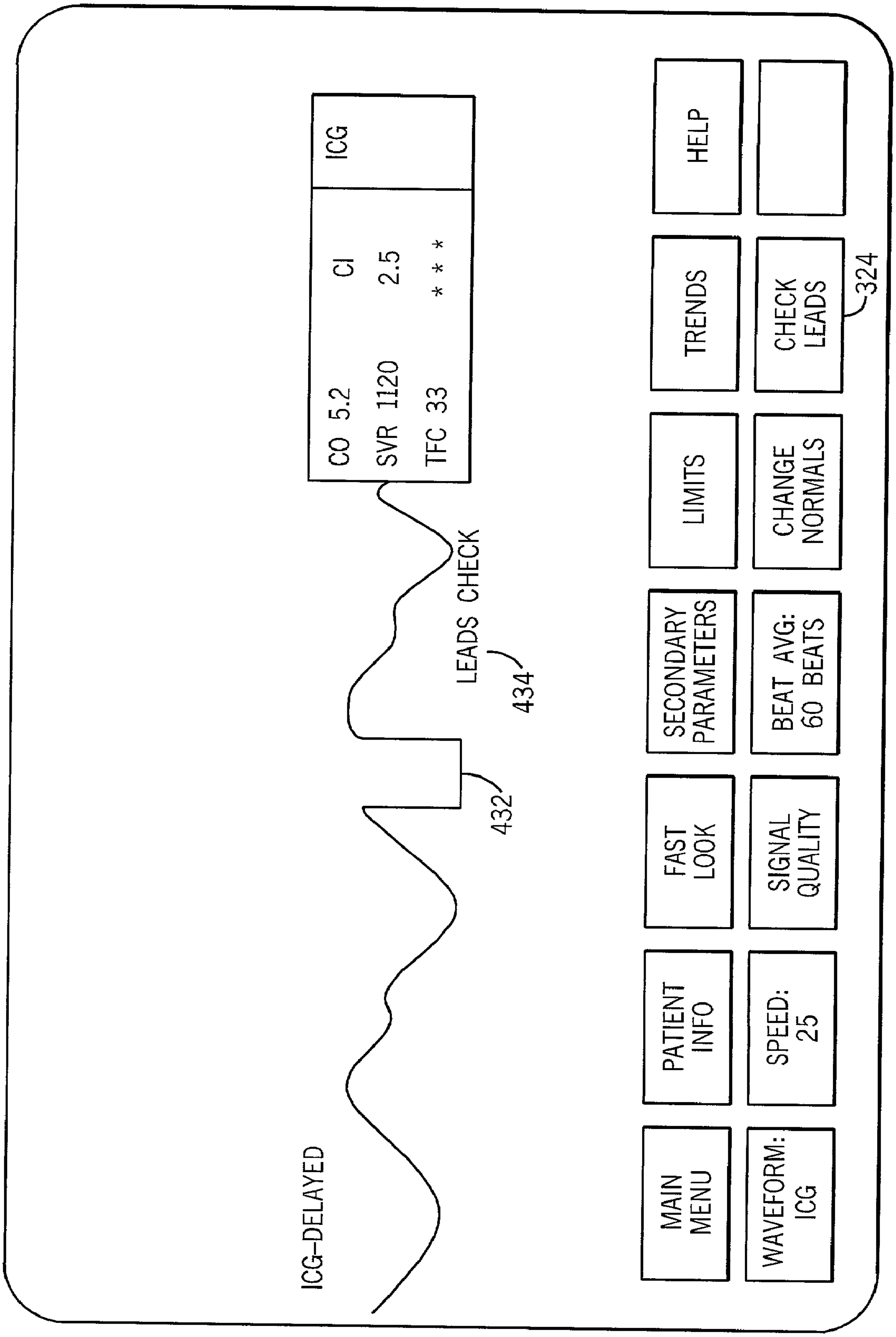
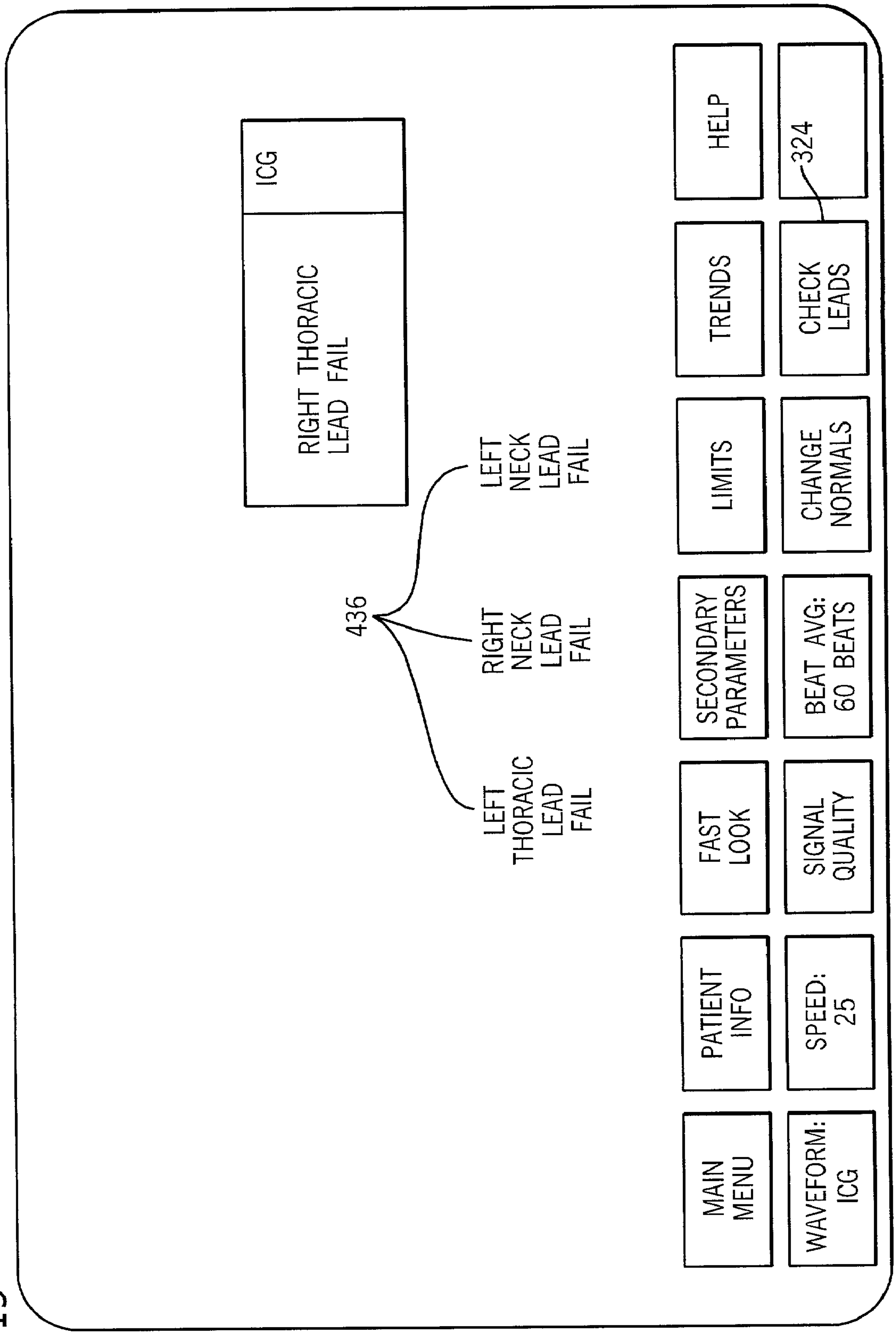

ICG
CO 5.2
CI
SVR 1120
2.5
TFC 33
* * *
ICG–DELAYED
LEADS CHECK
434
432
MAIN MENU
PATIENT INFO
FAST LOOK
SECONDARY PARAMETERS
LIMITS
TRENDS
HELP
WAVEFORM: ICG
SPEED: 25
SIGNAL QUALITY
BEAT AVG: 60 BEATS
CHANGE NORMALS
CHECK LEADS
324

FIG. 19


ICG
RIGHT THORACIC LEAD FAIL
LEFT NECK LEAD FAIL
RIGHT NECK LEAD FAIL
LEFT THORACIC LEAD FAIL
436
MAIN MENU
PATIENT INFO
FAST LOOK
SECONDARY PARAMETERS
LIMITS
TRENDS
HELP
WAVEFORM: ICG
SPEED: 25
SIGNAL QUALITY
BEAT AVG: 60 BEATS
CHANGE NORMALS
CHECK LEADS
324

