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[Original]

“THE DEVELOPMENT OF A SMART MONITORING SYSTEM FOR PREVENTING IN-HOSPITAL, PREVENTABLE DEATHS”p3. –p6.

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[Original]

THE DEVELOPMENT OF A SMART MONITORING SYSTEM FOR PREVENTING IN-HOSPITAL, PREVENTABLE DEATHS

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Abstract

In-hospital preventable deaths account for 3.4 to 6 % of all in-hospital deaths. A previous study found that poor clinical monitoring was the problem most associated with in-hospital preventable deaths. Medical staff are often away from the bedside or central station where an alarm is sounding because they may be required to take care of multiple patients and be expected to multitask. In such situations, medical staff might fail to notice monitor alarms. To detect an emergency as early as possible, we developed a smart monitoring system using a smart device. In this system, alarms from the monitoring device, electrocardiogram (ECG) waveforms, and calls from patients are sent to medical staff via their smart devices anywhere and anytime. Especially, the ECG waveform display on the smart device is useful for life-threatening ECG rhythms. The ECG waveform display enables medical staff to notice an emergency immediately after the life-threatening ECG rhythm occurs and they can start cardiopulmonary resuscitation and defibrillation in the shortest possible time. We have finished the trial phase in a ward and particular operational issues were not reported.

Conclusions: We developed a smart monitoring system that medical staff can use to respond promptly and appropriately to acute deterioration, anywhere and anytime. For the next step, we need to conduct studies to confirm whether this system reduces in-hospital preventable deaths.

Key Words: alarm, nurse call system, patient safety, preventable death, smart device.

1. Introduction

In-hospital preventable death is one of the biggest issues for patients, their families, medical staff, and hospitals. In-hospital preventable death account for 3.4 to 6 % of all in-hospital death.¹⁻⁴ According to a retrospective case record review, poor clinical monitoring was the problem most

associated with in-hospital preventable deaths.¹ In-hospital preventable deaths often occur in patients even if they are monitored with an electrocardiogram (ECG) or pulse-oximetry. Several reasons have been proposed regarding why such preventable deaths might occur in these situations. Neglect of monitor alarms due to alarm

fatigue is one of the most important reasons. Alarm fatigue is caused by many nuisance alarms and results in neglect of monitor alarms. In fact, only 11 to 15% of all alarms were considered clinically relevant in intensive care units.^{5, 6} According to national online surveys that investigated the problems associated with alarms in hospitals, the important issue for medical staff was “Frequent false alarms reduced attention to patient as they occur.”^{7, 8} Almost 80% of medical staff strongly agree or agree with the following items: nuisance alarms occur frequently, disrupt patient care, and reduce trust in alarms, and cause caregivers to inappropriately turn alarms off at times other than setup or procedural events.⁸ To prevent neglect of alarm monitoring due to alarm fatigue, setting appropriate alarm thresholds for avoiding needless alarms and proper staff education and training for reducing technical alarm (e.g., lead preparation, adhesive placement, and replacement) are particularly important. Another very important factor associated with preventable death is unawareness of monitor alarms. Medical staff are often away from the bedside or central station where the alarm is sounding because they need to take care of multiple patients and are required to multitask. In such situations, the bedside monitor alarm and central monitor alarm have little value to detect patient deterioration. In fact, a previous study reported that nurses spend approximately 30% of their time outside of the nurse station or patient

room.⁹ This means that 30% of all alarms might go unnoticed. Even if nurses are by the bedside or central station, many nuisance alarms could also be caused by the distribution of responsibility and poor management of patients.

2. Development of a smart monitoring system

To avert preventable deaths or life-threatening events, we developed a smart monitoring system using a smart device. The key concept is “medical staff can notice patients’ alarms, vital signs data, and their waveforms, anywhere and anytime.” In our hospital, nurses have to carry a feature phone to immediately communicate with patients on demand via the nurse call system (Carecom Co., Ltd, Tokyo, Japan). In the course of system development, first, we mounted an alarm notification system for SpO₂, respiratory rate, and pulse rate via Radical-7™ (Masimo Japan Co., Ltd, Tokyo, Japan) on the nurse call system. Next, we adopted a smart device instead of a feature phone because we needed to display the ECG waveform on the screen. We confirmed that the ECG waveform display and other alarms (Fukuda co., Ltd, Tokyo, Japan) operated without problems. Last, we provided education for nurses on how to use the system and reduce false alarms. We have already finished the trial phase in a ward and particular operational issues were not reported.

