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(54) Title: RESCUE PERFORMANCE METRIC

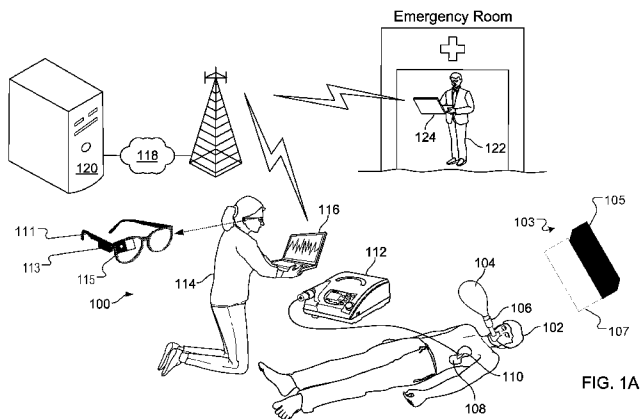


FIG. 1A

(57) Abstract: An external defibrillator system, the system comprising: one or more sensors configured to detect one or more parameters associated with performance of CPR; one or more wearable computing devices configured to provide feedback to a user about CPR performed by the user based on the one or more parameters associated with the performed CPR; and an external defibrillator comprising: a memory configured to store instructions; and a processor to execute the instructions to perform an operation comprising: analyzing the one or more parameters to determine a CPR performance metric indicative of an overall performance of the user.

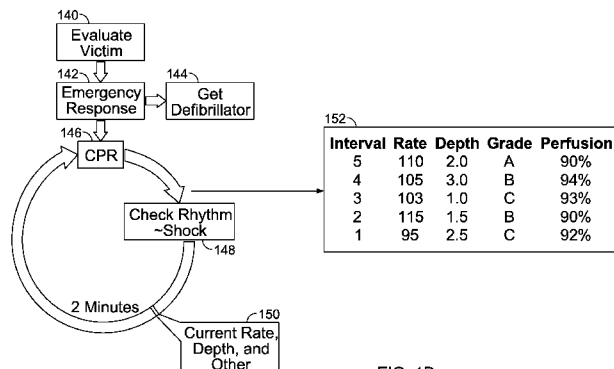


FIG. 1B



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TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU,
TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE,
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Rescue Performance Metric

CLAIM OF PRIORITY

[0001] This application claims priority under 35 USC §119(e) to U.S. Patent Application Serial No. 62/097,296, filed on December 29, 2014, and is a continuation-in-part of and claims priority under 35 USC §120 to U.S. Patent Application Serial No. 13/798,426, filed on March 13, 2013, which claims priority under 35 USC §119(e) to U.S. Patent Application Serial No. 61/643,540, filed on May 7, 2012, the entire contents of all of which are hereby incorporated by reference.

TECHNICAL FIELD

[0002] This document relates to computer-based systems and techniques for analyzing performance of a rescuer in performing CPR and other related lifesaving techniques.

BACKGROUND

[0003] Sudden cardiac arrest (colloquially “heart attack”) is a regular killer. The best treatment for cardiac arrest is quick and competent chest compressions to keep blood flowing through a victim’s heart. Generally, every minute of delay in treating a cardiac arrest victim lowers the chance of survival by about ten percent. As a result, the ability to provide CPR in a competent manner can be a very important personal skill, and is particularly important for professional healthcare workers such as emergency medical technicians (EMTs).

[0004] Various CPR feedback devices are available that indicate to a rescuer whether they are performing CPR chest compressions at an appropriate rate and an appropriate depth of compression, such as dictated by American Heart Association (AHA) guidelines. For example, the PocketCPR application for IPHONES™ and IPODS™ may be used for practicing CPR, such as on a dummy or foam block, and may indicate whether a recent series of compressions was performed at the proper rate and proper depth. Similarly, the ZOLL Medical CPR D-Padz are defibrillation pads that connect to a defibrillator and include an accelerometer that can be used to compute the depth and rate of chest compressions on the victim so that the defibrillator can indicate via recorded voice prompts that a rescuer should be instructed, for example, to “press harder” if the unit determines that the depth of compression is too shallow.

[0005] Professional responders such as EMTs may also receive after-the-fact feedback via processes sometimes referred to as code reviews. In particular, data from a patient monitor (which may be incorporated into a defibrillator) may be saved and may then be loaded into a computer where the responder and a supervisor may review the data and then may discuss where the responder made errors or performed well, and what the responder can do to improve his or her performance. Sometimes these code reviews may occur well after the event, after the responder has largely forgotten the key aspects of the event.

SUMMARY

[0006] This document describes systems and techniques that may be used to gather information regarding the performance of CPR and other lifesaving

techniques on a patient, and may provide one or more reports at a number of different locations for such performance. For example, data may be gathered for direct primary measurements of aspects of CPR, such as depth and frequency of compressions. That data may be reported immediately on a patient monitor while the rescuer is performing CPR. Additionally, derivative indicators of rescuer performance may also be determined for secondary indications of the performance of the CPR that are derived from two or more of the primary indicators. Such secondary indications may also be displayed to the rescuer while he or she is performing the CPR. In addition, while certain measurements may be reported for actions within a sub-set of a CPR cycle or interval, other measurements may be reported for a period across an entire interval, so that a rescuer can compare his or her current performance to performance for prior CPR intervals—where a CPR interval is the period for a complete cycle of monitoring, defibrillating, and providing a series of chest compressions to a patient, such as defined by the 2010 AHA CPR Guidelines.

[0007] Such information, and in particular the secondary derived information, may be used to generate a form of report card for the rescuer, where data for the report card may be displayed in real-time on a patient monitor along with the raw data (e.g., for rate and depth of compressions) used to generate the report card.

As a result, the rescuer may receive greater motivation to improve his or her performance, given that he or she is being shown parameters on which his or her performance will ultimately be reviewed. The primary and secondary measurements may also be stored on the monitor and transferred off-site for further

analysis. For example, other caregivers may receive the measurement data at substantially the same time it is being displayed to the rescuer. As one example, a team at an emergency room where the patient is to be taken may see the data either to provide direction to the rescuer or to identify opportunities to treat the victim while waiting for the victim to arrive at the emergency room. In some examples, a team in the emergency room can provide a communication (e.g., voice or data based communication) that is delivered to the device to provide an active prompt to the rescuer. In the data-based example, the team in the emergency room can provide a command that activates a prompt on the device. For example, for a traumatic brain injury patient, the team could provide a command that prompts the device to provide audio or visual prompts to recommend delivery of fluids if blood pressure is low.

[0008] Also, the primary and secondary measurements may be stored at a central system for later analysis and in-depth code reviews. For example, a particular rescuer may log into a patient monitor such as by typing a user name and password or by providing biometric identification (e.g., taking a digital picture of themselves or swiping a fingertip on an electronic fingerprint reader), and measurement data may subsequently be correlated to an identifier for the rescuer. When the data is provided to a central system, it may then be retrieved in combination with measurement data for other incidents with that rescuer by using the rescuer's identifier. Aggregate data across multiple rescue incidents may then be generated for a comprehensive code review, such as by determining the rescuer's perfusion level over multiple patients, so that the rescuer can determine

that he or she needs to provide more complete perfusion, or to alter his or her performance in other helpful manners. In some additional examples, the database can include a section for user-inputted comments about the rescue. For example, in one case a rescuer may have a low compression fraction (percent of time in CPR) because of challenges at the scene (e.g. disruptive family members, lots of stairs, narrow hallways, etc.) which make it impossible to perform high quality CPR. It would be helpful if notes like this can be included in the aggregate database for a particular rescuer. Additionally, information about the patient can be associated with the report card. For example, CPR quality may be affected by patient size (deeper compressions for larger patient, shallow compressions for small and fragile patient) and thus information about the patient may be helpful in understanding the CPR performance.

[0009] Such data may also be processed by a healthcare billing system so as to provide a check on a billing event submitted for a rescue event. In particular, the information may be used to verify a claim for payment made against the victim and by a caregiver organization. The content of the information may be reviewed to determine whether care was provided, and what care was provided, and may be checked against a formal claim for payment by the caregiver organization.

[0010] More general review of the data may also be performed across a larger rescuer population (i.e., across data for multiple different rescuers). For example, code reviews may be performed across rescuers in a single identified group—such as all rescuers who were trained in a particular class or program or all rescuers who are based out of a particular facility—to determine whether a particular endemic

problem is manifesting itself in their rescue performance, and thus whether remedial action may be required with respect to each of the members in the group. Also, secondary data may be generated by a central system from the stored primary data, and may be compared to the secondary data that was generated by the patient monitors for particular incidents. For example, a company may identify new ways to measure a rescuer's performance and may test those new techniques against the manner in which the performance has been determined by monitors in the past, in order to determine whether the new techniques are an improvement over the old.

[0011] In certain implementations, the systems and techniques discussed here may provide one or more advantages. For example, by providing a rescuer with a real-time grade in the form of secondary, derived performance measurements that coincide with general measurements on which the rescuer will be evaluated, a system may provide greater motivation for the rescuer to improve his or her performance in real-time. Also, by showing primary real-time data next to data for prior CPR cycles, a rescuer can quickly determine whether current out-of-band performance is a temporary problem or has been a problem throughout a rescue incident. In addition, the rescuer can compensate for problems made in prior CPR cycles. The provision of such data to off-site locations can have further advantages, such as by allowing third parties (e.g., emergency room teams or post hoc evaluators) to have a better picture of the care that was provided to a victim. In addition, broader analysis of rescuer data may be performed, such as by

researchers who may use the data to improve general procedures and guidelines for rescuers.

[0012] In one aspect, an external defibrillator system includes one or more sensors configured to detect one or more parameters associated with performance of CPR. The system also includes one or more wearable computing devices
5 configured to provide feedback to a user about CPR performed by the user based on the one or more parameters (or two or more of the parameters) associated with the performed CPR. The system also includes an external defibrillator that includes a memory configured to store instructions, and a processor to execute the
10 instructions to perform an operation. The operation includes analyzing the one or more parameters (or two or more of the parameters) to determine a CPR performance metric indicative of an overall performance of the user.

[0013] Implementations can include one or more of the following features.

[0014] In some implementations, the one or more wearable computing devices
15 include at least one of the following: a tablet computing device, a headset, wearable glasses, and a smartphone.

[0015] In some implementations, at least one of the one or more wearable computing devices directs feedback to one predetermined user.

[0016] In some implementations, the one or more wearable computing devices
20 includes one or more of a watch or wearable glasses.

[0017] In some implementations, the wearable computing device includes wearable glasses having one or more lenses.

[0018] In some implementations, the visual summary is displayed on at least one lens of the wearable glasses.

[0019] In some implementations, generating the CPR performance metric includes generating data reflecting measurements of two or more actions performed on the victim.

[0020] In some implementations, the CPR performance metric is based, at least in part, on weighted values applied to the one or more parameters, or two or more of the parameters.

[0021] In some implementations, the weighted values are applied to at least one of the following: rate of chest compressions, depth of chest compressions, and fraction based on a guideline.

[0022] In some implementations, the wearable computing device is configured to provide a visual summary including the CPR performance metric within five minutes of cessation of the CPR by the rescuer.

[0023] In some implementations, the CPR performance metric is based on a function that weights each of the parameters according to weights determined using a neural network.

[0024] In some implementations, the CPR performance metric is based on a function that weights each of the parameters according to weights determined using a linear regression technique.

[0025] In some implementations, the wearable computing device is configured to receive input data from the user.

[0026] In some implementations, the system includes a heads-up device to provide feedback to a user about CPR performed by the user based on the one or more parameters (or two or more of the parameters) associated with the performed CPR.

5 **[0027]** In another aspect, an external defibrillator system includes one or more sensors configured to detect one or more parameters associated with performance of CPR. The system also includes a heads-up device configured to provide feedback to a user about CPR performed by the user based on the one or more parameters (or two or more of the parameters) associated with the performed CPR.

10 The system also includes an external defibrillator that includes a memory configured to store instructions, and a processor to execute the instructions to perform an operation. The operation includes analyzing the one or more parameters (or two or more of the parameters) to determine a CPR performance metric indicative of an overall performance of the user.

15 **[0028]** Implementations can include one or more of the following features.

[0029] In some implementations, the CPR performance metric is based, at least in part, on weighted values applied to the one or more parameters, or two or more of the parameters.

20 **[0030]** In another aspect, a computer-implemented method for providing summary information for CPR performance includes sensing one or more parameters associated with performance of CPR performed on a victim by a rescuer. The method also includes identifying a timing interval over which performance is to be analyzed and gathering data from the sensing of the one or

more parameters during the time interval. The method also includes generating, from analysis of the parameters, a CPR performance metric that condenses data sensed for the one or more parameters (or two or more of the parameters) into a single metric indicative of overall performance of the CPR over the identified interval. The method also includes providing, for display on a wearable computing device, a visual summary including the CPR performance metric within five minutes of cessation of the CPR by the rescuer.

[0031] Implementations can include one or more of the following features.

[0032] In some implementations, the wearable computing device includes one or more of a watch or wearable glasses.

[0033] In some implementations, the wearable computing device includes wearable glasses having one or more lenses.

[0034] In some implementations, the visual summary is displayed on at least one lens of the wearable glasses.

[0035] In some implementations, generating the CPR performance metric includes calculating the CPR performance metric (CPM) according to

$$CPM = f(w_{rate} * X_{rate}, w_{Depth} * X_{depth}, w_{fraction} * X_{fraction}) \text{ where } w_{rate}, w_{depth}, \text{ and } w_{fraction}$$

include weighting factors for each of rate of chest compressions, depth of chest compressions and fraction and X_{rate} , X_{depth} , and $X_{fraction}$ are calculated metrics for rate of chest compressions, depth of chest compressions, and fraction based on a guideline.

[0036] In some implementations, generating the CPR performance metric includes calculating the CPR performance metric based on a function that weights each of the parameters according to weights determined using a neural network.

[0037] In some implementations, generating the CPR performance metric includes calculating the CPR performance metric based on a function that weights each of the parameters according to weights determined using a linear regression technique.

[0038] In some implementations, providing the visual summary includes providing a graphical display of CPR compression rate, CPR compression depth and CPR fraction during the identified interval.

[0039] In some implementations, providing the visual summary includes providing per-parameter metrics with each per-parameter metric condensing data for the parameter to provide a single metric indicative of the CPR quality for that parameter.

[0040] In some implementations, providing, for display to a user, a visual summary including the CPR performance metric includes providing the visual summary within one minute of cessation of the CPR by the rescuer.

[0041] In some implementations, the sensors include at least one of chest compression sensors, patient ventilation sensors, and electrocardiogram sensors.

[0042] In some implementations, providing the visual summary for display includes wirelessly transmitting data about the one or more activities from a device that senses the one or more activities to a remote device having a visual display device display.

[0043] In some implementations, the CPR performance metric includes a score that indicates, by one alpha-numeric indicator, a quality level with which one or more (or two or more) CPR related activities were performed.

[0044] In some implementations, the method also includes monitoring
5 electrocardiogram data of the victim while the one or more activities are occurring, and providing with a defibrillator at least one of charging the defibrillator and shocking the victim without manual intervention of a rescuer.

[0045] In some implementations, generating the CPR performance metric includes generating a single data value from information received from
10 measurement of two or more distinct actions performed on the victim.

[0046] In some implementations, generating the CPR performance metric includes generating a single data value from information about at least one of CPR depth, CPR compression rate, and CPR fraction.

[0047] In some implementations, the timing interval includes the entire duration
15 of CPR administration by the rescuer.

[0048] In another aspect, a computer readable medium stores instructions for causing a computing system to sense one or more parameters associated with performance of CPR performed on a victim by a rescuer. The instructions are also for causing the computing system to identify a timing interval over which
20 performance is to be analyzed and gather data from the sensing of the one or more parameters during the time interval. The instructions are also for causing the computing system to generate, from analysis of the parameters, a CPR performance metric that condenses data sensed for the one or more parameters (or

two or more of the parameters) into a single metric indicative of overall performance of the CPR over the identified interval. The instructions are also for causing the computing system to provide, for display on a wearable computing device, a visual summary including the CPR performance metric within five minutes of cessation of the CPR by the rescuer.

[0049] Implementations can include one or more of the following features.

[0050] In some implementations, the wearable computing device includes one or more of a watch or wearable glasses.

[0051] In some implementations, the wearable computing device includes wearable glasses having one or more lenses.

[0052] In some implementations, the visual summary is displayed on at least one lens of the wearable glasses.

[0053] In some implementations, the CPR performance metric includes a single data value from information about at least one of CPR depth, CPR compression rate, and CPR fraction.

[0054] In some implementations, the instructions for causing the computing system to sense one or more parameters includes instructions for monitoring electrocardiogram data of the victim while the one or more activities are occurring, and providing with a defibrillator at least one of charging the defibrillator and shocking the victim without manual intervention of a rescuer.

[0055] The details of one or more embodiments are set forth in the accompanying drawings and the description below. Other features and advantages will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

[0056] FIG. 1A shows a system for responding to an emergency medical condition.

[0057] FIG. 1B is a flow diagram of a CPR data acquisition process.

5 **[0058]** FIGS. 2A and 2B are screen shots of a tablet device showing a summary of rescuer performance in a CPR setting.

[0059] FIG. 3 is a flow chart of a process for capturing user performance data during the provision of CPR.

10 **[0060]** FIG. 4 is a swim lane diagram of a process for sharing CPR performance data between various sub-systems in a larger healthcare system.

[0061] FIG. 5 shows a screen shot of a tablet device showing a summary of rescuer performance.

[0062] FIG. 6 is a flow chart of a process for generating a CPR performance metric.

15 **[0063]** FIG. 7 is a flow chart of a process for training a model.

[0064] FIGS. 8A and 8B show examples of a wearable computing device in the form of a wrist-worn device.

[0065] FIGS. 9A and 9B show examples of a wearable computing device in the form of wearable glasses.

20 **[0066]** FIG. 10 shows an example of a generic computer device and a generic mobile computer device, which may be used with the techniques described here.

[0067] Like reference symbols in the various drawings indicate like elements.

DETAILED DESCRIPTION

[0068] This detailed description discusses examples of implementations that may be employed in capturing data from a rescuer performing CPR and other related activities on a patient or victim (the terms are used interchangeably here to indicate a person who is the subject of intended or actual CPR and related treatment, or other medical treatment). The data may include both primary data that directly measures a parameter of an action performed on the patient, as well as secondary data that is derived from multiple pieces of the primary data. Also, the data may include real-time data for portions of a current CPR interval, and past data for prior CPR intervals. For example, a device may show the depth and rate of compression for the last compression (e.g., for depth) or last few chest compressions (e.g., for rate) performed by a rescuer. Adjacent that representation, the device may show the average rate and depth of compressions performed for each of the prior several CPR intervals. In such a manner, the rescuer can quickly see how they are doing and can adjust their performance accordingly, and then receive immediate feedback on whether their adjustments have been effective.

[0069] FIG. 1 shows a system 100 for responding to an emergency medical condition of a victim 102. In general, system 100 includes various portable devices for monitoring on-site care given to a victim of an emergency situation, such as a victim 102 suffering from sudden cardiac arrest or a victim 102 at the scene of a traffic accident. The various devices may be provided by emergency medical technicians who arrive at the scene and who provide care for the victim 102, such as emergency medical technician 114. In this example, the emergency medical

technician 114 has deployed several devices and is providing care to the victim 102. Although not shown, one or more other emergency medical technicians may be assisting and working in coordination with emergency medical technician 114 according to a defined protocol and training.

