Letters to the Editor

Comparative study of telecommunication methods for emergency telemedicine

Sir, When a medical emergency occurs, the most important determinant of the mortality rate is the time taken for the patient to receive appropriate treatment[1]. If there is no one in the vicinity, there is likely to be a dangerous delay. A wearable device that continuously monitors the physical state of the user, in particular vital signs such as pulse rate, could assist with this problem if it had the ability to communicate with medical emergency centres[2]. A number of telecommunication methods are now available for this purpose, including radio frequency (RF) transmission, the short message service (SMS) on a mobile phone and Bluetooth transmission[3].

We have compared the characteristics of these three wireless telecommunication methods from the standpoint of emergency telemedicine.

System specification

To evaluate the candidate telecommunication methods, a wearable vital-signs monitoring device was developed (Fig 1). The physiological signals to be measured were single-channel electrocardiogram (ECG) output, respiratory chest wall movement and two-axis accelerations of the body (Fig 2). Three surface Ag–AgCl electrodes attached to the inner side of a chest belt were used for both ECG and impedance plethysmography to record the respiratory waveform. Body acceleration was monitored using a two-axis accelerometer (ADXL202, Analog Devices, USA). An 8-bit microcontroller (AT4433, Atmel, USA) performed the analogue-to-digital conversion of the signals, the subsequent signal analysis and data transfer to the telecommunication module.

We developed a simple algorithm to determine the onset of an emergency, based on abrupt changes in heart or respiration rate and excessive body acceleration. The monitoring device uses a 9 V battery power supply, and a rubber chest belt is used to hold the electronic unit and to obtain electrode contact with the skin. The RF transmission circuitry was implemented on the same printed circuit board as the monitoring device. The other two telecommunication methods used an external serial data port as an interface between the telecommunication module and the monitoring device. The monitoring unit measured 120 mm × 80 mm × 30 mm and it weighed 200 g, including the battery.

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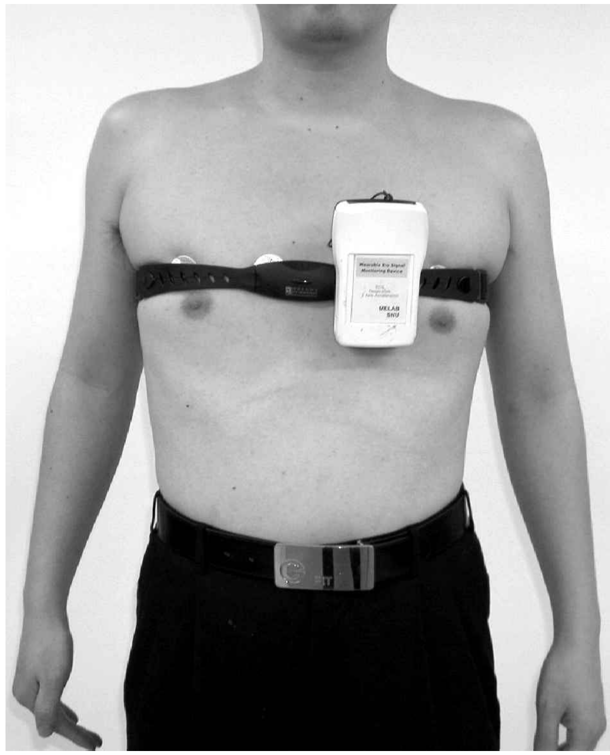

Fig 1 Vital signs monitoring device.

Radio frequency transmission

Because of its simplicity and relatively low cost, RF transmission is widely used. Various kinds of modules are available. Factors to be considered in choosing a suitable unit include the data transfer rate, carrier frequency, magnitude of the power amplification and modulation method. We used TX2 and RX2 modules (433 MHz, 10 mW, FM, Radiomatrix Inc., UK) for sending and receiving data, respectively. The receiving module was connected to a PC via an RS-232 connection. A PC program providing a realtime display of the acquired waveforms and for data management was also developed. A typical screen display generated by the monitoring program is shown in Fig 3.

Mobile phone

An IS-95C CDMA mobile phone (SCH-X420, Samsung, Korea) was connected to the wearable monitoring device through a serial data cable. The phone could be used in a number of ways. First, it could act as a modem, using the voice channel. However, this was not appropriate for our application because it requires special hardware and the data transfer rate is relatively low (10–56 kbit/s)[4]. Second, it could be used as a TCP/IP Internet connection, which is now available in Korea with a maximum speed of 144 kbit/s. Using this connection, the original waveforms could be transmitted in realtime. Third, it could be

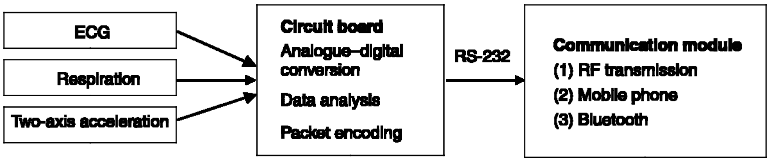

Fig 2 Block diagram of the vital signs monitoring device connected to its telecommunication module.

