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(54) **MODULAR PATIENT MONITOR**

(57) The present invention relates to a modular patient monitor comprising: a patient monitor in communication with a first and a docking base, the patient monitor, the first display, and the docking base configured to provide patient monitoring functionality with respect to a first set of physiological parameters; and a handheld monitor configured to communicate with the patient monitor via the docking base, the handheld monitor having a second display, the handheld monitor configured to provide patient monitoring functionality with respect to a second set of physiological parameters; wherein when the handheld monitor is in communication with the patient monitor, the first display and the second display are visible simultaneously, the first display and the second display displaying at least some measurements of the first set of parameters and at least some measurements of the second set of parameters, wherein the at least some measurements comprise at least one of a waveform and a numerical value; characterized in that the at least some measurements of either or both of the first set of parameters and the second set of parameters are spanned across the first display and the second display.

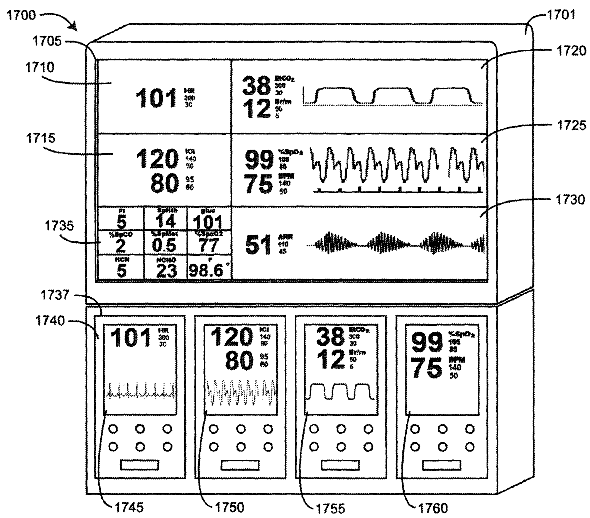

FIG. 17

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Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of pending Application 11/903,746, filed September 24, 2007, entitled Modular Patient Monitor, which claims the benefit under 35 U.S.C. of §119(e) of U.S. Provisional Application No. 60/846,471, filed Sept. 22, 2006, entitled Modular Patient Monitor, the disclosures of which are hereby incorporated by reference in their entirety.

BACKGROUND OF THE INVENTION

[0002] Pulse oximetry is a widely accepted continuous and non-invasive method of measuring the level of arterial oxygen saturation in blood. A typical pulse oximetry system has a sensor, a patient monitor and a patient cable. The sensor is placed on a patient fleshy tissue site, usually on the fingertip for adults and the hand or foot for neonates and connected to the patient monitor via the patient cable. The sensor provides a sensor signal detected from the patient tissue site to the patient monitor. The patient monitor displays the calculated data as a percentage value for arterial oxygen saturation (SpO2), as a pulse rate (PR) and as a pulse waveform (plethysmograph or "pleth").

SUMMARY OF THE INVENTION

[0003] A modular patient monitor provides a multipurpose, scalable solution for various patient monitoring applications. In an embodiment, a modular patient monitor utilizes multiple wavelength optical sensor and acoustic sensor technologies to provide blood constituent monitoring and acoustic respiration monitoring (ARM) at its core, including pulse oximetry parameters and additional blood parameter measurements such as carboxyhemoglobin (HbCO) and methemoglobin (HbMet). Pulse oximetry monitors and sensors are described in U.S. Pat. No. 5,782,757 entitled Low-Noise Optical Probes and U.S. Pat. No. 5,632,272 entitled Signal Processing Apparatus, both incorporated by reference herein. Advanced blood parameter monitors and sensors providing blood parameter measurements in addition to pulse oximetry are described in U.S. Pat. App. No. 11/367,013, filed 03/01/2006 entitled Multiple Wavelength Sensor Emitters and U.S. Pat. App. No. 11/367,014, filed 03/01/2006 entitled Non-Invasive Multi-Parameter Monitor, both incorporated by reference herein. Acoustic respiration sensors and monitors are described in U.S. Pat. No. 6,661,161 entitled Piezoelectric Biological Sound Monitor with Printed Circuit Board and U.S. Pat. App. No. 11/547,570 filed 06/19/2007 entitled Non-Invasive Monitoring of Respiration Rate, Heart Rate and Apnea, both incorporated by reference herein.

[0004] Expansion modules provide blood pressure BP, blood glucose, ECG, CO2, depth of sedation and cerebral oximetry to name a few. The modular patient monitor is advantageously scalable in features and cost from a base unit to a high-end unit with the ability to measure multiple parameters from a variety of sensors. In an embodiment, the modular patient monitor incorporates advanced communication features that allow interfacing with other patient monitors and medical devices.

[0005] The modular patient monitor is adapted for use in hospital, sub-acute and general floor standalone, multi-parameter measurement applications by physicians, respiratory therapists, registered nurses and other trained clinical caregivers. It can be used in the hospital to interface with central monitoring and remote alarm systems. It also can be used to obtain routine vital signs and advanced diagnostic clinical information and as an in-house transport system with flexibility and portability for patient ambulation. Further uses for the modular patient monitor are clinical research and other data collection.

[0006] The following aspects are preferred embodiments of the invention.

1. A modular patient monitor comprising:

    a docking station in communication with a first display and a handheld port, the docking station configured to provide patient monitoring functionality with respect to a first set of physiological parameters; and
    a handheld monitor removably attachable both mechanically and electrically to the docking station via the handheld port, the handheld having a second display, the handheld monitor configured to provide patient monitoring functionality with respect to a second set of physiological parameters,
    wherein when the handheld monitor is docked, the first display and the second display are visible simultaneously, the first display and the second display displaying at least some measurements of the first set of parameters and at least some measurements of the second set of parameters.

2. The modular patient monitor according to aspect 1 wherein at least one measurement displayed on the first display mirrors a measurement on the second display.
3. The modular patient monitor according to aspect 1 wherein at least one measurement displayed on the first display or second display is unique to that respective display.
4. The modular patient monitor according to aspect 1 wherein the first set of physiological parameters and the second set of physiological parameters at least partially overlap.
5. The modular patient monitor according to aspect 1 wherein the first set of physiological parameters are different from the second set of physiological pa-

rameters.

6. The modular patient monitor according to aspect 1 wherein the measurements comprise at least one of a waveform and a numerical value.

7. The modular patient monitor according to aspect 1 wherein the handheld port is integrated to the docking station.

8. The modular patient monitor according to aspect 1 wherein the handheld port is integrated to a docking base connected to the docking station.

9. The modular patient monitor according to claim 8 wherein the docking base is connected to the docking station through a communication medium.

10. The modular patient monitor according to aspect 1 wherein:

> the first set of physiological parameters is blood constituent related; and
> the second set of physiological parameters parameter is non-blood related.

11. The modular patient monitor according to aspect 1 further comprising:

> a second handheld monitor including a third display, the handheld monitor configured to provide patient monitoring functionality with respect to a third set of physiological parameters,
> wherein when the second handheld monitor is docked, the third display is viewable simultaneously with the first display and the second display, the three displays displaying at least some measurements of the first, second, and third set of parameters.

12. A method for displaying measurements of physiological parameters on a display, the method comprising:

> receiving patient data on a docking station in communication with a first display;
> determining a first set of measurements to display with respect to at least a first parameter of the patient data;
> receiving at least a second set of measurements of a second parameter from a handheld monitor having a display when the handheld monitor is docked to the docking station;
> displaying at least the first set and second set of measurements on the docking station display and the handheld monitor display,
> wherein the handheld monitor display and the first display are simultaneously viewable when the handheld monitor is docked.

13. The method according to aspect 12, wherein the first set or the second set of measurements comprises at least one of a waveform and a numerical value.

14. The method according to aspect 12, wherein the fist or second set of measurements is at least partially displayed simultaneously on the docked handheld monitor display and the first display.

15. The method according to aspect 12, wherein at least a portion of the first or second set of measurements is displayed uniquely on the docked handheld monitor display or the first display.

16. A modular patient monitor comprising:

> a handheld monitor removably connectable electrically to a docking station, the handheld monitor configured to provide patient monitoring functionality with respect to at least a first physiological parameter;
> a data input on the handheld monitor, the data input configured to receive patient data associated with at least a second physiological parameter over a communication medium,
> wherein the handheld monitor is configured to use the patient data associated with the second physiological parameters to improve patient monitoring functionality with respect to the first physiological parameter.

17. The modular patient monitor according to aspect 16 wherein the improved patient monitoring functionality comprises at least one of an improved sensor calibration, a validation of the first physiological parameter, a weighted measurement of the first physiological parameter, and a time-lapse measurement of the first physiological parameter.

18. The modular patient monitor according to aspect 16 wherein the monitoring device comprises at least one of a docking station and a second handheld monitor.

19. The modular patient monitor according to aspect 16 wherein the communication medium comprises at least one of a wireless signal and a data cable.

20. A method for improving patient monitoring functionality in a modular patient monitor comprising:

> monitoring at least a first physiological parameters of a patient;
> receiving patient data associated with a second physiological parameter of the patient; and
> improving the monitoring of the first physiological parameter by using the patient data associated with a second physiological parameter.

21. The method according to aspect 20 wherein improving the monitoring comprises at least one of improving sensor calibration, validating the first physiological parameter, weighting the first physiological parameter, and determining a time-lapse measurement of the first physiological parameter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007]

FIGS. 1A-E are top, side, front, right and back views of a modular patient monitor;

FIGS. 2A-B are front and perspective views of a handheld monitor;

FIG. 3 is a docking station multiple parameter display;

FIG. 4 is an illustration of a modular patient monitor having 90 degree rotation with corresponding display rotation;

FIGS. 5A-C are top, front and side views of a monitor cartridge;

FIGS. 6A-E are top, side, front, right and back views of another modular patient monitor embodiment having alternative cartridge embodiments;

FIGS. 7A-C are top, front and side views of an alternative cartridge embodiment;

FIGS. 8A-E are a front and various back views of yet another modular patient monitor embodiment having a shuttle, including a display and control; a docked shuttle; a docked shuttle with an undocked handheld; an undocked shuttle; and a shuttle having a handheld;

FIG. 9 is a modular patient monitor side view of a further modular patient monitor embodiment having a shuttle without a docking handheld;

FIGS. 10A-C are side views and a back view, respectively, of an additional modular patient monitor embodiment having dual dockable handhelds;

FIGS. 11A-C are illustrations of a tablet-configured handheld monitor;

FIGS. 12A-D are front perspective, top, front and side views of an alternative handheld embodiment;

FIGS. 13A-B are front perspective views of an alternative handheld embodiment plugged into, and removed from, a charger;

FIG. 14 is a perspective view of upgrade and legacy handhelds installable into a legacy docking station directly or via a docking station adapter;

FIGS. 15A-B are closed and opened views, respectively, of a notebook-style modular patient monitor embodiment having a foldable display;

FIG. 16 is a perspective view of a flat panel display docking station;

FIG. 17 illustrates a perspective view of a modular patient monitor embodiment having a docking station for handheld monitors;

FIG. 18 illustrates a perspective view of another embodiment of a modular patient monitor having a docking station.

FIG. 19 illustrates a perspective view of an embodiment of a modular patient monitor having an external, attachable docking base;

FIG. 20 illustrates a front view of an embodiment of a patient monitor having docking ports for parameter cartridges.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0008] **FIGS. 1A-E** illustrate a modular patient monitor embodiment **100** having a two-piece modular configuration, a handheld **200** unit and a configurable docking station **101.** The handheld **200** docks into a handheld port **110** of the docking station **101,** providing the modular patient monitor **100** with two-in-one functionality. In particular, the handheld **200** provides a specific set of clinically relevant parameters. The docking station **101** supports various parameters that are configured to specific hospital environments and/or patient populations including general floor, OR, ICU, ER, NICU, to name a few. Further, the docking station **101** has module ports **120** that accept plug-in expansion modules **500** for additional parameters and technologies. The handheld **200** docked into the docking station **101** allows access to all available parameters providing maximum connectivity, functionality and a larger color display **300.** The modular patient monitor **100** provides standalone multi-parameter applications, and the handheld **200** is detachable to provide portability for patient ambulation and in-house transport.

[0009] As shown in **FIGS. 1A-E**, the docking station **101** has a dashboard 130, with a trim knob **140** and buttons **150** so as to support system navigation and data entry. The trim knob **140** is a primary means for system navigation and data entry with an option of a keyboard and mouse as a secondary means.

[0010] The docking station **101** also has a power supply module **160** and connectivity ports **170.** The handheld **200** mechanically attaches to and electrically connects to the docking station **101** when docked, such that the two devices function as one unit and both the handheld display **210** and the docking station display **300** provide user information. In an embodiment, the handheld **200** docks on a docking station side such that the handheld display **210** is visible from that side of the docking station **101 (FIG. 1D).** In addition, the docking station **101** has one or more module slots **120** that accommodate external modules **400,** as described with respect to **FIGS. 5A-C**, below.

[0011] Also shown in **FIGS. 1A-E**, controls of the docking station **101** take precedence over those of the handheld **200** when docked. However, the handheld buttons **220** also work for back up purposes. In an embodiment, buttons **150, 220** on the docking station dashboard **130** and on the handheld **200** provide for alarm suspend/silence and mode/enter. The trim knob **140** is the primary method to toggle thru screen menus on the dashboard **130.** The procedure includes next, up, down or across page navigation, parameter selection and entry, data entry, alarm limit selection and selection of probe-off detection sensitivity. As a secondary control method, the modular patient monitor **100** has a port for an external keyboard for patient context entry and to navigate the menu.

In an embodiment, the docking station **150** has a touch screen. In an embodiment, the modular patient monitor **100** has a bar code scanner module adapted to automatically enter patient context data.

[0012] The modular patient monitor **100** includes an integral handle for ease of carrying and dead space for storage for items such as sensors, reusable cables, ICI cable and cuff, $EtCO_2$ hardware and tubing, temperature disposables, acoustic respiratory sensors, power cords and other accessories such as ECG leads, BP cuffs, temperature probes and respiration tapes to name a few. The monitor **100** can operate on AC power or battery power. The modular patient monitor **100** stands upright on a flat surface and allows for flexible mounting such as to an anesthesia machine, bedside table and computer on wheels.