5 **[0070]** The emergency medical technician 114 in this example is interacting with a computing device in the form of a touchscreen tablet 116. The tablet 116 may include a graphical display by which to report information to the emergency medical technician 114, and may have an input mechanism such as a keyboard or a touchscreen by which the emergency medical technician 114 may enter data into
10 the system 100. The tablet 116 may also include a wireless transceiver for communicating with a wireless network, such as a 3G or 4G chipset that permits long distance communication over cellular data networks, and further through the internet.

15 **[0071]** The emergency medical technician 114, in this example, is also interacting with a wearable computing device 111 in the form of wearable glasses. The wearable computing device 111 may include a graphical display 115 by which to report information to the emergency medical technician 114 and may include a device interface 113 for executing operations such as coordinating with the other components of the wearable computing device 111 (e.g., exchange information,
20 control signals, etc.), controlling of user interfaces, applications executed by wearable computing device 111, exchanging information with other devices (e.g., wirelessly communicate with other devices), etc.

[0072] The wearable computing device can provide the functionality of receiving, transmitting, and/or displaying data. Data processing may also be provided by such a wearable computing device (e.g., processing received data prior to display, processing data prior to sending to another computing device, etc.). In some instances, a wearable computing device can take the form of a head-mounted device that can include frame elements including lens-frames, a center support, one or more lenses, and side supports (for securing the device to a user). The wearable computing device may additionally include an on-board computing system, a still or video camera (mountable to the device at various locations), speakers, etc. The on-board computing system may have the capability to communicate with other computing devices, systems, etc. external to the wearable computing device, e.g., through a wireless network connection, a short-range (e.g., Bluetooth) connection, a cellular connection, or another type of connection.

[0073] Various techniques may be employed to exchange information between the wearable computing device and the wearer. For example, the wearable computing device may include one or more displays that may be coupled to the device. Such a display may be formed on one lens or multiple lenses of the wearable computing device and may be configured to overlay computer-generated images, graphics, etc. in the user's view of the physical world. The display can be positioned at one or more locations of the lens or lenses, for example, at the center of one or more of the lens. In general, the display is controllable by the on-board computing system and is in communication with the computing system by employing one or more data transmission techniques (e.g., an optical waveguide or

fiber, electrical conductor, etc.). In some arrangements, the frame of the wearable computing device can be similar to a frame of a pair of glasses (e.g., prescription glasses, sunglasses, reading glasses, etc.). In some instances, the lenses incorporated into the device may be less than a completely formed lenses typically included in eyeglasses. Due to the less than complete lens or lenses, the device may not include a lower frame portion typically used to secure a complete lens to the frame.

[0074] To interact with the wearable computing device, one or more techniques may be employed. For example, a touch-based input (e.g., a touchpad) may be incorporated to sense the position and movement of a user's finger by capacitive sensing, resistance sensing, or other techniques. Equipment (e.g., one or more acceleration sensors) may be incorporated to sense the movement of a portion of the user (e.g., the user's head). One or more microphones may also be incorporated into the device to collect audible signals (e.g., voice commands) from the user. Similar to sensing position and movement, the direction of a user's finger (interacting with the touch-based input), the level of applied pressure, etc. may be sensed by interacting with device input.

[0075] In some arrangements, the wearable computing device can provide networking functionality. For example, the wearable device can be used to provide a node of a network architecture (e.g., a node for a mesh network). As such, information can be exchanged with (e.g., transmitted to, received from) other network nodes (e.g., other wearable computing devices at nearby locations, mobile computing devices, medical devices such as defibrillating systems, wearable

medical devices, etc.). In one arrangement, multiple members of an emergency response team may each be outfitted with a wearable computing device that provides a network node. By employing data transmission techniques (e.g., one or more network protocols), information may be shared among the wearable
5 computing devices, e.g., so each member is provided the same information during the emergency or so that information can be exchanged among members during the emergency.

[0076] Such capabilities may be incorporated into other types of wearable computing devices, such as a timepiece (e.g., a watch), an ear piece, an article of
10 clothing or protective medical gear, etc. For example, while the wearable computing device 111 shown in FIG. 1A is in the form of wearable glasses, the wearable computing device 111 can have other configurations. Referring to FIGS. 8A and 8B, in some implementations, the wearable computing device is a wrist-worn device 800. The wrist-worn device 800 may be an exercise device and/or a smart watch,
15 for example, a FITBIT™ or an APPLE WATCH™.

[0077] As shown in figure FIG. 8A, the wrist-worn device 800 can provide information about the physiological state of the patient, as well as information about the quality of the CPR being performed by the rescuer. The wrist-worn device 800 includes a display for presenting CPR information. The CPR information may be
20 automatically displayed when compressions are detected. The displayed information about the chest compressions can include the rate of compressions 806 (e.g., number of compressions per minute) and the depth of compressions 804 (e.g., depth of compressions in inches or millimeters). The rate and depth of

compressions can be determined by analyzing accelerometer readings. Displaying the actual rate and depth data (in addition to, or instead of, an indication of whether the values are within or outside of an acceptable range) can provide useful feedback to the rescuer. A visual indicator 807, such as a color of the text or an applied highlighting, can be modified to indicate when a value for the depth and/or rate is outside of the preferred range. For example, if the rate of 88 compressions per minute as shown in FIG. 8A is too fast, the visual indicator 807 may include a red highlight indicating that the rescuer should slow down.

[0078] The displayed information about the chest compressions can also include a perfusion performance indicator (PPI) 808. The PPI 808 has a shape (e.g., a diamond) that is colored or shaded over time. The amount of the shape that is colored or shaded (e.g., the fill amount) provides feedback about both the rate and depth of the compressions. For example, when CPR is being performed adequately, the entire indicator may be filled. As the rate and/or depth decreases below acceptable limits, the amount of fill lessens. The PPI 808 provides a concise visual indication of the quality of the CPR such that the rescuer can aim to keep the PPI 808 completely filled.

[0079] In some implementations, the PPI 808 includes two axes – a vertical axis and a horizontal axis. The vertical axis may correspond to the depth of chest compressions, and the horizontal axis may correspond to the rate of chest compressions. For example, when the depth of chest compressions decreases below the acceptable limit, the fill amount of the PPI 808 in the vertical direction may be relatively small. Similarly, when the rate of chest compressions decreases

below the acceptable limit, the fill amount of the PPI 808 in the horizontal direction may be relatively small. For example, if the depth of chest compressions is adequate but the rate of chest compression is below the acceptable limit, the fill amount of the PPI 808 may appear as a tall, thin diamond; if the depth of chest compressions is below the acceptable limit but the rate of chest compressions is adequate, the fill amount of the PPI 808 may appear as a short, wide diamond. In some implementations, the wearable computing device may further provide a score indicative of the overall quality in the performance of CPR which condenses multiple parameters/data (weighted and/or unweighted) monitored during the act of administering CPR and/or shortly thereafter, so as to improve future CPR performance.

[0080] The wrist-worn device 800 may be configured to display a filtered ECG waveform 802. In some examples, other waveforms can also be displayed. For example, in some implementations, a second waveform (e.g., a CO₂ waveform, volumetric CO₂, ETCO₂, SpO₂, etc.) is also displayed.

[0081] The data displayed by the wrist-worn device 800 may change based on the rescuer's actions. For example, the data displayed can change based on whether or not the rescuer is currently administering CPR chest compressions to the patient. In some examples, if multiple rescuers are present, the CPR information may be displayed to only the rescuer who is performing the CPR, and other information, such as patient data and/or ventilation feedback, may be provided to the other rescuers.

[0082] As shown in figure FIG. 8B, the wrist-worn device 800 can additionally or alternatively provide concise, simplified feedback with instructions to the rescuer regarding how to perform CPR. In this example, the wrist-worn device 800 provides a reminder 820 regarding “release” in performing chest compression. Specifically,
5 a fatigued rescuer may begin to lean forward on the chest of a victim and not release pressure on the sternum of the victim at the top of each compression. This can reduce the perfusion and circulation accomplished by the chest compressions. The reminder 820 can be displayed when the system recognizes that release is not being achieved.

10 **[0083]** In some examples, the wrist-worn device 800 can be configured to provide other types of feedback to the rescuer. The reminder 820 can be coordinated with other feedback, and can be presented in an appropriate manner to get the rescuer’s attention. For example, the visual indication may be accompanied by vibration generated by the wrist-worn device 800 in order to indicate that a
15 rescuer is to stop and modify how they are performing the CPR. For example, the wrist-worn device 800 may be provided with mechanisms for vibrating the device similar to mechanisms provided for vibrating portable communication devices (e.g., when an incoming telephone call is received on a smartphone). Such vibrating may be provided so as to alert the user to particular information and/or minimize the
20 amount of information that can distract other rescuers in the area.

[0084] In some examples, the wrist-worn device 800 can generate periodic vibrations felt by the user to synchronize the chest compression activities with the desired rate. For example, the vibrations may be periodic occurring at the preferred

chest compression rate (approximate 100 times per minute) to indicate when the rescuer should be performing compressions. Such haptic feedback, when used to identify urgent information or provide instructions, may also relieve the rescuer of having to constantly monitor the information displayed by the wrist-worn device 800.

5 Thus, a first type of feedback, which may be visual, audible, or tactile, may be provided to signal the wearer of the wrist-worn device 800 to view information displayed on the wrist-worn device 800.

[0085] In some examples, the wrist-worn device 800 includes an audio output device such as a speaker for providing audible alerts and/or notification. The
10 speaker may emit periodic tones to synchronize the chest compression activities with the desired rate. For example, the tones may be periodic occurring at the preferred chest compression rate (approximately 100 times per minute) to indicate when the rescuer should be performing compressions. In some examples, the audible alerts and/or notifications may be indicative of the rescuer's performance
15 with regard to depth of chest compressions. For example, the speaker may provide spoken feedback to the rescuer (e.g., "push harder" or "push softer") if the rescuer is not administering the CPR appropriately.

[0086] In some examples, the wrist-worn device 800 includes a light (e.g., an LED) for providing visual alerts and/or notifications. The LED may emit periodic
20 flashes of light to synchronize the chest compression activities with the desired rate. For example, the flashes of light may be periodic occurring at the preferred chest compression rate (approximately 100 times per minute) to indicate when the rescuer should be performing compressions. In some examples, the emitted light

(e.g., the color of the emitted light) may be indicative of the rescuer's performance with regard to depth of chest compressions. For example, the LED may emit red light if the chest compressions are too hard (e.g., too deep), and the LED may emit a blue light if the chest compression are too soft (e.g., too shallow).

5 **[0087]** Feedback features similar to those described above with reference to the wrist-worn device 800 of FIGS. 8A and 8B may also be incorporated into the wearable glasses computing device 111 of FIG. 1A. For example, the graphical display 115 may present a filtered waveform, a depth of compressions, a rate of compressions, a PPI, a visual indicator, and/or a reminder directed to the rescuer.

10 In some implementations, the wearable glasses computing device 111 includes a speaker and/or a light for emitting audible and/or visual notifications directed to the rescuer.

15 **[0088]** In some implementations, the wearable computing device may be a mobile computing device such as a smartphone, a PDA, etc. that is configured to be worn on a hand, wrist, and/or arm of the rescuer. For example, the wearable computing device may be a smartphone that can be attached to or placed inside a band (e.g., a jogging band) to be worn by the rescuer. In some implementations, the wearable computing device is a fitness device (e.g., a pedometer) that can be clipped onto the clothing of the rescuer. The smartphone and/or the fitness device

20 can be configured to operate in a manner similar to that described above with reference to FIGS. 8A and 8B.

[0089] In some implementations (e.g., implementations in which the wearable computing device is a fitness device), the fitness device may also be configured to

provide additional feedback to the rescuer related to the effort exerted by the rescuer while performing the CPR. The fitness device may be configured to provide recommendations to the rescuer for helping the rescuer improve the administered CPR without causing the rescuer to become overtired. For example, if the fitness device determines that the rescuer is exerting too much energy (e.g., based on the rescuer's vitals as measured by the fitness device), the fitness device may suggest that the rescuer adjust his or her posture, breathing, positioning, etc. Such feedback may be provided after the CPR has been administered, so as not to distract the rescuer during administration. In some implementation, the fitness device may present the rescuer with a score indicative of both the CPR performance and the rescuer's fitness performance during administration.

[0090] In some examples, the emergency medical technician can interact with a computing device in the form of a heads-up device 103. The heads-up device 103 may include a graphical display 105 by which information is reported to the emergency technician. In some cases, the graphical display 105 includes a transparent plane upon which an image and/or graphic can be projected. The graphical display 105 can be attached or removably attached to the heads-up device 103. The emergency technician may interact with the heads-up device 103 to enter data into the system 100, receive feedback about the ongoing rescue efforts, or to receive guidance about the ongoing rescue efforts. The heads-up device 103 may include a device interface 107 for executing operations such as coordinating with the other components of the heads-up device 103 (e.g., exchange information, control signals, etc.), controlling of user interfaces, applications

executed by heads-up device 103, exchanging information with other devices (e.g., wirelessly communicate with other devices), etc.

[0091] The heads-up device 103 may be configured to provide information to the emergency technician while allowing the emergency technician to view the surrounding environment in a generally unobstructed manner. For example, the heads-up device 103 may be configured to overlay computer-generated images, graphics, etc. in the user's view of the physical world.

[0092] The heads-up device 103 may also include a wireless transceiver for communicating with a wireless network, such as a 3G or 4G chipset that permits long distance communication over cellular data networks, and further through the internet. In some examples, the heads-up device 103 is used in combination with one or more wearable devices.

[0093] To interact with the heads-up device 103, one or more techniques may be employed. For example, a touch-based input (e.g., a touchpad) may be incorporated to sense the position and movement of a user's finger by capacitive sensing, resistance sensing, or other techniques. Equipment (e.g., one or more acceleration sensors) may be incorporated to sense the movement of a portion of the user (e.g., the user's head or the user's hands). Specific user motions may be associated with specific inputs. For example, a specific motion may cause the device to power cycle. One or more microphones may also be incorporated into the device to collect audible signals (e.g., voice commands) from the user. Similar to sensing position and movement, the direction of a user's finger (interacting with the

touch-based input), the level of applied pressure, etc. may be sensed by interacting with device input.

[0094] In some arrangements, the heads-up device 103 can provide networking functionality. For example, the heads-up device 103 can be used to provide a node of a network architecture (e.g., a node for a mesh network). In one arrangement, multiple members of an emergency response team may each be outfitted with a wearable computing device that also provides a network node. By employing data transmission techniques (e.g., one or more network protocols), information may be shared among the wearable computing devices and the heads-up device 103, e.g., so each member is provided the same information during the emergency or so that information can be exchanged among members during the emergency.

[0095] While the heads-up device 103 is generally described as a separate device, it may be attached or removably attached to another device. For example, the heads-up device 103 may be attached or removably attached to a portable defibrillator.

[0096] Separately, a portable defibrillator 112 is shown in a deployed state and is connected to the victim 102. In addition to providing defibrillation, the defibrillator 112 may serve as a patient monitor via a variety of sensors or sensor packages. For example, as shown here, electrodes 108 have been applied to the bare chest of the victim 102 and have been connected to the defibrillator 112, so that electrical shocking pulses may be provided to the electrodes in an effort to defibrillate the victim 102, and electrocardiogram (ECG) signals may be read from the victim 102.

The defibrillator 112 may take a variety of forms, such as the ZOLL MEDICAL R Series, E Series, or M Series defibrillators.

[0097] The assembly for the electrodes 108 includes a center portion at which an accelerometer assembly 110 is mounted. The accelerometer assembly 110 may include a housing inside which is mounted an accelerometer sensor configuration. The accelerometer assembly 110 may be positioned in a location where a rescuer is to place the palms of their hands when performing cardio pulmonary resuscitation (CPR) chest compressions on the victim 102. As a result, the accelerometer assembly 110 may move with the victim's 102 chest and the rescuer's hands, and acceleration of such movement may be double-integrated to identify a vertical displacement of such motion (i.e., to compute the displacement of the victim's breastbone for comparison to American Heart Association (AHA) guidelines).

[0098] The defibrillator 112 may, in response to receiving such information from the accelerometer assembly 112, provide feedback in a conventional and known manner to a rescuer, such as emergency medical technician 114. For example, the defibrillator 112 may generate a metronome to pace such a user in providing chest compressions. In addition, or alternatively, the defibrillator 112 may provide verbal instructions to the rescuer, such as by telling the rescuer that they are providing compressions too quickly or too slowly, or are pushing too hard or too soft, so as to encourage the rescuer to change their technique to bring it more in line with proper protocol – where the proper protocol may be a protocol generated by the system, but that is inconsistent with any published protocols. In addition, similar feedback may be provided visually on a screen of the defibrillator, such as by showing a bar

graph or number that indicates depth and another that indicates rate, with appropriate mechanisms to indicate whether the depth and rate or adequate, too low, or too high.

[0099] The defibrillator 112 may communicate through a short range wireless data connection with the tablet 116, such as using BLUETOOTH technology. The defibrillator 112 can provide to the tablet 116 status information, such as information received through the electrode assembly 108, including ECG information for the victim 102. Also, the defibrillator 112 can send information about the performance of chest compressions, such as depth and rate information for the chest compressions. The tablet 116 may display such information (and also other information, such as information from the defibrillator regarding ETCO2 and SPO2) graphically for the emergency medical technician 114, and may also receive inputs from the emergency medical technician 114 to control the operation of the various mechanisms at an emergency site. For example, the emergency medical technician 114 may use the tablet 116 to change the manner in which the defibrillator 112 operates, such as by changing a charging voltage for the defibrillator 112.

[00100] Where described below, the processing and display of data may occur on the defibrillator 112, the tablet 116, or on both. For example, the defibrillator 112 may include a display that matches that of the tablet 116, and the two may thus show matching data. In contrast, the defibrillator 112 may have a more limited display than does the tablet 116, and might show only basic information about the technician's performance, while the tablet 116 may show more complete information such as secondary historic information. Also, the processing of primary

information to obtain secondary information may be performed by the defibrillator 112, the tablet 116, or a combination of the two, and the two devices may communicate back and forth in various manners to provide to each other information they have received or processed, or to relay commands provided to them by the technician 114.

[00101] Another electronic mechanism, in the form of a ventilation bag 104, is shown sealed around the mouth of the victim 102. The ventilation bag 104 may, for the most part, take a familiar form, and may include a flexible body structure that a rescuer may squeeze periodically to provide ventilation on the victim 102 when the victim 102 is not breathing sufficiently on his or her own.

[00102] Provided with the ventilation bag 104 is an airflow sensor 106. The airflow sensor 106 is located in a neck of the ventilation bag 104 near the mouthpiece or mask of the ventilation bag 104. The airflow sensor 106 may be configured to monitor the flow of air into and out of the patient's mouth, so as to identify a rate at which ventilation is occurring with the victim. In addition, in certain implementations, the airflow sensor 106 may be arranged to monitor a volume of airflow into and out of the victim 102.

