

# Improved Outcomes and Reduced Costs with Contact-free Continuous Patient Monitoring on a Medical-Surgical Hospital Unit

I n t e r i m   r e s u l t s

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## Introduction

Hospitalized patients who experience sudden unanticipated serious deterioration and subsequent cardio-respiratory arrests have very poor outcomes. In addition, the institutional and patient costs of such events are quite high<sup>23</sup>. A significant number of avoidable adverse and sentinel events occur on the medical-surgical floor, where nurse to-patient ratios often prevent continuous direct patient observation. Many of the patients that suffer either serious deterioration or sudden death have preceding predictive events<sup>1, 2, 3, 4, 5</sup>. Continuous monitoring of vital signs can provide early detection of deterioration and may improve patient outcomes. A report by the Institute for Health Care Improvement (IHI) suggests that in many instances, subjective complaints and changes in vital signs could be noticed hours or even days in advance of cardiac or respiratory arrests, and majority of the events were observed to be preventable<sup>6, 7</sup>.

According to CMS data extracted from Medicare patient discharge records between 2005 through 2007, respiratory failure and failure to rescue (prevent a clinically important deterioration) were two of the three medical indicators with the highest incidence, accounting for 26% of the 97,755 reported deaths and over \$1.82 billion in excess Medicare costs. More than 80% of patients who experienced a cardiopulmonary arrest had evidence of deterioration within eight hours preceding the event. If they were on a medical-surgical floor, they often exhibited changes in respiratory function<sup>8</sup>. A retrospective multi-center study of 14,720 cardiopulmonary arrest cases showed that 44% were respiratory-related and more than 35% occurred on the medical-surgical floor<sup>9</sup>.

As patients' acuity level continues to rise, hospitals are implementing new initiatives geared toward early detection of deterioration in a patient's condition and faster intervention once a problem is recognized. New technologies previously utilized in critical care are being adapted to non-critical care areas, and many hospitals have set-up Rapid Response Teams to assist in the early intervention of patients presenting with symptoms suggesting imminent deterioration. These Rapid Response systems rely on early warning indicators, including changes in pulse rate, respiratory rate and other information<sup>10, 11</sup>. Delays between the onset of patient deterioration and detection by clinicians on the medical-surgical floor significantly affect patient outcomes; delayed activation of the Rapid Response Team is the strongest predictor of patient mortality<sup>12</sup>.

The Joint Commission, in its 2010 Treatment and Services Standard PC.02.01.19, requires<sup>13</sup> hospitals to:

- 1) Have a process for recognizing and responding as soon as a patient's condition appears to be worsening;
- 2) Develop written criteria describing early warning signs of a change or deterioration in a patient's condition and when to seek further assistance;
- 3) Have staff seek additional assistance when they have concerns about a patient's condition;
- 4) Inform the patient and family how to seek assistance when they have concerns about a patient's condition.

In addition to detecting patients at risk for in-hospital deteriorations, clinicians face challenges in preventable patient safety risks such as falls and pressure ulcers<sup>14</sup>. An estimated 1.3 to 3 million patients in the U.S. have pressure ulcers<sup>20</sup>; the incidence is highest in older patients, especially when hospitalized or in long-term care facilities. The World Health Organization (WHO) emphasizes that nurses have a vital role in prevention of pressure ulcers among hospitalized patients by regularly changing the patient's position in bed. CMS no longer pays for hospital-acquired pressure ulcers, since they are considered preventable in the hospital setting<sup>15</sup>.

Falls are one of the major hazards leading to injuries, complications and mortality among hospitalized patients, especially in the elderly and those with dementia. Accidental falls in inpatients account for 30–40%