[0013] FIGS. 2A-B illustrate a handheld monitor **200,** which provides pulse oximetry parameters including oxygen saturation (SpO_2), pulse rate (PR), perfusion index (PI), signal quality (SiQ) and a pulse waveform (pleth), among others. In an embodiment, the handheld **200** also provides measurements of other blood constituent parameters that can be derived from a multiple wavelength optical sensor, such as carboxyhemoglobin (HbCO) and methemoglobin (HbMet). The handheld **200** has a color display **210,** user interface buttons **220,** an optical sensor port **230** and speaker **240.** The handheld **200** also has external I/O such as a bar code reader and bedside printer connectivity. The handheld **200** also has a flexible architecture, power and memory headroom to display additional parameters, such as Sp_vO_2, blood glucose, lactate to name a few, derived from other noninvasive sensors such as acoustic, fetal oximetry, blood pressure and ECG sensors to name a few. In an embodiment, the handheld unit **200** has an active matrix (TFT) color display **210,** an optional wireless module, an optional interactive touch-screen with on-screen keyboard and a high quality audio system. In another embodiment, the handheld **200** is a Radical® or Radical-7™ available from Masimo Corporation, Irvine CA, which provides Masimo SET® and Masimo Rainbow™ parameters. A color LCD screen handheld user interface is described in U.S. Provisional Patent Application No. 60/846,472 titled Patient Monitor or User Interface, filed 9/22/2006 and U.S. App. No. 11/904,046 titled Patient Monitor User Interface, filed 9/24/2007, both applications incorporated by reference herein.

[0014] FIG. 3 illustrates a modular patient monitor color display **300.** The modular patient monitor display **300** auto-scales its presentation of parameter information based upon the parameters that are active. Fewer parameters result in the display **300** of larger digits and more waveform cycles. In an embodiment, the display **300** has a main menu screen showing date and time **302,** patient data **304,** battery life and alarm indicators **306** and all enabled parameters **308.** Date and time **302** can be enabled or disabled. The display **300** may also have dynamic bar graphs or indicators to show perfusion index and signal quality. Waveforms are displayed for SpO_2, NIBP (non-invasive blood pressure), $EtCO_2$ (end-tidal carbon dioxide) and ECG (electrocardiogram) if enabled. Trend waveforms are displayed for parameters that are less dynamic, such as HbCO and HbMet. Further, the display **300** has individual text displays for alarms, alarm suspend, sensor off or no sensor, battery condition, sensitivity, trauma mode, AC power, printer function, recording function, connectivity messages and menus to name a few. Pulse search is indicated by blinking dashes in the pulse and parameter displays. In an embodiment, the color display **300** is an 11.1" LCD with allowance for the use of a 10.4" LCD within the standard mechanical design for the 11.1" display. The docking station 101 also supports any external VGA display.

[0015] An exemplar color print illustration of the color display **300** is disclosed in U.S. Provisional Application No. 60/846,471 entitled Modular Patient Monitor, cited above. In particular, each of the displayed parameters are variously presented in one of a off-white to white shade, lime green to green shade, crimson to red shade, generally turquoise shade, generally chartreuse shade, yellow to gold shade, generally blue and generally purple shade, to name a few.

[0016] FIG. 4 illustrates a modular patient monitor **100** having a vertical orientation **401** and a horizontal orientation **403.** In the vertical orientation **401,** the display **300** presents data in a vertical format, such as shown in **FIG. 3,** above. In the horizontal orientation **403,** the display **300** presents data in a horizontal format, so that the data appears upright with respect to the viewer. That is, the display 300 automatically switches format according to the patient monitor **100** orientation. A patient monitor having a rotatable display format is described in U.S. Pat. No. 6,770,028 entitled Dual Mode Pulse Oximeter and incorporated by reference herein.

[0017] FIGS. 5A-C illustrate an expansion module **500,** which the docking station **101 (FIGS. 1A-E)** accepts for additional parameters and technologies, such as ICI-NIBP, glucose monitoring, ECG, $EtCO_2$, conscious sedation monitoring, cerebral oximetry, anesthetic agent monitoring, lactate, patient body temperature and assay cartridges, to name a few. The expansion module **500** has an indicator **510** indicating parameters to be provided. In one embodiment, the expansion module **500** provides two parameters to the docking station, which is adapted to accept two modules **500** for four additional parameters. In an embodiment, an ECG module is used to provide an R-wave trigger for ICI-NIBP.

[0018] As shown in **FIGS. 1A-E**, the modular patient monitor **100** includes various connectivity ports **170** such as Ethernet, USB, RS-232, RS-423, nurse call, external VGA and I/O ports for a keyboard and a bar code reader to name a few. As an option, the modular patient monitor **100** has on-board and bedside recorder capability. The modular patient monitor **100** also supports multiple wireless and hardwired communication platforms, web server technology that allows remote viewing of data as well as limited bi-directional control of module functionality and an optional wireless connectivity standards base technology, such as IEEE **802**.11x. The wireless option is provided in the handheld **200** and the docking station **101.** A wireless module supports the downloading and temporary storage of upgrade software from a remote central server to a destination docking station or a specific module. In an embodiment, the modular patient monitor **100** supports patient context management, specifically the ability to upload or alternatively enter patient unique identification. The modular patient monitor **100** also connects both wired and wirelessly to other patient monitors.

[0019] The modular patient monitor **100** may be logged onto via the Internet so as to download raw waveforms and stored trending data for both customer service purposes and for data mining to enhance algorithms and so as to be uploaded with firmware updates. The modular patient monitor **100** may also incorporate removable storage media for the same purpose. In an embodiment, removable storage media functions as a black box, which is a diagnostic tool to retrieve device use information. In particular, the black box can record values displayed, raw waveforms including sounds, and buttons touched by the end user. A patient monitor with removable storage media is described in U.S. Pat. No. 10/983,048 entitled Pulse Oximetry Data Capture System filed 11/05/2004 and incorporated by reference herein.

[0020] The modular patient monitor **100** may also have an audio module slot (not shown) accommodating an external audio system and wireless headphone module. In an embodiment, the docking station **101** audio system is configured to reproduce respiratory sounds from an ARR (acoustic respiratory rate) sensor.

[0021] In an embodiment, the modular patient monitor **100** has a redundant speaker system for alarms. The modular patient monitor **100** may also include alarms for all parameters and a parameter fusion alarm that involves analysis of multiple parameters in parallel. A user can select custom default alarm parameters for adult, pediatric and neonatal patients. A patient monitor having redundant alarm speakers is described in U.S. Pat. App. No. 11/546,927 entitled Robust Alarm System, filed 10/12/2006 and incorporated by reference herein.

[0022] An alarm condition exists for low battery, sensor-off patient, defective sensor, ambient light, parameter limit exceeded and defective speakers, as examples. Audible alarm volume is adjustable and when muted, a visual indicator is illuminated. In an embodiment, the volume is adjustable in at least of four discrete steps. The parameter display flashes to indicate which values are exceeding alarm limits, the parameter is enlarged automatically, and numerics are displayed in either RED or with a RED background. The audible alarm is silenceable with a default alarm silence period for up to two minutes. This delay can be user configurable. Separate from sleep mode, the audible alarms are permanently mutable via a password-protected sub-menu. The visual alarm indicator still flashes to indicate an alarm condition. A visual indicator on the dashboard indicates an alarm silence condition, such as blinking for temporary silence and solid for muted. An alarm speaker is mounted so as not to be susceptible to muffling from a bed surface, attached external monitor surface or other type of flat resting surface. Redundant and smart alarm annunciation is also provided.

[0023] The user accesses the setup menu via a front dashboard knob **140** and mode/enter button **150. TABLE 1** shows user settable parameters. The user can override default settings on a patient-by-patient basis via setup menus.

TABLE 1

PARAMETER SETTINGS
SpO_2 high & low limit
Pulse Rate high & low limit
Pulse Tone volume
MetHb high and low limit
HbCO high & low limit
ICI high and low limit
tHb high and low limit
$EtCO_2$ high and low limit
ARR high and low limit
Temp high and low limit
Glucose high and low limit
Audible alarm volume

[0024] Default settings are stored in non-volatile memory (NVM). There is a factory, hospital and user default setting which may be automatically based on patient recognition. The user can choose any of the three at any time. The user may over-write hospital and user default settings with their own preferences via a password protected "save as default" setup menu function. All parameters return to hospital default settings after a power cycle.

[0025] In one embodiment, the default settings are as shown in **TABLE 2,** stored in NVM. These settings are also over-written into NVM as a result of a factory reset or return to factory defaults function from within the setup menus.

TABLE 2

PARAMETER	FACTORY DEFAULT
SpO_2 high limit	Off
SpO_2 low limit	90
Pulse Rate high limit	140
Pulse Rate low limit	40

(continued)

PARAMETER	FACTORY DEFAULT
Alarm Volume	2 (of 4)
Pulse tone volume	2 (of 4)
MetHb high limit	5%
MetHb low limit	Off
HbCO high limit	10%
HbCO low limit	Off
LCD brightness	3 (of 5)

[0026] **FIGS. 6A-E** illustrate another modular patient monitor **600** embodiment having a docking station **601,** a handheld monitor **602** and parameter cartridges **700.** Each cartridge **700** provides one parameter to the docking station **601,** which accepts four cartridges **700** for a total of four additional parameters. Further, the patient monitor **600** also has a cord management channel **630,** an oral temperature probe **660** and probe covers **670** located on the docking station **601.** The docking station **601** has a trim knob **652** and control buttons **654** on a front stand **653** so as to support system navigation and data entry. The docking station **601** also has a color display **605,** a thermal printer **620,** an alarm indicator light bar **651,** a thermal printer paper door **657** and a handle **659,** a sensor holder **655,** connectivity ports **680** and a power supply module **690. FIGS. 7A-C** illustrate a parameter cartridge **700** having an indicator **710** indicating the parameter or technology provided.

[0027] **FIGS. 8A-D** illustrate a three-piece modular patient monitor **800** including a handheld monitor **810,** a shuttle station **830** and a docking station **850.** The docking station **850** has a shuttle port **855** that allows the shuttle station **830** to dock. The shuttle station **830** has a handheld port **835** that allows the handheld monitor **810** to dock. Accordingly, the modular patient monitor **800** has three-in-one functionality including a handheld **810,** a handheld **810** docked into a shuttle station **830** as a handheld/shuttle **840** and a handheld/shuttle **840** docked into a docking station **850.** When docked, the three modules of handheld **810,** shuttle **830** and docking station **850** function as one unit.

[0028] As shown in **FIGS. 8A-D**, the handheld module **810** functions independently from the shuttle **830** and docking station **850** and is used as an ultralight weight transport device with its own battery power. The handheld **810** docked into the shuttle module **830** functions independently of the docking station **850** and expands the handheld parameter capability to the ability to measure all parameters available. The docking station **850,** in turn, provides the shuttle **830** or handheld/shuttle **840** with connectivity ports **852,** a power supply module **854,** a large color display **856,** wireless and hardwired communications platforms, a web server and an optional printer. As such, the docking station **850** charges the handheld **810** and shuttle **830,** provides a larger screen and controls, such as a trim knob, allows wireless, hardwired and Internet communications and provides connectivity to various external devices. **FIG. 8E** illustrates another modular patient monitor embodiment **805** having a shuttle **870** with plug-in modules **860** for expanded parameter functionality.

[0029] In an embodiment, the handheld monitor **810** incorporates blood parameter measurement technologies including HbCO, HbMet, SpO_2 and Hbt, and the shuttle station **830** incorporates non-blood parameters, such as intelligent cuff inflation (ICI), end-tidal CO_2 ($EtCO_2$), acoustic respiration rate (ARR), patient body temperature (Temp) and ECG, to name a few. In an alternative embodiment, parameters such as SpO_2, ARR and ECG that clinicians need during in-house transports or patient ambulation are loaded into the handheld **810.**

[0030] **FIG. 9** illustrates a two-piece modular patient monitor **900** having a shuttle **930** and a docking station **950** without a corresponding handheld. In an embodiment, the shuttle **930** has plug-in modules **960** for added parameter functions.

[0031] **FIGS. 10A-C** illustrate yet another modular patient monitor **1000** embodiment having dual removable handhelds **1010** and a docking station **1050** without a corresponding shuttle. For example, the handhelds **1010** may include one blood parameter monitor and one non-blood parameter monitor.

[0032] **FIGS. 11A-C** illustrate a handheld tablet monitor **1100** having a display **1110,** a trim knob **1120** and control buttons **1130.** An electroluminescent lamp **1140** on the front panel provides a thin uniform lighting with low power consumption. A temperature probe **1150** is attached to the monitor **1100.** The tablet monitor **1100** connects to a multiple parameter sensor through a patient cable **1160. FIGS. 12-13** illustrate a handheld monitor **1200** configured to plug into a compact holder/battery charger **1300.** The handheld monitor **1200** is adapted to plug into the compact charger **1300.**

[0033] **FIG. 14** illustrates a modular patient monitor **1400** embodiment having various handheld monitors **1410,** a docking station adapter **1430** and a legacy docking station **1450.** The handheld monitors **1410** can include legacy handhelds **1411** and upgrade handhelds **1412.** The docking station adapter **1430** is configured for the legacy docking station **1450** so that both legacy handhelds **1411** and upgrade handhelds **1412** can dock into the legacy docking station 1450 directly or via the docking station adapter **1430.**

[0034] **FIGS. 15A-B** illustrate a "notebook" modular patient monitor **1500** embodiment having a foldable lid **1510,** a fixed body **1530** and a foldable docking station **1550.** The fixed body **1530** houses patient monitor electronics and provides external device connectivity at a back end (not visible). The lid **1510** has a notebook display **1511,** such as a color LCD. The docking station **1550** has a port **1551** that removably connects, both mechanically and electrically, a corresponding handheld monitor **1590,** such as the handheld embodiments described above. In a closed position **(FIG. 15A),** the notebook monitor **1500** can be carried via an optional handle or simply in hand or under an arm. In an open position **(FIG. 15B),** the notebook monitor is operational, connecting to patient sensors via the handheld **1590** or a sensor connector (not shown) on the back end of the notebook. In the open position, the docking station **1550** can stay in a stowed or folded position (not shown) so that the handheld screen **1591** faces upward. Alternatively, in the open position, the docking station **1550** is unfolded as shown **(FIG. 15B)** so that the handheld display **1591** can be easily viewed from the front of the notebook in conjunction with the notebook display **1511** in the lid **1510.** In an embodiment, the notebook **1500** can have a conventional keyboard and touch pad, have conventional monitor controls, incorporate a conventional computer and peripherals or a combination of the above. As shown, the notebook display **1511** faces inward, so that the display **1511** is protected in the folded position. In another embodiment, the display **1511** faces outward (not shown).