[00103] In this example, the airflow sensor 106 is joined to a short-range wireless data transmitter or transceiver, such as a mechanism communicating via BLUETOOTH technology. As such, the airflow sensor 106 may communicate with the tablet 116 in a manner similar to the communication of the defibrillator 112 with the tablet 116. For example, the airflow sensor 106 may report information that enables the computation of a rate of ventilation, and in some circumstances a

volume of ventilation, that is being provided to the patient. The tablet 116, for example, may determine an appropriate provision of ventilation and compare it to the level of ventilation that the victim is receiving, and may provide feedback for a rescuer, either directly such as by showing the feedback on a screen of the tablet 116 or playing the feedback through an audio system of the tablet 116, or indirectly, by causing defibrillator 112 or airflow sensor 106 to provide such feedback. For example, defibrillator 112 or airflow sensor 106 may provide a metronome or verbal feedback telling a rescuer to squeeze the ventilation bag 104 harder or softer, or faster or slower. Also, the system 100 may provide the rescuer was an audible cue each time that the bag is to be squeezed and ventilation is to be provided to the victim 102.

[00104] Such feedback may occur in a variety of manners. For example, the feedback may be played on built-in loudspeakers mounted in any of tablet 116, defibrillator 112, or airflow sensor 106. Alternatively, or in addition, visual notifications may be provided on any combination of such units. Also, feedback may be provided to wireless headsets (or other form of personal device, such as a smartphone or similar device that each rescuer may use to obtain information and to enter data, and which may communicate wirelessly over a general network (e.g., WiFi or 3G/4G) or a small area network (e.g., BLUETOOTH) that are worn by each rescuer, and two channels of communication may be maintained, so that each rescuer receives instructions specific to their role, where one may have a role of operating the defibrillator 112, and the other may have the role of operating the

ventilation bag 104. In this manner, the two rescuers may avoid being accidentally prompted, distracted, or confused by instructions that are not relevant to them.

[00105] A central server system 120 may communicate with the tablet 116 or other devices at the rescue scene over a wireless network and a network 118, which may include portions of the Internet (where data may be appropriately encrypted to protect privacy). The central server system 120 may be part of a larger system for a healthcare organization in which medical records are kept for various patients in the system. Information about the victim 102 may then be associated with an identification number or other identifier, and stored by the central server system 120 for later access. Where an identity of the victim 102 can be determined, the information may be stored with a pre-existing electronic medical record (EMR) for that victim 102. When the identity of the victim 102 cannot be determined, the information may be stored with a temporary identification number or identifier, which may be tied in the system to the particular rescue crew so that it may be conveniently located by other users of the system.

[00106] Information that is stored for a rescue incident may also include an identifier for the technician 114 and any other technician that participated in the rescue. Using such identifiers, the server system 120 may later be queried so as to deliver data for all incidents that the particular technicians have been involved in.

The tablet 116 or defibrillator 114 may include mechanisms so that the technicians can identify themselves and thus have their identifier stored with the information. For example, the technicians may be required to log in with the tablet 116 when their shift starts, so that all information subsequently obtained by the tablet 116 or

components in communication with the tablet may be correlated to the identifier.

Such logging in may require the entry of a user name and password, or may involve biometric identification, such as by the pressing or swiping of a technician's fingertip on a fingerprint reader that is built into the tablet 116.

5 **[00107]** The information that is stored may be relevant information needed to determine the current status of the victim 102 and the care that has been provided to the victim 102 up to a certain point in time. For example, vital signs of the victim 102 may be constantly updated at the central server system 120 as additional information is received from the tablet 116 (e.g., via the defibrillator 114). Also, ECG
10 data for the victim 102 may be uploaded to the central server system 120.

Moreover, information about drugs provided to the victim may be stored. In addition, information from a dispatch center may also be stored on the central server system 120 and accessed by various users such as rescuers. For example, a time at which a call came in may be stored, and rescuers (either manually or
15 automatically through their portable computing devices) can use that time to determine a protocol for treating the patient (e.g., ventilation or chest compression needs may change depending on how long the victim has been in need of treatment).

[00108] Other users may then access the data in the central server system 120.

20 For example, as shown here, an emergency room physician 122 is operating his or her own tablet 124 that communicates wirelessly, such as over a cellular data network. The physician 122 may have been notified that victim 102 will be arriving at the emergency room, and, in preparation, may be getting up-to-speed regarding

the condition of the victim 102, and determining a best course of action to take as soon as the victim 102 arrives at the emergency room. As such, the physician 122 may review the data from central server system 120. In addition, the physician 122 may communicate by text, verbally, or in other manners with emergency medical technician 114. In doing so, the physician 122 may ask questions of the emergency medical technician 114 so that the physician 122 is better prepared when the victim 102 arrives at the emergency room. The physician 122 may also provide input to the emergency medical technician 114, such as by describing care that the emergency medical technician 114 should provide to the victim 102, such as in an ambulance on the way to the emergency room, so that emergency room personnel do not have to spend time performing such actions. Also, physicians could see aspects of a currently-operating protocol on the system (e.g., an AHA CPR protocol), and could act to override the protocol, with or without the rescuers needing to know that such a change in the protocol has been made (e.g., their devices will just start instructing them according to the parameters for the manually-revised protocol).

[00109] In some implementations, the data provided by the wearable computing device 111, including the calculated CPR metrics and/or the feedback information described above, may also be provided to the central server system 120 and accessed by other users, such as the emergency room physician 122. The data may be provided in real time. For example, the calculated CPR metrics and/or the feedback information can be provided and accessed in real time such that remote medical personnel can continuously monitor the administration of the CPR to verify

proper compliance. The calculated CPR metrics may include a score indicative of the overall quality in the performance of CPR which aggregates multiple parameters/data monitored during the act of administering CPR and/or shortly thereafter.

5 **[00110]** Where the published protocol is organized in a flowchart form, the flowchart may be displayed to a rescuer or a physician, and such user may drag portions of the flowchart to reorder the protocol. Alternatively, the user could tap a block in the flowchart in order to have parameters for that block displayed, so that the user can change such parameters (e.g., ventilation volume or time between
10 ventilations). Data describing such an edited protocol may then be saved with other information about an incident so that later users may review it, and a user may save reordered protocols so that they can be employed more easily and quickly in the future.

15 **[00111]** In this manner, the system 100 permits various portable electronic devices to communicate with each other so as to coordinate care that is provided to a victim 102. In addition, the system 100 allows the technician 114 and others to see raw real-time data and derived real-time or historical data about a rescue attempt. Such data may be arranged so that a technician can immediately see whether his or her performance is matching or has matched agreed-upon standard,
20 and can quickly adjust his or her performance while the incident is still going on. In addition, such information may be aggregated across multiple incidents for a particular rescuer, and across multiple incidents for multiple rescuers so as to be able to provide more broad-based report cards for performance, and to permit more

general modification of future performance (e.g., for a rescuer who regularly under-perfuses victims).

[00112] Each device in the system 100 may sense information about the care provided to the victim 102, and/or may provide instructions or may store data about such care. As a result, the system 100 may provide improved care for the victim 102 by better integrating and coordinating each form of the care that the victim 102 receives. The victim 102 made thus receive improved care and an improved chance of obtaining a positive outcome from an event.

[00113] In certain instances, a condition of a victim that is used to generate a protocol for treatment of the victim may be based on on-site observations made by a rescuer, by information in an EMR for the victim, or both. For example, a determination from an EMR that a victim is taking a particular drug may result in a change in protocol for ventilation rate. Likewise, an observation by a rescuer that the victim has suffered a head injury on site may also affect the protocol for ventilation rate. The two factors may also be considered together to determine yet a more refined ventilation rate for which a rescuer will be instructed to provide to the victim. Also, the real-time feedback that is provided to a technician 114 may be automatically altered in response to identifying such special cases in an EMR or in information entered by the technician 114 (e.g., after a conscious victim has provided the information to the technician 114).

[00114] Thus, in operation, a two-person rescue team may arrive at a scene. One member of the team may set up and attach a defibrillator/monitor to a victim, and do the same with a ventilation bag assembly. The other member may begin an

examination of the victim and may enter information obtained from the examination into a portable computing device such as a general tablet computer (e.g., an iPad or netbook) or a wearable computing device. In some situations, the second rescuer may be able to verbally interview the victim, at least initially, so as to
5 determine whether the victim is lucid, what drugs the victim may be taking, and the like. The second rescuer could also make visual observations (e.g., types of trauma to the victim) and record those in the computing device. Moreover, one of the rescuers may obtain vital sign information for the victim, and such information may be entered manually into the computing device or automatically, such as
10 through wireless links from a blood pressure cuff, or other relevant medical device.

[00115] The computing device, using all of the entered information, may then generate a protocol for treating the victim. Such a generating may occur by selecting from among a plurality of available protocols by plugging the observations into a protocol selector. The generation may also be more dynamic, and may
15 depends on a series of heuristics that use the observations as inputs, and generate a protocol (which may be made up of one or more sub-protocols) as an output. Moreover, a lookup table may be consulted, where the table may define correlations between particular observed patient conditions or physical parameters, and a particular feature of a treatment protocol.

[00116] The computing device may also submit the observation information over
20 a network such as the internet, and a protocol may be generated by a central computer server system and then automatically downloaded to, and implemented

by, the portable computing device. Such an approach may have the benefit of being able to easily update and modify protocol-generation rules.

[00117] The computing device may then receive information about the performance by the rescuers, such as from wired or wireless transmitters on a defibrillator, an assisted ventilation unit, or other medical device (e.g., blood pressure reader). The computing device may provide feedback or coaching when the performance falls out of line with a defined protocol, or may provide feedback to maintain the performance in line with the protocol. In providing the feedback, the computing device or the defibrillator/monitor may generate a number of derived parameters from measure parameters of the victim, and both the measured parameters and the more comprehensive derived parameters may be reported visually or audibly by the computing device, the defibrillator/monitor, or both. Also, the computing device may update the protocol as care is being provided to the victim. For example, the rate of required ventilation or chest compressions may change as a function of time. Also, if one of the rescuers attaches an oxygen source to a ventilation assembly (as sensed, e.g., by a switch where the connection occurs, by a manual rescuer input to the system, or by sensors in the assisted ventilation system), the rate of required ventilation may change. Other changes in the patient condition, such as changes in measured levels of ETCO₂ or SpO₂, can lead to the computing device generating a revised protocol and providing feedback to the rescuers so that they adapt to the revised protocol (sometimes without consciously knowing that the protocol has been revised). In some additional examples, the rescuer can manually change the protocol. For example, the rescuer

could indicate that the patient has achieved ROSC and the protocol would automatically switch to a post-resuscitative care protocol. Further, in some examples, the change of protocol could be automated, for example, the identification of ROSC could be automated (e.g., automatically determined by a computing device based on a jump in ETCO₂ and/or presence of spo₂ waveform), which the rescuer would simply need to confirm. If the patient rearrests, and chest compressions resume, the protocol would automatically return to cardiac resuscitation.

[00118] FIG. 1B is a flow diagram of a CPR data acquisition process. In general, the data acquisition occurs in parallel with performance of CPR according to the 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Data acquisition in this example occurs in real-time throughout the provision of CPR to a victim, and such real-time data may be continuously updated and displayed to rescuers or others. Also, certain secondary information may be generated from the real-time information, either periodically such as at the end of each CPR interval in the cycles, or at the end of a rescue incident (where an incident is an entire attempt to rescue a victim, from the beginning of data collection to the time a patient monitor is removed from a patient, the patient leaves the scene of the incident, or another rescuer or group of rescuers takes over).

[00119] According to the CPR guidelines, the process begins at box 140, where a rescuer endeavors to evaluate a victim. Such evaluation may occur by familiar mechanisms, such as by determining whether the victim is breathing, responsive, or

has a pulse. If a problem with the victim is determined, the rescuer begins an emergency response at box 142. For example, the rescuer may cause an emergency response team to be called to the scene and may get a defibrillator 144 or cause another person to get a defibrillator if the victim appears to suffer from sudden cardiac arrest or a similar problem.

[00120] Having performed such actions, the rescuer may begin performing cardio pulmonary resuscitation (CPR) on the victim at box 146. According to protocol, CPR involves a cyclical process that is repeated every two minutes, as indicated by the circular arrow in the figure. At the beginning of each cycle, a defibrillator that has had leads attached to the victim may analyze the victim, such as by analyzing an ECG reading for the victim or other information to determine whether the victim has a shockable rhythm. Techniques for performing such analysis are well-known and the particular technique that is used here is not critical. If a shockable rhythm is determined to be present, a shock may be delivered as shown by box 148. For example, the defibrillator may provide a display to a rescuer or may speak words to the rescuer indicating that a shock should be delivered. The rescuer may then press a button on the defibrillator to cause a shock to be delivered, after all people around the victim have moved away from the victim.

[00121] The rescuer may then perform chest compressions on the victim for the remainder of the cycle or interval. After a predetermined time period of providing chest compressions, or during the chest compressions, the defibrillator may again analyze the victim's condition to determine whether they have a shockable rhythm. For example, the defibrillator may include componentry for filtering out CPR

artifacts from chest compressions as compared to an ECG signal, and may perform the analysis on the filtered signal.

[00122] Box 150 is shown along the loop of the CPR cycle to indicate a current time in the cycle. In particular, the box 150 indicates that the defibrillator or another device may, at the current point in time, be computing and displaying certain parameters regarding the care that is being provided to the victim. Certain of those parameters may be initial or primary parameters in that they are direct representations of values read from the patient. Such parameters may include depth and rate of chest compressions provided to the victim. Other of the reported parameters may be secondary parameters in that they are derived from the initial parameters, either from one or a multiple of different initial parameters. For example, certain values may be computed from a combination of the compression rate and the compression depth. Also more general composite values may be generated, such as a letter or number grade that indicates how the rescuer is currently performing. In some examples, the general composite value can be based in part on multiple variables including one or more of compression rate, compression depth, compression release, and compression fraction (e.g., the percent of time in compressions).

[00123] Box 152 represents values that are generated periodically, such as with each cycle of a CPR interval in a particular location in the interval, or at the end of an incident. The values that are generated may include, for example, average values for particular primary parameters over a period of an interval. For example, the average rate and depth over an interval may be computed at the end of each

interval and may be saved in a database such as in a manner shown by box 152.

Additional data such as compression fraction and compression release velocity can be computed at the end of each interval and may be saved in the database. The compression release velocity can be either an actual release velocity or a
5 categorical indicator of release such as - excellent, good, poor- to allow simpler analysis.

[00124] Also, the saved parameters may include derived or secondary parameters that are computed from initial parameters, such as from average values of initial parameters, or by combining multiple initial parameters from throughout an
10 interval, and then averaging the combination. In this example, a perfusion percentage is given as one example of a secondary or derived parameter, and letter grades for each interval are also secondary or derived parameters. In some examples, if multiple rescuers are participating in the rescue, the data stored in the database for each CPR cycle can include an indication of which rescuer performed
15 compressions in each interval (e.g., based on an assigned anonymous ID).

[00125] In this manner, a performance reporting approach may be implemented in coordination with standard CPR techniques so as to capture and report information that is particularly relevant to a rescuer or to a party after the fact of a rescue. The information may include basic measurements from the performance of
20 CPR on a patient, and may also include derived values that may provide a model or compelling or understandable representation of the rescuers performance. For example, the parameter that is displayed to the rescuer may be similar to or the same as a parameter on which the rescuers performance will be judged by a later

review work of an incident as part of the code review. The rescuer may thus be more responsive to such a displayed parameter if the rescuer is performing poorly, than the rescuer would be in response to simple values of depth and rate of compressions. As a result, the rescuer may be more likely to change his or her behavior in a positive manner so as to improve the care that is provided to a patient or victim.

[00126] The monitoring and feedback provided by such a process may also be affected by basic configuration data obtained by the system. For example, before monitoring by the system begins, a process may have gathered certain data to aid in the monitoring. For example, as a rescuer sets up a defibrillator and hooks it to a victim, the defibrillator may ask the rescuer (on a display or via a spoken request) whether the rescuer is alone or is being aided, and might also ask how many additional rescuers are available. If the rescuer indicates that he or she is alone, then the system may follow a branch of programming that does not recommend switching of rescuers, but might more aggressively provide feedback in order to overcome the extra fatigue a solo rescuer will face. If the rescuer is accompanied, then the system may subsequently indicate when rescuers are to switch roles. The system may also assign a label to each rescuer, such as “Rescuer 1” and “Rescuer 2” or the actual names of the rescuers (which could have been programmed previously, such as for EMTs who use the system frequently, or could be obtained, such as by lay rescuers speaking their names into the device in response to prompts from the device). If there are three or more rescuers, instructions for rotating may be more complex—i.e., involving more than simply an instruction to

switch positions, but instead telling each rescuer what component of CPR they should be performing for any particular time period. Additionally, the protocol used to direct the rescue can be changed based on the number of rescuers at the scene. For example, if the rescue begins with a single rescuer and another rescuer arrives subsequently, the additional rescuer can change the protocol to a two rescuer protocol.

[00127] A determination about the number of rescuers may also be made inferentially. For example, a ventilation bag may include electronics that report to a defibrillator or other box, and the box may sense that the bag is being deployed or used, or is being used simultaneous with chest compressions being performed, in order to infer that there are at least two rescuers. The defibrillator may adjust its operation accordingly in the manners discussed above in such a situation (e.g. by enabling prompts for rescuers to switch roles).

[00128] As for operation of the system during performance of CPR, in certain circumstances, prompts for performing CPR may change the way in which CPR is to be performed in response to indications that there has been a degradation in performance. For example, a protocol by which a user is instructed may change based on such an observation that performance has degraded, so as hit a performance level that the user can better maintain, even if that level is sub-optimal. In particular, prompting of CPR at a sub-optimal level may be provided, as long as that sub-optimal level is better than wholly fatiguing a rescuer.

[00129] For example, hemodynamics data has indicated that depth of chest compressions may be more important to victim well-being than is rate of

compressions—i.e., it may essentially not matter how fast you are performing compressions if none of those compressions is truly effective. As a result, a system may slow a rate (e.g., a metronome) of prompting compressions and may monitor how the depth of compressions changes in response to the prompted change in rate. Using stored hemodynamic data correlating depths and rates to effectiveness, the system may identify a most-preferred rate that maximizes the hemodynamic effect for a particular rescuer (using, e.g., the well-known Windkessel model or other approach). While such modifications may be made only after sensing that a particular rescuer is fatiguing, they can also be initiated at other points and in response to other criteria, including by making such adjustments throughout a rescue cycle (e.g., the rate of a metronome may be adjusted slightly and essentially continuously, and the combination of depth and rate that is measured from the rescuer may be input in real-time to a formula for computing hemodynamic effect, with subsequent changes in the rate of the metronome being made in an attempt to increase the hemodynamic effect within bounds of safety).

[00130] Also, physical data of the rescuer or rescuers may also be monitored while care is being provided to a victim, such as to determine whether the rescuers are tiring and should be prompted in a different manner, or should be instructed to switch out to other rescuers as they fatigue. For example, a rescuer may be outfitted with a pulse oximeter such as one that can be attached to a CPR puck on a victim's chest and into which the rescuer can place one or more fingers. The readings of the rescuer's blood oxygen level and pulse rate may be used to determine that the rescuer is fatiguing and will not be able to continue performance

at a current level for very long. As a result, a medical device can cause the rescuer to switch places with another rescuer, may provide encouragement to the rescuer, or may reduce the rate or severity with which the rescuer is providing care so as to maximize the work the rescuer can do, even if it is below what would otherwise be considered an optimum level of care.

