Expanding the Role of Mobile Devices in the Operating Room: Direct Wireless Connection to the Anesthesia Monitor

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MOST MODERN ANESTHESIA monitors provide an open-source communication interface to the monitored data. These interfaces are included in order to permit the hard-wired connection of the monitor to a separate recording system and to allow the integration of the monitor's data with that generated by other medical devices.

If the monitors are connected to a server-based patient information system, it is possible (but expensive) to transmit a subset of the monitored data to a mobile device ("the device") with a significant delay.[1,2] However, with the advent of wireless RS232 serial adapters, a direct connection between the device and the monitor (using either 'Bluetooth' or 'Wi-Fi' technologies) can be implemented and the complete monitored dataset then made available in near real time to the device user.

The processing power, display resolution, storage capacity, and connectivity of these devices is now so great that they can easily manage such connections. Furthermore, they can be "paired" simultaneously with other devices (such as "smart glasses" or "smart watches"), which then can process subsets of the monitored data in novel ways.

In this technical communication, a method for implementing real-time, wireless data transfer from an anesthesia monitor to a mobile device is described, and the feasibility of the technique is demonstrated using a simple data display and recording application. The potential applications of this technology are outlined, and, finally, the problems posed by direct wireless data transfer are mentioned.

IMPLEMENTATION

The requisite hardware and the programming techniques used in this implementation are described in greater detail in the Supplemental Digital Content. The technique required to implement the direct, wireless connection of a mobile device to an anesthesia monitor is illustrated here by reference to a version that runs on an Android® tablet or smartphone. The device acquires data wirelessly from a transmitter (Fig 1) attached to the monitor (GE Datex Ohmeda S5 Anaesthesia Monitor) and displays it in real-time as a series of user-selectable wave forms and numeric data fields (Fig 2). The user also is able to record the data on the device itself or to a web-based location.

Data Acquisition

Data are acquired using a Bluetooth adapter connected to the serial port (USB or RS232) of the monitor. The device is paired with the adapter and requests the monitor to transmit a stream of Datex-Ohmeda Records, which comprise continuous waveform data together with instantaneous values (such as heart rate or oxygen saturation).[3] The effective wireless range of the connection is 10 to 15 meters and the latency of signal display less than 1.5 seconds. If used with a Wi-Fi RS232 adapter, this effective range can be greatly increased.

Data Display

A single graphical waveform is displayed on the user interface (UI) of the device, but the user is able to view any other waveform variable by simply swiping the graphical display to the right or left. Five instantaneous values (such as heart rate, F_IO_2, SaO_2, $ETCO_2$, and respiratory rate) are displayed in numeric format at the bottom of the UI. These displayed values are also user-selectable. The waveform data are updated at 50 Hz and the instantaneous data at 0.2 Hz. Many mobile devices now incorporate Miracast® technology in which case the display can be mirrored onto a full high-definition television (HDTV) up to 10 meters away.

Data Recording

Data can be recorded on the device as fixed-length Datex-Ohmeda Records that accrue at a rate of about 6.5 MB/h. Used in this way, a 64-GB Micro SD card of the kind used by the device can hold about 10,000 hours of complete anesthetic data. If connected to the internet, the user also has the opportunity to upload the data to a remote storage site. In this way, the complete anesthetic record of a patient undergoing, for example, cardiac surgery, can be transferred to a remote site within a few seconds.

POTENTIAL APPLICATIONS OF THE TECHNOLOGY

Jorm and O'Sullivan[4] recently have drawn attention to the pervasive presence of personal mobile computing devices in the operating room and have remarked that although these devices can be used "to find out essential information for care of the current patient …this appears to be a rare occurrence."

However, it seems likely to the author that if the user has immediate, direct access to the monitor's complete dataset on their device, then its role in the operating room could be

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Fig 1. **A Bluetooth RS232 serial adapter. Numerous such devices are available. The adapter enables the anesthesia monitor to appear as a pairable Bluetooth device on the user's mobile device. The adapters are typically Class 1 devices and have a range of about 100 meters. However, most mobile devices are Class 2 devices and have a range of only 10 to 15 meters.**

significantly expanded. An enumeration of its potential roles might then include use as a secondary display, pairing with additional displays, data recording, the development of smart alarms, the integration of anesthetic data with data generated by other medical devices, retrospective data analysis, presentation of data in a novel fashion, development of novel performance indicators, and conduct of real-time randomization studies.

Use as a Secondary Display

In Figure 3, a Nexus 7 tablet is shown positioned just above the blood pressure transducers. It is being used as a secondary display and is able to present data that are not displayed currently on the primary monitor.

Pairing with Additional Displays

The author is experimenting with the simultaneous tethering of the mobile device to a pair of smart glasses (Fig 4). In this application, a dynamic, iconic representation of the current physiologic state is displayed at a constant position in the user's visual field (Video clips 1 and 2). The icon presents the patient's systolic blood pressure, pulse rate, saturation, and respiratory activity in an entirely graphical manner and is updated at 25 Hz (Fig 5). In designing the icon, the author has attempted to depict many of the important variables that are tracked during cardiac anesthesia and to present them in a manner that can be assimilated rapidly and in which deviation from normality can be readily detected. The author also has attempted to comply with the principles of graphical data display described by Drews and Westenskow.[5] The geometry of the display is such that if an adult is under stable anesthesia, the icons will be green, and the values they represent will be positioned in the central area of the reticule. This will symbolize a state in which the SaO_2 is greater than 95%, the systolic blood pressure is between 100 and 150 mmHg, the Bispectral index (BIS) between 40 and 60, and the end-tidal CO_2 between 30 and 45 mmHg. The current heart rate is indicated by the blink rate of the triangular icons and the respiratory rate by the rise and fall of the vertical bar icon. The efficacy of this display has not been formally evaluated. However, Liu et al[6] examined the utility of an (early) head-mounted display in the operating room and concluded that it "could help anesthesiologists free their attention from the patient monitor and focus on monitoring the patient's clinical signs and the surgical field."

Data Recording

Mobile devices are optimized for efficient internet activity and are well suited for contributing to internet-accessible registries of anesthetic monitoring data. Several uses for such registries have been described including pharmacodynamic

Fig 2. **The user interface of the mobile device application. In this case, the application is being used to play back the anesthetic data of a patient shortly before weaning from cardiopulmonary bypass. Swiping the graphical display allows the user to switch between the available waveform variables. The Galaxy S4 display resolution is the same as that of an HDTV (1920 * 1080 pixels). The green triangular buttons to the left of the Y axis allow the signal gain to be varied. This image was acquired using the screenshot facility of a Galaxy S4.**