[0035] **FIG. 16** illustrates a flat panel modular patient monitor embodiment 1600 having a flat panel body **1610** housing a flat panel display **1611** and a handheld port **1620.** The handheld port **1620** removably accepts a handheld monitor **1690** having a handheld display **1691,** such as the handheld monitors described above. The flat panel monitor **1600** can be free-standing on a table top, wall-mounted or mounted on or integrated within a patient bed, as a few examples. The flat panel monitor **1600** can be simply a docking and display device or can provide built-in patient monitoring functions and parameters not available to the handheld **1690.**

[0036] **FIG. 17** illustrates a perspective view of a modular patient monitor **1700** embodiment having a docking station **1701** for handheld or portable monitors. The docking station includes a display 1705 for displaying one or more physiological parameters **1710, 1715, 1720, 1725, 1730, 1735.** The docking station further includes one or more docking ports **1737** for receiving one or more handheld monitors **1740** having a display. In the illustrated embodiment, the modular patient monitor includes four docking ports integrated into the docking station for receiving handheld monitors. In some embodiments, the docking ports can be positioned on the docking station such that the docking station display and the handheld monitor displays are viewable at the same time. Typically, the docking station display will be several times larger than a handheld monitor display. Measurements of a physiological parameter can be spanned across the docking station display and the handheld monitor displays **1745, 1750, 1755, 1760.**

[0037] In some embodiments, the display **1705** or additional displays can be physically separate from the docking station **1701.** In such embodiments, the separate display is in communication with the docking station, either wirelessly or through a wire. In one embodiment, multiple displays can be in communication with the docking station simultaneously, allowing measurements of physical parameters to be spanned across multiple docking station displays and multiple handheld monitors.

[0038] In one embodiment, the docking station **1701** can have its own stand-alone patient monitoring functionality, such as for pulse oximetry, and can operate without an attached handheld monitor. The docking station receives patient data and determines measurements to display for a monitored physiological parameter.

[0039] One or more of handheld monitors **1740** can be docked to the docking station **1701.** A handheld monitor **1740** can operate independently of the docking station. In some embodiments, a particular handheld monitor can be configured to receive patient data and determine measurement to display for a particular physiological parameter, such as, for example, blood pressure, other blood parameters, ECG, and/or respiration. In one embodiment, the handheld monitor can operate as a portable monitor, particularly where only some parameters need to be measured. For example, the handheld monitor, while providing patient monitoring, can travel with a patient being moved from one hospital room to another or can be used with a patient travelling by ambulance. Once the patient reaches his destination, the handheld monitor can be docked to a docking station at the destination for expanded monitoring.

[0040] In some embodiments, when a handheld monitor **1740** is docked to the docking station **1701,** additional parameters can become available for display on the docking station display **1705.** The docking station **1701** can auto-scale existing measurements on the display to make room for measurements of the additional parameters. In one embodiment, a user can select which measurements to display, drop, and/or span using the controls on the patient monitor **1700.** In some embodiments, the patient monitor can have an algorithm for selecting measurements to display, drop, and/or span, such as by ranking of measurements, display templates, and/or settings. In one embodiment, the additional parameters can be removed from the docking station display when the handheld monitor associated with the parameters is undocked from the docking station.

[0041] In order to expand display space on the docking station display **1705,** measurements can be spanned across the docking station display **1705** and the handheld monitor displays **1745, 1750, 1755, 1760.** In one embodiment, the measurements can be spanned by displaying a partial set of the measurements on the docking station and additional measurements on the portable monitor. For example, portions of the docking station display **1710, 1715** can show some measurements of a parameter, such as a numerical value, while the handheld monitor display **1745, 1750** shows additional measurements, such as the numerical value and an associated waveform. By keeping the additional measurements on a particular handheld monitor, such as heart rate waveform on a heart monitor, the measurements can be more easily recognizable to a caregiver, increasing monitoring efficiency and expanding the display area.

[0042] Alternatively, measurements can be spanned by mirroring on the docking station display **1705** a handheld monitor display. For example, portions of the docking station display **1720** can display all the measurements on a handheld monitor display **1755,** such as a numerical value and a waveform.

[0043] In one embodiment, the spanning feature can take advantage of the docking station display's **1705** greater size relative to the handheld monitor displays to display additional measurements and/or to display a measurement in greater detail. For example, portions of the docking display **1725** can display numerical values and a waveform while a handheld monitor display **1760** shows only a numerical value. In another example, the docking station can display a waveform measured over a longer time period than a waveform displayed on the handheld monitor, providing greater detail.

[0044] In some embodiments, the portable monitor **1740** displays a set of measurements when operating independently (e.g. a numerical value and a waveform), but only a partial set of the measurement when docked to the docking station (e.g. numerical value), thereby freeing up display space on the handheld monitor's display for additional uses, such as, for example, increasing the size of the measurements displayed or displaying other parameters. The remaining measurements (e.g. waveform) can be displayed on the docking station display **1705.** A measurement can be uniquely displayed either on the docking station display or on the handheld monitor display. The additional display space can be used for enlarging the partial measurement (e.g. numerical value) on the portable monitor to increase readability, showing the partial measurement in greater detail, and/or displaying an additional measurement.

[0045] **FIG. 18** illustrates a perspective view of another embodiment of a modular patient monitor **1800** having a docking station **1801.** In the illustrated embodiment, docking station includes a display **1802** and three docking ports **1805** for receiving three handheld monitors. One handheld monitor **1740** is shown in its independent configuration. The handheld monitor **1740** can mechanically attach to the docking port **1805** and/or electrically attach to the docking station **1801** via an electrical and/or data port **1810.** In one embodiment, patient data, such as measurements of physiological parameters, can be transferred between the docking station and portable monitor through the data port in either direction. In some embodiments, the docking station can provide electrical power to the handheld monitor and/or charge the handheld monitor's battery.

[0046] Data can also be transmitted between individual handheld monitors **1740** through a data connection. The data can be transferred from one monitor through the docking station's data port **1810** to the docking station **1801** and then to another handheld monitors. In one embodiment, a cable can be used to connect an input on one monitor to an output on another monitor, for a direct data connection. Data can also be transmitted through a wireless data connection between the docking station and handheld monitors and/or between individual monitors. In some embodiments, the docking station can further analyze or process received data before transmitting the data. For example, the docking station can analyze data received from one or more monitors and generate a control signal for another monitor. The docking station can also average, weight and/or calibrate data before transmitting the data to a monitor.

[0047] Data from other handheld monitors can be used to improve the measurements taken by a particular monitor. For example, a brain oximetry monitor can receive patient data from a pulse oximetry monitor, or vice versa. Such data can be used to validate or check the accuracy of one reading against another, calibrate a sensor on one monitor with measurements taken from a sensor from another monitor, take a weighted measurement across multiple sensors, and/or measure the time lapse in propagation of changes in a measured physiological parameter from one part of the body to another, in order, for example, to measure circulation. In one example, a monitor can detect if the patient is in a low perfusion state and send a calibration signal to a pulse oximetry monitor in order to enhance the accuracy of the pulse oximetry measurements. In another example, data from a pulse oximetry monitor can be used as a calibration signal to a blood pressure monitor. Methods and systems for using a non-invasive signal from a non-invasive sensor to calibrate a relationship between the non-invasive signal and a property of a physiological parameter are described in U.S. 6,852,083, titled System and Method of Determining Whether to Recalibrate a Blood Pressure Monitor, issued Feb. 8, 2005, incorporated by reference herein in its entirety.

[0048] **FIG. 19** illustrates a perspective view of an embodiment of a modular patient monitor **1900** having a patient monitor **1905** and an external, attachable docking base **1915** having docking ports **1916** for receiving portable monitors **1920, 1925.** In some embodiments, the docking base can have docking ports for any number of portable monitors. The docking base can be connected to the patient monitor through a communication medium, such as wirelessly or through a wire. The docking base can be positioned such that a user can view both the handheld monitor displays and patient monitor display simultaneously. In some embodiments, measurements of physiological parameters can be spanned over the handheld monitor displays and patient monitor display.

[0049] **FIG. 20** illustrates a front view of an embodiment of a patient monitor **2000** having docking ports for parameter cartridges **2010.** The patient monitor can have one or more docking ports for one or more parameter cartridges. In the illustrated embodiment, a parameter cartridge includes a display **2015** for displaying a measurement of the parameter. For example, a temperature cartridge can display the patient's temperature on its own display. In some embodiments, measurements can be spanned across the patient monitor display **2005** and one or more of the cartridge displays **2015.**

[0050] Furthermore, in certain embodiments, the systems and methods described herein can advantageously be implemented using computer software, hardware, firmware, or any combination of software, hardware, and firmware. In one embodiment, the system includes a number of software modules that comprise computer executable code for performing the functions described herein. In certain embodiments, the computer-executable code is executed on one or more general purpose computers or processors. However, a skilled artisan will appreciate, in light of this disclosure, that any module that can be implemented using software can also be implemented using a different combination of hardware, software or firmware. For example, such a module can be implemented completely in hardware using a combination of integrated circuits. Alternatively or additionally, such a module can be implemented completely or partially using specialized computers or processors designed to perform the particular functions described herein rather than by general purpose computers or processors.

[0051] Moreover, certain embodiments of the invention are described with reference to methods, apparatus (systems) and computer program products that can be implemented by computer program instructions. These computer program instructions can be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the acts specified herein to transform data from a first state to a second state.

[0052] Conditional language used herein, such as, among others, "can," "could," "might," "may," "e.g.," and the like, unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain embodiments include, while other embodiments do not include, certain features, elements and/or states. Thus, such conditional language is not generally intended to imply that features, elements and/or states are in any way required for one or more embodiments or that one or more embodiments necessarily include logic for deciding, with or without author input or prompting, whether these features, elements and/or states are included or are to be performed in any particular embodiment.

[0053] A modular patient monitor has been disclosed in detail in connection with various embodiments. These embodiments are disclosed by way of examples only and are not to limit the scope of the claims that follow. One of ordinary skill in art will appreciate many variations and modifications. Indeed, the novel methods and systems described herein can be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the methods and systems described herein can be made without departing from the spirit of the inventions disclosed herein. The claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of certain of the inventions disclosed herein. One of ordinary skill in the art will appreciate the many variations, modifications and combinations. For example, the various embodiments of the patient monitoring system can be used with sensors that can measure any type of physiological parameter. In various embodiments, the displays used can be any type of display, such as LCDs, CRTs, plasma, and/or the like. Further, any number of handheld monitors can be used as part of the patient monitoring system.

Claims

1. A modular patient monitor comprising:

a patient monitor (1905) in communication with a first display (300; 856; 1511; 1611; 1705; 1802; 2005) and a docking base (1915), the patient monitor (1905), the first display (300; 856; 1511; 1611; 1705; 1802; 2005), and the docking base (1915) configured to provide patient monitoring functionality with respect to a first set of physiological parameters; and

a handheld monitor (200; 602; 810; 1200; 1410; 1590; 1690; 1740; 1920; 1925) configured to communicate with the patient monitor (1905) via the docking base (1915), the handheld monitor (200; 602; 810; 1200; 1410; 1590; 1690; 1740; 1920; 1925) having a second display (210; 1591; 1691; 2015), the handheld monitor (200; 602; 810; 1200; 1410; 1590; 1690; 1740; 1920; 1925) configured to provide patient monitoring functionality with respect to a second set of physiological parameters;

wherein when the handheld monitor (200; 602; 810; 1200; 1410; 1590; 1690; 1740; 1920; 1925) is in communication with the patient monitor (1905), the first display (300; 856; 1511; 1611; 1705; 1802; 2005) and the second display (210; 1591; 1691; 2015) are visible simultaneously, the first display (300; 856; 1511; 1611; 1705; 1802; 2005) and the second display (210; 1591; 1691; 2015) displaying at least some measurements of the first set of parameters and at least some measurements of the second set of parameters, wherein the at least some measurements comprise at least one of a waveform and a numerical value; and

wherein a user can select which measurements of either or both of the first set of parameters and the second set of parameters are displayed on or spanned across the first display (300; 856; 1511; 1611; 1705; 1802; 2005) and the second display (210; 1591; 1691; 2015).

2. The modular patient monitor according to claim 1 wherein the handheld monitor (200; 602; 810; 1200; 1410; 1590; 1690; 1740; 1920; 1925) is removably attachable both mechanically and electrically to the docking base (1915).

3. The modular patient monitor according to claim 1 wherein the patient monitor (1905) is in wireless communication with the docking base (1915).

4. The modular patient monitor according to claim 1 wherein at least one measurement displayed on the first display (300; 856; 1511; 1611; 1705; 1802; 2005) mirrors a measurement on the second display (210; 1591; 1691; 2015).

5. The modular patient monitor according to claim 1 wherein at least one measurement displayed on the first display (300; 856; 1511; 1611; 1705; 1802; 2005) or second display (210; 1591; 1691; 2015) is unique to that respective display.

6. The modular patient monitor according to claim 1 wherein the first set of physiological parameters and the second set of physiological parameters at least partially overlap.

7. The modular patient monitor according to claim 1 wherein the first set of physiological parameters are different from the second set of physiological parameters.

8. The modular patient monitor according to claim 1 wherein the docking base (1915) is separate from the patient monitor (1905).

9. The modular patient monitor according to claim 1 wherein:

   the first set of physiological parameters is blood constituent related; and
   the second set of physiological parameters parameter is non-blood related.

10. The modular patient monitor according to claim 1 further comprising:

   a second handheld monitor including a third display, the handheld monitor configured to provide patient monitoring functionality with respect to a third set of physiological parameters;
   wherein when the second handheld monitor is in communication with the patient monitor (1905), the third display is viewable simultaneously with the first display and the second display, the three displays displaying at least some measurements of the first, second, and third set of parameters.

11. The modular patient monitor according to claim 1, further comprising:

   a data input on the handheld monitor (200; 602; 810; 1200; 1410; 1590; 1690; 1740; 1920; 1925), the data input configured to receive a parameter measurement from another monitor over a communication medium;
   wherein the handheld monitor (200; 602; 810; 1200; 1410; 1590; 1690; 1740; 1920; 1925) is configured to provide improved patient monitoring for a first physiological parameter of the second set of physiological parameters based upon the parameter measurement from the other monitor.

12. The modular patient monitor according to claim 11 wherein the improved patient monitoring comprises at least one of an improved sensor calibration, a validation of the first physiological parameter, a weighted measurement of the first physiological parameter, and a time-lapse measurement of the first physiological parameter.

13. A method for displaying measurements of physiological parameters on a display, the method comprising:

   receiving patient data on a patient monitor (1905) in communication with a first display (300; 856; 1511; 1611; 1705; 1802; 2005);
   determining measurements to display with respect to a first set of physiological parameters of the patient data;
   receiving measurements of a second set of physiological parameters from a handheld monitor (200; 602; 810; 1200; 1410; 1590; 1690; 1740; 1920; 1925) having a display (210; 1591; 1691; 2015) when the handheld monitor (200; 602; 810; 1200; 1410; 1590; 1690; 1740; 1920; 1925) is in communication with the patient monitor (1905); and
   displaying at least some measurements of the first set of physiological parameters and at least some measurements of the second set of physiological parameters on the first display (300; 856; 1511; 1611; 1705; 1802; 2005) and the handheld monitor display (210; 1591; 1691; 2015), wherein the at least some measurements comprise at least one of a waveform and a numerical value;
   wherein the handheld monitor display (210; 1591; 1691; 2015) and the first display (300; 856; 1511; 1611; 1705; 1802; 2005) are simultaneously viewable when the handheld monitor

(200; 602; 810; 1200; 1410; 1590; 1690; 1740; 1920; 1925) is in communication with the patient monitor (1905); and
wherein a user can select which measurements of either or both of the first set of physiological parameters and the second set of physiological parameters are displayed on or spanned across the first display (300; 856; 1511; 1611; 1705; 1802; 2005) and the handheld monitor display (210; 1591; 1691; 2015).