[00131] Thus, these techniques may be used to identify rescuer performance, including indications of fatigue while providing such performance, for review by the rescuers or other at various points in time. For example, a medical device may immediately monitor the performance to provide feedback or adjust the manner in which it provides feedback so as to maintain a best level of performance over the length of a rescue operation, including by instructing rescuers to switch places at appropriate times so as to lessen the effect of fatigue. The rescuers themselves may also be provided with information as described above and below so that they may adjust their performance of care on a victim in real-time as they perform the care. Also, care may be reviewed after the fact, such as by rescuers to determine how they can perform better as a team or perhaps to determine that they should increase their physical conditioning to combat fatigue, and also by supervisors.

[00132] FIG. 2A is a screen shot of a tablet device showing a summary of rescuer performance in a CPR setting. In general, the screen shot shows roughly the sort of parameters that may be displayed on a tablet computer, a wearable computing device, etc. as feedback for a rescuer at the scene of an accident, or to a physician who is following the performance of care on a victim remotely.

[00133] The presentation of information in this example is split into two portions—a top portion that shows averaged performance over an entire incident, and a bottom portion that shows the performance average over each of the last three CPR intervals, with display of current depth and rate displayed immediately under the second portion.

[00134] Referring now to particular portions of the display, a rescuer is shown that their average depth of compression in performing CPR has been 1.8 inches for an incident, and that the appropriate range for compression is 1.5 inches to 3.0 inches. Similarly, the rescuer is shown that their average rate of compressions is 118 compressions per minute (CPM), which is within the approved range of 100 to 120 CPM. The approved range for compression fraction is over 75%, but the average for this rescuer is 73%. The fact that the rescuer is outside of the approved range is indicated here by a dashed box around the average value, to draw attention of the rescuer to the fact that improvement is needed in this value. Similarly, values are displayed for the rescuer's delay in pre-shock and post-shock activity and for a perfusion index by the rescuer. The particular values shown here were selected merely to demonstrate how values may be displayed to a rescuer, such as on a defibrillator/monitor, tablet computer, or similar device, and are not meant to represent actual values that would necessarily be displayed in an actual situation.

[00135] In the minute-by-minute CPR area of the display, three lines of values are shown, where the values are average values for each of the last three CPR intervals performed on the victim, so they represent approximately the last six minutes of CPR performed on the victim, though perhaps not the entirety of CPR

that has been performed on the victim. Again, individual values are provided for each of the intervals, and values that are outside of range are highlighted by a dashed box, though as discussed below, other mechanisms for drawing attention to out-of-range or in-range values may be employed.

5 **[00136]** Also, two of the values -- for depth and rate of compression -- are shown according to their current states. Specifically, the last compression performed by the rescuer had 3.2 inches of travel, and the last several compressions were performed at a rate of 110 CPM. Solid boxes are shown around these values to draw particular attention to them for the rescuer, so that the rescuer can quickly see what his or her
10 immediately current performance has been.

[00137] Additional guidance may be provided to a viewer of the display, such as to a rescuer, by using color, animation, and sound feedback. For example, any values on the display that are outside a desired range may be displayed in red, while values at the edge of the range may be displayed in yellow, and values inside
15 the range may be displayed in green color. Also, particularly important values may be highlighted by making them blink, wiggle, or shimmer, so as to call a viewer's attention particularly to them. Also, the device may beep or speak recorded instructions when the rescuer needs guidance in returning to approved performance ranges.

20 **[00138]** The particular arrangement of values on the display here is provided merely as an example of data that may be shown to a rescuer or to a physician while care is being provided to a victim. Other arrangements of information may also be employed. In particular, less information than is shown here may be

provided, and may be shown in a smaller portion of the screen, thus leaving room for the display of other information that may be pertinent to a rescuer. One such example is shown in FIG. 2B.

[00139] In particular, FIG. 2B shows another screen from a device such as a patient monitor or tablet computer that may be displayed to a rescuer. In this example, a performance area 238 (i.e., an area that rates and reports on the rescuer's performance) takes up a relatively small part of the entire display. The data that is displayed is similar to that displayed in FIG. 2A, but only average values across the entire incident, and immediate values for depth and rate, are displayed. A numerical or alphabetical grade (not shown) may also be provided near this area as a higher level, more summarized, view of the performance.

[00140] The relatively small size of the performance area 238 leaves additional room on the display to show other data about a rescue incident. For example, a victim identification area in the upper left corner of the display includes an image 232 of the victim and personal information 234 about the victim. The image 232 may be obtained from a central server system in response to entering identification information for the victim. For example, a driver's license found with the victim may indicate a name of the victim, or a fingerprint may be obtained from a fingerprint reader for the victim, where the fingerprint reader may be incorporated with a blood oxygenation sensor. Such a mechanism for identifying the victim may be used to recover limited medical record information about the victim, such as the blood type, allergies and medications taken by the victim. The image 232 may be displayed so that the rescuer may manually confirm that the patient who is identified by the

system is the same person as the victim who is lying front of them (where the victim is unable to identify himself or herself).

[00141] An ECG display 236 is also provided in a familiar manner in an area the display 236, showing an ECG trace and may also display warnings or other data such as an indication of the amount to which capacitors on a defibrillator have been charged, and whether they are ready for discharge. Other information that is not shown here may also be provided on the display. For example, countdown timers may be shown to indicate future activities that will need to be performed by the rescue team. As one example, a countdown timer may indicate the amount of time left in a CPR interval. Also a countdown timer may indicate time for another rescuer, such as time for providing ventilation to the patient or victim, or time until a particular drug is to be provided by the rescuers to the victim.

[00142] The display may also show content that is typed by a physician at an emergency room, or other similar content. For example, the physician may monitor information like that shown in this figure, and may provide guidance to a rescuer by typing it, similar to an online chat system. In other implementations, a voice connection may be made up with the physician, and instructions from the physician may be heard through the tablet computer, the defibrillator monitor, a BLUETOOTH headset that is provided with data from the tablet or monitor, or through another form of communication device employed by the rescuer.

[00143] Using displays like those shown in FIGS. 2A and 2B, a system may provide improved feedback to a rescuer in an emergency situation. The feedback may be provided in a graphical manner that indicates information that is most

important to the rescuer, and is thus most likely to be acted upon by a rescuer.

Also, the information that is provided may be a form of combined information that provides a higher level view of the rescue operation. For example, a number of

different actions or activities that are performed by a rescuer on a victim may be

combined using a predetermined formula or algorithm to produce a more general

descriptor of the quality of care that is given to the victim. Such automatic

combination by the system may relieve a rescuer of having to make such

determinations themselves. For example, a particular combination of compression

rate and depth, albeit nominally out of range for either rate or depth or both, may be

within a desired range when the values for rate and depth are applied against each

other, such that out of range values for each variable cancel each other out. Also,

where the information is more generalized, it may be more in line with the form of

information on which the rescuer will be judged in the performance of their job, so

that a rescuer may be more likely to respond to it.

[00144] In some implementations, the information described above with respect to FIGS. 2A and 2B may also or instead be presented by the heads-up device (103

of FIG. 1A) and/or the wearable computing device (e.g., the wearable computing

device 111 in the form of wearable glasses of FIG. 1A, the wrist-worn device 800 of

FIGS. 8A and 8B, etc.). In some implementations, the heads-up device and/or the

wearable computing device is configured to provide feedback to the rescuer

performing the CPR, as described above with reference to FIGS. 8A and 8B. The

feedback may be based on the parameter(s) associated with the performed CPR,

such as the rate of chest compressions, the depth of chest compressions, and the compression fraction, among others.

[00145] FIG. 3 is a flow chart of a process for capturing user performance data during the provision of CPR. In general, the process involves receiving raw

5 information from sensors that are connected to a patient monitor, which may be incorporated into a defibrillator as described above, generating derivative data, displaying to a user of the monitor values for the raw data and the derivative data, and also displaying values for real-time measurements and historic measurements.

For example, the real-time raw measurements may include depth and rate of

10 compression during CPR that is being performed on a patient who is being monitored. The derived measurements may include a perfusion performance indicator and overall letter or number grade for the performance of the user. The historical measurements may include measurements for portions of, or all of, prior CPR intervals, or for averages from such periods or across multiple intervals.

15 **[00146]** The process begins at box 302, where a medical device/monitor, such as a defibrillator with built-in capabilities for monitoring motion of chest compressions and ECG signals, among other parameters, senses cyclical activities that are being performed on a patient. Such cyclical activities may include the provision of CPR in a recursive cycle following the 8H a guidelines discussed above, where the cycle

20 involves analyzing a patient such as to determine whether the patient exhibits a shock of all heart rhythm, providing a shock if the patient has such a rhythm, and providing chest compressions to the heart to cause perfusion of blood in and through the heart. The particular activities may generate data from sensors, and the

step of sensing the activities may include converting the data to a more usable form, such as by converting a voltage received from an accelerometer into a computed depth of compression for a patient's chest.

[00147] At box 304, the process identifies intervals for the cycles in the provision

5 of care to the victim or patient. Thus, for example, the process may identify starting and ending points for each of the CPR intervals and may thereby associate data received between each start point and end point with a particular one of the

intervals. Such association of received data with particular intervals may enable the presentation of information about the data to a user in a manner that the information
10 is correlated to the particular intervals in which it was received.

[00148] At box 306, data is gathered for sensing activities during the identified

cycles. Such data gathering may be continuous during the performance of CPR and other activities on a patient or victim, such that particular ones of the actions described here may be repeated over and over until a rescuer terminates a

15 monitoring described here. As the data is gathered, it may receive a first level

processing, such as described above to convert voltages into more usable values

such as displacements or accelerations. Similarly, the monitor may change voltages

from leads that are attached to the patient into values for an ECG signal that may

be easily graphed on the monitor or on another device. Such initially-processed

20 data may then be stored on the device, and copies of some or all of the data may

be provided to other devices. For example, the data may be transferred over a short range wireless connection to a device such as a tablet 116 or server 120 in FIG. 1.

Such transfer of data may be in batches or may be continuous or substantially

continuous. For example, an automatic batch upload of data may be triggered at particular points during treatment of a patient, such as after a rescuer terminates treatment. A proximity sensor may be used to determine that treatment has terminated because the monitor has returned to a vehicle such as ambulance, and such sensing may be used to trigger the batch transfer of data between the monitor and devices in the ambulance, and then further to a separate device such as server 120. In another implementation, the batch transfer may be triggered by a GPS unit in the device sensing that the device is moving above a particular speed, such as 15 mph, and thus concluding that the device has been placed in an ambulance and that its use is complete. In another implementation, the batch transfer may be triggered by data from a dispatch center indicating that the victim has been transferred to an ambulance. Such determination may also be combined with a determination that patient conditions are no longer being received from the various sensors to which the device has been connected. Continuous transfer of data may occur by a variety of mechanisms, such as by caching received and initially-processed data, and then uploading or otherwise transferring the data at close-spaced periods.

[00149] In some examples, the analysis of the rescue does not cease at the arrival of the victim to the ambulance. Rather, similar analysis of rescue performance can be applied to separate phases of treatment. For example, once the patient is in transport, it is hard to perform high quality CPR. The device automatically determines when transport begins, and marks the received rescue data as “during transport” on the report card. When a final analysis information is

displayed to the rescuer, the analysis can include summary statistics for care on scene only in addition to the entire treatment. Additionally, in some examples, the rescue data can include an indication of arrival at an emergency department, and data gathered after arrival could be excluded from the analysis of the rescue performance. Excluding this data can be useful because in many cases, care is continued for the EMS defibrillator even after arrival at the hospital.

[00150] At box 308, the gathered data is processed to generate summarized data, which is a derivative form of the initially gathered data. For example, information about rate and depth of chest compressions may be used along with other information obtained by a system to identify a level of perfusion for a patient. In addition, summaries may be generated for entire CPR intervals or multiple CPR intervals. As one example, particular values that have been captured and recorded for performance of activities on a patient may be aggregated, such as by generating an average value for a CPR interval or an average value across multiple CPR intervals. Thus, for example, a perfusion level for the entire time that a rescuer has been performing CPR on a patient may be computed and may be reported back out to the rescuer.

[00151] Also, as shown at box 310, summarized data may be consolidated across a number of activities, such as data relating to chest compressions and data relating to ventilation that can be combined to identify an overall indicator of care that is been provided to the patient. Thus, in such examples, the derivative data may not only be derived from the original data, such as depth of compression, but may also be derived from two separately obtained pieces of original data. Such

combining of data sources across multiple activities being performed on the patient may also be used to generate a score or grade for the care provided so far to the patient, so as to indicate manners in which the rescuer can change subsequent care that is given. For example, monitoring of parameters like those discussed in FIGS. 2A and 2B may indicate that a rescuer is too excited or too relaxed in giving their care (e.g., because they are compressing the chest too soft or too hard, or they are acting too quickly or too slowly in certain parts of the CPR interval). In such a situation, a score from -5 to +5 may be assigned, where a score of 0 is perfect, scores farther below 0 indicate that the rescuer needs to be more active in their care, and scores above 0 indicate that the rescuer needs to take a deep breath and relax a bit. Such a score may be displayed in a location on a screen of a monitor, tablet computer or similar computing device. The score or grade for the entire session may also be submitted to a supervisor of the rescuer as part of a post hoc code review of the session. In some examples, in a multi-person rescue, separate scores can be displayed for each rescuer. Displaying scores separately can allow each rescuer to know how to modify their technique.

[00152] Such presentation of the raw and derived data is represented by box 312, where a visual summary of the user's performance is displayed. Such display, as discussed above, can be on a monitor, on a tablet, on a separate computer used by another caregiver, or by other mechanisms. The display may take a form, for example, similar to that shown in FIGS. 2A and 2B.

[00153] At box 314, summary information for an incident or session is saved. Such a step could take place continuously or semi-continuously throughout an

incident or may occur as a batch upload once the incident is over, as discussed above. The information may be saved locally and may also be saved on a more global server system from which supervisors or analysts may access both the raw and derived data. Presentations of the data similar to those shown above may be provided, and a replay may be had of the data that would have been displayed to the rescuer. As a result, the rescuer and an official may step through the session step-by-step, and the official may point out exactly what the rescuer did right and wrong. The presentation may also take a more summarized form, and can roll in data from multiple different incidents, such as all recent incidents of a particular type for a particular rescuer (e.g., all incidents in which a victim suffered a severe sudden cardiac arrest or similar trauma). For example, using the -5 to +5 scoring technique described above, a supervisor may be presented with scores for a dozen recent incidents for a rescuer, and may notice that the scores are generally below 0. The supervisor may then determine to provide the rescuer with training in being more aggressive (i.e., providing harder chest compressions, and reacting more quickly to prompts during a CPR interval). In some additional examples, a + or – score for each CPR parameter can be provided instead of or in addition to the composite score.

[00154] FIG. 4 is a swim lane diagram of a process for sharing CPR performance data between various sub-systems in a larger healthcare system. In general, the process discussed here is similar to those discussed above, though actions performed on particular components of a larger system are shown in more detail to

indicate examples of a manner in which such actions may be performed in one implementation.

[00155] The process begins at an accident scene, where a rescuer has deployed equipment from a rescue vehicle, such as a defibrillator and an associated
5 computing device such as a tablet computer, which may communicate with the defibrillator through a wireless data connection. At boxes 402, 404, the two devices are powered up by the rescuer, and when they have performed initial activities to become active, they may automatically establish a data connection, such as by performing BLUETOOTH pairing between the devices (boxes 406, 408). The
10 rescuer may then enter patient information, at box 410, into the tablet computer, such as basic information regarding the condition of the patient, blood pressure and pulse for the patient, and gender of the patient. Information such as blood pressure and pulse may be recorded automatically by the tablet, such as by way of wired or wireless connection with tools for taking the victim's blood pressure and pulse.

[00156] At box 414, the rescuer connects sensors to the patient. For example, the
15 rescuer may open a shirt of a patient and place defibrillation pads on the patient. The defibrillation pads may also include ECG electrodes for sensing cardiac activity of the patient. At this point, the defibrillator may begin performing according to standard protocols for delivering care to a patient, such as by analyzing cardiac
20 activity of the patient. Such action may also lead to the rescuer performing chest compressions and other CPR activities on the patient. Thus, at box 422, the defibrillator may begin capturing CPR data, such as depth and rate of compressions data and other data discussed above. Also, the defibrillator may identify the

beginning point for each interval or cycle in the performance of CPR, so as to associate the data with a particular cycle. At box 424, the defibrillator generates, displays, and transmits a report regarding data that is being captured from the performance of CPR. Such a report may take a variety of forms. For example, the report may simply indicate initial or primary parameters that are being captured in real time, and the reporting for those parameters may be continuously updated such as every second or portion of a second. Later, the report may include such real-time data, but may also include summarized, secondary data for one or more CPR intervals or for an entire time period of an incident.

[00157] At various points in time, the defibrillator may also transfer data for generating similar reports to the tablet computer, and the tablet computer may display information related to the provision of CPR to the patient, and may also to further transmit the data to a computing device in an area of an emergency room where the victim is to be taken (box 426). The information may then be displayed as a report in the emergency room. The report for the emergency room may take the same form or different forms than that shown on the defibrillator or the tablet computer. For example, if one is to assume that the viewer in the emergency room can give less attention to the report than can the rescuer, the emergency room report may provide less information and be updated less frequently than is the report on the defibrillator or the tablet computer. Particular values that are shown in each report, the frequency with which they are updated, the manner in which they are displayed, and the order in which they are displayed may vary depending on the particular application and the needs of the particular users.

[00158] At box 434, the defibrillator identifies that the incident has ended. For example, if no ECG signals are received for a predetermined period of time, the defibrillator may assume that it has been disconnected from the victim and that it will not be used on the victim again. Other mechanisms for determining that an incident has ended are discussed above. When such a determination is made, the defibrillator may transfer its remaining data to the tablet computer and may also generate a summary of the incident and transmit that summary to the tablet computer (box 438). At box 446, the tablet computer displays the summary and also transmits information for the summary to a central server system. Such transmission may be directed toward providing a semi-permanent or permanent record regarding the care that was provided to the victim.

[00159] Thus, at box 450, the central server system processes the information received from the tablet computer and stores information about the incident. In certain embodiments, all or substantially all of the information captured by the defibrillator may be stored. Where space limitations or other considerations prevail, summary information may be stored. For example, average values for various parameters may be stored for each cardiac or CPR interval, rather than storing raw values for much smaller but more numerous time segments within each interval.

[00160] At some later date, the rescuer or another individual may be interested in analyzing the data that was saved for the particular incident or a group of incidents. Therefore, at box 452, when such a request is received by the central server system, the system may serve responses to the request for data about the incident or other incidents. At the time of serving the data for the incident, the central server

system may generate one or more additional reports for presenting the information about the incident or incidents. For example, graphs for each incident at which a particular rescuer acted may be displayed side-by-side, and trend lines or other trend features may be displayed, so that the progression in the skills of a rescuer may be judged, and a reviewer or the rescuer may determine whether the rescuer needs to adjust his or her approach to providing care in a rescue situation.