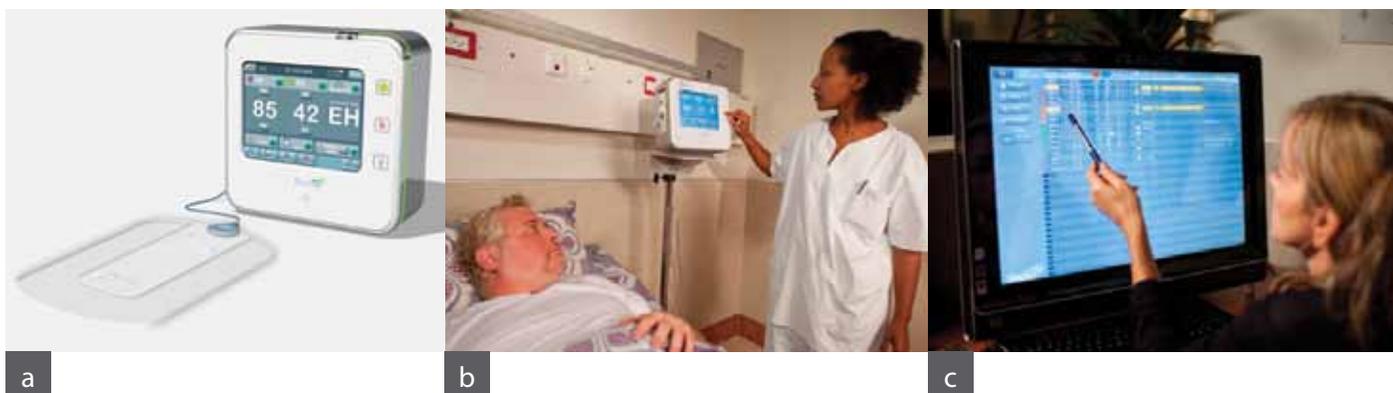
of reported safety incidents<sup>16</sup>. Falls occur at a frequency of 4–14 per 1,000 bed-days, or approximately 10 falls per month on a 28-bed ward<sup>17</sup>. Regulatory bodies have implemented strict standards regarding the use of restraints in the acute care setting.

In order to address the issues of detecting early clinical deterioration, and preventing falls and pressure ulcers, there is a need for continuous monitoring systems that alert nurses to risks in real time. Ideally, such a system should be noninvasive, user friendly, and easily integrated into nurses' routine workflow.

## EarlySense System Monitoring Device

The EarlySense System (EarlySense, Waltham, MA) is specifically designed to address patient care, safety and quality issues on the medical-surgical unit. The EarlySense System Bed-side units and Central Display Station (CDS) enable continuous monitoring of patients where nurse-to-patient ratios prevent continuous patient observations. The system transfers alerts directly to the nurse's cell phone or pager. Setup is rapid and flexible utilizing the user friendly touch screen. All monitoring is performed without direct contact between the patient and the device, using a sensor placed under the mattress. EarlySense System produces a low rate of false alerts, and compares favorably with standard devices such as pulse oximetry and continuous ECG monitoring (telemetry). The information stored in the display unit can be accessed at any time. Parameters and alerts can be individually customized and reports can be printed for off-line documentation and review.

The flexibility and user friendliness of the EarlySense System and its Central Display station allow the system to easily integrate with nurse work flow.



**The EarlySense System:** a. sensor and bedside monitor, b. bedside monitor, c. central display station

EarlySense System provides continuous surveillance of heart rate, respiratory rate and movement (a, b). The system provides alerts if any of the parameters exceed predefined thresholds. EarlySense System also provides bed exit alerts for patients at risk of falls, and a timer reminds nurses of when to turn the patient to prevent the development of pressure ulcers. The Central Display Station (c) displays live updates of patient data on large screens placed at the nurse station in real time. Additionally, alerts are sent directly to nurses' mobile phones or pagers.

## Alert Management

The ECRI Institute has identified alarm hazards as the number one technology hazard for patient safety, accounting for 12% of 2,200 reports received through its Problem Reporting Network from 2000 to 2006<sup>18</sup>. An essential feature of an effective patient supervision system is a configurable alert management capability that allows the nurse to activate and adjust the relevant alert thresholds according to individual patient conditions, reducing alerts to only those that require intervention.

The EarlySense System has a user friendly, configurable alert setup that allows nurses to set the relevant alarms by a “single touch”. Through the use of innovative algorithms, the EarlySense System minimizes and filters out false alerts due to motion artifacts. The nurse can silence the audible alert at the central station to preserve a quiet care environment, but the visual alert indicator will continue to be displayed until addressed by the nurse at the patient’s bedside.

## Clinical Validation

The EarlySense System Patient Monitoring System was evaluated by a team of clinicians at a community hospital in California. To establish a control baseline, patient outcome variables, including patients’ length of stay, total ICU days, number of falls and in-hospital developed pressure ulcers in a designated medical-surgical unit, were reviewed for six months. The EarlySense System was then introduced to the same medical-surgical unit, and was used to monitor every patient admitted for the subsequent six months. The study evaluated patient outcomes, system performance and nursing acceptance before and after introduction of the EarlySense System monitors.

## Methods

The hospital selected a 33-bed, medical-surgical unit for the study, and included general medical, trauma and surgical patients, where the nurse-patient ratio was 1:5. Each bed was equipped with an EarlySense System unit that continuously monitored pulse rate, breathing rate, movement rate, bed occupancy and alerted the nurses for scheduled patient turns. The EarlySense System bedside units were connected to the EarlySense System Central Display Station (CDS) via a wired LAN.