14. The method according to claim 13, wherein at least a portion of the at least some measurements of the first set of physiological parameters and the at least some measurements of the second set of physiological parameters is displayed uniquely on the handheld monitor display (210; 1591; 1691; 2015) or the first display (300; 856; 1511; 1611; 1705; 1802; 2005).

15. The method according to claim 13 wherein the docking base (1915) is in wireless communication with the patient monitor (1905).

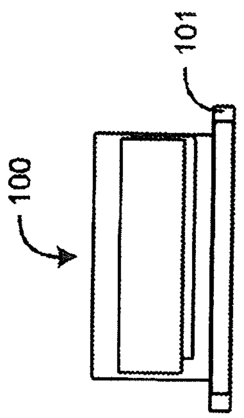

FIG. 1A

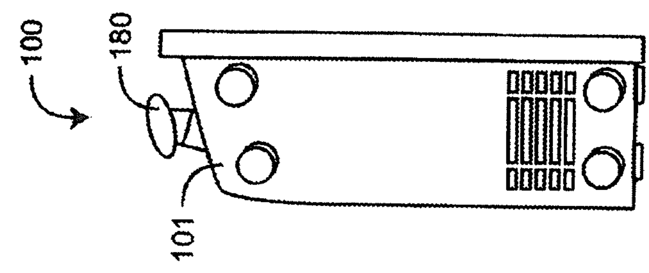

FIG. 1B

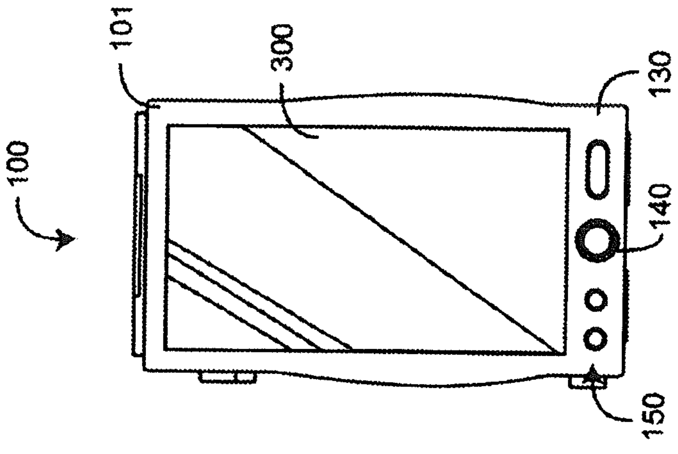

FIG. 1C

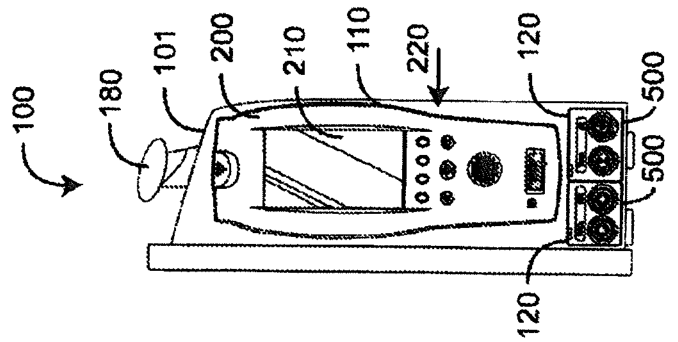

FIG. 1D

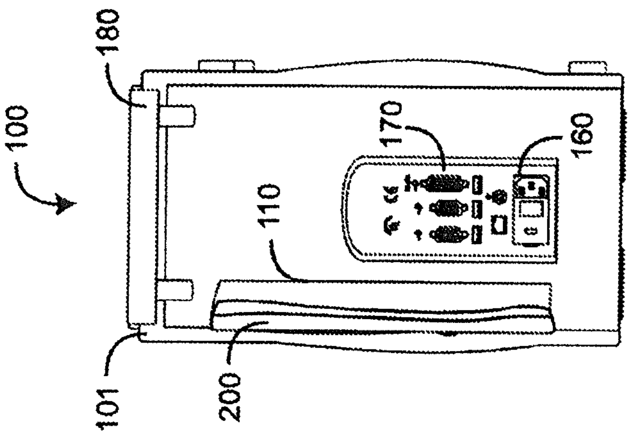

FIG. 1E

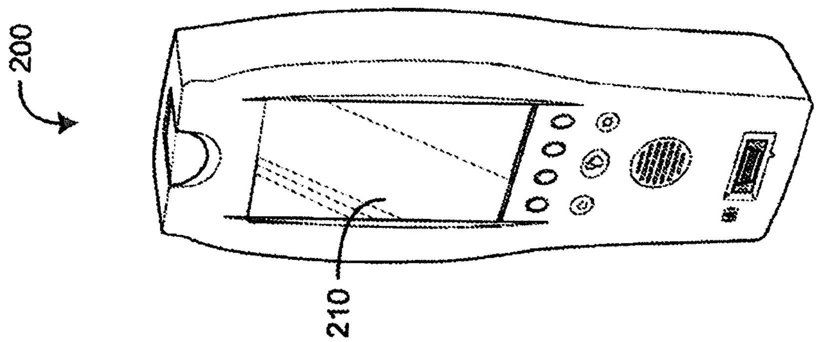

FIG. 2B

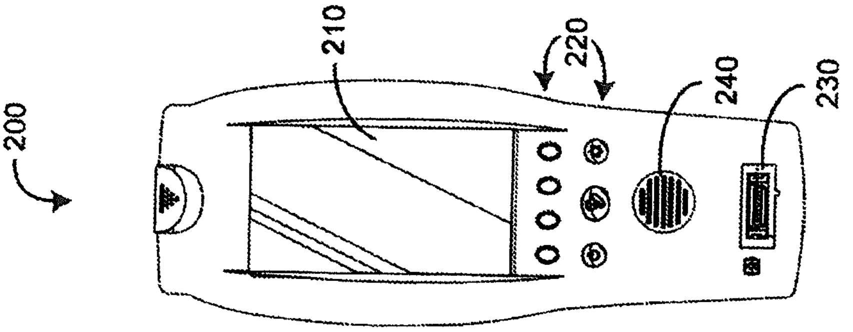

FIG. 2A

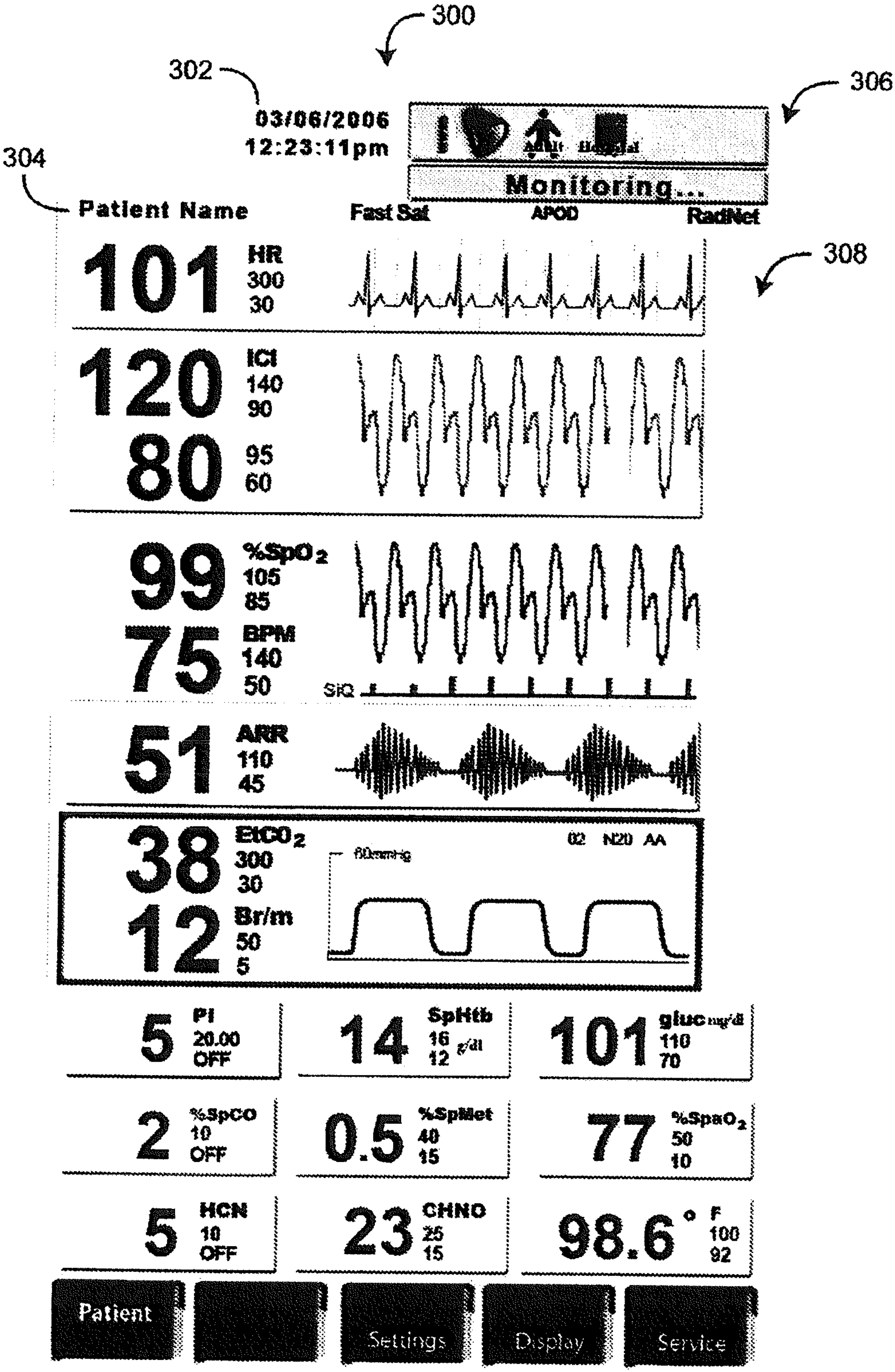
300
302
03/06/2006
12:23:11pm
306
304
Patient Name
Monitoring...
Fast Sat
APOD
RadNet
308
101 HR 300 30
120 ICI 140 90
80 95 60
99 %SpO2 105 85
75 BPM 140 50
SIQ
51 ARR 110 45
38 EtCO2 300 30
12 Br/m 50 5
O2 N20 AA
5 PI 20.00 OFF
14 SpHtb 16 12 g/dl
101 gluc mg/dl 110 70
2 %SpCO 10 OFF
0.5 %SpMet 40 15
77 %SpaO2 50 10
5 HCN 10 OFF
23 CHNO 25 15
98.6 ° F 100 92
Patient
Settings
Display
Service