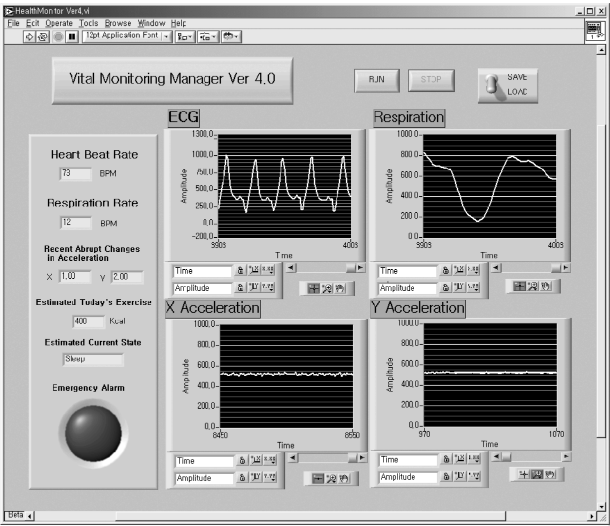

Fig 3 Typical screen display of the monitoring program.

connected to the short message service (SMS), which is basically a text transmission service. This allows text to be sent denoting vital information, such as heart rate, respiration rate, recent rapid acceleration and the location of the user, as represented by the base station identifier of the mobile phone service. A pre-assigned doctor or family member could receive this message on a mobile phone. To program the mobile phone for serial connection and SMS initiation, we used the General Virtual Machine (GVM)[5] ported on to the mobile phone.

Bluetooth

Bluetooth is a technique that enables the wireless connection of any information appliance, such as a notebook computer, printer, personal data assistant (PDA) or mobile phone. To use a Bluetooth connection, which is basically a 2.4 GHz RF module, a rather complicated Bluetooth protocol stack must be used. The strength of the Bluetooth system centres on this intelligent protocol stack. However, at present the protocol stack requires a great deal of computing power—up to 20 million instructions per second (MIPs) using Host Controller Interface (HCI) implementation on an 8-bit microcontroller[6].

In the present study, an embedded LINUX board (Axis Developer Board for Bluetooth, Axis Inc., USA) was used to handle an open-source Bluetooth protocol stack (Figs 4, 5). At the receiver side, another Bluetooth module (Bluetooth Application and Training Kit, Ericsson Inc., USA) was connected to a LINUX-based PC, on which we developed a similar monitoring program to display and manage the transmitted data to that for the RF system (shown in Fig 3).

Results

Although RF transmission can be established in a relatively simple and inexpensive manner, it offers no security, and the system is vulnerable to cross-talk from other RF appliances. It also suffers from attenuation effects (e.g. due to buildings), which cause an increase in output level and battery exhaustion. RF transmission is, therefore, suitable for relatively short-range transmission, such as inside a home for monitoring a single user. To overcome the attenuation problem, multiple receiver units are sometimes used to ensure coverage of, for example, a large house[7]. Once the data are acquired at one receiver, they can be transferred to the first responder via a telephone line or the Internet.

The mobile phone as a telecommunication method has the advantage of connectivity to virtually anywhere within the service area. One of the shortcomings of using a mobile phone is that it is dependent on a commercial service and therefore its cost is relatively high. SMS communication may be a cost-effective solution, however. The peer-to-peer SMS model obviates the cost of establishing a centralized large-scale service system.

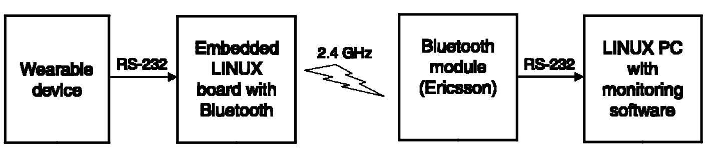

Fig 4 Block diagram of the Bluetooth connection system.

Fig 5 A person wearing the Bluetooth-based communication system. Because of the embedded LINUX board, the system is rather bulky (compare Fig 1).

Furthermore, it is possible to assign multiple receivers, including doctors or family members, so that interested parties may receive the message simultaneously. An advantage of using a mobile phone is that it can give a geographical position: recently, mobile phones have been equipped with a global positioning system (GPS), which can directly guide the rescue team to the precise emergency location.

Bluetooth is a low-power, short-range, wireless networking standard designed for local-area voice and data communication. Mobile computers, mobile phones and headsets, PDAs and PCs can exchange information on a globally available band (2.4 GHz), for worldwide compatibility, using specifications agreed by over 2400 companies in the Bluetooth Special Interest Group (SIG). The SIG companies are working together to ensure interoperability between products. The Bluetooth protocol provides security, low power consumption, encryption and easy access, for which it has sacrificed simplicity. At the moment the unit required is too expensive and heavy to be implemented as a portable system. But, given that in some situations, such as in hospital, a number of patients must be monitored in a particular area, Bluetooth will probably provide the best solution. By installing several access points at different locations, both the physical state and the location of the patient can be monitored.