EarlySense System provided alert annunciations both at the central Nurses Station (on the CDS) and directly to the nurse assigned to each patient via Spectralink phones<sup>19</sup> that were routinely used by the hospital’s nursing staff. Default alarm settings were: Low/High Pulse Rate=40/130 beats/min., and Low/High Respiratory Rate =8/32 breaths/min.

A standing-order policy was instituted to continuously monitor all patients admitted to the unit regardless of admission diagnosis. System data was analyzed for uptime reliability, number of alert annunciation, and alert profiles. Nurses decided whether to activate the Bed-Exit and Patient Turn alarms. Although alarm threshold were set to default values, nurses were permitted to make adjustments, if necessary, to allow for individual patient conditions.

## Results

Data were collected on over 1000 patients over a six month period; The average patient age was 46, with an almost equal mix of males (47.6%) and females (52.4%).

### Patient outcome data

TABLE 1 % IMPROVEMENT PRE VS POST EARLYSENSE SYSTEM IMPLEMENTATION		
	% Improvement	Statistical Significance *
Average length of stay in Hospital (days)	-13.8%	P<0.003
No. of Patients Transferred to Higher Level of Care	-60.5%	P<0.001
• Pt. transferred to ICU	-63.0%	P<0.01
• Pt. transferred to Telemetry	-49.5 %	P<0.06
• Total ICU days	-48.4%	NS (P<0.14)
• Total Telemetry days	-42.8%	NS (P<0.09)
• Total "Higher Level of Care" days	-47.9%	P<0.05
In-unit developed Pressure ulcers (stage II and above)	-74.7%	P<0.04
No. of Falls	-62.0%	NS (P<0.1)

The results indicate significant decreases in the average length of stay in the hospital and the total "higher level of care days", both of which impacted on the cost of patient care. Particularly significant was the decrease in the development of pressure ulcers, a preventable hospital complication. The incidence of falls also trended downward, but did not reach statistical significance.

## Alert Rate and Effectiveness

Multiple alerts can jeopardize the effectiveness of continuous monitoring. Excessive alerts may result in alarm fatigue<sup>20</sup>, potentially causing nurses to ignore true clinically actionable alarms when they occur. Average alerts-per shift-per nurse is an indicator of the frequency with which nurses are called to the bedside to assess a patient's condition. The average number of alerts per shift for a typical week during the study period is shown in Table 2. There was an average of 12 alerts per shift, or 1 alert per hour.

Total beds	33
Heart Rate (HR) Alerts	0.1
Respiration Rate (RR) Alerts	0.7
"Turn Patient" Alerts	0.7
Bed Exit Alerts	0.4
Total Alerts	2

Patient turn and bed-exit alerts accounted for 58% of all alerts, and the results show that this led to a substantial decrease in the rate of pressure ulcers and a trend toward reduced falls. Heart and respiration rate alerts accounted for 42% of the alerts. Nurses found 48% of these alerts to be clinically warranted. The average number of alerts per shift was low and was well tolerated by the staff.

Heart rate alerts occasionally led to the discovery of cardiac arrhythmias that were verified with subsequent bedside EKGs, including atrial fibrillation and other arrhythmias, resulting in transfer of some patients to telemetry or the ICU. The system alerts also helped identify cases of GI bleeding, aspiration of feedings, and bradypnea due to respiratory depression following administration of narcotics. Nurses reported that EarlySense System was effective in annunciating actionable alarms requiring intervention at the bedside or activation of the Rapid Response team. Trends of respiration and heart rate for several of these case studies are presented below.



**Pulmonary Aspiration**

High respiratory alert led to identified aspiration from PEG feedings. Patient improved with suctioning and respiratory therapy, and was discharged the following day.



**Pain**

Post-op laparotomy with high heart rate, caused by severe pain. Following the administration of pain medication, patient's pain level and HR decreased.



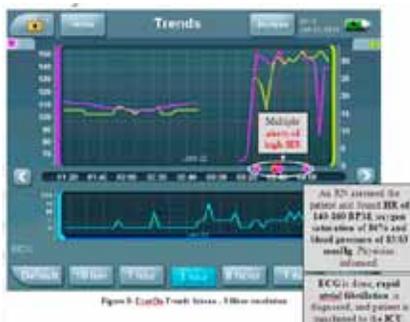
**GI bleeding**

EarlySense System generated five high HR alerts in an interval of 125 mins. Physician was informed; patient was diagnosed with GI bleeding and transferred to the ICU.