[00161] As discussed above, when a determination is made that a rescue incident has ended, the defibrillator transfers data to a computer and the computer generates a summary of the incident. This summary can include a CPR performance metric such as single score or grade for the entire rescue session (e.g., an alpha-numeric score). This CPR performance metric can provide useful, high-level information to the rescuer about their performance by providing a single alpha-numeric score that gives the rescuer an indication of how well they performed the CPR relative to pre-established guidelines. The CPR performance metric, e.g., the score or grade, can be presented within a limited time (e.g., within less than 5 min) after completion of the rescue attempt (e.g., within a limited time after the cessation of CPR chest compressions). In some applications, the CPR performance metric can be presented to the user within 1 minute or less after completion of the rescue attempt. It is believed that presenting the information quickly will help the rescuer to better correlate the score with their performance and infer ways to improve their future performance.

[00162] The CPR performance metric can be an indicator that summarizes CPR performance parameters (e.g., a percentage, a letter grade, a score on a predefined

scale such as 1-10). The CPR performance metric is based on CPR parameters such as rate of CPR compressions, depth of CPR compressions, compression fraction (e.g., a measure of interruptions to CPR compressions), ventilation rate, pre-shock pause, and/or post-shock pause. These factors are weighted such that the CPR performance metric can be correlated with of survival rate. As such, a better score of the CPR performance metric can indicate that CPR performance has been optimized for maximum chances of survival for the victim.

[00163] The algorithms used to generate the CPR performance metric can be generated using a linear regression technique and or using a neural network analysis technique. For example, the different measured factors or parameters (e.g., rate, depth, and fraction) can be input into a linear regression or other analytical model such as a neural network which can adapt the model to derive a predictor of survival. The weightings that are assigned to each of the parameters can then be optimized based on maximizing the survival rate. After generating the model and training the model using past performance data and clinical outcomes, the model can then be used to provide real-time or substantially immediate feedback to a rescuer based on their performance for a particular rescue attempt. This will include inputting the various factors such as rate, compression depth, fraction, and any other factors used by the model, weighting the factors based on the model, and calculating the performance metric. The performance metric can be displayed to the rescuer in a variety of formats. In some additional examples, in addition to factors such as rate, compression depth, fraction, the performance

metric could additionally be based on patient size (e.g. weight, chest diameter, chest circumference), gender, and/or age.

[00164] FIG. 5 is a screenshot of the tablet device showing a summary of rescuer performance in the CPR setting after the completion of the rescue attempt. The presentation of information in this example is split into two portions - a top portion dedicated to overall performance and a bottom portion dedicated to displaying performance information for smaller time periods, such as minute-by-minute. The information presented to the rescuer immediately subsequent to completion of the rescue attempt includes the overall performance metric, which in this case is displayed as performance grade 502.

[00165] Referring now to particular portions of the display, a rescuer is shown their overall performance in the form of a grade 502. The overall grade 502 provides an easily understandable measure of the overall performance. In addition to providing the grade 502 for overall performance of CPR, information about multiple key factors in determining overall performance can additionally be displayed. In the example shown in figure 5, this information includes a grade for the depth of CPR compressions 504a, a grade for the overall rate of CPR compressions 504b, a grade for compression fraction 504c, and a grade for compression release 504d. These scores for the individual factors can help the rescuer to understand why they have received the overall grade 502 and help the rescuer to know how to improve their overall performance. The grade can be similar to a grade scale used by a learning institution and include F, D, C, B, and A grades. The display can also include a rescuer ID to allow each rescuer to know

how their performance related to guideline performance. For example, in a multi-rescue performance overall performance can be displayed separately for each rescuer.

[00166] Referring now to the second portion of the display, in addition to providing overall performance metrics which relate to the performance across the entire rescue attempt, additionally, performance information is displayed for smaller time intervals 508a, 508b, 508c, 508d, and 508e, such as minute-by-minute. In this example, for each of multiple CPR intervals, the display includes a grade for that interval. The grade for that interval is generated based on performance data collected during the associated time period. Displaying grades for more finely subdivided time intervals can help the rescuer to understand whether their overall performance improved or degraded during the rescue attempt. For example, in the exemplary display shown in figure 5, the rescuer performed well in the first two time intervals and the final time interval but the rescuer's performance degraded during time intervals, three and four. As such, upon review, the rescuer could think about differences in how they performed the rescue during the time intervals for which they received lower grades and use that information to improve their CPR technique.

[00167] Additionally, the second portion of the display includes graphical information about key performance factors. For example, the depth of CPR compressions, rate of CPR compressions, and compression fraction metrics are individually displayed graphically by portions 510a, 510b, and 510c. In the graphical display, both the actual measured parameter and an acceptable range of

parameters can be displayed to the rescuer. For example, in the graph of depth 510a, an acceptable range of depth is indicated by shaded portion 512a and the actual depth measured for the compressions performed during the rescue attempt is displayed as line 514a. Displaying both the acceptable range and measured data for the parameter allows the rescuer to see how their performance varied during the rescue attempt and to understand how their performance deviated from desired performance (e.g., performance as provided in CPR guidelines).

[00168] FIG. 6 is a flowchart of a process for generating the CPR performance metric. In general, the process involves receiving information about CPR parameters such as rate, depth, fraction, pause, and/or ventilation, and inputting the information into a weighted model, to generate and display a CPR performance metric within a limited time after completion of the rescue attempt (e.g., within one minute of completion).

[00169] The process begins at box 602, where a defibrillator with built-in capabilities for monitoring motion of chest compressions and ECG signals, among other parameters monitors inputs to generate information about the patient and CPR performance. This information is used to identify that CPR has begun.

[00170] At box 604, sensors are used to collect information and data about the CPR activities. This information can include information about the rate of CPR chest compressions, depth of CPR chest compressions, fraction in compressions, pauses prior to or subsequent to defibrillation, and ventilation rate. The particular activities performed during CPR may generate data from the sensors and the step of measuring these parameters can also include converting the data to a more usable

form. For example, the voltage received from accelerometer can be used to compute a depth of compression.

[00171] At box 606, a computer or processing device calculates the score for each of the measured parameters. These per-parameter scorers provide an

5 indication of the effectiveness or accuracy of the factor over the entire rescue performance. For example, a desired depth range for CPR chest compressions can be 2.0 inches. Based on a comparison of the actual measured depths to the desired depth, the system can calculate a chest compression depth score that is indicative of how closely the performed chest compression depth match the desired depth.

10 Similarly, based on other desired ranges, the other performance factors can provide a measure of how well the rescuer has stayed within the desired performance ranges. In one particular example, the per-parameter score can be a percentage of the CPR that was within guidelines. For example, the percentage of compressions having a measured depth that is within the desired compression depth range
15 outlined by the CPR guidelines. In some examples, the parameter is summarized based on whether the patient has return of spontaneous circulation (ROSC). If a patient obtains ROSC 10 seconds into an interval, the chest compressions fraction will be very low. Thus, excluding this data can provide more useful information for the rescuer about their rescue technique.

20 **[00172]** At box 608, the individually generated per-parameter scorers are entered into a weighted model. The weighted model can be generated according to a variety of mathematical processes, such as by using a linear regression or other analytical model such as a neural network, which is been previously trained based

on CPR performance data and patient outcome associated with the performance data.

[00173] At box 610, the system generates a CPR performance metric score based on the outcome of the weighted model calculation. The CPR performance metric score provides a single value or parameter indicative of the overall performance throughout the entire rescue. For example, the CPR performance metric (CPM) score can be calculated according to the following:

$CPM = f(w_{rate} * X_{rate}, w_{Depth} * X_{depth}, w_{fraction} * X_{fraction})$ where w_{rate} , w_{depth} , and $w_{fraction}$ are weighting factors for rate, depth and fraction and X_{rate} , X_{depth} , and $X_{fraction}$ are

calculated metrics for the overall performance of CPR rate, depth, and fraction relative to a guideline or desired performance. At box 612, the total score is displayed on a wearable computing device (e.g., to the rescuer) within a limited time after the completion of the rescue attempt. For example, the score can be displayed within 5 minutes of completion of the rescue attempt. In another

example, the score can be displayed within one minute of completion of the rescue attempt.

[00174] In some examples, only data collected prior to arrival of the victim at the hospital (e.g., prehospital data) is used to generate the performance metrics. Thus, the system identifies when the victim has arrived at the hospital and excludes any subsequent data from the performance metric calculations. In some additional examples, the system could calculate the performance metrics upon receipt or determination of an end of case indicator which could be time of pad removal, time

that a soft key is pressed to indicate case end, time of arrival at ED as determined from GPS or dispatch.

[00175] As described above, the wearable computing device (e.g., the wearable computing device 111 in the form of wearable glasses of FIG. 1A, the wrist-worn device 800 of FIGS. 8A and 8B, etc.) is configured to provide feedback to the rescuer performing the CPR. In some implementations, the feedback may be based on one of more of the calculated metrics (e.g., the rate, depth, and/or fraction metric).

[00176] FIG. 9A shows an example of the wearable glasses computing device 111 presenting CPR feedback information via the graphical display 115. The displayed information can include the rate of compressions 906 (e.g., number of compressions per minute) and the depth of compressions 904 (e.g., depth of compressions in inches or millimeters). Displaying the actual rate and depth data (in addition to, or instead of, an indication of whether the values are within or outside of an acceptable range) can provide useful feedback to the rescuer. A visual indicator 907, such as a color of the text or an applied highlighting, can be modified to indicate when a value for the depth or rate is outside of the preferred range. For example, if the rate of 88 compressions per minute as shown in FIG. 9A is too fast, the visual indicator 907 may include a red highlight indicating that the rescuer should slow down.

[00177] The displayed information about the chest compressions can also include a perfusion performance indicator (PPI) 908. The PPI 908 has a shape (e.g., a diamond) that is colored or shaded over time. The amount of the shape that is

colored or shaded (e.g., the fill amount) provides feedback about both the rate and depth of the compressions. For example, when CPR is being performed adequately, the entire indicator may be filled. As the rate and/or depth decreases below acceptable limits, the amount of fill lessens. The PPI 908 can provide a
5 concise visual indication of the quality of the CPR such that the rescuer can aim to keep the PPI 908 completely filled. As discussed further herein, the wearable computing device may also aggregate multiple parameters/data monitored during the act of administering CPR to provide a score, where the individual parameters/data may be weighted and/or unweighted, to indicate to a user the
10 overall quality in the performance of CPR, so as to improve the quality of future CPR.

[00178] The graphical display 115 may be configured to display a filtered ECG waveform 902. In some examples, other waveforms can also be displayed.

[00179] In some implementations, the CPR feedback information may be related
15 to a particular metric that has an unsatisfactory value (e.g., such that the CPR performance metric (CPM) score is negatively impacted by the metric). For example, if the depth of chest compressions and the compression fraction have satisfactory values, but the rate of chest compressions is inadequate, the wearable computing device may provide feedback directed at the inadequate rate metric. The
20 feedback may include a spoken message emitted by a speaker of the wearable computing device (e.g., “slow down” or “speed up”). The feedback may include a periodic vibration indicative of the desired rate of chest compressions, as described above with reference to the wrist-worn device 800. The feedback may include a

visual indicator, such as a light flashing at a rate that corresponds to the desired rate of chest compressions.

[00180] As shown in FIG. 9B, in some implementations, the wearable glasses computing device 111 is configured to present (e.g., via the graphical display 115) a CPM score 910 and the calculated metrics 912, 914, 916 to the rescuer. Any combination of the CPM score 910 and the calculated metrics 912, 914, 916 may be displayed continuously. In this example, the compression depth metric 912, the compression rate metric 914, and the compression fraction metric 916 are displayed. Each of the calculated metrics may be presented in a way that corresponds to the impact that the particular metric has on the CPM score 910. For example, calculated metrics that have a relatively negative impact on the CPM score 910 may be presented in bold text, and calculated metrics that have a relatively positive impact on the CPM score 910 may be presented in non-bold text. Similarly, if the CPM score 910 is unsatisfactory, it may be presented in bold text, and if the CPM score 910 is satisfactory, it may be presented in non-bold text. In this way, the rescuer can quickly determine whether the CPM is being adequately administered, and if not, the rescuer can quickly determine which of the CPR parameters additional attention should be afforded to.

[00181] In the example shown in FIG. 9B, the CPM score 910 is 86 (e.g., 86 out of 100). A score of 86 may be deemed satisfactory, and thus the CPM score 910 is presented in non-bold text. However, there exists room for improvement of the CPM score 910. The depth metric 912 and the fraction metric 916 have satisfactory values, and are thus presented in non-bold text. However, the rate metric 914 has

an unsatisfactory value of 65 compressions per minute. Therefore, the rate metric 914 is presented in bold text. The bold text of the rate metric 914 can serve to catch the rescuers attention, and the rescuer can focus on improving the metric (e.g., by speeding up the rate of chest compressions). Once the rate metric 914 has a
5 satisfactory value, the bold text can become non-bold and the CPM score 910 can increase accordingly.

[00182] If one or both of the depth metric 912 and the fraction metric 916 assumes an unsatisfactory value, the CPM score 910 may decrease accordingly. If the CPM score 910 falls below a particular (e.g., predetermined) threshold, the
10 CPM score 910 may be presented in bold text.

[00183] One or more other visual techniques may be employed instead of or in addition to the bold/non-bold text feature described above, for example, in some implementations, each of the calculated metrics 912, 914, 916 is presented as text having a color that correspond to the impact of the calculated metric on the CPM
15 score. For example, calculated metrics that have a relatively negative impact on the CPM score may be presented in red text; calculated metrics that have a relatively neutral impact on the CPM score may be presented in yellow text; and calculated metrics that have a relatively positive impact on the CPM score may be presented in green text. In this way, the rescuer can quickly determine whether additional
20 attention should be afforded to one or more of the CPR parameters. For example, the CPM score 910 having a value of 86 may be presented in yellow text, indicating that the CPM score 910 is within acceptable limits but there is room for improvement. The compression depth metric 912 may be presented in green text,

the compression rate metric 914 may be presented in red text, and the compression fraction metric 916 may be presented in green text. Based on the text colors, the rescuer can quickly determine that the rate of compressions metric 914 is unsatisfactory and is a major factor in the CPM score 910 being suboptimal.

5 **[00184]** In some implementations, feedback may be provided only when one or more aspects of the CPR performance is unsatisfactory. For example, if each of the calculated metrics 912, 914, 916 falls within acceptable ranges and the CPM score 910 is acceptable, the wearable computing device 111 may refrain from providing feedback to the rescuer so as not to distract the rescuer. In some implementations, 10 positive feedback is provided to the rescuer, but such positive feedback may be minimal so as not to distract the rescuer.

[00185] One of more of the feedback features described above with reference to FIGS. 9A and 9B may be included in other implementations of the wearable computing device. For example, while the wearable computing device 111 in the 15 form of wearable glasses is shown in FIGS. 9A and 9B, similar feedback may be provided by a wrist-worn device (e.g., the wrist-worn device 800 of FIGS. 8A and 8B), a fitness device, a portable computing device (e.g., a smartphone), etc.

[00186] Figure 7 is a flowchart illustrating a method for producing an artificial neural network capable of generating the CPR performance metric. In general the 20 neural network receives sets of data from past rescue attempts and trains a neural network model based on the data. This generates weightings for various factors that are used to calculate the CPR performance metric.

[00187] At box 702, CPR performance information and patient outcome information are stored in an electronic database. More particularly, the data can include a plurality of sets of data with each set having multiple parameters related to CPR performance such as rate, depth, and fraction. Additionally, each of the sets of data has a parameter relating to patient outcome such as whether the patient survived.

[00188] At box 704, a computer-generated artificial neural network that includes interconnected nodes is generated. Each node has multiple inputs and associated weights. The nodes include a plurality of artificial neurons, each artificial neuron having at least one input and associated weight. For example, the neural network maybe a mathematical model or computational model simulating the structure and/or functional aspects of the biological neural network.

[00189] At box 706, the system trains the artificial neural network using the stored information about the CPR performance and patient outcome. This training adjusts the weights of at least one input of each artificial neuron of the plurality of artificial neurons responsive to the different parameters in the different sets of data. This results in the artificial neural network being trained to produce a prediction of the patient outcome based on the CPR performance data. For example, as noted above, artificial neural networks are based on pattern recognition tasks and are used to provide artificial intelligence-based approach to solve classification problems. Thus, a model is formed during the training process using previously known input/output pairs. The trained model can then be tested with new data to verify the model and subsequently used to provide a desired output. Various known

artificial neural network topologies can be used to generate the CPR performance metric. Exemplary neural network topologies include single layer and multilayer feed-forward networks which are based on weights of hidden layers that are adjusted during training to minimize an error function. Training of the artificial neural network can be based on back propagation learning, such as use of the Levenberg-Marquardt algorithm. At box 708, the weights for the various parameters are stored. These weights can later be used to calculate the performance metric for a new set of CPR performance data.

[00190] In some examples, the model can also be based on information about the patient such as weight, age or gender.

[00191] FIG. 10 shows an example of a generic computer device 1000 and a generic mobile computer device 1050, which may be used with the techniques described here. Computing device 1000 is intended to represent various forms of digital computers, such as laptops, desktops, workstations, personal digital assistants, servers, blade servers, mainframes, and other appropriate computers. The functionality, components, etc. of the computing device 1000 can also be employed by a wearable computing device (e.g., in the form of a pair of glasses) Computing device 1050 is intended to represent various forms of mobile devices, such as personal digital assistants, cellular telephones, smartphones, and other similar computing devices. The components shown here, their connections and relationships, and their functions, are meant to be exemplary only, and are not meant to limit implementations of the inventions described and/or claimed in this document.

[00192] Computing device 1000 includes a processor 1002, memory 1004, a storage device 1006, a high-speed interface 1008 connecting to memory 1004 and high-speed expansion ports 1010, and a low speed interface 1012 connecting to low speed bus 1014 and storage device 1006. Each of the components 1002, 1004, 1006, 1008, 1010, and 1012, are interconnected using various busses, and may be mounted on a common motherboard or in other manners as appropriate. The processor 1002 can process instructions for execution within the computing device 1000, including instructions stored in the memory 1004 or on the storage device 1006 to display graphical information for a GUI on an external input/output device, such as display 1016 coupled to high speed interface 1008. In other implementations, multiple processors and/or multiple buses may be used, as appropriate, along with multiple memories and types of memory. Also, multiple computing devices 1000 may be connected, with each device providing portions of the necessary operations (e.g., as a server bank, a group of blade servers, or a multi-processor system).

[00193] The memory 1004 stores information within the computing device 1050. In one implementation, the memory 1004 is a volatile memory unit or units. In another implementation, the memory 1004 is a non-volatile memory unit or units. The memory 1004 may also be another form of computer-readable medium, such as a magnetic or optical disk.