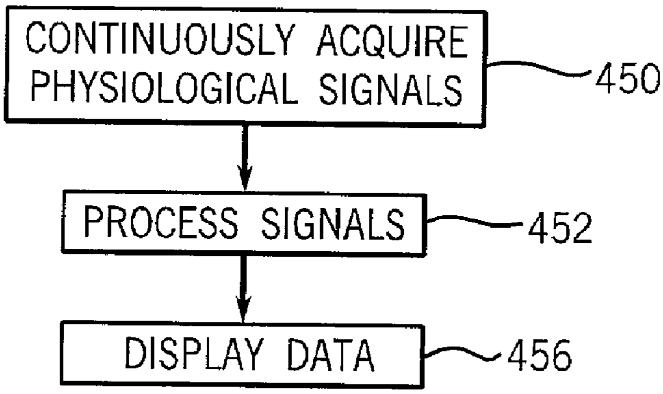


FIG. 20A

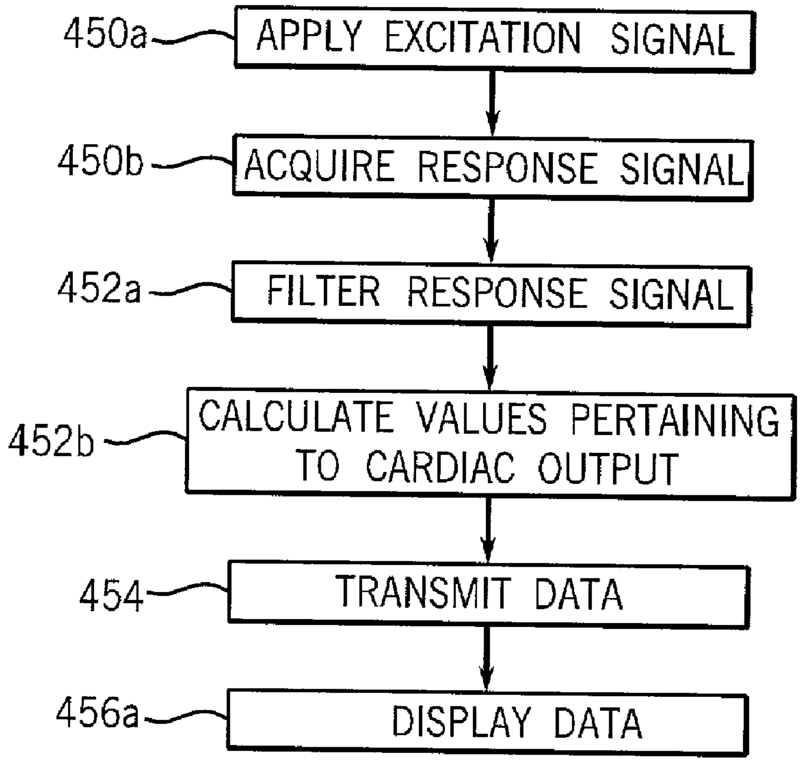


FIG. 20B

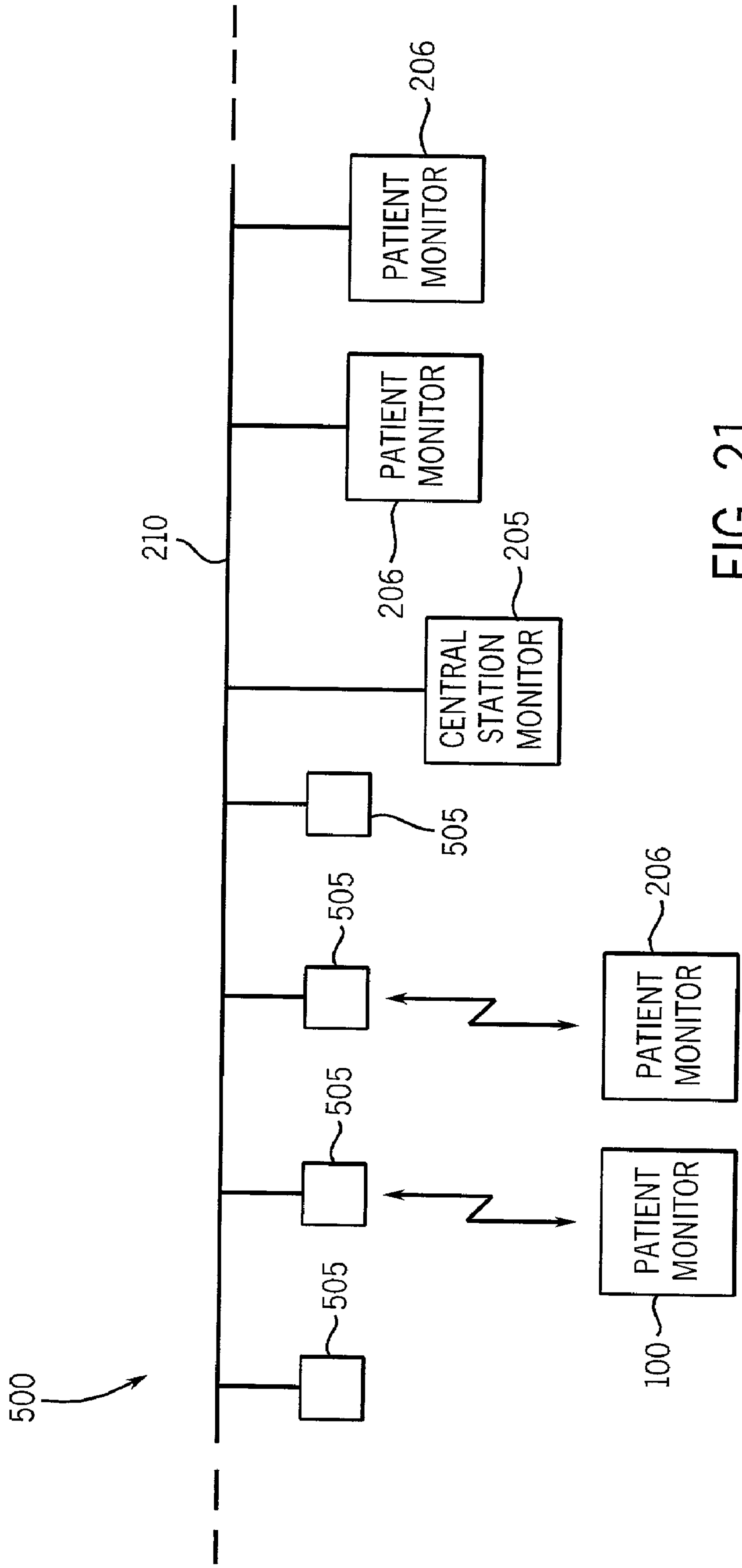

500
505
505
505
505
210
PATIENT MONITOR
100
PATIENT MONITOR
206
CENTRAL STATION MONITOR
205
PATIENT MONITOR
206
PATIENT MONITOR
206

FIG. 21

PATIENT MONITOR AND METHOD WITH NON-INVASIVE CARDIAC OUTPUT MONITORING

FIELD OF THE INVENTION

[0001] The invention relates to a patient monitoring systems and methods and, particularly, to patient monitoring systems and methods for non-invasively monitoring cardiac output of a patient.

BACKGROUND OF THE INVENTION

[0002] There is an ongoing need for medical equipment and procedures that allow for quick and accurate diagnosis of patient conditions. For example, in the context of myocardial infarctions, patients frequently arrive at emergency rooms of hospitals complaining of chest pain. The chest pain may be a symptom indicating the patient is experiencing a myocardial infarction or, alternatively, the chest pain may be a symptom indicating the patient is experiencing a lesser medical condition such as heartburn or indigestion. Statistics show that quickly identifying whether a patient is having a myocardial infarction and treating such condition may minimize the amount of damage to the heart. Therefore, there is an ongoing need for systems that can be used to quickly identify whether a patient has had a myocardial infarction.

[0003] Additionally, in the context of congestive heart failure, patients benefit from the use of intermittent inotrope infusions, such as milrinone. These infusions, while usually beneficial, are also costly and carry attendant risks such as dysrhythmias and infection, from both indwelling infusion catheters and pulmonary artery catheters used to document the necessity of inotropic support. Therefore, there is an ongoing need for systems that can be used to conduct a pre-assessment of patients scheduled for intermittent inotrope infusion to ascertain whether or not such infusions are needed.

[0004] Further, in the context of circulatory deficiencies, acutely ill emergency room patients often have circulatory deficiencies that ultimately lead to shock, organ failure, and death. Early diagnosis is often difficult and subjective, and therefore these deficiencies are currently diagnosed in late stages when therapy is ineffective. Diagnosing these circulatory deficiencies in their early stages allows the patient to be treated before the course of these deficiencies becomes irreversible. Therefore, there is an ongoing need for systems that can be used to assist early detection of such circulatory deficiencies.

[0005] It has been found that cardiac output monitoring is useful for diagnosing medical conditions such as those described above. Impedance cardiography techniques for non-invasive monitoring cardiac output are known in the art. However, existing devices that are capable of monitoring cardiac output are cumbersome to utilize. Therefore, improved patient monitoring systems and methods that are capable of monitoring cardiac output would be highly beneficial.