FIG. 3

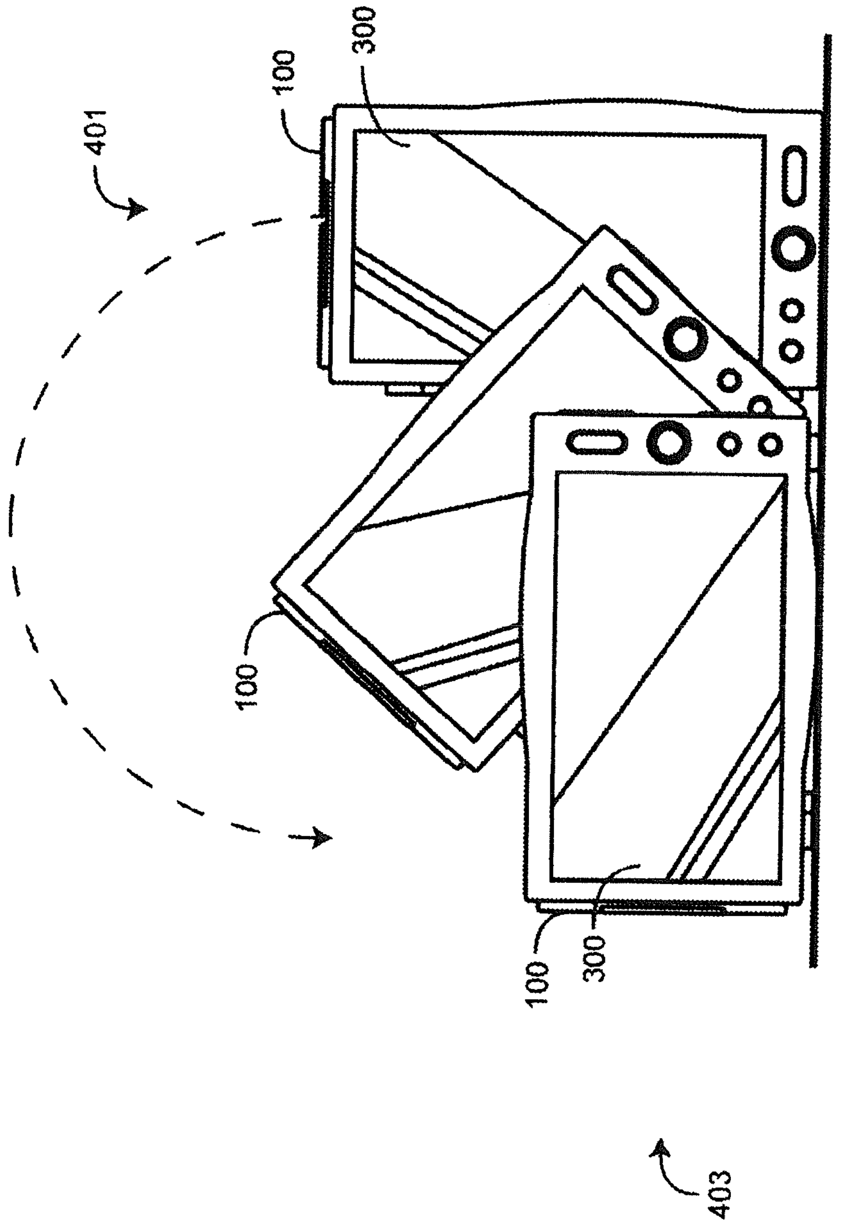

FIG. 4

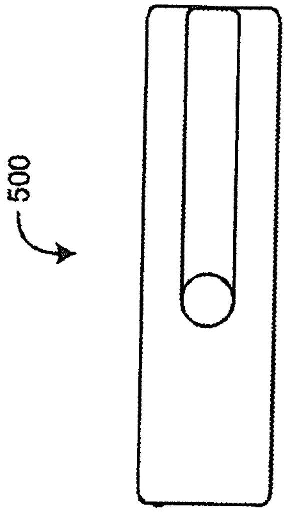

FIG. 5A

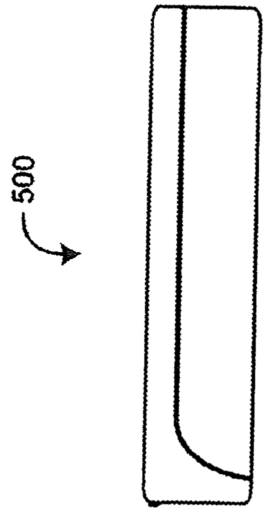

FIG. 5C

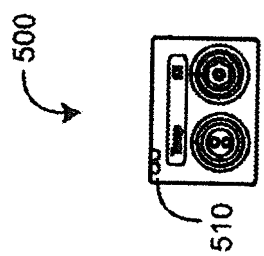

FIG. 5B

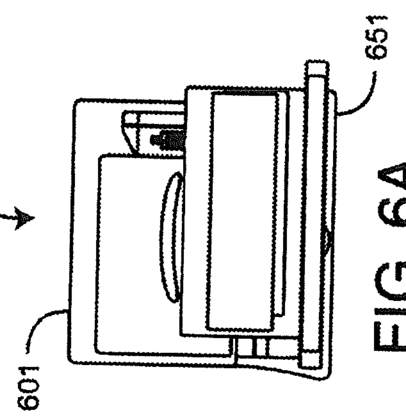

FIG. 6A

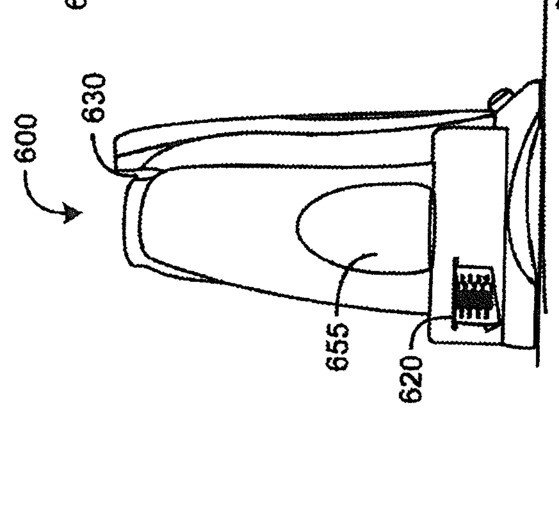

FIG. 6B

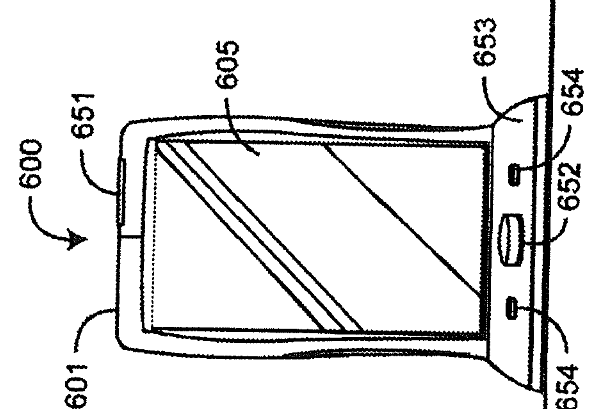

FIG. 6C

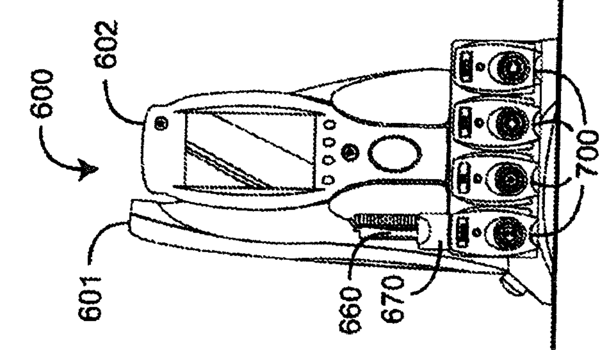

FIG. 6D

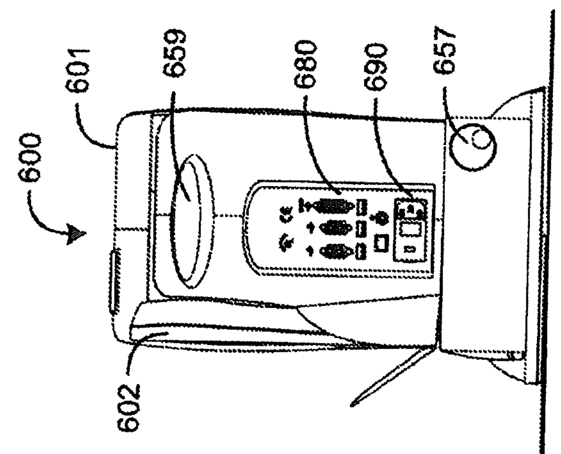

FIG. 6E

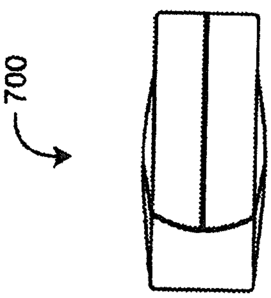

FIG. 7A

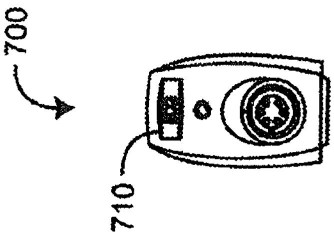

FIG. 7B

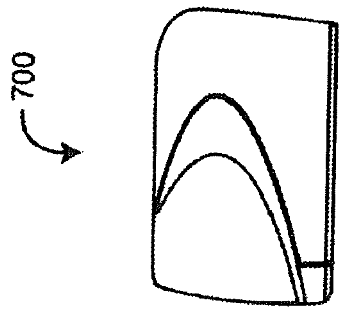

FIG. 7C

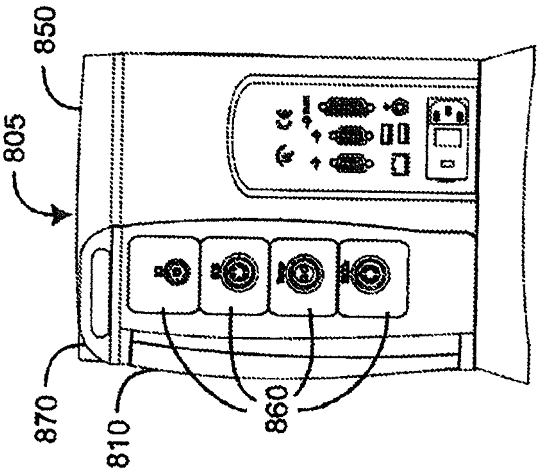

FIG. 8E

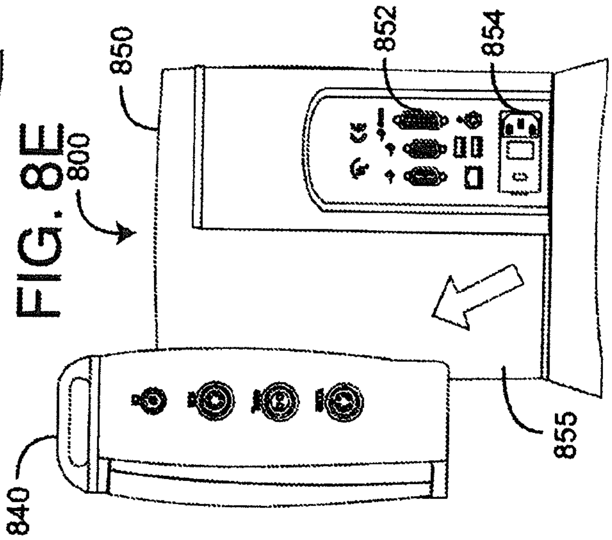

FIG. 8D