**Respiratory depression**

Post-op orthopedic surgery with narcotics administered for pain in PACU. Multiple alerts for low respiratory rate leading to identification of respiratory depression. Patient was treated with Narcan and respiratory rate normalized.



**Atrial fibrillation**

Newly diagnosed small cell lung cancer with progressive dyspnea. EarlySense System alerted for tachycardia of over 150 bpm. The patient was diagnosed with atrial fibrillation and transferred to the ICU.

## Nursing satisfaction surveys

Nursing acceptance surveys were collected to assess overall end user acceptance. Forty-one staff nurses who routinely worked on the floor where the EarlySense System was in use participated in the survey.

TABLE 3 NURSING SATISFACTION SURVEYS	
	Rate of Satisfaction
EarlySense System is a useful tool for supervision of patients	87.8%
Heart Rate and respiratory rate measurements and alerts were useful for watching over the patients	86.5%
EarlySense System helps the nurse to reduce patient fall risk	92.0%
EarlySense System heart and respiratory alerts enhance nurses' care of patients	89.0%
Turn Alerts help nurse to reduce risk of pressure ulcers	88.0%
Over-all EarlySense System helps increase the quality of care that I give to my patients	78.0%
Overall I am satisfied with the EarlySense System	84.6%

Overall positive nursing satisfaction results were associated with acceptable level of alert frequency and overall ease of use with the system. Considering that this hospital unit transitioned from no electronic monitoring to continuous electronic monitoring of all patients, the high rate of acceptance supports the nurse's perception that EarlySense System improved patient care with minimal impact on work flow.

## Impact on Costs

Factors such as length of hospital stay, number of ICU days, pressure ulcers and falls influence the total cost for a patient stay in the hospital. These parameters improved with the introduction of EarlySense System on the medical-surgical unit. The projected cost savings per patient are summarized in Table 4.

TABLE 4 DIRECT COST SAVINGS				
	Cost Per Event (\$)	Rate of Event per Admission	Measured Reduction Percentage	Total savings per patient (\$)
ICU days for required transfers	\$ 3,000 (a)	14.1%	63%	266
Patient Fall	\$ 3,230 (b,c)	0.8%	62%	16
Pressure Ulcer	\$ 10,845 (d)	1.2%	75%	97
	Cost Per day	Reduction in Average length of Stay (days)		
	\$ 1000	0.48		480
Net Savings per Patient Admission				859
Patients per bed per year (e)				63
Saving per bed per year				54,117

a. EarlySense data

b. Journal Gen Intern Med 2003, Feb 18(2) 77-83

c. AJIC: American Journal of Infection Control. Volume 30, Issue 6 (AJIC) 30(6) 376-380, 2002

d. Health grades quality study 2007

e. Assuming an average length of stay of 4 days and 69% occupancy

Lower direct cost has a financial benefit in a DRG environment and will become more significant if the pattern of non-recoverable reimbursement for avoidable adverse events continues, as is the case for hospital-

acquired pressure ulcers. The reduction in length of stay increases hospital patient flow and capacity, resulting in improved operational effectiveness by admitting more patients without adding to overhead costs.

## System Reliability

Uptime reliability was 99.8%, which translated to 10 hours of system unavailability over six months. The downtime was caused mainly by configuration changes performed to respond to clinician requests and short term power failures that occurred in hospital.

## Conclusions

The use of the EarlySense System to provide continuous monitoring in the medical-surgical environment improved patient care. There were statistically significant reductions in ICU days, lengths of stay, and pressure ulcers, and a trend toward fewer falls. Actionable alerts at the bedside led nurses to take immediate action for dangerous conditions that would have otherwise gone unnoticed. Nurse satisfaction scores supported the use of the EarlySense System. The low rate of alerts and the ability to transmit them directly to the nurse's cellular phones contributed to the high acceptance of the system.

Today's hospital environment places increasing emphasis on (1) early detection of deterioration in a patient's condition and (2) faster intervention once a problem is detected. EarlySense System has shown that new monitoring concepts can be successfully adapted to non-ICU areas with minimal interference to existing workflows, using contact-free technologies and special algorithms that minimize alerts. By providing early warning of changes in a patient's condition, the interval between the onset of patient deterioration and detection/action by clinicians on the medical-surgical unit can be reduced, diminishing the impact of possible life threatening situations. This technology also has the net effect of "upgrading" medical-surgical beds to a higher level of care, providing an alternative to telemetry for those patients who need more than standard medical-surgical care but do not require continuous ECG monitoring. The implementation of EarlySense System on a medical-surgical unit provided a new clinical tool set that resulted in measurable improvements in patient care and safety, nursing acceptance and reduced costs.

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