BRIEF SUMMARY OF THE INVENTION

[0006] According to one preferred aspect, an embodiment of a patient monitoring system comprises a non-invasive cardiac output sensor, a multi-lead electrocardiogram (ECG) sensor, and a patient monitor console. The non-invasive cardiac output sensor being capable of acquiring a signal from a patient indicative of blood flow through a heart of the patient. The multi-lead ECG sensor comprises a plurality of ECG electrodes capable of acquiring a plurality of ECG signals from the patient. The patient monitor console includes an analysis module and a display. The analysis module is coupled to the non-invasive cardiac output sensor and to the multi-lead ECG sensor, and processes the signal from the patient indicative of blood flow to produce a value pertaining to cardiac output. The display is coupled to the analysis module, and displays the value pertaining to cardiac output and an ECG waveform generated based on the ECG signals.

[0007] According to another preferred aspect, an embodiment of a patient monitoring system comprises a non-invasive cardiac output sensor, a communication interface, and a patient monitor console. The non-invasive cardiac output sensor is capable of acquiring a signal from a patient indicative of blood flow through a heart of the patient. The communication interface is capable of establishing a communication link between the patient monitoring system and a local area network of a medical facility in which the patient monitoring system is located. The patient monitor console includes an analysis module and a display. The analysis module is coupled to the non-invasive cardiac output sensor, and processes the signal from the patient indicative of blood flow to produce a value pertaining to cardiac output. The display is coupled to the analysis module, and displays the value pertaining to cardiac output. The communication interface is capable of transmitting the value pertaining to cardiac output over the local area network.

[0008] Other features and advantages of the invention will become apparent to those skilled in the art upon review of the following detailed description, claims, and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] **FIG. 1** is a schematic diagram of a patient monitoring system according to a preferred embodiment of the invention;

[0010] **FIG. 2** is a diagram showing electrode placement for a preferred non-invasive cardiac output sensor used in the patient monitoring system of **FIG. 1**;

[0011] **FIG. 3** is a top level menu displayed by a display of the patient monitoring system of **FIG. 1**;

[0012] **FIG. 4** is a top level cardiac output menu displayed by the display of the patient monitoring system of **FIG. 1**;

[0013] **FIG. 5** is a patient information menu displayed by the display of the patient monitoring system of **FIG. 1**;

[0014] **FIG. 6** is a fast look menu displayed by the display of the patient monitoring system of **FIG. 1**, in which cardiac output data is displayed in a units of measure format;

[0015] **FIG. 7** is a fast look menu displayed by the display of the patient monitoring system of **FIG. 1**, in which cardiac output data is displayed in a normal ranges format;

[0016] **FIG. 8** is a secondary parameters menu displayed by the display of the patient monitoring system of **FIG. 1**;

[0017] **FIG. 9** is a limits menu displayed by the display of the patient monitoring system of **FIG. 1**;

[0018] FIGS. **10-12** are help menus with different help information windows displayed by the display of the patient monitoring system of **FIG. 1**;

[0019] **FIG. 13** is a waveform menu displayed by the display of the patient monitoring system of **FIG. 1**;

[0020] **FIG. 14** is a speed menu displayed by the display of the patient monitoring system of **FIG. 1**;

[0021] **FIG. 15** is a signal quality menu displayed by the display of the patient monitoring system of **FIG. 1**;

[0022] **FIG. 16** is a beat average menu displayed by the display of the patient monitoring system of **FIG. 1**;

[0023] **FIG. 17** is a change normals menu displayed by the display of the patient monitoring system of **FIG. 1**;

[0024] **FIG. 18** is a check leads menu displayed by the display of the patient monitoring system of **FIG. 1**;

[0025] **FIG. 19** is a check leads menu corresponding to **FIG. 18** in which a failed lead condition is detected;

[0026] FIGS. **20A-20B** are flowcharts showing the preferred operation of the patient monitoring system of **FIG. 1**; and

[0027] **FIG. 21** is a block diagram showing the patient monitoring system of **FIG. 1** networked with other monitoring devices.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0028] Referring now to **FIG. 1, a** patient monitoring system **100** according to a preferred embodiment of the invention is schematically shown. In general terms, the system **100** includes one or more input devices **105**, a patient monitor console **110**, a data entry device **115** connected to the console **110**, and one or more output devices **120** connected to the console **110**. In the preferred embodiment, the patient monitor console is portable and is implemented using a GE Medical Systems Information Technologies, Inc. DASH® 3000 Pro™ brand portable monitor, modified to incorporate additional features described below.

[0029] The input devices **105** include a multi-lead ECG sensor comprising a plurality of electrodes $E_1, E_2 \ldots E_n$ that are connectable to a patient. The electrodes are capable of acquiring ECG signals generated by the patient. The number of electrodes $E_1, E_2 \ldots E_n$ may vary. For example, three, five, ten or twelve ECG leads may be used. In the preferred embodiment, the number of electrodes is equal to ten and the leads are connected to the patient in a standard twelve-lead configuration for 12SL processing.

[0030] The electrodes $E_1, E_2 \ldots E_n$ are connected to the console **110** by an interface cable **125**. The interface cable **125** provides direct communication between the electrodes $E_1, E_2 \ldots E_n$ and an input port **130**. The input port **130** comprises a connector that mates with a corresponding connector on the cable **125**. The interface cable **125** allows for transmission of the acquired ECG signals from the patient to the console **110**. The interface cable **125** is preferably a passive cable but, alternatively, the cable **125** may contain active circuitry for amplifying and combining the ECG signals into ECG leads (discussed further below). In other embodiments, the electrodes $E_1, E_2 \ldots E_n$ may be in communication with the console **110** through a telemetry-based transmitter transmitting a radio frequency ("RF") signal to one or more antennas connected to console **110** through a conventional RF receiver.

[0031] The input devices **105** further include one or more sensors which are connectable to the patient and acquire additional physiological signals from the patient. Example sensors may include an invasive and/or non-invasive blood pressure sensor **141**, a pulse-oximetry sensor **142**, a temperature sensor **143**, a carbon dioxide sensor **144**, a respiration sensor **145**, and a cardiac output sensor **146**. Similar to electrodes $E_1, E_2 \ldots E_n$ and for the embodiment shown, the sensors **140** may be connected to the console **110** at respective input ports **150** by interface cables **152** or via telemetry transmitters as described above.

[0032] Additional sensors may also be connected to the console **110**. For example, many commercially available sensors are capable of transmitting data via an RS-232 link. In **FIG. 1**, respective RS-232 links may be used to transmit data from a plurality of additional sensors **155** to an interface **157**, with the interface **157** retransmitting the data to the console **110** by a serial or network link. The sensors **155** may be the same or different types of sensors as the sensors **141-145**.

[0033] The input signals from the sensors **141-145** are processed at the console **110** by amplifying-and-filtering circuitry **165**, analog-to-digital (A/D) conversion circuitry **170**, and an analysis module **175**. Depending on the manner in which the sensors **155** provide data to the console **110**, the signals from the sensors **155** may be processed by some or all of this circuitry as well. The amplifying-and-filtering circuitry **165**, the A/D conversion circuitry **170**, and the analysis module **175** may be discrete circuitry, may be incorporated as an integrated circuit (e.g., an application specific integrated circuit), or may be a combination of both.

[0034] The amplifying-and-filtering circuitry **165** receives the physiological signals from the input ports **130** and **150**, and amplifies and filters (i.e., conditions) the physiological signals. For example, the amplifying-and-filtering circuitry **165** includes an instrumentation amplifier **180**. The instrumentation amplifier **180** receives the ECG signals, amplifies the signals, and filters the signals to create a multi-lead ECG. The number of leads of the multi-lead ECG may vary without changing the scope of the invention.

[0035] The A/D conversion circuitry **170** is electrically connected to the instrumentation amplifier **180**. The A/D conversion circuitry **170** receives the amplified and filtered physiological signals and converts the signals into digital physiological signals (e.g., a digital multi-lead ECG). The digital physiological signals are then provided to the analysis module **175** which is electrically connected to the A/D conversion circuitry **170**.

[0036] The analysis module **175** reads the digital physiological signals, analyzes the signals from the A/D conversion circuitry **170**, and displays the signals and the resulting analysis to an operator. The analysis module **175** includes a controller or microprocessor **182** and internal memory **185**. The internal memory **185** includes program storage memory **190** for storing a software program and data storage memory **195** for storing data. The microprocessor **182** executes the software program to control the monitoring system **100**. The implementation of the software program, including the operator interface, is discussed in further below.

[0037] The console **110** also includes a power supply **196**. The power supply **196** powers the console **110** and receives input power from either an external power source **197** or an internal power source **198**. The console **110** is preferably capable of being connected to the external power source **197** by way of a port or docking station. The internal power source **160** is preferably a rechargeable battery and is capable of being recharged when the console **110** is received by the docking station.

[0038] The data-entry device **115** allows an operator (e.g., a technician, nurse, doctor, etc.) to enter data into the console **110**. The data-entry device **115** may be incorporated within the console **110** (e.g., a dial control device) or, alternatively, may be a stand-alone device (e.g., a stand-alone keyboard). Other example data-entry devices **115** include a keypad, a touch screen, a pointing device (e.g., a mouse, a trackball), etc.