[00194] The storage device 1006 is capable of providing mass storage for the computing device 1000. In one implementation, the storage device 1006 may be or contain a computer-readable medium, such as a floppy disk device, a hard disk

device, an optical disk device, or a tape device, a flash memory or other similar solid state memory device, or an array of devices, including devices in a storage area network or other configurations. A computer program product can be tangibly embodied in an information carrier. The computer program product may also
5 contain instructions that, when executed, perform one or more methods, such as those described above. The information carrier is a computer- or machine-readable medium, such as the memory 1004, the storage device 1006, memory on processor 1002, or a propagated signal.

[00195] The high speed controller 1008 manages bandwidth-intensive operations
10 for the computing device 1000, while the low speed controller 1012 manages lower bandwidth-intensive operations. Such allocation of functions is exemplary only. In one implementation, the high-speed controller 1008 is coupled to memory 1004, display 1016 (e.g., through a graphics processor or accelerator), and to high-speed expansion ports 1010, which may accept various expansion cards (not shown). In
15 the implementation, low-speed controller 1012 is coupled to storage device 1006 and low-speed expansion port 1014. The low-speed expansion port, which may include various communication ports (e.g., USB, Bluetooth, Ethernet, wireless Ethernet) may be coupled to one or more input/output devices, such as a keyboard, a pointing device, a scanner, or a networking device such as a switch or router,
20 e.g., through a network adapter.

[00196] The computing device 1000 may be implemented in a number of different forms, as shown in the figure. For example, it may be implemented as a standard server 1020, or multiple times in a group of such servers. It may also be

implemented as part of a rack server system 1024. In addition, it may be implemented in a personal computer such as a laptop computer 1022.

Alternatively, components from computing device 1000 may be combined with other components in a mobile device (not shown), such as device 1050. Each of such devices may contain one or more of computing device 1000, 1050, and an entire system may be made up of multiple computing devices 1000, 1050 communicating with each other.

[00197] Computing device 1050 includes a processor 1052, memory 1064, an input/output device such as a display 1054, a communication interface 1066, and a transceiver 1068, among other components. The device 1050 may also be provided with a storage device, such as a micro drive or other device, to provide additional storage. Each of the components 1050, 1052, 1068, 1058, 1066, and 1068, are interconnected using various buses, and several of the components may be mounted on a common motherboard or in other manners as appropriate.

[00198] The processor 1052 can execute instructions within the computing device 1050, including instructions stored in the memory 1064. The processor may be implemented as a chipset of chips that include separate and multiple analog and digital processors. The processor may provide, for example, for coordination of the other components of the device 1050, such as control of user interfaces, applications run by device 1050, and wireless communication by device 1050.

[00199] Processor 1052 may communicate with a user through control interface 1058 and display interface 1056 coupled to a display 1054. The display 1054 may be, for example, a TFT LCD (Thin-Film-Transistor Liquid Crystal Display) or an

OLED (Organic Light Emitting Diode) display, or other appropriate display technology. The display interface 1056 may comprise appropriate circuitry for driving the display 1058 to present graphical and other information to a user. The control interface 1058 may receive commands from a user and convert them for submission to the processor 1052. In addition, an external interface 1062 may be provide in communication with processor 1052, so as to enable near area communication of device 1050 with other devices. External interface 1062 may provide, for example, for wired communication in some implementations, or for wireless communication in other implementations, and multiple interfaces may also be used.

[00200] The memory 1064 stores information within the computing device 1050. The memory 1064 can be implemented as one or more of a computer-readable medium or media, a volatile memory unit or units, or a non-volatile memory unit or units. Expansion memory 1074 may also be provided and connected to device 1050 through expansion interface 1072, which may include, for example, a SIMM (Single In Line Memory Module) card interface. Such expansion memory 1074 may provide extra storage space for device 1050, or may also store applications or other information for device 1050. Specifically, expansion memory 1074 may include instructions to carry out or supplement the processes described above, and may include secure information also. Thus, for example, expansion memory 1074 may be provide as a security module for device 1050, and may be programmed with instructions that permit secure use of device 1050. In addition, secure applications

may be provided via the SIMM cards, along with additional information, such as placing identifying information on the SIMM card in a non-hackable manner.

[00201] The memory may include, for example, flash memory and/or NVRAM memory, as discussed below. In one implementation, a computer program product is tangibly embodied in an information carrier. The computer program product contains instructions that, when executed, perform one or more methods, such as those described above. The information carrier is a computer- or machine-readable medium, such as the memory 1064, expansion memory 1074, memory on processor 1052, or a propagated signal that may be received, for example, over transceiver 1068 or external interface 1062.

[00202] Device 1050 may communicate wirelessly through communication interface 1066, which may include digital signal processing circuitry where necessary. Communication interface 1066 may provide for communications under various modes or protocols, such as GSM voice calls, SMS, EMS, or MMS messaging, CDMA, TDMA, PDC, WCDMA, CDMA2000, or GPRS, among others. Such communication may occur, for example, through radio-frequency transceiver 1068. In addition, short-range communication may occur, such as using a Bluetooth, WiFi, or other such transceiver (not shown). In addition, GPS (Global Positioning System) receiver module 1070 may provide additional navigation- and location-related wireless data to device 1050, which may be used as appropriate by applications running on device 1050.

[00203] Device 1050 may also communicate audibly using audio codec 1060, which may receive spoken information from a user and convert it to usable digital

information. Audio codec 1060 may likewise generate audible sound for a user, such as through a speaker, e.g., in a handset of device 1050. Such sound may include sound from voice telephone calls, may include recorded sound (e.g., voice messages, music files, etc.) and may also include sound generated by applications
5 operating on device 1050.

[00204] The computing device 1050 may be implemented in a number of different forms, as shown in the figure. For example, it may be implemented as a cellular telephone 1080. It may also be implemented as part of a smartphone 1082, personal digital assistant, or other similar mobile device.

10 **[00205]** Various implementations of the systems and techniques described here can be realized in digital electronic circuitry, integrated circuitry, specially designed ASICs (application specific integrated circuits), computer hardware, firmware, software, and/or combinations thereof. These various implementations can include implementation in one or more computer programs that are executable and/or
15 interpretable on a programmable system including at least one programmable processor, which may be special or general purpose, coupled to receive data and instructions from, and to transmit data and instructions to, a storage system, at least one input device, and at least one output device.

[00206] These computer programs (also known as programs, software, software applications or code) include machine instructions for a programmable processor, and can be implemented in a high-level procedural and/or object-oriented programming language, and/or in assembly/machine language. As used herein, the
20 terms “machine-readable medium” “computer-readable medium” refers to any

computer program product, apparatus and/or device (e.g., magnetic discs, optical disks, memory, Programmable Logic Devices (PLDs)) used to provide machine instructions and/or data to a programmable processor, including a machine-readable medium that receives machine instructions as a machine-readable signal.

5 The term "machine-readable signal" refers to any signal used to provide machine instructions and/or data to a programmable processor.

[00207] To provide for interaction with a user, the systems and techniques described here can be implemented on a computer having a display device (e.g., a CRT (cathode ray tube) or LCD (liquid crystal display) monitor) for displaying
10 information to the user and a keyboard and a pointing device (e.g., a mouse or a trackball) by which the user can provide input to the computer. Other kinds of devices can be used to provide for interaction with a user as well; for example, feedback provided to the user can be any form of sensory feedback (e.g., visual feedback, auditory feedback, or tactile feedback); and input from the user can be
15 received in any form, including acoustic, speech, or tactile input.

[00208] The systems and techniques described here can be implemented in a computing system that includes a back end component (e.g., as a data server), or that includes a middleware component (e.g., an application server), or that includes a front end component (e.g., a client computer having a graphical user interface or
20 a Web browser through which a user can interact with an implementation of the systems and techniques described here), or any combination of such back end, middleware, or front end components. The components of the system can be interconnected by any form or medium of digital data communication (e.g., a

communication network). Examples of communication networks include a local area network ("LAN"), a wide area network ("WAN"), and the Internet.

[00209] The computing system can include clients and servers. A client and server are generally remote from each other and typically interact through a communication network. The relationship of client and server arises by virtue of computer programs running on the respective computers and having a client-server relationship to each other.

[00210] A number of embodiments have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. For example, much of this document has been described with respect to ICU monitoring with attending physicians, but other forms of patient monitoring and reporting may also be addressed.

[00211] In addition, the logic flows depicted in the figures do not require the particular order shown, or sequential order, to achieve desirable results. In addition, other steps may be provided, or steps may be eliminated, from the described flows, and other components may be added to, or removed from, the described systems. Accordingly, other embodiments are within the scope of the following claims.

WHAT IS CLAIMED IS:

1. An external defibrillator system, the system comprising:
 - one or more sensors configured to detect one or more parameters associated with performance of CPR;
 - one or more wearable computing devices configured to provide feedback to a user about CPR performed by the user based on the one or more parameters associated with the performed CPR; and
 - an external defibrillator comprising:
 - a memory configured to store instructions; and
 - a processor to execute the instructions to perform an operation comprising:
 - analyzing the one or more parameters to determine a CPR performance metric indicative of an overall performance of the user.
2. The system of claim 1, wherein the one or more wearable computing devices include at least one of the following: a tablet computing device, a headset, wearable glasses, and a smartphone.
3. The system of claim 1, wherein at least one of the one or more wearable computing devices directs feedback to one predetermined user.
4. The system of claim 1, wherein the one or more wearable computing devices includes one or more of a watch or wearable glasses.
5. The system of claim 4, wherein the wearable computing device includes wearable glasses having one or more lenses.
6. The system of claim 5, wherein the visual summary is displayed on at least one lens of the wearable glasses.

7. The system of claim 1, wherein generating the CPR performance metric includes generating data reflecting measurements of two or more actions performed on the victim.
8. The system of claim 1, wherein the CPR performance metric is based, at least in part, on weighted values applied to the one or more parameters.
9. The system of claim 8, wherein the weighted values are applied to at least one of the following: rate of chest compressions, depth of chest compressions, and fraction based on a guideline.
10. The system of claim 1, wherein the wearable computing device is configured to provide a visual summary including the CPR performance metric within five minutes of cessation of the CPR by the rescuer.
11. The system of claim 1, wherein the CPR performance metric is based on a function that weights each of the parameters according to weights determined using a neural network.
12. The system of claim 1, wherein the CPR performance metric is based on a function that weights each of the parameters according to weights determined using a linear regression technique.
13. The system of claim 1, wherein the wearable computing device is configured to receive input data from the user.
14. The system of claim 1, comprising a heads-up device to provide feedback to a user about CPR performed by the user based on the one or more parameters associated with the performed CPR.
15. An external defibrillator system, the system comprising:

one or more sensors configured to detect one or more parameters associated with performance of CPR;

a heads-up device configured to provide feedback to a user about CPR performed by the user based on the one or more parameters associated with the performed CPR; and

an external defibrillator comprising:

a memory configured to store instructions; and

a processor to execute the instructions to perform an operation comprising:

analyzing the one or more parameters to determine a CPR performance metric indicative of an overall performance of the user.

16. The external defibrillator system of claim 15, wherein the CPR performance metric is based, at least in part, on weighted values applied to the one or more parameters.

17. A computer-implemented method for providing summary information for CPR performance, the method comprising:

sensing one or more parameters associated with performance of CPR performed on a victim by a rescuer;

identifying a timing interval over which performance is to be analyzed and gathering data from the sensing of the one or more parameters during the time interval;

generating, from analysis of the parameters, a CPR performance metric that condenses data sensed for the one or more parameters into a single metric indicative of overall performance of the CPR over the identified interval; and

providing, for display on a wearable computing device, a visual summary including the CPR performance metric within five minutes of cessation of the CPR by the rescuer.

18. The method of claim 17, wherein the wearable computing device includes one or more of a watch or wearable glasses.
19. The method of claim 18, wherein the wearable computing device includes wearable glasses having one or more lenses.
20. The method of claim 19, wherein the visual summary is displayed on at least one lens of the wearable glasses.
21. The method of claim 17, wherein generating the CPR performance metric comprises calculating the CPR performance metric (CPM) according to $CPM = f(w_{rate} * X_{rate}, w_{Depth} * X_{depth}, w_{fraction} * X_{fraction})$ where w_{rate} , w_{depth} , and $w_{fraction}$ comprise weighting factors for each of rate of chest compressions, depth of chest compressions and fraction and X_{rate} , X_{depth} , and $X_{fraction}$ are calculated metrics for rate of chest compressions, depth of chest compressions, and fraction based on a guideline.
22. The method of claim 17, wherein generating the CPR performance metric comprises calculating the CPR performance metric based on a function that weights each of the parameters according to weights determined using a neural network.
23. The method of claim 17, wherein generating the CPR performance metric comprises calculating the CPR performance metric based on a function that weights each of the parameters according to weights determined using a linear regression technique.
24. The method of claim 17, wherein providing the visual summary comprises providing a graphical display of CPR compression rate, CPR compression depth and CPR fraction during the identified interval.

25. The method of claim 17, wherein providing the visual summary comprises providing per-parameter metrics with each per-parameter metric condensing data for the parameter to provide a single metric indicative of the CPR quality for that parameter.
26. The method of claim 17, wherein providing, for display to a user, a visual summary including the CPR performance metric comprises providing the visual summary within one minute of cessation of the CPR by the rescuer.
27. The method of claim 17, wherein the sensors comprise at least one of chest compression sensors, patient ventilation sensors, and electrocardiogram sensors.
28. The method of claim 17, wherein providing the visual summary for display comprises wirelessly transmitting data about the one or more activities from a device that senses the one or more activities to a remote device having a visual display device display.
29. The method of claim 17, wherein the CPR performance metric comprises a score that indicates, by one alpha-numeric indicator, a quality level with which one or more CPR related activities were performed.
30. The method of claim 17, comprising monitoring electrocardiogram data of the victim while the one or more activities are occurring, and providing with a defibrillator at least one of charging the defibrillator and shocking the victim without manual intervention of a rescuer.
31. The method of claim 17, wherein generating the CPR performance metric comprises generating a single data value from information received from measurement of two or more distinct actions performed on the victim.

32. The method of claim 17, wherein generating the CPR performance metric comprises generating a single data value from information about at least one of CPR depth, CPR compression rate, and CPR fraction.
33. The method of claim 17, wherein the timing interval comprises the entire duration of CPR administration by the rescuer.
34. A computer readable medium storing instructions for causing a computing system to:
- sense one or more parameters associated with performance of CPR performed on a victim by a rescuer;
 - identify a timing interval over which performance is to be analyzed and gather data from the sensing of the one or more parameters during the time interval;
 - generate, from analysis of the parameters, a CPR performance metric that condenses data sensed for the one or more parameters into a single metric indicative of overall performance of the CPR over the identified interval; and
 - provide, for display on a wearable computing device, a visual summary including the CPR performance metric within five minutes of cessation of the CPR by the rescuer.
35. The computer readable medium of claim 34, wherein the wearable computing device includes one or more of a watch or wearable glasses.
36. The computer readable medium of claim 34, wherein the wearable computing device includes wearable glasses having one or more lenses.
37. The computer readable medium of claim 34, wherein the visual summary is displayed on at least one lens of the wearable glasses.

38. The computer readable medium of claim 34, wherein the CPR performance metric includes a single data value from information about at least one of CPR depth, CPR compression rate, and CPR fraction.
39. The computer readable medium of claim 34, wherein the instructions for causing the computing system to sense one or more parameters includes instructions for monitoring electrocardiogram data of the victim while the one or more activities are occurring, and providing with a defibrillator at least one of charging the defibrillator and shocking the victim without manual intervention of a rescuer.

