MEDINFO 2007
HISA Ltd Australia
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Development of Smart Stretcher Equipped with Continuous Vital Signs Monitoring and Location Detection

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Abstract

Ubiquitous communication technologies are transforming medical practice. In these technologies, especially RFID or small sensor networks can provide information about medical practices and patient status in real time and therefore improve the quality of medical care. We developed a new system named "smart stretcher" which is continuously monitoring patient's vital signs during transfers within the hospital. This system consists of a small air-mat type pressure sensor measuring both heart and respiration rate and a wireless network transmitting these vital data as well as patient ID to the alert system to notify patient's emergency. Also we added function of location detection to the smart stretcher by using a wireless sensor network. We conducted experiments in the clinical settings. It was found that this system showed reliable performances in continuous respiration monitoring and detection of apnea during patient's transfer on this stretcher, suggesting its high feasibility for real clinical usage.

Keywords:

medical errors, safety of medical care, wireless network

Introduction

Ubiquitous communication technologies are transforming medical practice. Conventional hospital information systems have not been yet been able to make use of all information that can be collected with simple sensors. RFID or small sensor networks can provide information about medical practices and patient status and therefore improve the quality of medical care. As an example of this application, we developed a new system named "smart stretcher" which continuously monitors patient's vital signs during transfers within the hospital. This monitoring system consists of air-mat type supersensitive pressure sensor measuring heart rates and respiration rates and an ad hoc wireless communication network ZigBee that transmits these vital data to the hospital LAN and to an alert system to notify patient's emergency immediately when it happens. Patient ID read from the RFID wristband is transmitted to prevent misidentification of the patients. Also we addedÅ@a function of location detection to the smart stretcher by using a wireless sensor network.

We conducted experiments to estimate the feasibility of this wireless monitoring system in real clinical situation to examine whether it can detect apnea of the patient reliably during patient's transfer within the hospital.

Methods

To realize the smart stretcher, we equipped three kinds of measurement devices with the stretcher: one is the measurement system for the vital signs such as heart rates and respiration rates, the second is the system for automatic patient ID recognition and the last is the detection system for patient location within the hospital.

These kinds of information are transmitted by ZigBee wireless network.

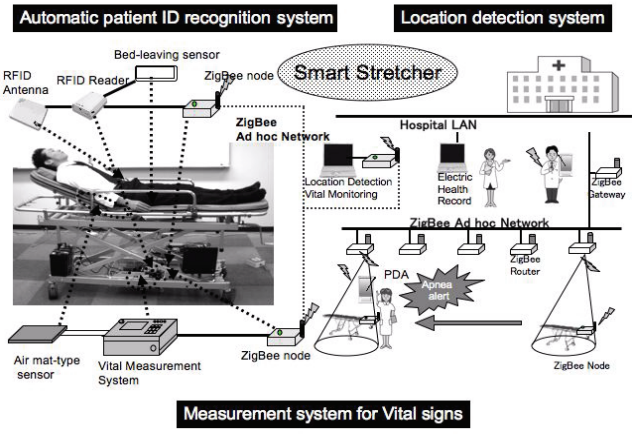

Figure 1- Smart stretcher system

These measurement systems work together to monitor the patient physiological status and give a warning against patient emergency such as apnea and transmit this

emergency information to the alert system in the ward (Fig. 1).

We conducted the feasibility experiment of the smart stretcher in the real clinical setting. In the experiment, three experimental subjects, two males and one female, were taking the role of the patients transferred on the stretcher who wore the RFID wristband on their left hands and were asked to stop respiration for 7 seconds during their transfer in the hospital.

First, the readability of wristband patient ID was examined. The readable distance in which patient wristband ID can be recognized by the RFID reader equipped on the left side surface of stretcher was measured. Secondly, the experimental subject was transported on the stretcher for fifteen meters in one minute, and was asked to stop breathing intentionally in the mean time to investigate whether the monitoring system would detect the apnea in spite of the stretcher movement and emitting the warning signal. This experiment was repeated with three subjects.

Results

Readability of patient ID

In almost all cases, the RFID was recognized within 15 seconds after the reader started reading and patient ID was displayed on the monitoring screen in real time. Readable distances were increased in proportion to the size of a tag. The difference of readable distance between the patient postures of a face-up position and a semi-sitting position was not found. In the case we set the RFID reader antenna under the stretcher mat, RFID was difficult to read, whereas in the case an antenna is setting in left side, RFID was able to well read. RFID was most reliably to read, when the patient's hand wearing RFID wristband is straight along with the edge line of the stretcher, whereas RFID was rather difficult to read if the direction of the hand is other direction.

Measurement of vital signs and detection of apnea

The three subjects were reliably measured for their respiration rate during their transfer. Figure 2 shows an example of experimental results of respiration waveforms. We can see from this figure that apnea was detected for about 10 seconds. Apnea was detected in all subjects. In contrary to the respiration rate, it was difficult to reliably detect the heart rate during the movement of the stretcher. Through the ZigBee wireless network, the patient's name, respiration rates and heart rates were correctly displayed on the PDA screen. The apnea warning alert and the warning screen in PDA were displayed mostly in real time. As the conclusion it was found that the aimed functions of the smart stretcher work in good performance.

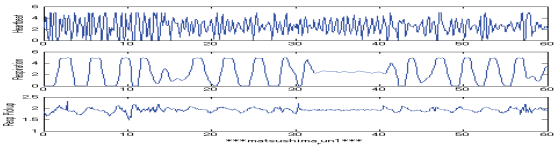

Figure 2 – Result of respiration waveform

Location detection of the Smart Stretcher

We detected the location of the smart stretcher within the hospital by location detection system using ZigBee ad hoc network. For the experimental settings, we installed five ZigBee routers and one gateway configured at even intervals onto the ceiling of the hospital corridor. Two members of hospital staffs carried the experimental subject on the smart stretcher in the hospital corridor for eighty meters. We monitored the patient location in the display by floor map in the terminal connected to the ZigBee network. The location detection system showed good performance providing the correct location in real time (Shown in fig.3). Serious errors and delays in the display of the detected location were not observed in this location detection experiment.

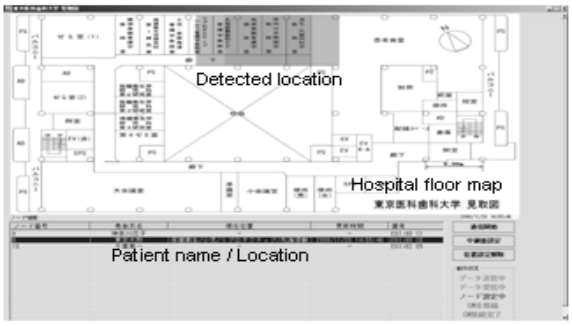

Figure 3 –The floor map of detecting Location

Discussion

From these primary results, the patients' vital signs, patient IDs and locations could be obtained in real time during a patient's transfer on the smart stretcher. By utilizing of the three kinds of information, the smart stretcher may be able to contribute to medical safety in the clinical settings.

However, the measurement precision in this system is sometimes sensitive to the various environmental factors. We should investigate the factors that influence the precision of the measurements in details to improve precision in recognition of RFID and in monitoring of vital signs. A further direction of this study will be to apply these basic technologies for medical use in a wheel chair or bedside care in home health environments.

Conclusion

This system was able to show the feasibility of the medical malpractice preventive measures by ubiquitous technology. This study is another step towards the ultimate goal to realize a smart medical space with security and safety.