[0039] The output devices **120** preferably include a printer **201**, a display **202**, a storage device (e.g., a magnetic disc drive, a read/write CD-ROM, etc.) **203**, and a speaker **204**, any or all of which may be integrally provided with the console **110**. The output devices **120** further include a central monitor **205** and one or more additional patient monitors **206**. The patient monitoring system **100** is connected to the central monitor **205** and the patient monitor **206** by way of a communication interface **197** and a medical communication network **210** of the medical facility in which the patient monitoring system is located. Of course, other output devices may be added or attached (e.g., a defibrillator), and/or one or more output devices may be incorporated within the console **110**. Additionally, not all of the input devices **105** and output devices **120** are required for operation of the monitoring system **100**.

[0040] Referring now to **FIG. 2**, the cardiac output sensor **146** is shown in greater detail. The cardiac output sensor **146** is non-invasive and preferably employs impedance cardiography to measure cardiac output. Impedance cardiography utilizes changes in thoracic electrical impedance to estimate changes in blood volume in the aorta and fluid volume in the thorax. The changes in thoracic electrical impedance are measured by measuring changes in voltage in response to an applied current. Specifically, an excitation signal is applied to the patient using electrodes **221***a***-221***b* and **222***a***-222***b* The electrodes **221***a***-221***b* are placed vertically along each side of the neck, directly below the earlobe. The superior thoracic electrodes **222***a***-222***b* are located in-line with the xiphoid process on either side of the thorax along the mid-auxiliary line. The electrodes **221***a***-221***b* are positioned directly opposite each other, as are the electrodes **222***a***-222***b*. The excitation signal is a low amplitude (e.g., 1-4 milliamps), high frequency (e.g., 30-100 kHz), constant magnitude alternating current which is applied to the thoracic volume.

[0041] A response signal indicative of blood flow is produced in response to the excitation signal. The response signal is acquired by another pair of electrodes **223***a***-223***b* below the current injecting electrodes **221***a***-221***b* on the neck, and another pair of electrodes **224***a***-224***b* above the current injecting electrodes **222***a***-222***b* on the lower thorax. When the constant magnitude current is applied to the thorax, the voltage of the response signal is proportional to the impedance between the electrodes **223***a***-223***b* and the electrodes **224***a***-224***b*. This impedance is a function of an amount of blood located in a blood flow path that passes through the heart of the patient.

[0042] Thus, in the embodiment of **FIG. 2**, the total thoracic impedance $Z(t)$ at any time is equal to the overall thoracic impedance Z_0 plus changes in impedance ΔZ corresponding to both the ventilation and pulsatile blood flow: $Z(t)=Z_0+\Delta Z(t)$. The overall thoracic impedance Z_0 is determined by the impedances of the various tissues of the thorax including cardiac and skeletal muscle, fat, lung, bone, vascular tissue, and the ratio of air to liquids in the thorax. The changes in impedance ΔZ corresponding to both the ventilation and pulsatile blood flow result from the fact that blood is highly conductive. Thus, blood volume increases in the thoracic aorta and, to a lesser extent, in the pulmonary artery, are presumed to cause a decrease in impedance to current flow. Beat-to-beat dynamic impedance ($\Delta Z(t)$), for practical purposes, is the impedance change due to ventricular ejection. The change in impedance caused by respiration can be removed using electronic filtering techniques because it is of larger magnitude and lower frequency. The cardiac output sensor **146** in the embodiment of **FIG. 2** is manufactured by CardioDynamics, 6175 Nancy Ridge Drive, San Diego, Calif. 92121.

[0043] The following tables describe exemplary parameters which pertain to cardiac output and which are measured (Table 1) or calculated (Table 2) by the monitoring system **100**.

TABLE 1

Measured Parameters				
Label	Parameter	Definition	Normal Ranges	Derivation/Formula
TFC	Thoracic Fluid Content	The electrical conductivity of the chest cavity, which is primarily determined by the intravascular, intraalveolar, and the interstitial fluids in the thorax.	Males 30–50/kohm Females: 21–37/kohm	$TFC = \frac{1}{TFI}$

TABLE 1-continued

Measured Parameters				
Label	Parameter	Definition	Normal Ranges	Derivation/Formula
ACI	Acceleration Index	Initial acceleration of blood flow in the aorta, which occurs within the first 10 to 20 milliseconds after the opening of the aortic valve.	Males: 70–150/100 sec^2 Females: 90–170/100 sec^2	$ACI = \frac{d^2Z/d^2t\,MAX}{TFI}$
VI	Velocity	Peak velocity of blood flow in the aorta.	35–65/1000 sec	$VI = \frac{dZ/dt\ MAX}{TFI}$
HR	Heart Rate	Number of heart beats each minute.	60–100 bpm	HR = Beats per minute

[0044]

TABLE 2

Calculated Parameters				
Label	Parameter	Definition	Normal Ranges	Derivation/Formula
CO	Cardiac Output	Amount of blood pumped by the left ventricle each minute	4.0–8.0 l/min	$CO = HR \cdot SV$
CI	Cardiac Index	Cardiac output normalized for body surface area.	2.5–4.5 l/min/m^2	$CI = \frac{CO}{BSA}$
SV	Stroke Volume	Amount of blood pumped by the left ventricle each heartbeat.	60–130 ml	$SV = VEPT \cdot LVET \cdot VI$
SI	Stroke Index	Stroke volume normalized for body surface area.	35–65 ml/m^2	$SI = \frac{SV}{BSA}$
SVR	Systemic Vascular Resistance	The resistance to the flow of blood in the arterial system (often referred to as "afterload").	900–1400 dynes sec/cm^5	$SVR = 80 \cdot \frac{(MAP - CVP)}{CO}$
SVRI	Systemic Vascular Resistance Index	The resistance to the flow of blood in the arterial system normalized for body surface area.	1900–2400 dynes sec m^2/cm^5	$SVRI = 80 \cdot \frac{(MAP - CVP)}{CI}$
LVSWI	Left Ventricular Stroke Work Index	The work performed by the left ventricle to eject the stroke volume into the aorta.	40–60 gm m/m^2	$LVSWI = (MAP - PAWP) \cdot SI \cdot 0.0136$
LCWI	Left Cardiac Work Index	An indicator of the amount of work the left ventricle must perform to pump blood each minute, normalized for body surface area.	3.0–5.5 kg m/m^2	$LCWI = (MAP - PAWP) \cdot Cl \cdot 0.0144$

TABLE 2-continued

Calculated Parameters				
Label	Parameter	Definition	Normal Ranges	Derivation/Formula
STR	Systolic Time Ratio	The ratio of the electrical and mechanical systole.	0.30–0.50	$STR = \frac{PEP}{LVET}$
eDO_2I	Estimated Delivered Oxygen Index	The rate of oxygen transport in the arterial blood.	Dependent on clinical pathology	$DO_2I = Cl \cdot SpO_2 \cdot 1.38 \cdot Hb \cdot 10$ (estimated value)
PEP	Pre Ejection Period	The time interval from the beginning of electrical stimulation of the ventricles to the opening of the aortic valve (electrical systole).	Depends on HR preload and contractility	Time interval from beginning of Q wave on the ECG to the B point on the dZ/dt waveform
LVET	Left Ventricular Ejection Time	The time interval from opening to the closing of the aortic valve (mechanical systole).	Depends on HR preload and contractility	Time interval from the B point to the X point on the dZ/dt waveform

[0045] In Table 2, VEPT is volume of electrically participating tissue (volume conducted for size of thorax affected by height, weight, and sex), TFL is thoracic fluid index, which is the baseline thoracic impedance, Z_0, dZ/dtMAX is maximum of the first derivative of ΔZ, d^2Z/d^2tMAX is maximum of the second derivative of ΔZ, BSA is body surface area, CVP is central venous pressure, PAWP is pulmonary artery wedge pressure, B point is opening of aortic valve, and X point is closing of aortic valve. MAP (mean arterial pressure or the mean pressure that comes from an arterial or femoral invasive blood pressure reading), PAWP, SpO2 (pulse oximetry), and Hb (hemoglobin) are hemodynamic input data used for calculation of individual cardiac output parameters. The parameters in Table 2 are calculated by the analysis module **175**.

[0046] Referring now to FIGS. **3-19**, an operator interface that assists monitoring and displaying cardiac output information is shown. Referring first to **FIG. 3, a** top level screen display **240** is shown. The screen display **240** comprises a plurality of information fields, a plurality of waveforms, and a plurality of parameter windows. The information fields include a field **242** that displays care unit, a field **244** that displays bed number, a field **246** that displays patient name, and a field **248** that displays date and time. The plurality of waveforms include ECG waveforms **250**, cardiac output waveform **252**, a CO2 waveform **254**, and other waveforms.