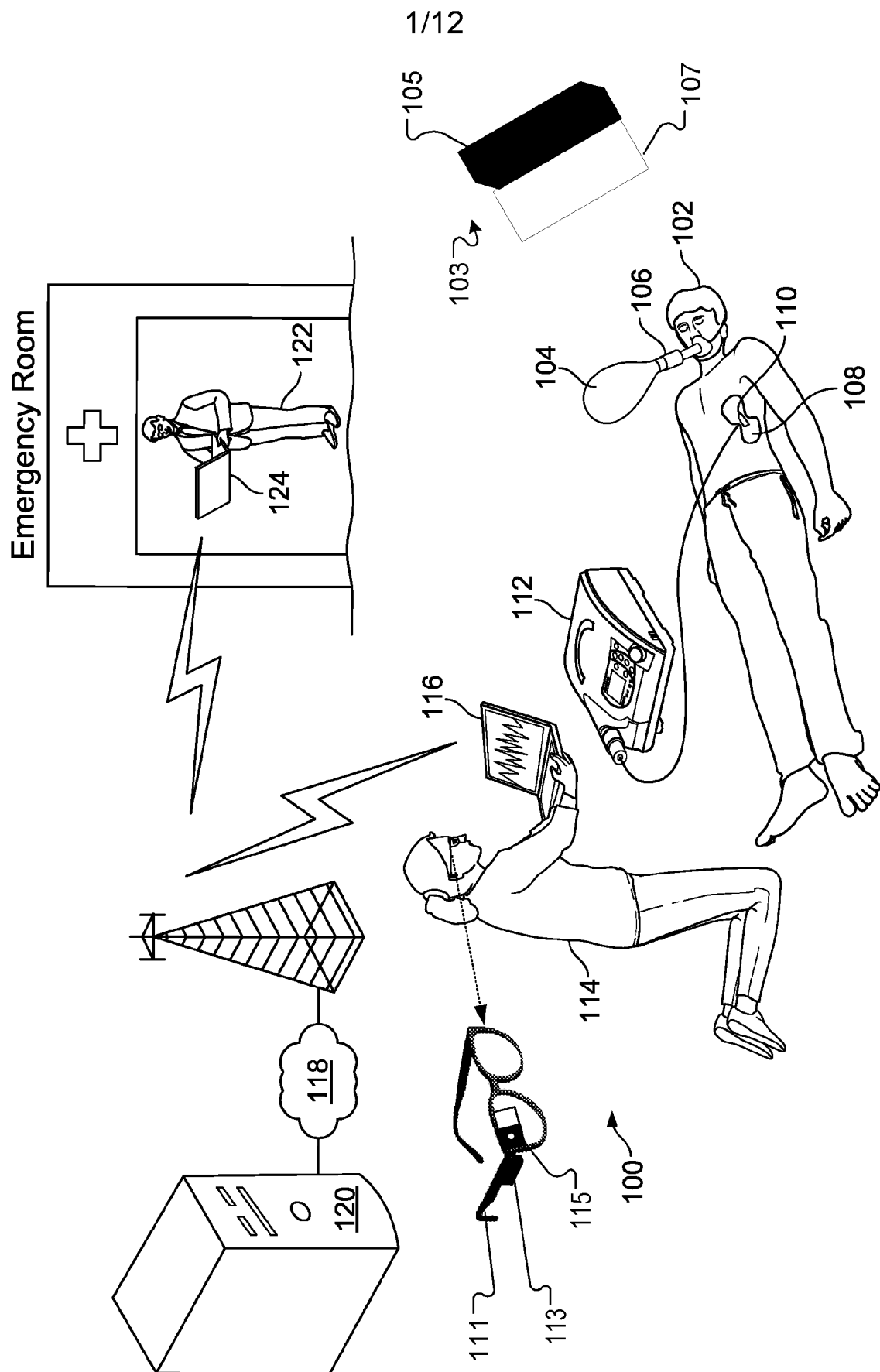


FIG. 1A

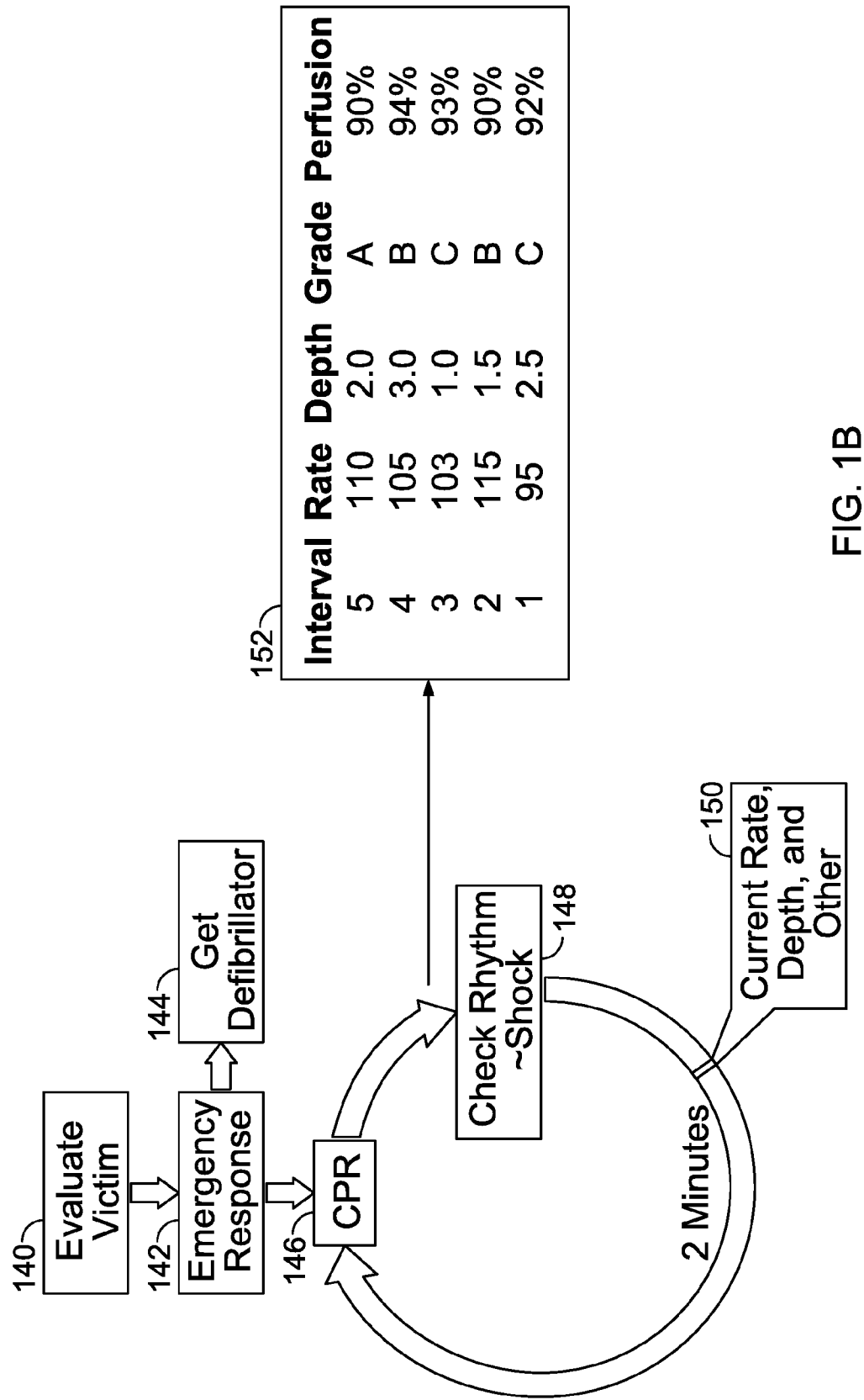


FIG. 1B

Overall Performance						
Depth		Rate	Compression Fraction	Pre-shock Pause	Post-shock Pause	Perfusion Index
1.8 in		118 cpm	[73%]	2.5 sec	3.1 sec	91%
[1.5-3.0 in]		[100-120 cpm]	[75%+]	[<3 sec]	[<6 sec]	[90%+]
Minute-by-Minute CPR						
CPR Interval	Depth	Rate	Compression Fraction	Pre-shock Pause	Post-shock Pause	Perfusion Index
1	1.9 in	120 cpm	78%	2.7	3.0	90%
2	1.2 in	118 cpm	70%	2.5	3.3	94%
3	1.5 in	116 cpm	70%	2.3	3.8	86%
Resuscitation?						

FIG. 2A

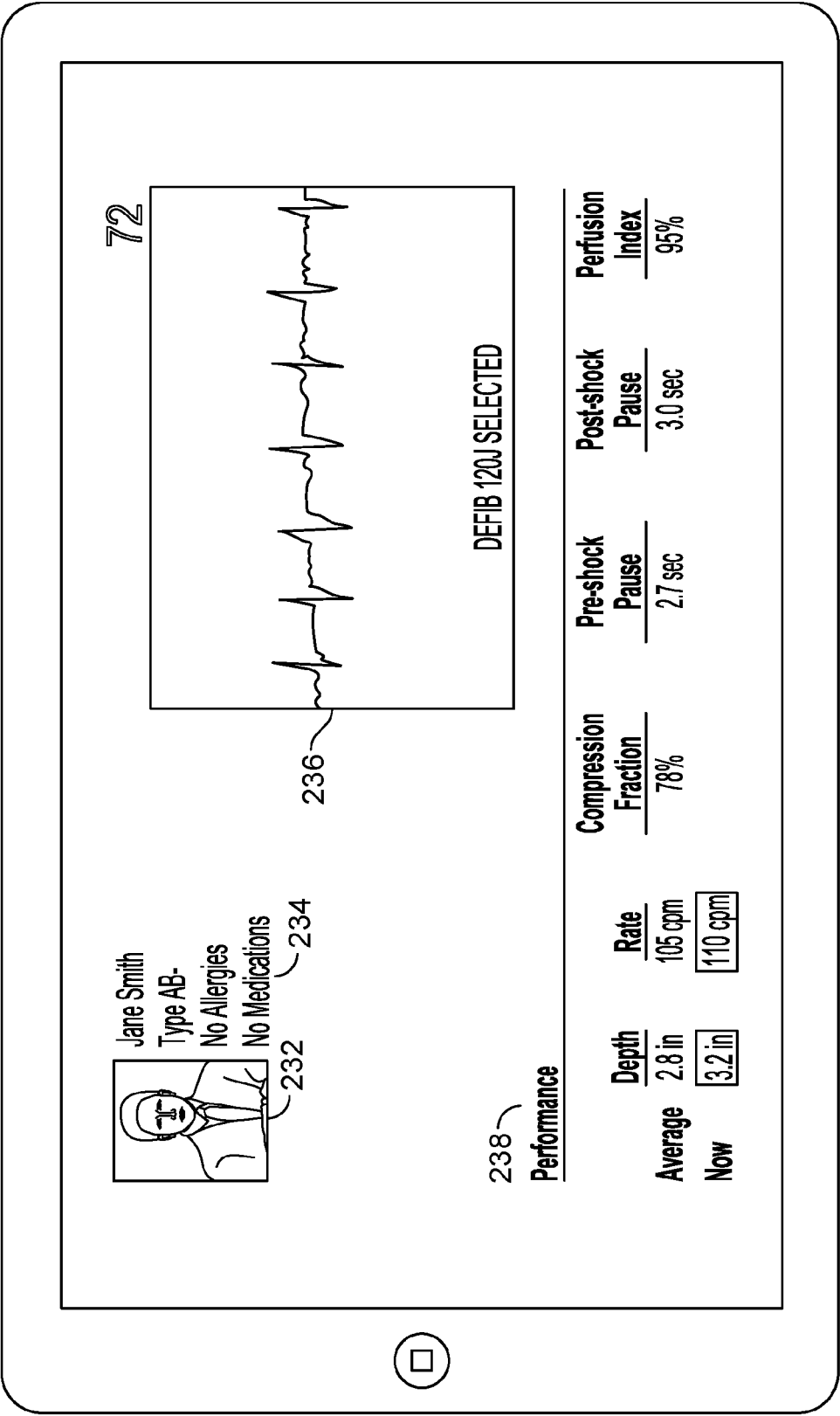


FIG. 2B

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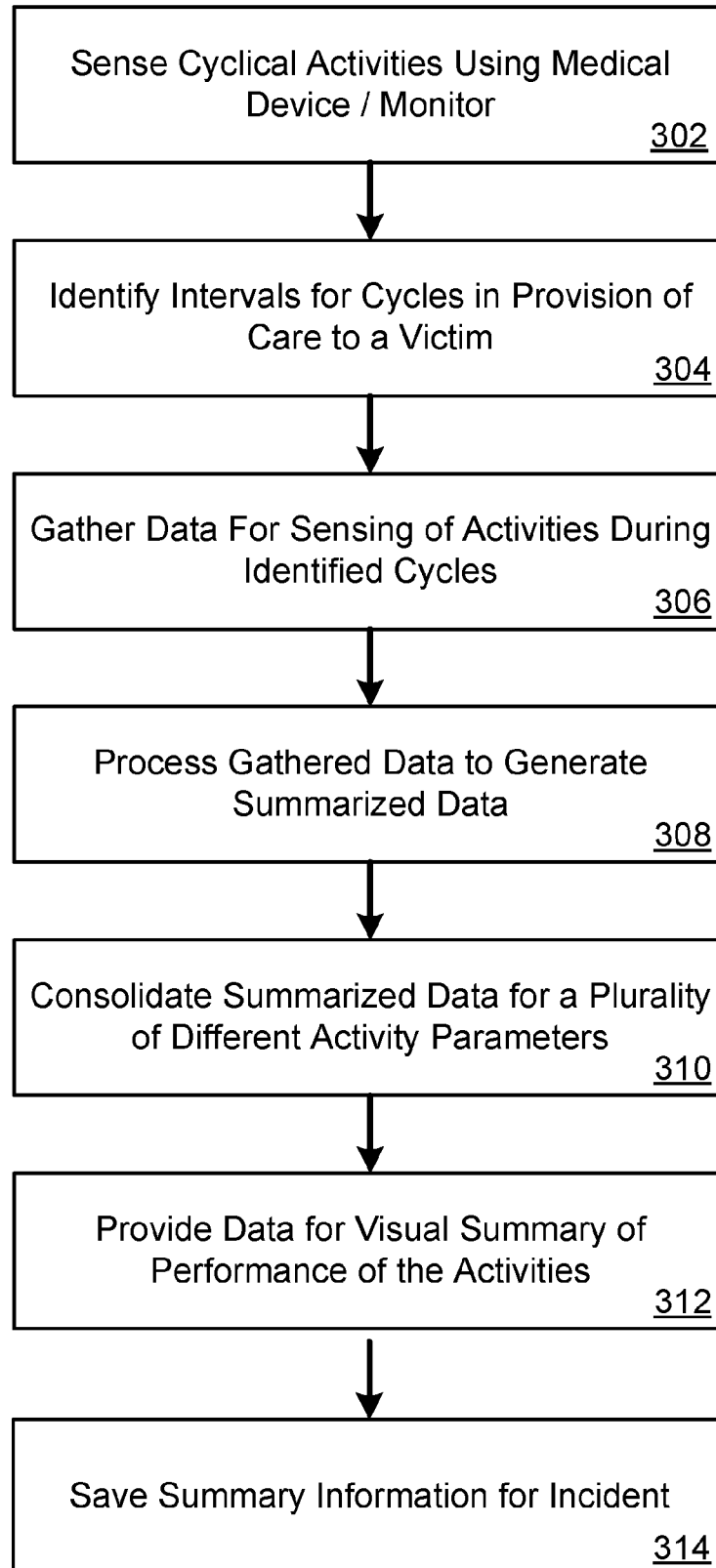


FIG. 3

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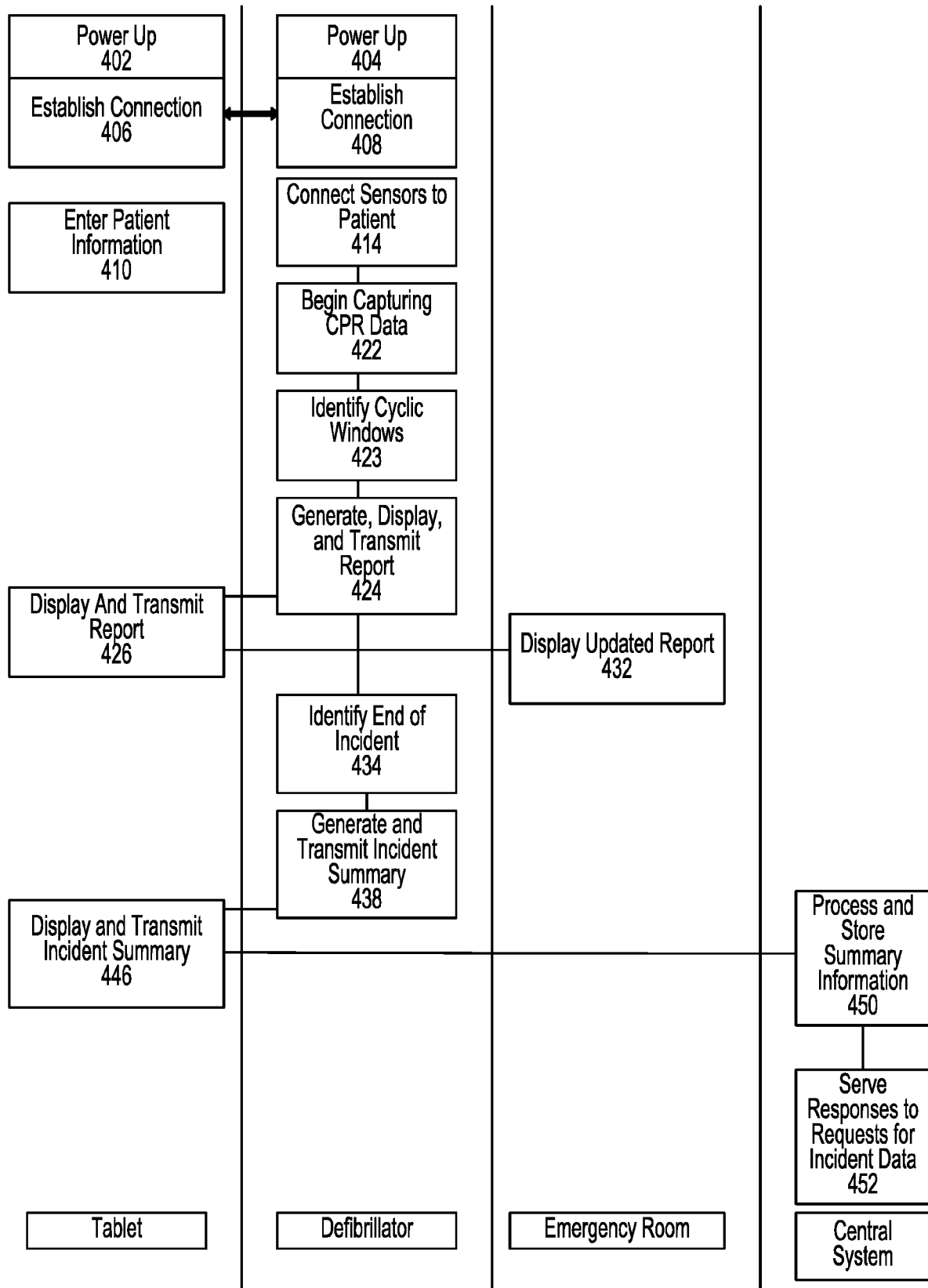