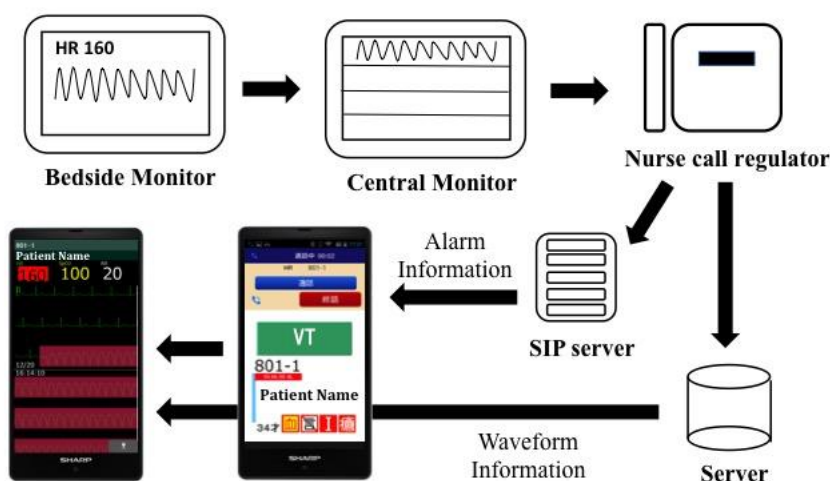


Figure1. The process by which alarm information is transmitted from the bedside monitor to the smart device. Medical staff can confirm the ECG waveform in addition to the alarm type on the smart device.

SIP server: Session Initiation Protocol.

3. Discussion

There are several novel features in our system. First, nurses can confirm ECG waveforms in addition to alarm types (asystole, ventricular fibrillation, ventricular tachycardia, slow ventricular tachycardia, tachycardia, bradycardia, short run, apnea, bradypnea, tachypnea and desaturation, pulse oximetry probe off, and ECG leads fail) and their values, anywhere and anytime. It is important to display the ECG waveforms on the smart device because nurses can distinguish whether the alarms are emergency alarms or non-emergency alarms, which reduces neglect of alarms. Especially, it is useful when the ECG shows a shockable rhythm because patients with a shockable rhythm have a two to three times higher survival discharge rate compared with a non-shockable rhythm.¹⁰ The ECG waveform display on the smart device enables medical staff to notice the emergency immediately after the life-threatening ECG rhythm occurs even if they are not by the bedside or central monitors, and they can start resuscitation and defibrillation in the shortest possible time. Second, screen displays and sounds using the smart device effectively enable medical staff to distinguish the alarm type compared to a feature phone. Displayed characters are colorful and attractive, and different alarm sounds can be chosen depending on the priority of alarms. In fact, in a previous online survey, 95% of medical staff strongly agreed or agreed that alarm sounds and the visual display should differentiate the priority of the alarm.⁴ Last, this smart device can be used not only as an alarm notification system but also a nurse call system with which patients can communicate with their nurses. As far as we know, this is the first system that is both an alarm notification system and a nurse call system mounted in one device. Nurses take care of multiple patients, so it is possible for multiple alarms from different patients to occur at the same time. To cope with such situations, alarm priorities are given to the system corresponding to the clinical importance of the alarm type and nurse call type. If multiple alarms occur at the same time, first, nurses can receive the highest priority alarm on the smart device. After they respond the first alarm, they can receive the next alarms.

This system could also be useful for the care of patients with COVID-19. To decrease the risk of cross-infection, medical staff should avoid frequent contact with patients. Although some

patients with COVID-19 show no or minimal symptoms, SPO₂ could be severely reduced.¹¹ In such situations, remote continuous SpO₂ monitoring should be used instead of monitoring in the patient's room. However, as mentioned previously, a central alarm system is not enough to reduce unawareness of monitor alarms. It is also important to notice deterioration as early as possible in patients with COVID-19 because medical staff need to put on personal protective equipment before contacting patients. Thus, we believe our system can contribute to the staff and patient's safety concerning COVID-19. This system enables nurses to cope with acute deterioration promptly and appropriately. However, frequent false alarms still occurred that sometimes interrupted their work. Repeated education for nurses to reduce false alarms (e.g., electromagnetic interference and motion artifacts) should be implemented. It is also expected that technology will be developed that can accurately detect false alarms by artificial intelligence.

4. Conclusions

We developed a smart monitoring system through which medical staff can notice patients' alarms, anywhere and anytime. This system enables medical staff to respond to patients' deterioration promptly and appropriately. For the next step, we need to conduct studies on whether this innovative system can reduce preventable deaths in hospitals.

5. Acknowledgments

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6. Disclosure

All the authors declare no conflict of interests associated with this manuscript.

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