[0047] The parameter windows are displayed on the far right of the screen display and, when necessary, across the bottom. The number of parameter windows that are displayed depends on the number of sensors connected to the patient monitoring system **100**. Preferably, every monitored parameter has a parameter window. In **FIG. 3**, the parameter windows include an ECG window **260**, an NBP (non-invasive blood pressure) window **262**, an ART (blood pressure from an invasive arterial blood pressure reading) window **264**, an ICG (impedance cardiography or cardiac output) window **266**, an SP02 window **268**, a CO2 (carbon dioxide) window **270**, an alarm window **272**, and a temperature window **274**. Parameter labels may be displayed in different sizes depending on the display layout and the number of parameters being monitored. The parameter windows may be double high sized (as with the ECG parameter window **260**), normal size, (as with the remaining parameter windows **262-274**), or reduced size (not shown). Each parameter window has two parts: a parameter label portion **276** and a measured value portion **278**. Each parameter window **260-274** displays one primary parameter and three secondary parameters. Limits and units of measure may also be displayed under the parameter label.

[0048] For example, the ICG parameter window **266** displays four of the sixteen parameters identified in Tables 1 and 2 along with a signal quality **280** indicator for the impedance waveform **252**. The ICG parameter window **266** has one large primary subparameter value and three other secondary subparameters, all of which are selectable for display. The selectable subparameters may be any of those in Tables 1 and 2. The signal quality indicator **280** comprises one to three asterisks which reflect the confidence in the value correctness: Three asterisks is high confidence, two asterisks is average confidence, and one asterisk is low confidence. During normal monitoring, values in the parameter window **266** updates periodically (e.g., every two seconds).

[0049] The main operator control is preferably a dial input device. The dial input device rotates in either direction to highlight parameter labels and menu options. After highlighting the desired selection, the dial input device may be pressed by the operator to view a new menu or a small pop-up menu. Thus, from the main menu shown in **FIG. 3**, the operator accesses a parameter menu by selecting the appropriate parameter label using the dial input device. The operator can also access other menus (not related to a specific parameter) by selecting the more menus option.

[0050] When the ICG window **266** is highlighted and the operator pushes the dial input device, a top level ICG menu **300** as shown in **FIG. 4** is displayed. The top level ICG menu **300** comprises a patient information button **302**, a fast look button **304**, a secondary parameters button **306**, a limits button **308**, a trends button **310**, a help button **312**, a waveform button **314**, a speed button **316**, a signal quality button **318**, a beat average button **320**, a change normals button **322**, and a check leads button **324**.

[0051] All available menu options appear with the current selection being highlighted. In some instances, arrows are also highlighted, indicating that the dial input device can be rotated (or scrolled) to change the selection. When the dial input device is rotated, the new selection is highlighted and the operator is permitted to press the dial input device to select a particular menu option (i.e., button). If the data entry device **115** is a touch screen integrated with the video display **202**, then the buttons **302-324** may be activated by the operator by pressing the appropriate location on the video display **202**. Preferably, however, the buttons **302-324** merely appear as buttons and instead are activated by the dial input device.

[0052] When an operator input is received selecting the patient info button **302**, a patient info menu **330** is displayed as shown in **FIG. 5**. The patient info menu **330** includes an information display window **332** which prompts an operator to enter patient information. There are four primary patient demographic values used for cardiac output monitoring: height, weight, sex, and age. Additional information is used for monitoring specific parameters. The information display window **332** prompts an operator to choose an option for MAP source (e.g., either non-invasive blood pressure or arterial line). The information display window **332** also prompts the operator to manually enter a value for CVP or alternatively to permit the system **100** to use an invasive CVP value. The information display window **332** also prompts the operator to enter a PAW (pulmonary artery wedge pressure) value or alternatively to permit the system **100** to use the invasive PAW sensor as the source of this information. Finally, the information display window **332** prompts the operator to enter an Hb (hemoglobin) value. The information window **332** is superimposed over the upper left portion of the screen display. Information windows are displayed when a help option is selected with certain menu options, as described below. The information window contains instructions or other non-real time information.

[0053] If an operator input is received selecting the fast look button **304**, then a fast look menu **340** is displayed to the operator as shown in **FIG. 6**. The fast look menu **340** allows the operator to quickly view a comprehensive list of cardiac output parameter data in an information window **342**.

[0054] As previously noted, the arrows **344** indicate that the dial input device can be rotated to change the selection between normal ranges, units of measure, and return. The change is implemented when the dial input device is pressed. Thereafter, the pop-up menu closes and the change is in effect.

[0055] In **FIG. 6**, the cardiac output data is displayed in "units of measure" format in the information display window **342**, in which the cardiac output data is displayed along with units of measure in a region **346** of the information display window **342**. The cardiac output data may also be stored in a "normal ranges" format in which the information display window **342** displays the ICG data along with normal ranges as shown in **FIG. 7**. A plus (+) **348** or minus (−) **349** is used to indicate data that falls outside of the specified ranges.

[0056] If an operator input is received selecting the secondary parameters button **306**, then a secondary parameters menu **350** is displayed as shown in **FIG. 8**. The secondary parameters menu **350** permits the operator to select which parameters are to be displayed as secondary parameters in the ICG parameter window **266**. Three secondary parameters from Tables 1 and 2 are set forth in a displayed list **352** and can be selected for display in the parameter window **366**. The menu **350** permits the operator to select three choices from the parameter list, and these choices are then displayed in the parameter window **366**. The parameter that has been assigned to the primary parameter position is not included in the list of parameters available for secondary parameter display.

[0057] If an operator input is received selecting the limits button **308**, then a limits menu **360** is displayed as shown in **FIG. 9**. The limits menu permits the operator to adjust alarm limits for TFC and Cl. High and low limits can be adjusted for both parameters. The current limit settings are shown in an information window **362**, and the current value of that parameter for the monitored patent is also shown using arrows **364**. As long as that value remains between the high and low limits, there will be no alarm. Should a limit be exceeded, an alarm will occur.

[0058] If an operator input is received selecting the trends button **310**, then trending information for the cardiac parameters is displayed in tabular or graphical format. A trend is a graphic representation of one parameter over a specified period of time. Every non-episodic parameter is sampled 30 times a minute. A median value is determined and that value is stored for trend display at one-minute resolution. Episodic parameters (NBP, etc.) are stored every time one occurs. Any combination of parameters may be trended as determined by operator inputs. The cardiac output information in Tables 1 and 2 can be trended along with ECG data and all of the other information collected by the sensors **141-145** and **155**.

[0059] If an operator input is received selecting the help button **312**, then the help information windows **370**, **372**, **374** are displayed as shown in FIGS. **10-12**. Three help information windows **370**, **372**, **374** provide information for cardiac output setup and monitoring. Topics include skin preparation (window **370**, **FIG. 10**), proper sensor placement (window **372**, **FIG. 11**), and troubleshooting issues (window **374**, **FIG. 12**).

[0060] If an operator input is received selecting the waveform button **314**, then a waveform menu **380** is displayed as shown in **FIG. 13**. The waveform menu **380** provides the operator with the option of selecting a waveform which reflects beat-to-beat changes in impedance consistent with the events of the cardiac cycle, or a dZ/dt waveform which reflects the rate of change in the impedance waveform. The selected waveform **252** is labeled in the waveform area on the display **240**. The cardiac output waveform **252** can be turned on or off using the waveform menu **380**. In **FIG. 13**, the displayed waveform is the impedance waveform, as indicated by arrow **382**.

[0061] If an operator input is received selecting the speed button **316**, then a speed menu **390** is displayed as shown in

FIG. 14. The speed menu **390** is used to select a sweep speed for the displayed cardiac output waveform **252**. In **FIG. 14**, the speed selected is 25 mm/sec as indicated by arrow **392**.

[**0062**] If an operator input is received selecting the signal quality button **318**, then a signal quality menu **400** is displayed as shown in **FIG. 15**. Upon start-up, the analysis module **175** selects what is considered to be the best signal for optimum data acquisition and processing. The signal quality menu **400** allows the operator to manually override this process. The menu **400** provides the operator with choices including auto search and signal **1** through signal **4**. If the operator selects auto search, the system **100** searches for a new optimal signal. If the operator selects signal **1** through signal **4**, the system **100** uses the selected signal.

[**0063**] If the operator selects the beat average button **320**, then a beat average menu **410** is displayed as shown in **FIG. 16**. The beat average menu **410** permits the operator to select the number of beats that are averaged for data update. Beat average choices are 5, 10, 20, 30, and 60 beats. The smaller the number of beats average, the more likely it is that the data will be affected by artifact. A high number of beats averaged smoothes out the acquired data with a minimum of fluctuation.

[**0064**] If the operator selects the change normals button **322**, then a change normals menu **420** is displayed as shown in **FIG. 17**. The change normals menu **420** permits the operator to change the normal ranges for cardiac flow parameters. Default normal ranges are displayed in an information window **422**. Default normal ranges may be changed in accordance with the medical judgment of the attending physician.

[**0065**] If the operator selects the check leads button **324**, then a lead check of the electrodes **221***a*-**221***b*, **222***a*-**222***b*, **223***a*-**223***b*, and **224***a*-**224***b* is initiated as shown in **FIG. 18**. When monitoring cardiac flow parameters, electrodes are checked periodically for leads fail condition. During the lead check process, the cardiac flow waveform exhibits an approximately one-half second period of flat line **432** and the message "leads check" is displayed (**434**). The check leads menu option allows the system **100** to check for a leads fail condition in response to operator inputs. Should the monitor detect a leads fail condition, a message indicating the position of the failed lead may be displayed, as shown by messages **436** in **FIG. 19**.