FIG. 4

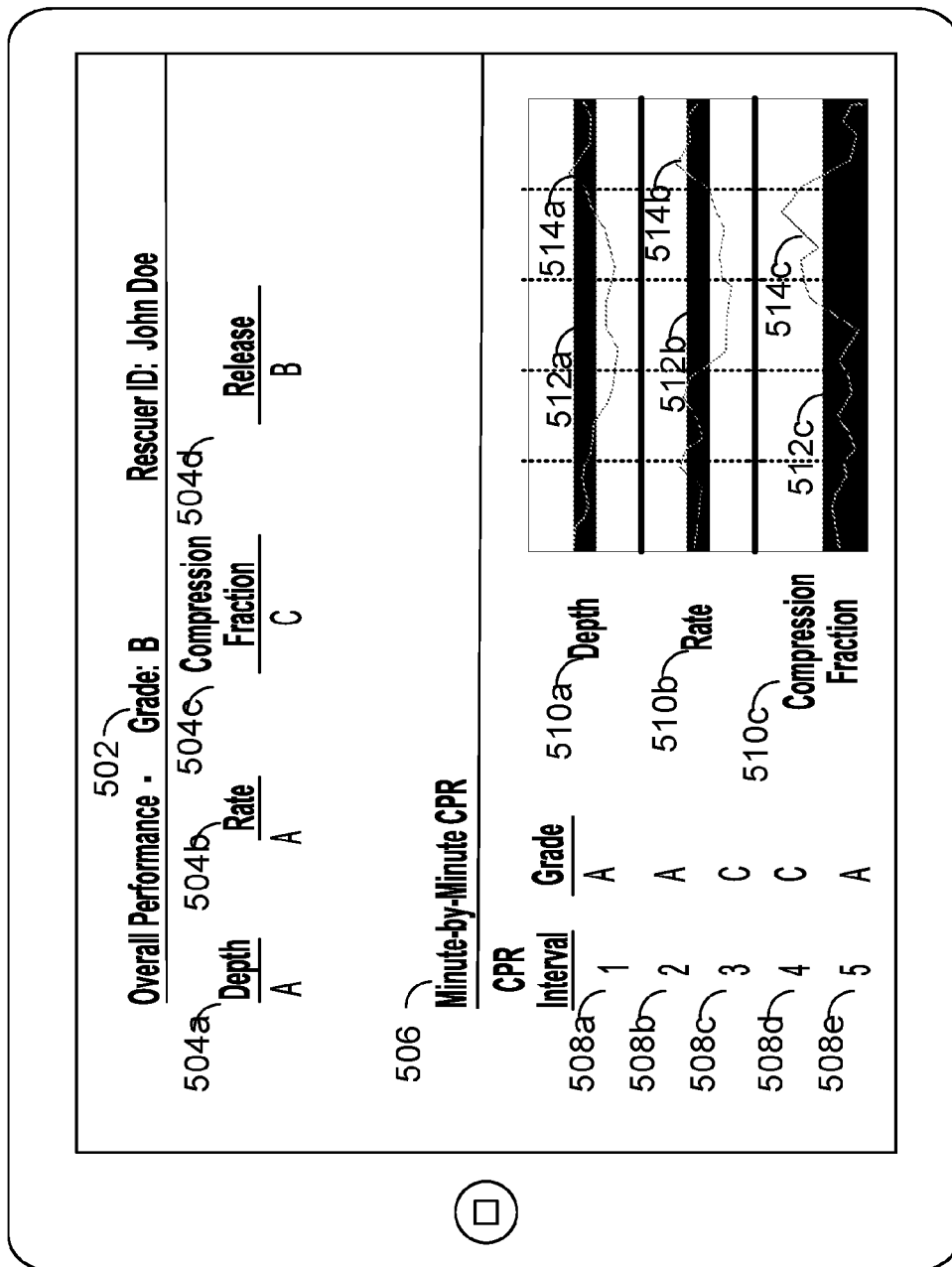


FIG. 5

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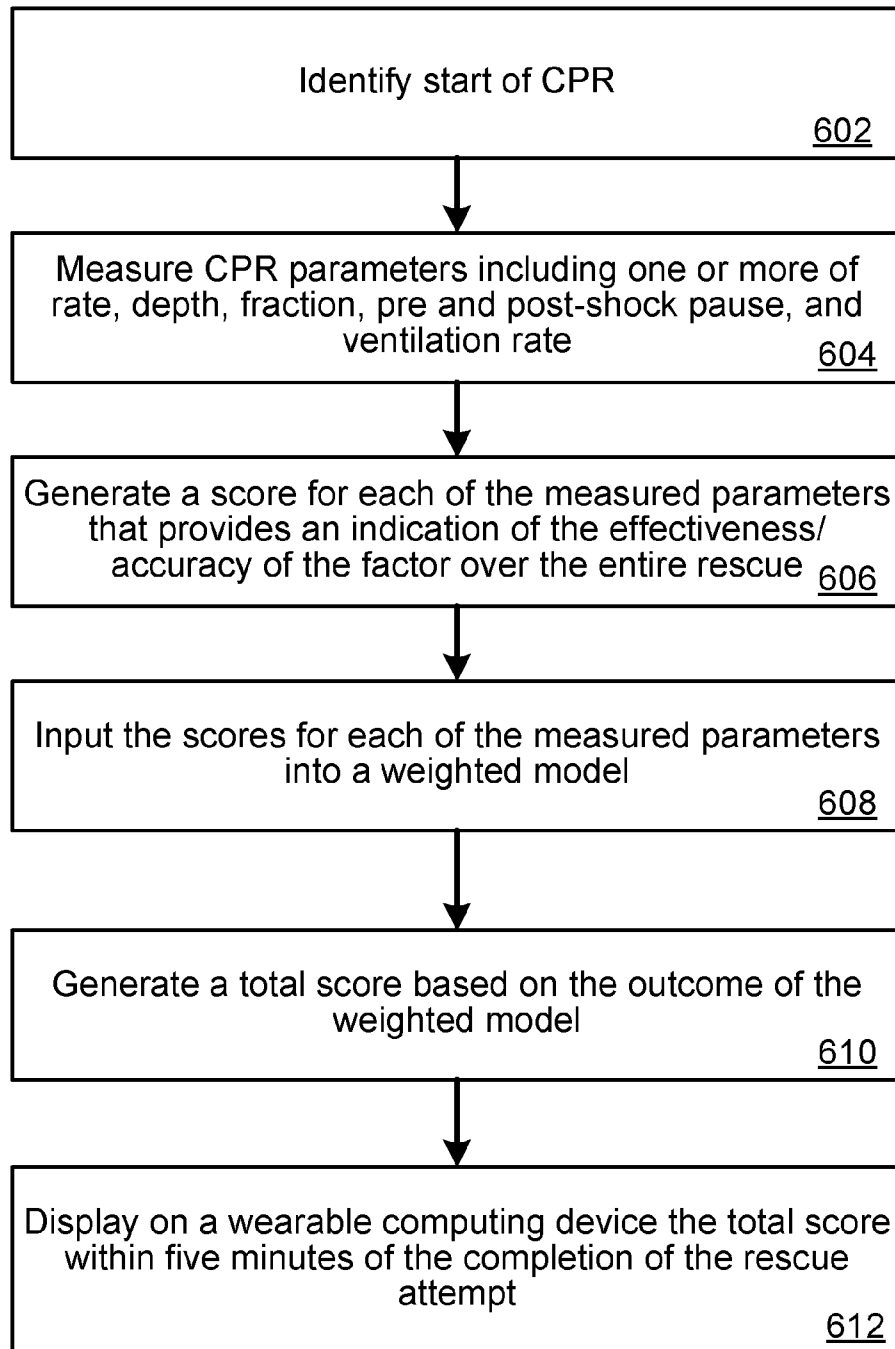


FIG. 6

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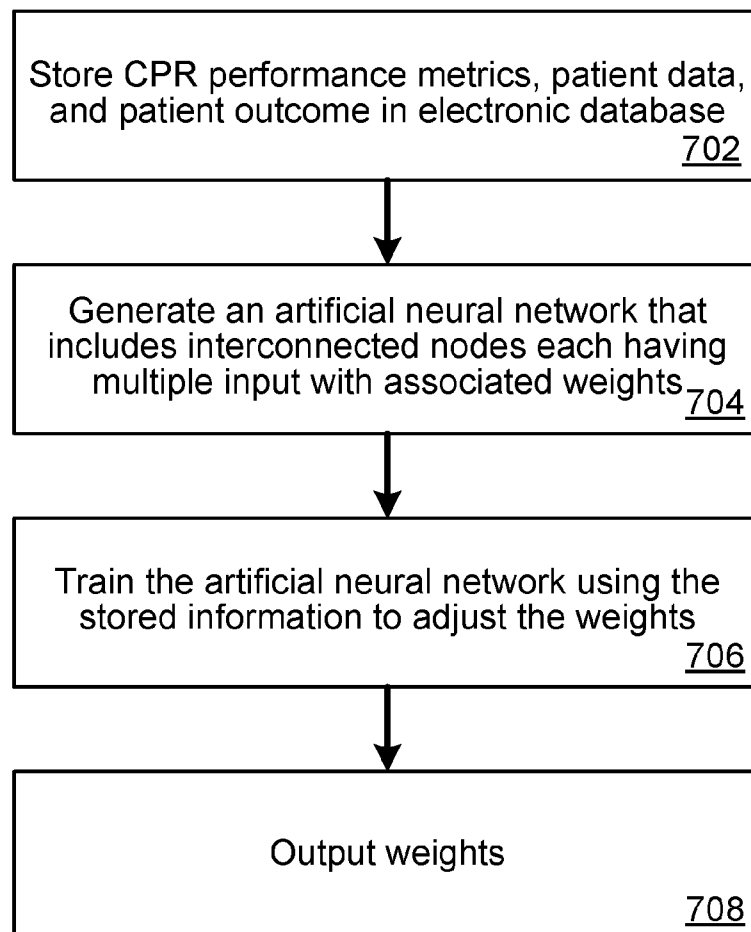


FIG. 7

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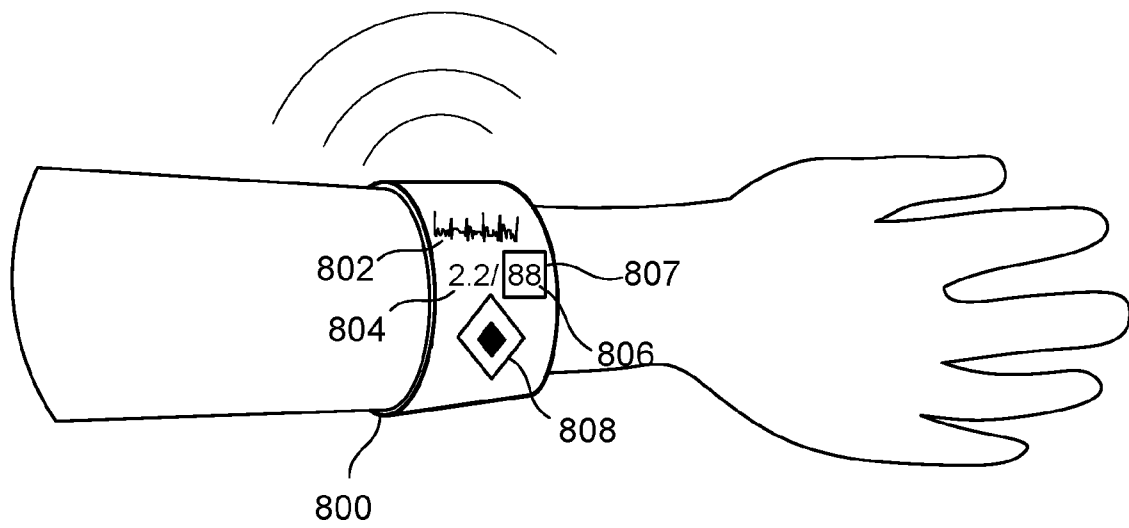


FIG. 8A

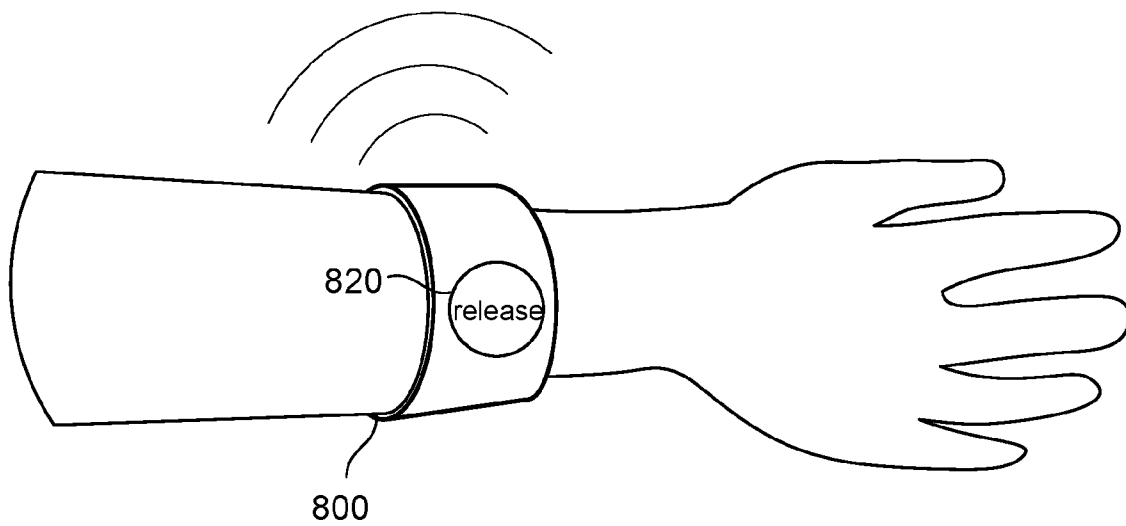


FIG. 8B

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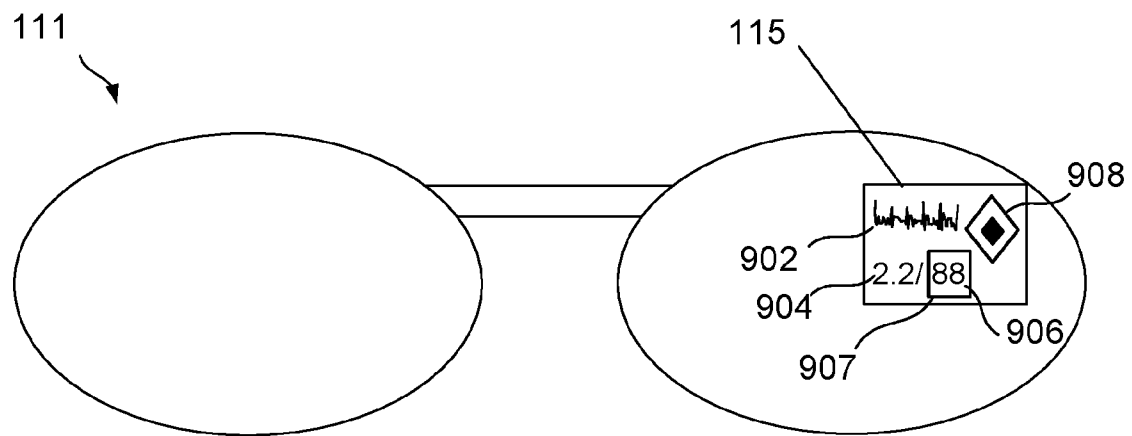


FIG. 9A

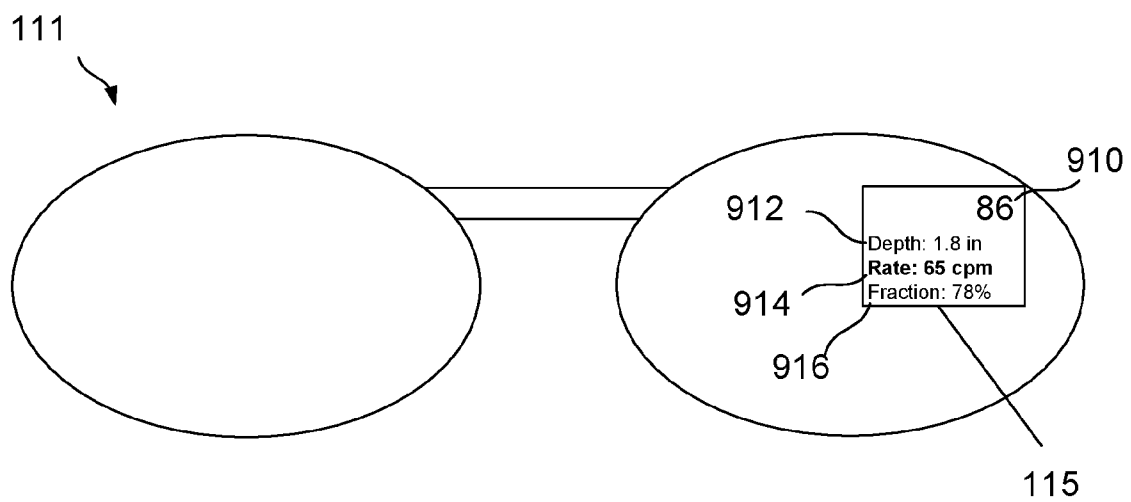


FIG. 9B

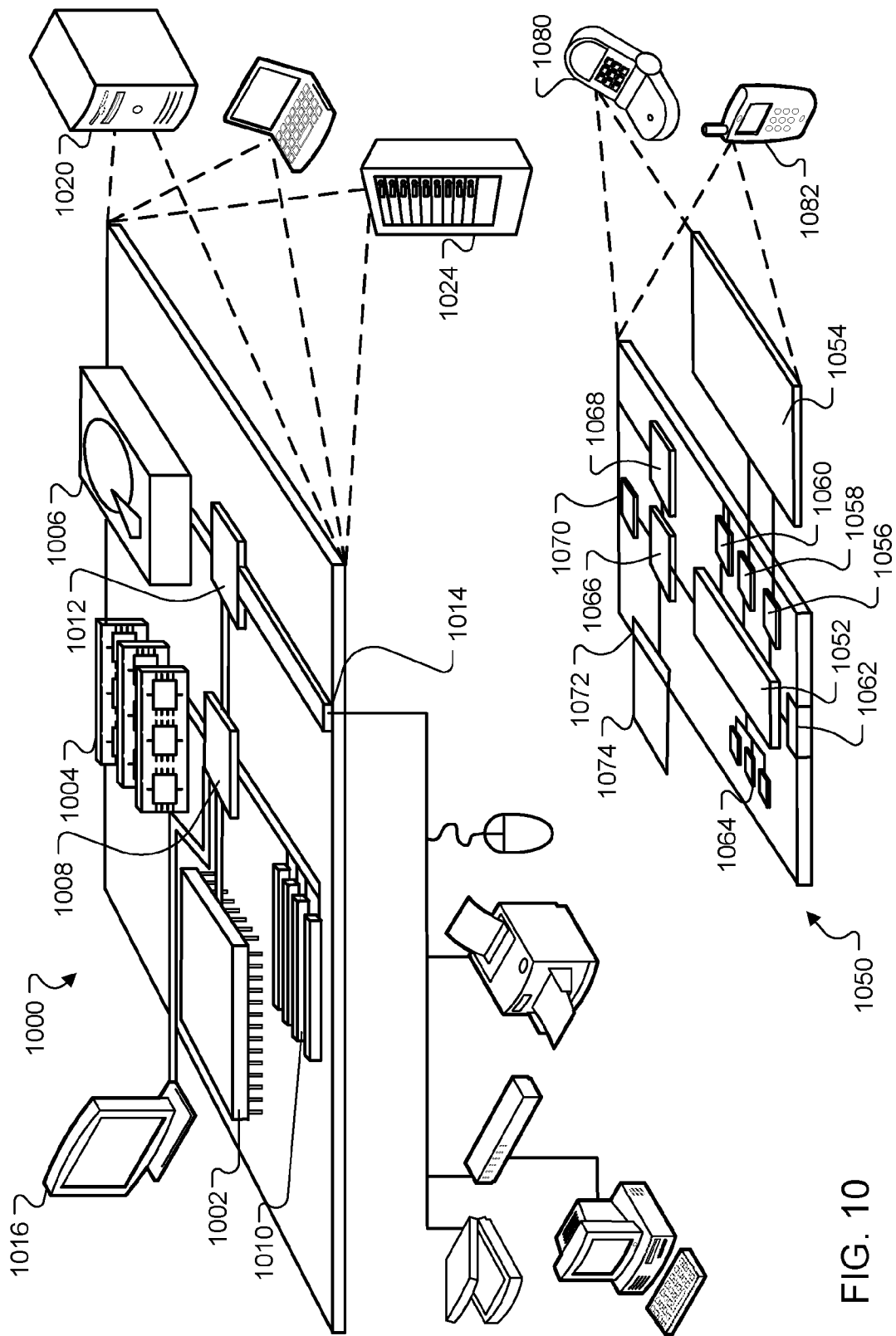


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US15/67603

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - A61N 1/39; A61B 5/0205, 5/113 (2016.01)

CPC - A61B 5/044, 5/4836, 5/0205

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - A61N 1/39; A61B 5/0205, 5/113, 5/044; G06 F3/0485, F3/0484 (2016.01)

CPC: A61B 5/044, 5/4836, 5/0205, 5/08, 5/7405, 5/1135; A61N 1/3987; G06 F19/327, F19/3406, F19/3418, 19/345; G06F 3/048

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PatSeer (US, EP, WO, JP, DE, GB, CN, FR, KR, ES, AU, IN, CA, Other Countries (INPADOC), RU, AT, CH, TH, BR, PH); Google Scholar, EBSCO, IEEE/IEEExplore; Keywords: CPR, Cardiopulmonary resuscitation, Defibrillator, AED, smart phone, heads up display, Smart glasses, Wearable computer, Performance, Report, Metric, Feedback, Frequency, Interval, depth

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ----- Y	US 2014/0257054 A1 (ZOLL MEDICAL CORPORATION) 11 September 2014. Paragraphs [0027], [0028], [0054], [0073], [0089].	1-3, 7, 10, 13, 17, 26-31, 33-34, 39 ----- 4-6, 8-9, 11-12, 14-16, 18-25, 32, 35-38
Y	US 2013/0296719 A1 (ZOLL MEDICAL CORPORATION) 07 November 2013. Paragraphs [0005], [0097].	8-9, 11-12, 16, 21-25, 32, 38
Y	US 2014/0201627 A1 (ZOLL MEDICAL CORPORATION) 17 July 2014. Paragraphs [0111], [0125].	4-6, 14-15, 18-20, 35-37

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

* Special categories of cited documents:

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"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

10 March 2016 (10.03.2016)

Date of mailing of the international search report

28 MAR 2016

Name and mailing address of the ISA/

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