In our study, we measured three physiological variables using one chest unit. As the number of measured variables increases, it may be necessary to distribute the sensors or the related electronic units over the body. In this situation, another wireless communication network, the so-called personal area network (PAN), will be necessary to gather the various physiological data. Bluetooth technology seems to be the most suitable for such a PAN, since it can offer encryption, security, low power consumption and ad hoc networking, and it works at short range. Furthermore, a Bluetooth-enabled mobile phone will be available soon, and is expected to provide a practical solution for the central unit of a PAN.

Conclusion

The characteristics of the three telecommunication methods are summarized in Table 1. The advantages and disadvantages of each should be considered according to the specific application.

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Table 1 Summary of the three telecommunication methods

	Radio frequency	Mobile phone	Bluetooth
Power consumption	12 mA	400 mA in 'talk' mode 4 mA in 'standby' mode	50 μA in 'park' mode 300 μA in 'standby' mode 30 mA maximum
Range	100 m	Virtually everywhere	10 m
Security	Poor	Good	Good
Encryption	No	Yes	Yes
Computation power required	Small	Small	Large (for full protocol)
Cost	Low (about $10)	High (about $500)	Medium (about $100)
Hardware complexity	Low (radio frequency circuitry)	High (mobile phone and accessory cables)	Medium (radio frequency circuitry)
Appropriate use	Home monitoring Fast prototype development	Daily use outdoors Emergency workers	Inside hospital

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A focus tool as an aid to video-otoscopy

Sir, The video otoscope is commonly used in telemedicine for imaging the external ear and tympanic membrane (TM). In Alaska, approximately 250 sites use an AMD/WelchAllyn video otoscope (AMD 2450 or AMD 2015). Since September 2001, approximately 3600 store-and-forward telemedicine cases have been created using a video otosope, with an average of three images per case. Most of these patients presented to community health aides or audiologists, and were referred for telemedicine assessment to family physicians and otolaryngologists.

Some users have had difficulty capturing images of satisfactory quality for remote assessment. Anecdotal evidence suggests that improper focus, a dirty tip and movement are the most frequent causes of blurred images. The otoscope needs to be focused before it is inserted into the ear. Once the tip is in the auditory canal, it is difficult, dangerous and painful to manipulate the focus ring. In Alaska, health-care workers are given the following instructions on how to focus the video otoscope:

> Focus the ear scope by clasping the end as shown and turning the focus ring with your other hand until the image on the screen is sharp, not blurry. The tip should be ½ inch from your little finger. Practice focusing on your fingernail or fingerprint ridges. Check the focus by holding the tip ½ inch from some tiny print. The letters should be sharp and easy to read.[1]

Observations from training indicate that users have difficulty focusing using this technique. It is not easy to judge the proper distance and it is difficult to hold the probe tip steady. We have therefore developed a tool that simplifies the process of pre-focusing the AMD/WelchAllyn video otoscope.

Designing the focus tool

The purpose of a focus tool is to provide a well defined object that is easily focused at a distance comparable to that used when imaging the TM. We assume that this distance is similar for most patients.

We focused the video otoscope on an artificial TM, comprising a 1.0 cm circle. The vertical dimension of a human TM is reported[2] to range from 8.5 to 10 mm, and the horizontal diameter from 8 to 9 mm. As the artificial TM was positioned further away from the tip of the otoscope, it appeared to be smaller on the video-display. A tip-to-TM distance of 7–13 mm corresponded to areas of 25–50% of the video-display. Clinical experience indicates that ideal images of the TM are obtained when it represents approximately 25–50% of the image area. Any smaller proportion means that the tip is too far away and fewer details of the TM are seen. Any larger proportion may exclude detail of the ear canal immediately surrounding the edges of the TM. Furthermore, inserting the tip closer than 7 mm from the TM (to achieve a percentage larger than 50%) may be painful for the patient.

A previous study had shown that this model of video otoscope has a 78° field of view at the tip[3]. Therefore, a 1 cm disk would cover 25% of the image area at a distance of 12.8 mm.

We also imaged two adults' ears. Images were obtained while the distance from the TM to tip of the otoscope was measured with monofilament line. The ideal distance to capture a reasonably sized image without causing patient discomfort was 11–13 mm. Since 11 mm was not uncomfortable, we chose the closer distance for focusing purposes. A closer distance also gives a little leeway for imaging children.

Materials

The focus tool was constructed from a marker pen (the type used for drawing on a whiteboard). Plastic Magic Markers (Avery Hi-Liter #240X or 0774X series) were chosen because of their shape and durability. The dimensions of the plastic body allow it to fit nicely over the end of the video otoscope and the hollow tip of the marker roughly mimics an ear canal.

The shaft (body) of the marker was cut to reduce its length to 93 mm. Once cut, the inner diameter of the

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