[**0066**] Referring now to **FIG. 20**A, in operation and after system initialization, the monitoring system **100** continuously acquires the physiological signals from the patient using the input devices **105** (the electrodes $E_{1,}$ $_{E2}$ . . . E_n and the sensors **141**-**145** and **155**) at step **450**. At step **452**, the analysis module processes the physiological signals from the patient. At step **456**, the processed data is displayed to the operator.

[**0067**] **FIG. 20B** shows this process in the context of the cardiac output data in one preferred manner of operation. Thus, in step **450***a* (corresponding to step **450**), the monitoring system applies an excitation signal to a patient using electrodes **221***a*-**221***b* and **222***a*-**222***b*. The excitation signal is a low amplitude (e.g., 1-4 milliamps), high frequency (e.g., 30-100 kHz), constant magnitude alternating current which is applied to the thoracic volume. At step **450***b* (also corresponding to step **450**), a response signal is acquired using the electrodes **223***a*-**223***b* and the electrodes **224***a*-**224***b*. The response signal is indicative of blood flow and is produced in response to the excitation signal. In particular, the voltage of the response signal is proportional to the impedance between the electrodes **223***a*-**223***b* and the electrodes **224***a*-**224***b*, and the impedance in turn is a function of an amount of blood located in a blood flow path that passes through the heart of the patient. The response signal indicates the response characteristics of the heart to the excitation signal and is usable to measure the impedance of the heart.

[**0068**] At steps **452***a* and **452***b* (corresponding to step **452**), the analysis module **175** processes the response signal to produce a value pertaining to cardiac output. In the preferred embodiment, at step **452***a*, the response signal is electronically filtered to remove the change in impedance caused by respiration. At step **452***b*, the equations set forth in Tables 1 and 2 are then performed by the analysis module **175** to yield the sixteen preferred values pertaining to cardiac output set forth in Tables 1 and 2.

[**0069**] Step **454** is an additional step which is shown in **FIG. 20B**. At step **454**, the cardiac output information is transmitted from the patient monitoring system **100** to a remote patient monitor by way of a local area network **210** of a medical facility in which the portable patient monitoring system **100** is located. This allows, at step **456***a* (corresponding to step **456**), the cardiac output information to be displayed on a display at the remote patient monitor **205**, **206**. Therefore, a physician or nurse can monitor patient status while also attending to other tasks outside the patient's room. Of course, the cardiac output information can also be displayed at the display **202** which is directly coupled to the analysis module.

[**0070**] The patient monitoring system **100** also processes information from other sensors. For example, in connection with ECG monitoring, 12SL monitoring is performed. In the illustrated embodiment, ten electrodes are used to continuously acquire ECG signals from the patient (RA, LA, LL, RL, V1, V2, V3, V4, V5 and V6). The ECG signals are transmitted to the input terminal **130** of the console **110** via the interface cable **125**. The ECG signals **110** are provided to the instrumentation amplifier **180** which combines, amplifies and filters the ECG signals resulting in a standard twelve-lead ECG. The resulting multi-lead ECG is provided to the A/D conversion circuit **170** which samples each lead of the multi-lead ECG to create a digital signal representing the multi-lead ECG, and provides the digital multi-lead ECG to the analysis module **175**. The multi-lead ECG provided to the analysis module **175** includes ECG leads I, II, V1, V2, V3, V4, V5 and V6 which are acquired directly from the patient leads and leads III, aVR, aVF, and aVL which are derived.

[**0071**] The analysis module **175** includes an arrhythmia analyzer module which includes high and low frequency detect modules which evaluate each of the leads for high frequency and low frequency noise, a QRS detection module which detects signals falling within the physiologic band and which it recognizes as valid ECG signals, a QRS correlation module which passes the ECG data stream through a list of active templates, which are incrementally updated so that they are progressively changed along with the beat shape. The analysis module **175** further includes an arbitrator module which processes beats recognized by the QRS correlator and beats which do not match any of the existing templates, and a determination is made whether to create a new template and replace the least useful of the active templates. These would-be templates which are matched with the least frequency or have not been recently matched or classified as likely to be artifacts. The analysis module further includes a classifier module which receives the template information associated with the beats and takes all the feature and temporal measurements and arrives at a determination as to what is represented by that particular beat, that is a normal QRS, an atrial artificially paced normal QRS, a premature supraventricular QRS, ventricular artificially paced QRS, a ventricular premature QRS, a T wave, a P wave, a ventricular artificial pacing spike, an atrial artificial pacing spike or an artifact. The measurements made to determine individual beat characteristics are R amplitude, S amplitude, QRS polarity, T wave polarity, ST segment, noise level, PR interval, P wave presence, QT interval, QRS duration, RR interval, RR interval variance, pacemaker signals and rotation of cardiac vector. The analysis module further includes an arrhythmia call logic module which employs well-known criteria to make an arrhythmia call. These include the duration of usable ECG data, heart rate, the time between QRS complexes, the occurrence of a ventricular complex within a repolarization period, the occurrence of one or more ventricular beats preceded or followed by nonventricular beats, ST deviations of a predetermined magnitude, R-to-R intervals and the intervals between the QRS complex and a pacemaker spike. With this information, the arrhythmia call logic can determine if one of the following has occurred: an artifact, ventricular asystole, ventricular fibrillation, ventricular tachycardia, VT3-5, R-on-T, ventricular bradycardia, couplet, bigeminy, accelerated ventricular rhythm, pause, trigeminy, isolated premature ventricular complexes, ST deviation, tachycardia, bradycardia, irregular heartbeat or electronic pacemaker nonsensing. If an arrhythmia call is indicated, an appropriate alarm signal is provided to the display **202**.

[0072] In operation, the analysis module **175** receives the ECG leads I, II, III, V1-V6, aVF, aVR, and aVL. Initially, the beat select section makes a template for each lead. From this point on, the QRS selector looks for the same shape. If it finds a match, the program classifies it as another QRS detection. In addition, the program slides the wave forms past one another looking for the optimal match. If the output of the filters in the acquisition modules exceed a preselected value, but there is no match, it is assumed that a different beat type has been detected and an additional set of templates are made for further matching tests. Thus, the beat selector uses a filter and template matching techniques to both detect and group by shape the QRS complexes which occur in the ECG record. The QRS detector also defines the points on the ECG record that can be used to align and time with maximum correlation, the respective beats of a beat type.

[0073] The program then determines which beat type will be used for the morphology measurements. The program uses the RR intervals and the location of any pacer spikes in order to decide which beat has the highest level of origin in the conduction system. Identical QRS shapes can even be subdivided as in the case of a sinus rhythm with premature beats. The selection is not dependent upon the number of beats per beat type but rather the beat type which is the most informative for analysis is the one sought after and any beat type with three or more complexes can qualify. The beat type that the computer considers to be most informative of normal conduction is often referred to as the primary beat.

[0074] After a primary beat has been chosen, each of its associated beats is used in generating a representative complex for each lead. This is done using the sample times generated by the QRS detector. These times not only indicate the occurrence of a QRS but also indicate when the QRS for a specific beat type are optimally matched. The representative complex is then generated with the median voltages from the aligned group of beats, that is, it is formed by taking, at each sample time, the middle voltage of the superimposed beats.

[0075] After the median for the primary cycle has been established for each of the twelve leads, the waves of each complex are identified. This is done separately for each lead. The program finds the points at which the signal crosses the baseline within each complex. If the crossing points define a wave that has an area greater than a predetermined value, the wave is considered to be significant. If the area is less than this value, the program considers the wave to be insignificant and it will not label it as a separate wave. The measurement matrix contains the amplitudes, with respect to QRS onset, and durations of all of the individuals waves, including the amplitude and duration of the P, P', Q, R and S waves, the amplitude of the T wave, the PR and QT intervals, the QRS duration and the STJ, STM and STE amplitudes.

[0076] The program then utilizes these measurements in making an interpretation. This includes a rhythm analysis and a morphology interpretation. The rhythm analysis first determines the origins of the predominant rhythm in the sample and chooses from the major categories consisting of electronic atrial pacing, atrial flutter, ectopic atrial rhythm, sinus rhythm, junction rhythm and atrial fibrillation.

[0077] The morphology interpretation will determine the existence of Wolff-Parkinson-White, atrial hypertrophy, QRS abnormalities such as low voltage QRS, pulmonary disease pattern, QRS axis, conduction abnormalities, ventricular hypertrophy, infarction, ST+T abnormality with ventricular hypertrophy, dating infarcts, epicardial injury, pericarditis, early repolarization, nonspecific ST elevation, subendocardial injury, nonspecific ST depression, digitalis effect, junctional ST depression, ischemia, QRS-T angle and QT interval.