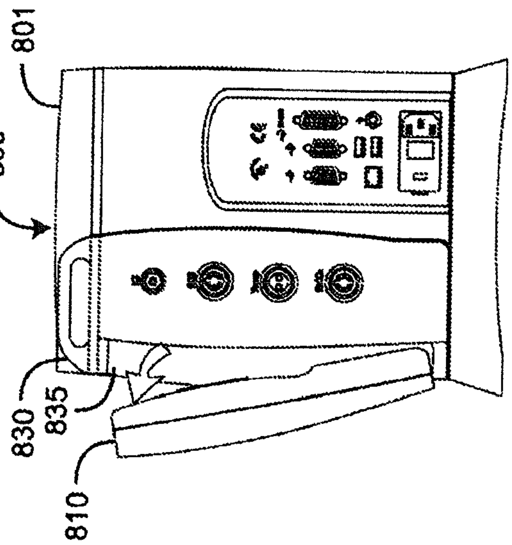

FIG. 8C

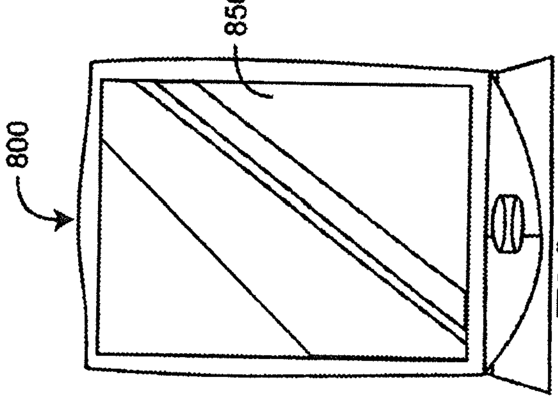

FIG. 8A

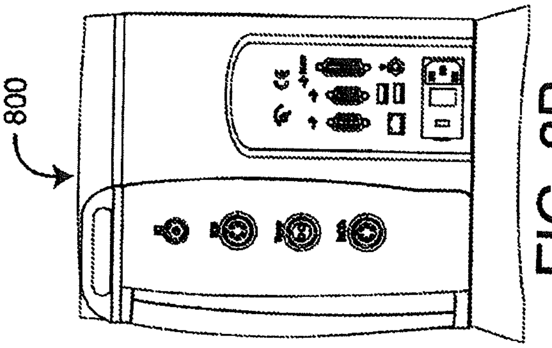

FIG. 8B

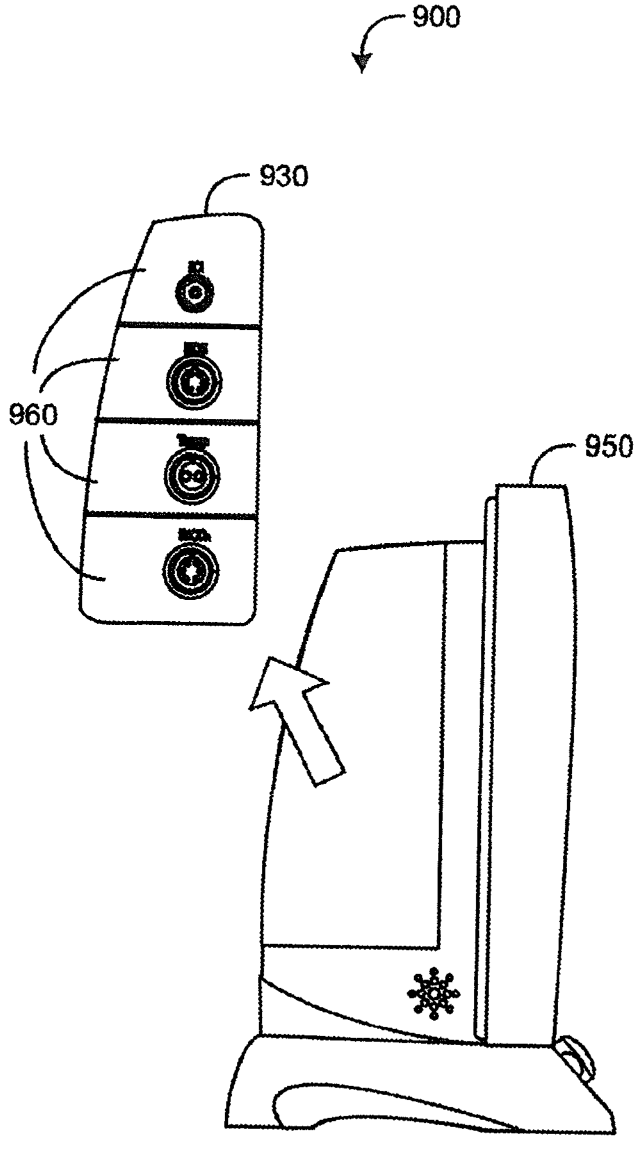

FIG. 9

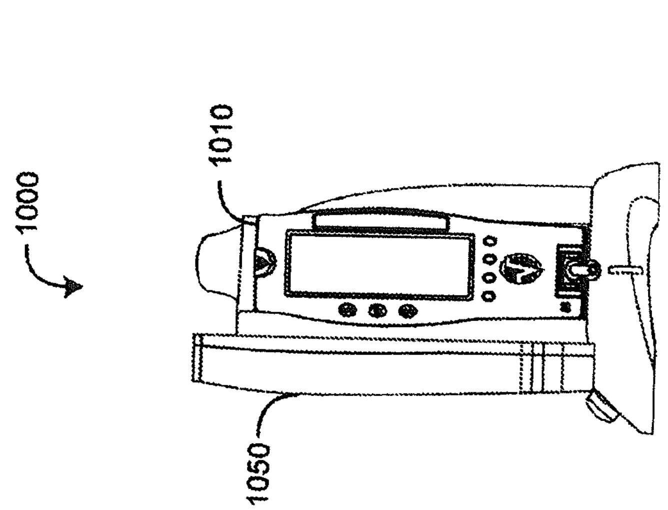

FIG. 10A

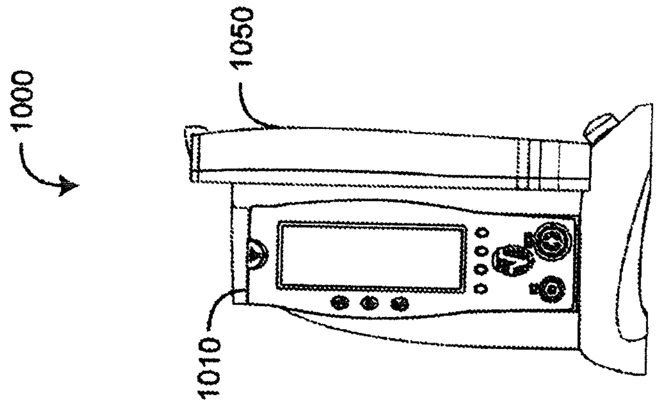

FIG. 10B

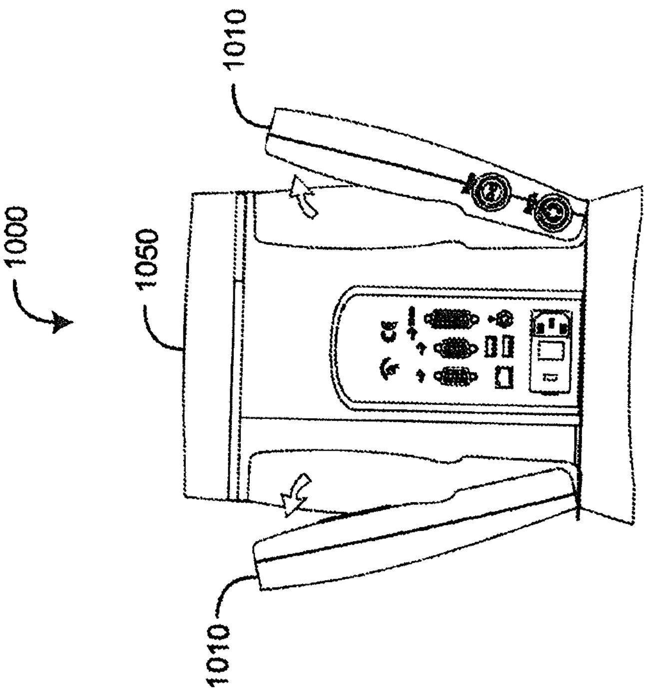

FIG. 10C

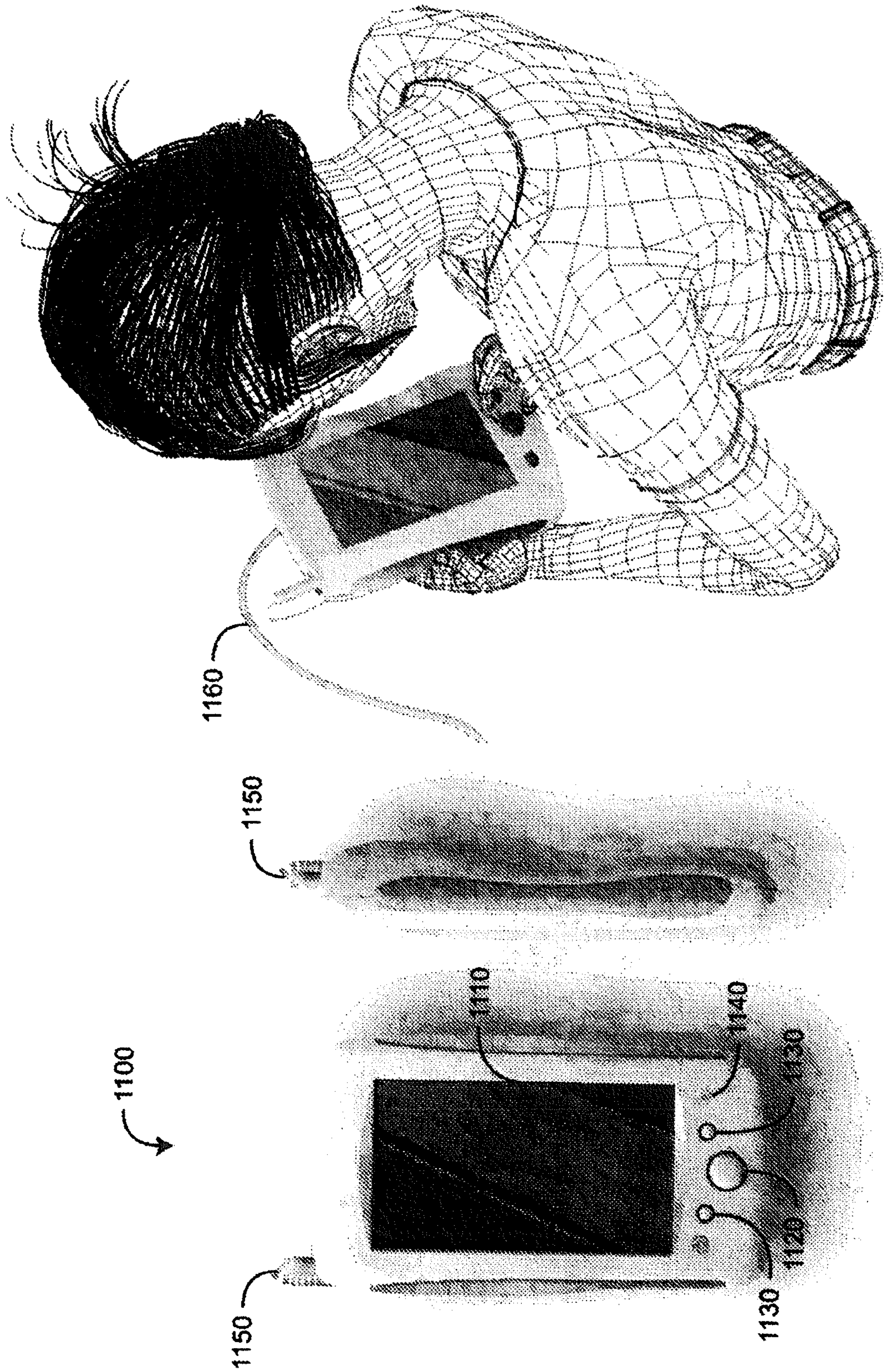

FIG. 11A FIG. 11B FIG. 11C

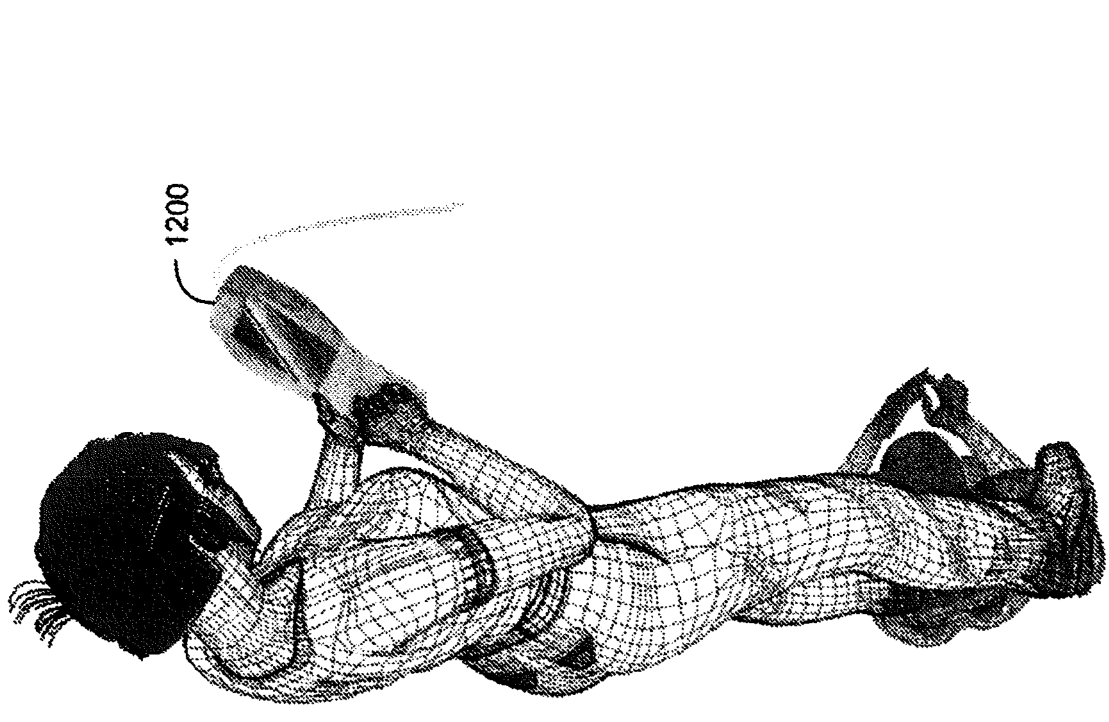

FIG. 12A

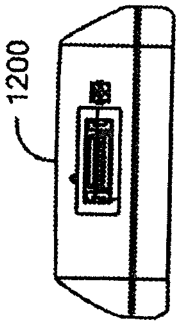

FIG. 12B

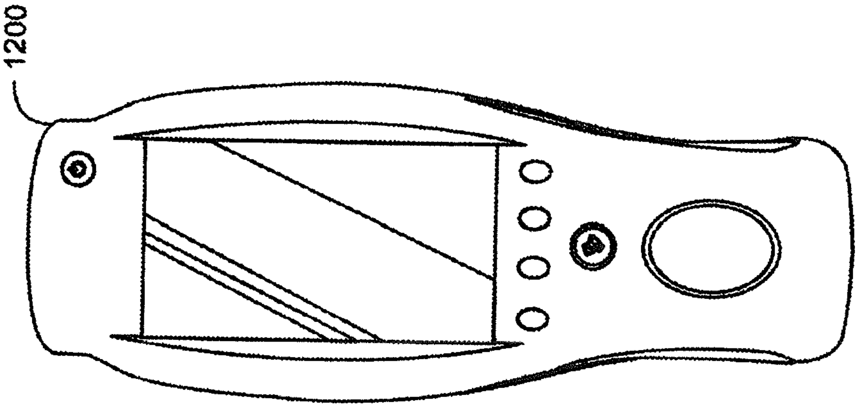

FIG. 12C

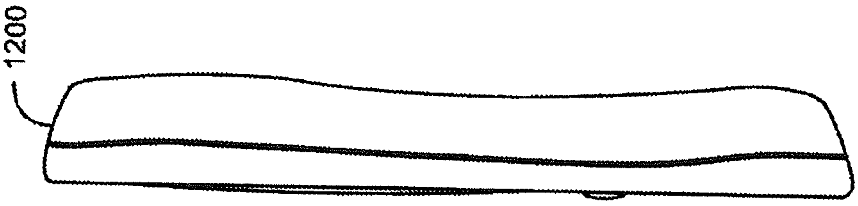

FIG. 12D

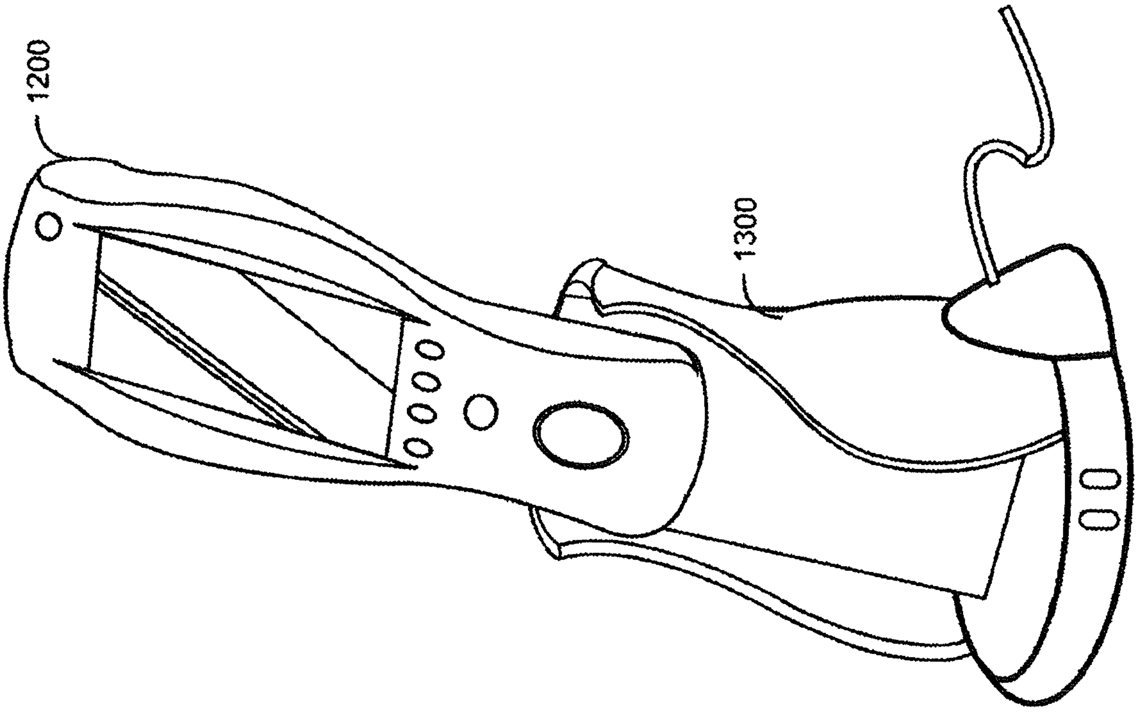

FIG. 13B

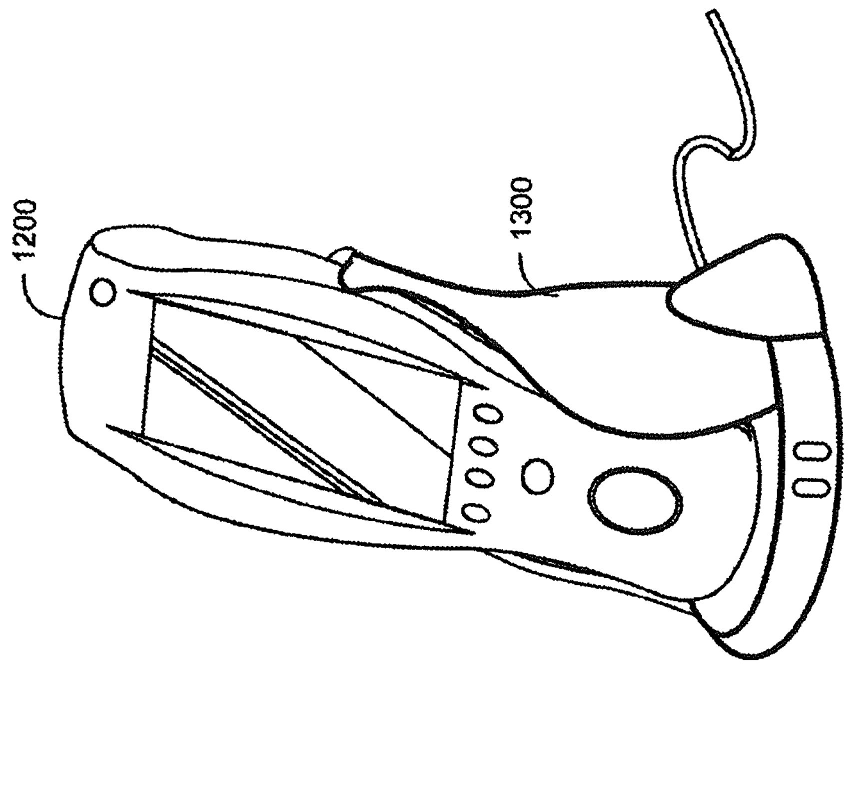

FIG. 13A