[0078] Other monitoring applications are performed similarly to cardiac output monitoring. Thus, blood pressure information from the blood pressure sensor **141**, pulse oximetry information from the pulse oximetry sensor **142**, temperature information from the temperature sensor **143**, carbon dioxide information from the carbon dioxide sensor **144**, and respiration gas information from the respiration sensor **145** are acquired, processed, and displayed either locally at the display **202** or remotely at another display. All of the data may also be printed by the printer **201**, stored in the data storage memory **195** for analysis or later recall, provided to the external storage device **203** for storage, and/or provided to remote devices **205** and **206** connected to the patient monitoring system by way of the hospital communication network.

[0079] Referring to **FIG. 21, a** patient monitoring network **500** is shown, some of the components of which have been previously described. The patient monitoring network **500** comprises the hospital communication network **210**, a plurality of the patient monitoring systems **206** (preferably constructed in the same manner as the patient monitoring system **100** as previously described), and the central monitor **205**. The hospital communication network establishes bed-to-bed communication and allows patient data to be sent to the central monitor **205**. Patient data including cardiac output data can be communicated over the hospital communication network **210** and the patient monitors **205, 206** can view and trend data acquired from other patient monitors. Alarms may also be transmitted over the network **210**.

[0080] To facilitate remote viewing, one of the menu selections that is preferably reachable by way of the more menus button **275** in **FIG. 3** is a view other patients option. The view other patients option allows the operator to select any patient monitoring system **206** on the hospital communication network **210** to view at a particular monitoring system **100**. Locally, the display screen is then divided in half and data from one patient is displayed on one half the screen and data from the other patient is displayed on the other half of the screen. Continuous waveform and parameter value data, such as cardiac output waveforms and parameters, is displayed for both patients.

[0081] As previously noted, the console **110** is preferably portable. The console **110** may for example comprise a carrying handle and weigh less than twenty pounds, or preferably less than 15 pounds, and most preferably about 12 pounds. Each patient monitoring system **100, 206** preferably includes a docking station capable of receiving the patient monitor console **110** and connecting the console to electrical power and to the hospital communication network **210**. Additionally, the communication interface **197** is capable of establishing a wireless communication link between the patient monitoring system **100** and the hospital communication network **210**.

[0082] To facilitate portability, the hospital communication network **210** includes a plurality of access points **505** and allows an operator to roam from one access point **505** to another while maintaining a connection to the network. The access points **505** connect the patient monitoring systems **100, 206** to the hospital communication network **210**, and act as a bridge between the wired and wireless portions of the network **210**. The areas covered by each access point **505** are overlapping to ensure continuous coverage. The monitoring system **100** switches automatically between hard-wired (docking station or cable connection) and wireless network communication.

[0083] The preferred embodiment of the patient monitoring system offers several advantages. First, the console **110** is portable. This allows for allows monitoring while the patient is in transport from the emergency room to the next stop for the patient. Additionally, the console **110** monitors not only cardiac output, but also 12 lead ECG and other parameters. Therefore, medical personnel only need one device to do all of their monitoring instead of a patient monitor along with a separate cardiac output monitor. Also, 12 lead analysis and other ECG analysis can be performed from a single monitor. This is important because space at a bedside is critical, and it is less expensive for the hospital to purchase only one unit. Further, cardiac output data can be trended along with all other paramater data. This allows the clinicians to compare the changes in cardiac output parameters alongside all other monitored parameters over time. This is important because correct diagnoses often need to take into account all parameter data, instead of only looking at one parameter. Usually a change in one parameter will also indicate a change in other parameters, and medical personnel wish to take into account all of these changes when evaluating the treatment of a patient.

What is claimed is:

1. A patient monitoring system comprising:

(A) a non-invasive cardiac output sensor, the non-invasive cardiac output sensor being capable of acquiring a signal from a patient indicative of blood flow through a heart of the patient;

(B) a multi-lead electrocardiogram (ECG) sensor, the multi-lead ECG sensor comprising a plurality of ECG electrodes capable of acquiring a plurality of ECG signals from the patient; and

(C) a patient monitor console, including

(1) an analysis module, the analysis module being coupled to the non-invasive cardiac output sensor and to the multi-lead ECG sensor, the analysis module processing the signal from the patient indicative of blood flow to produce a value pertaining to cardiac output, and

(2) a display, the display being coupled to the analysis module, and the display displays the value pertaining to cardiac output and an ECG waveform generated based on the ECG signals.

2. A system according to claim 1, wherein the non-invasive cardiac output sensor further comprises first and second electrodes, and wherein the analysis module produces the value pertaining to cardiac output by determining an impedance between the first and second electrodes, the impedance between the first and second electrodes being a function of an amount of blood located in a blood flow path that passes through the heart of the patient.

3. A system according to claim 2, wherein the non-invasive cardiac output sensor further comprises third and fourth electrodes, wherein an excitation signal is applied to the patient using the third and fourth electrodes, and wherein the signal from the patient indicative of blood flow is a response signal that is generated in response to the excitation signal.

4. A system according to claim 1, wherein the value pertaining to cardiac output pertains to a volume of blood pumped by the heart per unit time.

5. A system according to claim 1, wherein the value pertaining to cardiac output pertains to a volume of blood pumped by the heart each heartbeat.

6. A system according to claim 1, wherein the value pertaining to cardiac output pertains to a resistance to flow of blood in an arterial system of the patient.

7. A system according to claim 1, wherein the value pertaining to cardiac output is a work index indicative of an amount of work performed by the heart to eject a volume of blood into an aorta of the patient.

8. A system according to claim 1, further comprising

a blood pressure sensor, the blood pressure sensor being connected to the analysis module, and wherein the display displays blood pressure information based on a signal acquired from the blood pressure sensor;

a pulse oximetry sensor, the pulse oximetry sensor being connected to the analysis module, and wherein the display displays information pertaining to pulse oximetry based on a signal acquired from the pulse oximetry sensor;

a carbon dioxide sensor, wherein the analysis module is connected to the carbon dioxide sensor and wherein the display further displays information pertaining to carbon dioxide content in respiratory gas based on a signal from the carbon dioxide sensor.

9. A system according to claim 8, wherein at least one of the blood pressure sensor, the pulse oximetry sensor, and the carbon dioxide sensor is connected to the analysis module by way of a network communication link.

10. A system according to claim 1, further comprising a communication interface capable of establishing a communication link between the patient monitoring system and a local area network of a medical facility in which the patient monitoring system is located.

11. A system according to claim 10, wherein the patient monitor console is portable and the communication interface is capable of wirelessly connecting the patient monitoring system to the local area network.

12. A system according to claim 1, wherein the patient monitor console is portable and wherein the system further comprises a docking station capable of receiving the patient monitor console and connecting the console to electrical power and a local area network of a medical facility in which the patient monitoring system is located.

13. A system according to claim 1, wherein the patient monitor console is portable and comprises a carrying handle and weighs less than twenty pounds.

14. A system according to claim 1,

wherein the system further comprises a plurality of additional sensors and a dial operator input device,

wherein the display displays a cardiac output parameter window and a plurality of additional parameter windows corresponding to parameters sensed by respective ones of the plurality of additional sensors,

wherein the dial operator input device is rotatable in either direction to highlight different parameter windows, and

wherein, when the cardiac output parameter window is highlighted, and the dial operator input device is pressed while the cardiac output parameter window is highlighted, the display displays a plurality of cardiac output menu options, the cardiac output menu options being selectable by an operator to cause the display to display additional information pertaining to cardiac output to the operator and to receive inputs from the operator to adjust processing of the signal from the cardiac output sensor.

15. A system according to claim 14, wherein the non-invasive cardiac output sensor further comprises first and second electrodes, and wherein the analysis module produces the value pertaining to cardiac output by determining an impedance between the first and second electrodes, the impedance between the first and second electrodes being a function of an amount of blood located in a blood flow path that passes through the heart of the patient.

16. A system according to claim 15, wherein the plurality of menu options includes an option that causes the patient monitoring system to test placement of the first and second electrodes on the patient.

17. A system according to claim 15, wherein the plurality of menu options includes a help option that causes the display to display help information describing proper electrode placement locations on the patient.

18. A system according to claim 15, wherein the plurality of menu options includes a help option that causes the display to display help information describing proper skin preparation prior to electrode placement on the patient.

19. A system according to claim 15, wherein the plurality of menu options includes an option to change a type of impedance waveform that is displayed to an operator.

20. A patient monitoring system comprising:

(A) means for non-invasively monitoring cardiac output, including means for acquiring a signal from a patient indicative of blood flow through a heart of the patient;

(B) means for acquiring a plurality of ECG signals from the patient;

(C) means for processing the signal from the patient indicative of blood flow to produce a value pertaining to cardiac output; and

(D) means for displaying the value pertaining to cardiac output and an ECG waveform generated based on the ECG signals.

21. A patient monitoring system comprising:

(A) a non-invasive cardiac output sensor, the non-invasive cardiac output sensor being capable of acquiring a signal from a patient indicative of blood flow through a heart of the patient;

(B) a communication interface, the communication interface being capable of establishing a communication link between the patient monitoring system and a local area network of a medical facility in which the patient monitoring system is located; and

(C) a patient monitor console, including

(1) an analysis module, the analysis module being coupled to the non-invasive cardiac output sensor, the analysis module processing the signal from the patient indicative of blood flow to produce a value pertaining to cardiac output, and

(2) a display, the display being coupled to the analysis module, and the display displays the value pertaining to cardiac output; and

wherein the communication interface is capable of transmitting the value pertaining to cardiac output over the local area network.

22. A system according to claim 21, wherein the non-invasive cardiac output sensor further comprises first and second electrodes, and wherein the analysis module produces the value pertaining to cardiac output by determining an impedance between the first and second electrodes, the impedance between the first and second electrodes being a function of an amount of blood located in a blood flow path that passes through the heart of the patient.

23. A system according to claim 21, wherein the non-invasive cardiac output sensor further comprises third and fourth electrodes, wherein an excitation signal is applied to the patient using the third and fourth electrodes, and wherein the signal from the patient indicative of blood flow is a response signal that is generated in response to the excitation signal.

24. A system according to claim 21, wherein the value pertaining to cardiac output pertains to a volume of blood pumped by the heart per unit time.

25. A system according to claim 21, further comprising

a blood pressure sensor, the blood pressure sensor being connected to the analysis module, and wherein the display displays blood pressure information based on signals acquired from the blood pressure sensor;

a pulse oximetry sensor, the pulse oximetry sensor being connected to the analysis module, and wherein the display displays information pertaining to pulse oximetry;

a carbon dioxide sensor, wherein the analysis module is connected to the carbon dioxide sensor and wherein the display further displays information pertaining to carbon dioxide content in respiratory gas.

26. A system according to claim 21, wherein the patient monitor console is portable and the communication interface is capable of wirelessly connecting the patient monitoring system to the local area network.

27. A system according to claim 21, wherein the patient monitor console is portable and wherein the system further comprises a docking station capable of receiving the portable monitor console and connecting the console to electrical power and a local area network of a medical facility in which the patient monitoring system is located.

28. A system according to claim 21,

wherein the system further comprises a plurality of additional sensors and a dial operator input device,

wherein the display displays a cardiac output parameter window and a plurality of additional parameter windows corresponding to parameters sensed by respective ones of the plurality of additional sensors,

wherein the dial operator input device is rotatable in either direction to highlight different parameter windows, and

wherein, when the cardiac output parameter window is highlighted, and the dial operator input device is pressed while the cardiac output parameter window is highlighted, the display displays a plurality of cardiac output menu options, the cardiac output menu options being selectable by an operator to cause the display to display additional information pertaining to cardiac output to the operator or to receive inputs from the operator to adjust processing of the signal from the cardiac output sensor.

29. A system according to claim 28, wherein the non-invasive cardiac output sensor further comprises first and second electrodes, and wherein the analysis module produces the value pertaining to cardiac output by determining an impedance between the first and second electrodes, the impedance between the first and second electrodes being a function of an amount of blood located in a blood flow path that passes through the heart of the patient; and wherein the plurality of menu options includes an option that causes the patient monitoring system to test placement of the first and second electrodes on the patient.

30. A system according to claim 28, wherein the non-invasive cardiac output sensor further comprises first and second electrodes, and wherein the analysis module produces the value pertaining to cardiac output by determining an impedance between the first and second electrodes, the impedance between the first and second electrodes being a function of an amount of blood located in a blood flow path that passes through the heart of the patient; and wherein the plurality of menu options includes a help option that causes the display to display help information describing proper electrode placement on the patient.

31. A system according to claim 21, further comprising a multi-lead electrocardiogram (ECG) sensor, the multi-lead ECG sensor comprising a plurality of ECG electrodes capable of acquiring a plurality of ECG signals from the patient, and wherein the display displays an ECG waveform generated based on the ECG signals.

32. A system according to claim 31, wherein the plurality of ECG signals include leads I, II, III, V1, V2, V3, V4, V5, V6, aVR, aVL and aVF.

33. A patient monitoring method comprising:

(A) acquiring cardiac output information using a non-invasive cardiac output sensor of a patient monitoring system, the non-invasive cardiac output sensor being capable of acquiring a signal from a patient indicative of blood flow through a heart of the patient, the acquiring step including

(1) applying an excitation signal to a patient, the excitation signal being applied using first and second electrodes, and

(2) measuring cardiac impedance based on response characteristics of the heart of the patient to the excitation signal;

(B) acquiring a plurality of electrocardiogram (ECG) signals from the patient using a multi-lead ECG sensor of the patient monitoring system;

(C) transmitting the ECG signals and the cardiac output information from the patient monitoring system to a remote device by way of a local area network of a medical facility in which the patient monitoring system is located; and

(D) displaying an ECG waveform and the cardiac output information on a display.

34. A method according to claim 33, wherein the displaying step is performed at the remote patient monitor.

35. A method according to claim 33, wherein the displaying step is performed at the patient monitoring system.

36. A method according to claim 33, further comprising displaying trending information, the trending information including historical information regarding variation of a cardiac output value over a period of time.

37. A patient monitoring system comprising:

(A) a non-invasive cardiac output sensor, the non-invasive cardiac output sensor being capable of acquiring a signal from a patient indicative of blood flow through a heart of the patient, the non-invasive cardiac output sensor comprising first and second electrodes;

(B) a multi-lead electrocardiogram (ECG) sensor, the multi-lead ECG sensor comprising a plurality of ECG electrodes capable of acquiring a plurality of ECG signals from the patient;

(C) a blood pressure sensor, the blood pressure sensor being capable of acquiring blood pressure information from the patient;

(D) a pulse oximetry sensor, the pulse oximetry sensor being capable of acquiring pulse oximetry information from the patient;

(E) a carbon dioxide sensor, the carbon dioxide sensor being capable of acquiring information pertaining to carbon dioxide content in respiratory gas of the patient;

(F) a patient monitor console, including

(1) an analysis module, the analysis module being coupled to the non-invasive cardiac output sensor, the multi-lead ECG sensor, the blood pressure sensor, the pulse oximetry sensor, and the carbon dioxide sensor, the analysis module processing the signal from the patient indicative of blood flow to produce a value pertaining to cardiac output, the analysis module producing the value pertaining to cardiac output by determining an impedance between the first and second electrodes, the impedance between the first and second electrodes being a function of an amount of blood located in a blood flow path that passes through the heart of the patient, the value pertaining to cardiac output pertains to a volume of blood pumped by the heart per unit time,

(2) a display, the display being coupled to the analysis module, and the display displaying the ECG waveform, the value pertaining to cardiac output, the blood pressure information, the carbon dioxide information, and the pulse oximetry information,

(3) communication interface capable of establishing a communication link between the patient monitoring system and a local area network of a medical facility in which the patient monitoring system is located, and

(4) a dial operator input device,

wherein the display displays a plurality of parameter windows which respectively display the cardiac output information, the ECG information, the blood pressure information, the pulse oximetry information, and the carbon dioxide information;

wherein the dial operator input device is rotatable in either direction to highlight different parameter windows; and

wherein, when the cardiac output parameter window is highlighted, and the dial operator input device is pressed while the cardiac output parameter window is highlighted, the display displays a plurality of cardiac output menu options, the cardiac output menu options being selectable by an operator to cause the display to display additional information pertaining to cardiac output to the operator or to receive inputs from the operator to adjust processing of the signal from the cardiac output sensor.

38. A system according to claim 37, wherein the plurality of ECG signals include eight leads which are acquired directly and four leads which are derived.

39. A system according to claim 37, wherein the plurality of ECG signals include leads I, II, III, **V1**, **V2**, **V3**, **V4**, **V5**, **V6**, aVR, aVL and aVF.

* * * * *

专利名称(译)	具有非侵入性心输出量监测的患者监测器和方法		
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[标]申请(专利权)人(译)	GE医疗系统信息技术公司		
申请(专利权)人(译)	GE医疗系统信息技术股份有限公司.		
当前申请(专利权)人(译)	GE医疗系统信息技术股份有限公司.		
[标]发明人	NIELSEN ERIC RYZIN PATRICK A VAN		
发明人	NIELSEN, ERIC RYZIN, PATRICK A. VAN		
IPC分类号	A61B5/00 A61B5/0205 A61B5/021 A61B5/0245 A61B5/026 A61B5/029 A61B5/04 A61B5/044 A61B5/0452 A61B5/05 A61B5/053 A61B5/08 A61B5/083		
CPC分类号	A61B5/02055 A61B5/021 A61B5/029 A61B5/04525 A61B5/0535 A61B5/061 A61B5/002 A61B5/7203 A61B5/7264 A61B5/7435 A61B2560/0431 A61B5/7239 A61B5/1455 A61B5/0295 A61B5/742		
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摘要(译)

患者监测系统包括非侵入性心输出量传感器和患者监测器控制台。非侵入性心输出量传感器能够从患者获取指示血流通过患者心脏的信号。患者监视器控制台包括分析模块和显示器。分析模块耦合到非侵入性心输出量传感器，并处理来自患者的指示血流的信号，以产生与心输出量有关的值。显示器耦合到分析模块并显示与心输出量有关的值。