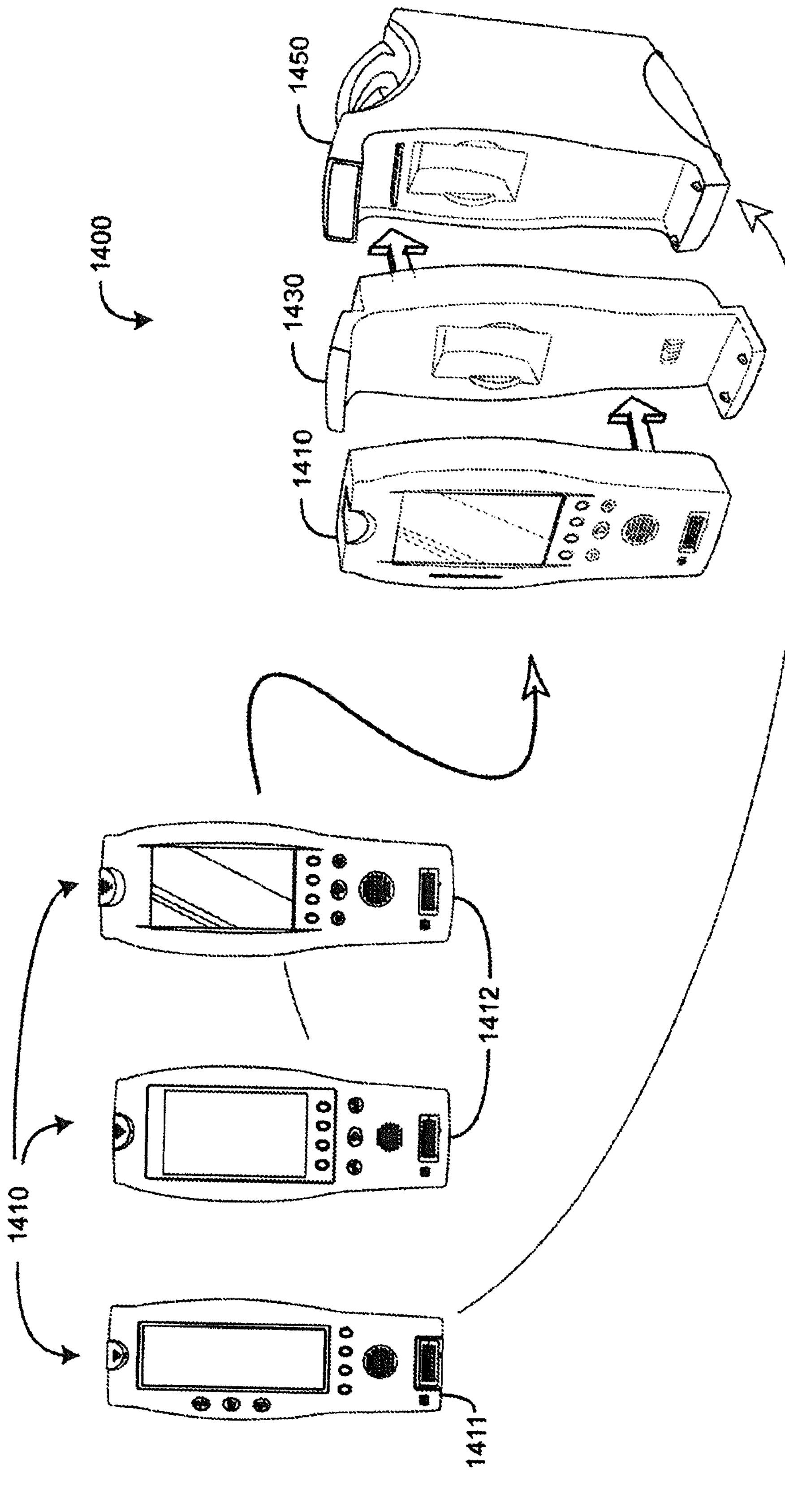

FIG. 14

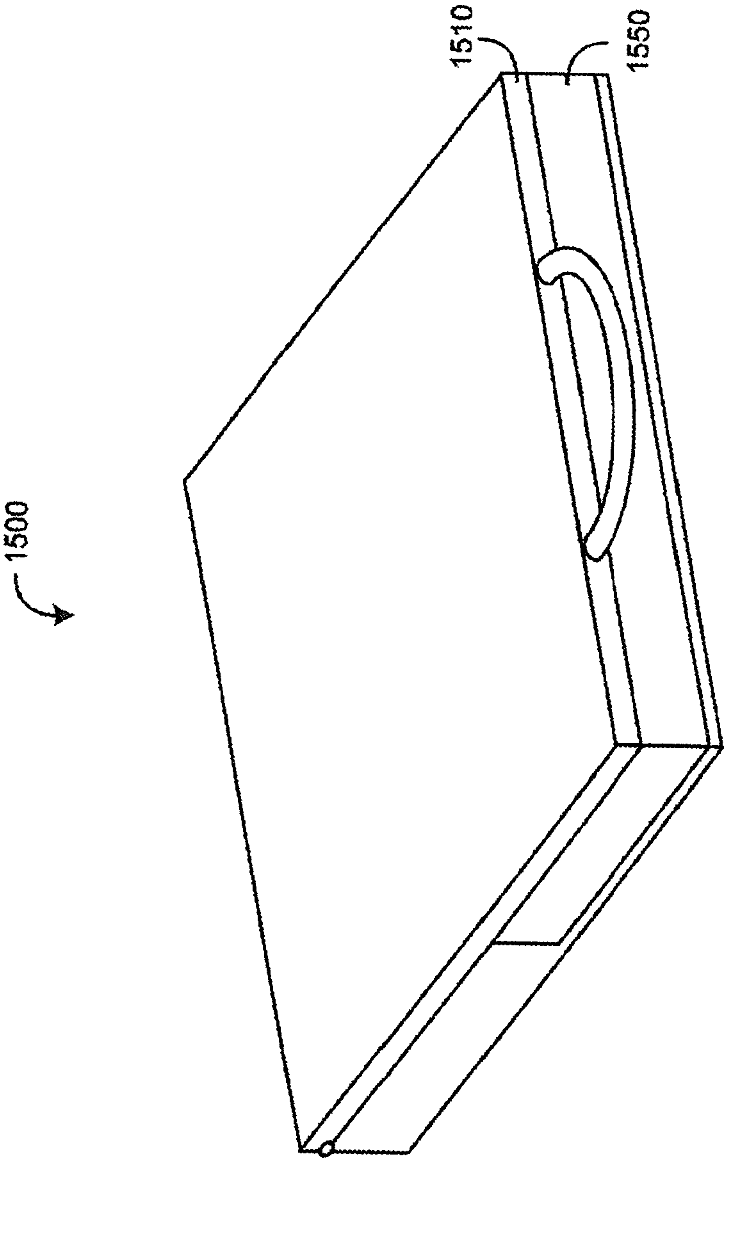

FIG. 15A

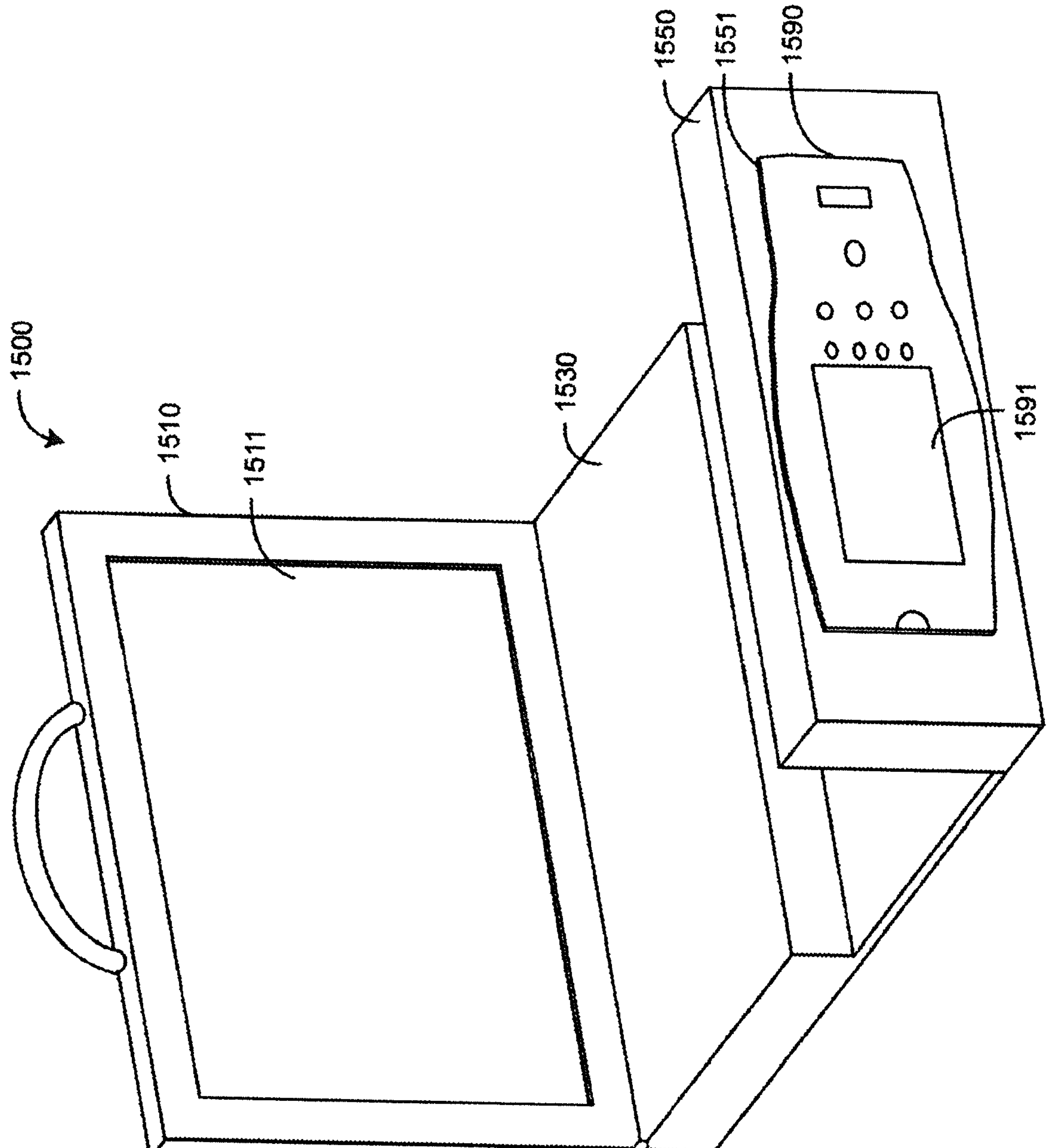

FIG. 15B

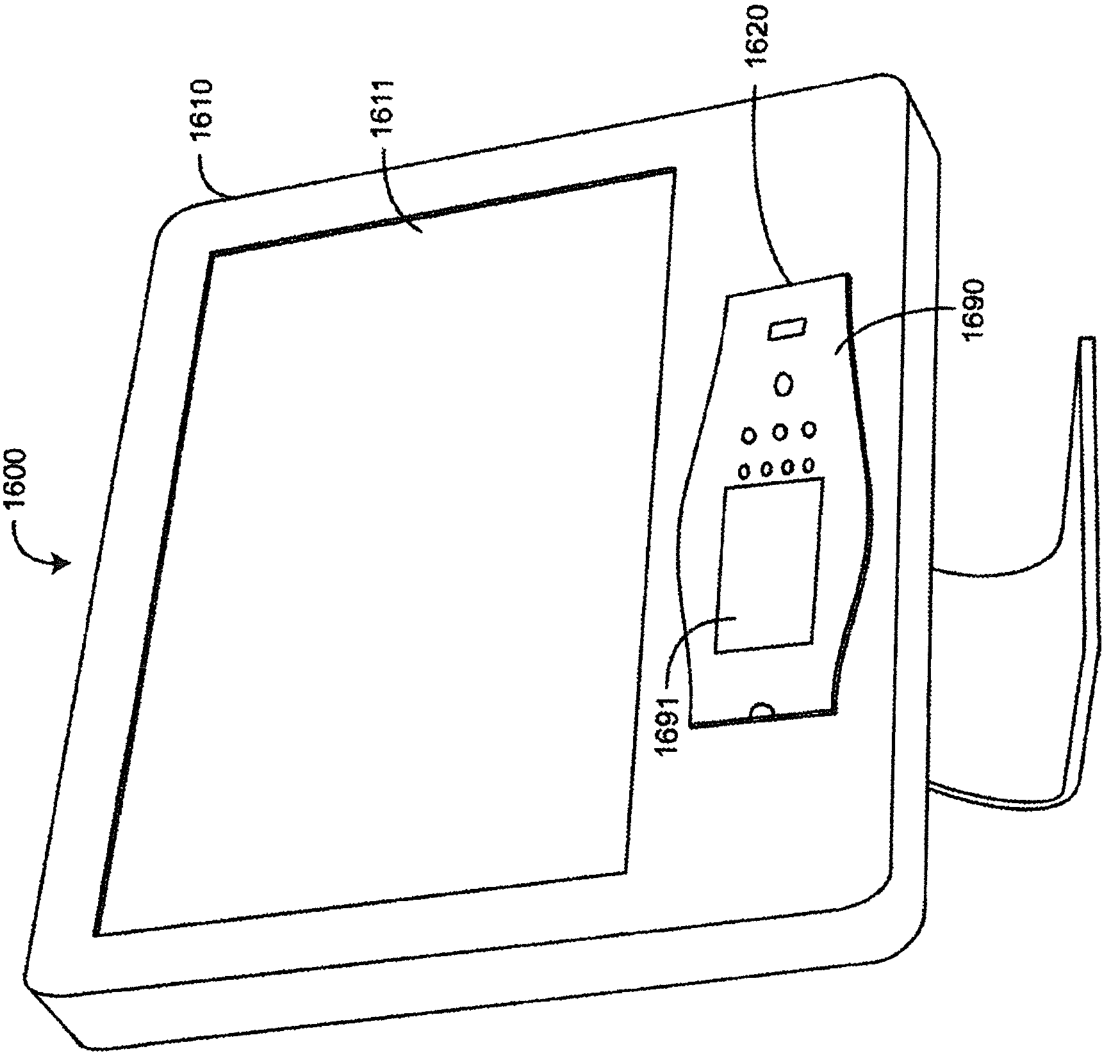

FIG. 16

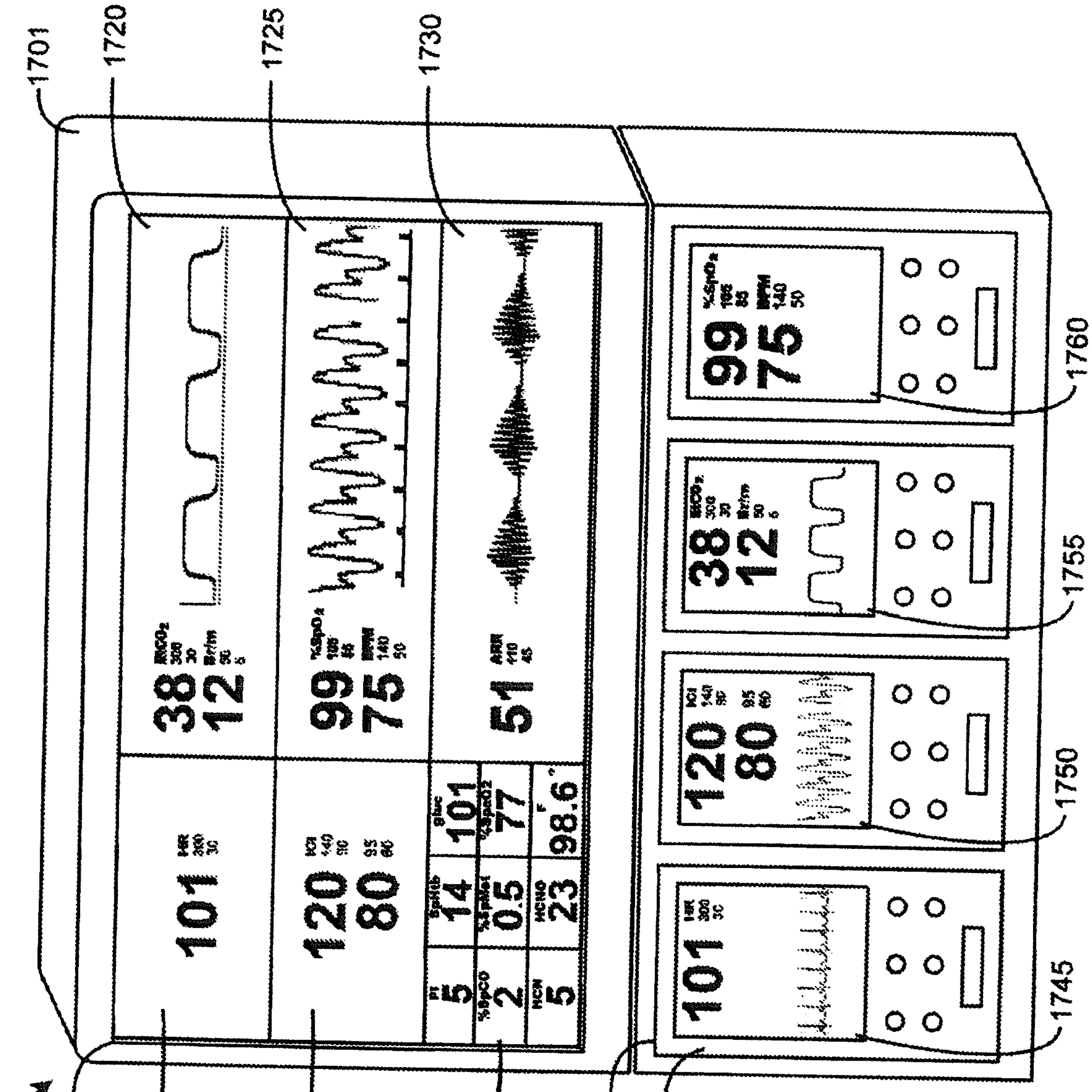
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FIG. 17

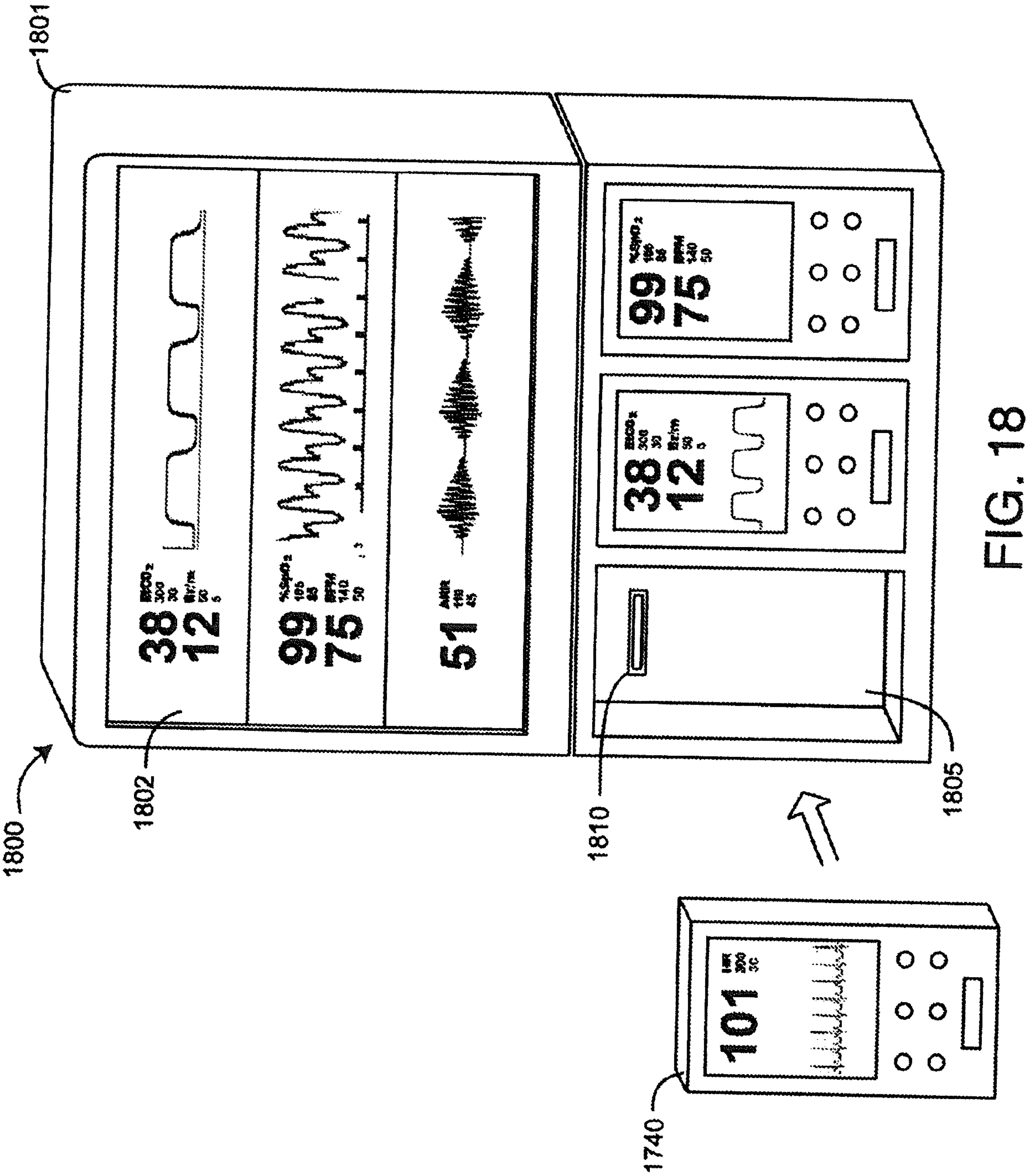

FIG. 18

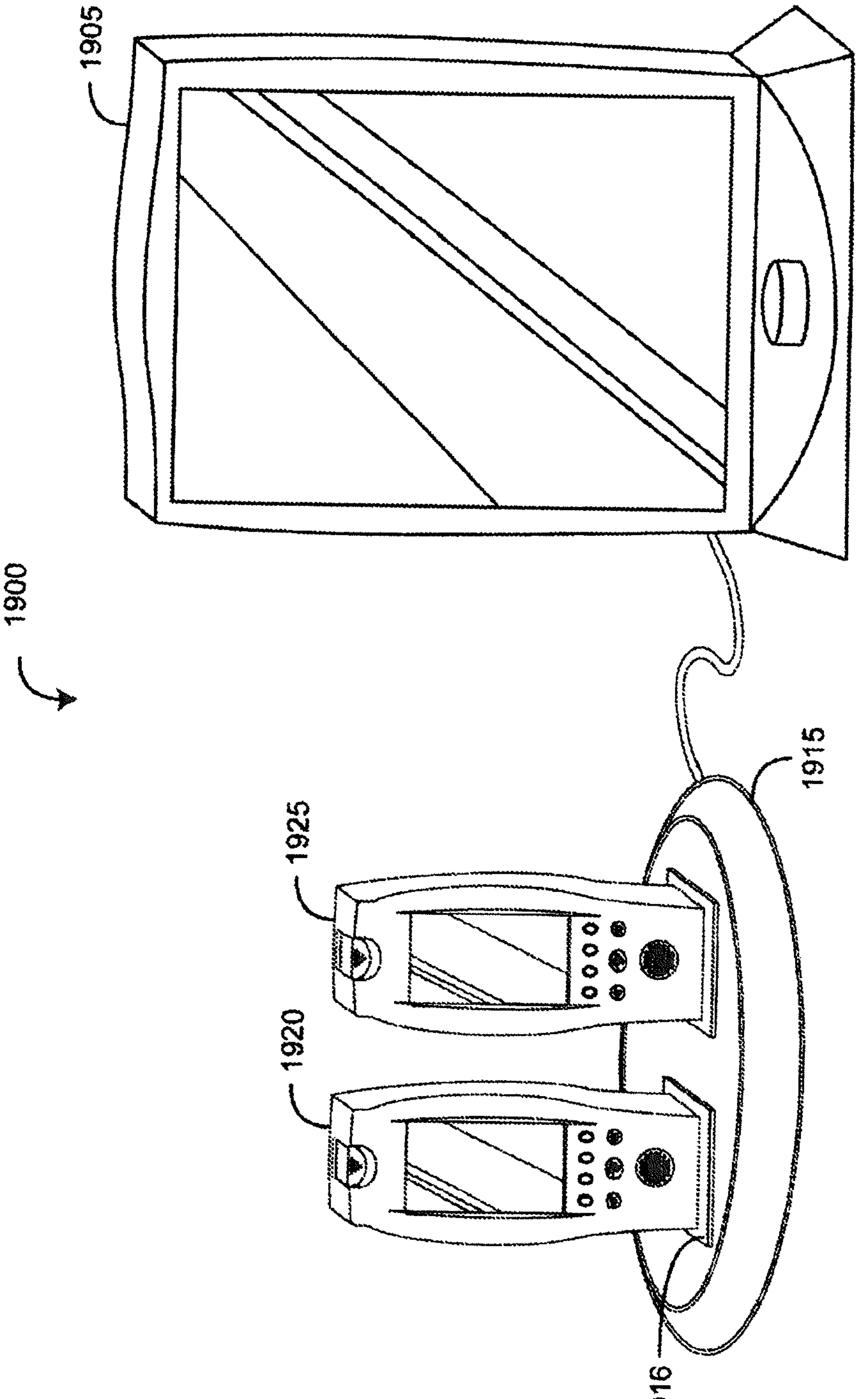

FIG. 19

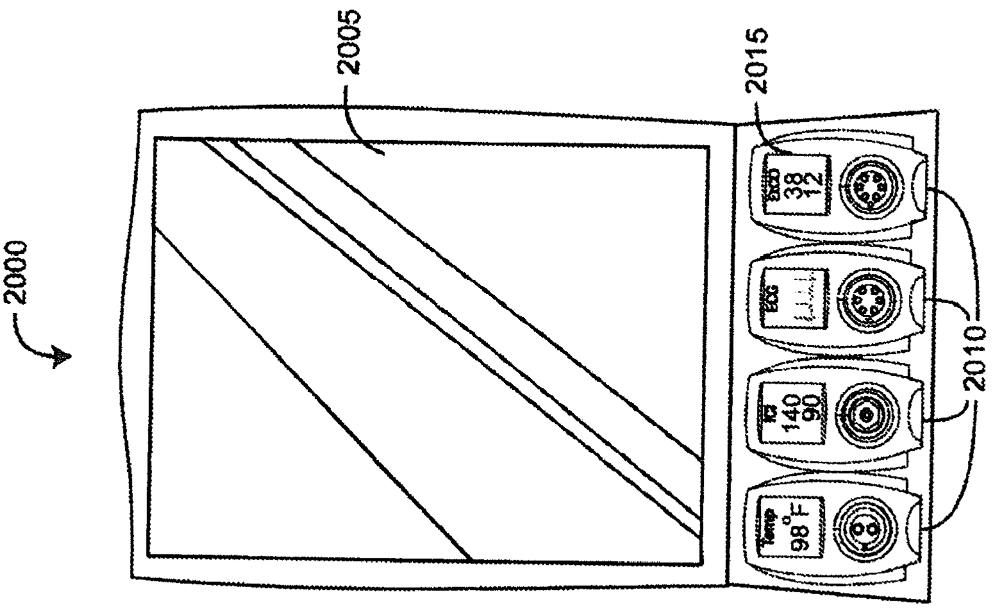

FIG. 20

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EUROPEAN SEARCH REPORT

Application Number
EP 20 19 1704

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 7 530 949 B2 (ALI AMMAR AL [US] ET AL AL ALI AMMAR [US] ET AL) 12 May 2009 (2009-05-12) * column 5, line 39 - column 6, line 40; figures 2-6 * * column 9, lines 1-13 * * column 14, line 60 - column 15, line 2 * * column 15, line 3 - column 17, line 34; figures 11-13 * -----	1,13	INV. A61B5/0205 ADD. A61B5/145
A	US 2009/005651 A1 (WARD SUZANNE MARIE [US] ET AL) 1 January 2009 (2009-01-01) * paragraphs [0024] - [0035] * * paragraphs [0053] - [0055], [0061] - [0062]; figures 1-6 * -----	1,13	
A	US 2008/108884 A1 (KIANI MASSI E [US]) 8 May 2008 (2008-05-08) * the whole document * * paragraphs [0048] - [0049]; claim 4; figures 15a,15b,16 * -----	1,13	

TECHNICAL FIELDS SEARCHED (IPC)

A61B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Berlin	11 November 2020	Kronberger, Raphael

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