ORIGINAL ARTICLE

Incidence and Significance of Clinically Abnormal Events in a Tertiary Referral Medical Center: Implementation of the Clinical Alert System (CAS)

Jih-Shuin Jerng,[1] Wen-Je Ko,[2] Frank Leigh Lu,[3] Yih-Sharng Chen,[2] Szu-Fen Huang,[4] Chong-Jen Yu,[1] Ming-Jiuh Wang,[5] Fang-Yue Lin[2]*

Background: The prognosis of in-hospital cardiopulmonary arrest remains very poor. Reports have shown patients often have clinically abnormal events prior to arrest. To improve patient outcome and prevent arrest, detection of the abnormal events with early intervention has been advocated. However, the incidence of these events in Taiwan and their clinical significance remain unclear.

Methods: We conducted a prospective observational study with the implementation of the clinical alert system (CAS) in a university-affiliated tertiary referral medical center. Clinically abnormal events were detected using the CAS criteria for acute physiologic deterioration, and reported to experienced physicians for management. Patient and report data were retrieved, collected and analyzed.

Results: During the 14-month study period, a total of 2050 events were detected in 1640 patients. The estimated incidence of the events was 3.19 per 1000 bed-days, which occurred in 2.14% of admissions. The most common event was abnormal heart rate (36.5%), followed by desaturation (26.7%), abnormal respiratory rate (24.5%), and abnormal blood pressure (23.1%). The majority of the events were reported in the day time, and nurses contributed most of the reports (66.4%). The 30-day and in-hospital mortality rates were 26.3% and 34%, respectively. Multivariate survival analysis showed that desaturation (relative risk [RR] = 1.715; $p < 0.001$), abnormal respiratory rate (RR = 1.652; $p < 0.001$), abnormal blood pressure (RR = 1.460; $p = 0.001$), coma (RR = 1.918; $p < 0.001$), and oliguria (RR = 1.424; $p = 0.0024$) were significantly associated with 30-day mortality. Mortality of patients in the last 2 months was significantly lower than that in the first 2 months (20.5% *vs.* 35.4%; $p < 0.001$), which suggests the effectiveness of the CAS.

Conclusion: The development of clinically abnormal events is associated with poor outcome, which suggests that early detection and timely management of these events is necessary. Implementation of the CAS may improve the in-hospital outcome of these patients. [*J Formos Med Assoc* 2008;107(5):396–403]

Key Words: cardiopulmonary arrest, medical emergency team, rapid response system, resuscitation

Unexpected cardiopulmonary arrest is a common and devastating event in the in-hospital setting.[1,2] Since the advent of cardiopulmonary resuscitation (CPR) four decades ago, it has evolved to be an accepted practice for sudden in-hospital and out-of-hospital arrests, and standards for resuscitation registry and outcome have been proposed.[3] However, the outcome of these patients remains

Departments of [1]Internal Medicine, [2]Surgery, [3]Pediatrics, [4]Nursing and [5]Anesthesiology, National Taiwan University Hospital and National Taiwan University College of Medicine, Taipei, Taiwan.

Received: December 26, 2007
Revised: September 1, 2007
Accepted: January 15, 2008

***Correspondence to:** Dr Ming-Jiuh Wang, Department of Anesthesiology, National Taiwan University Hospital, 7 Chung-Shan South Road, Taipei 100, Taiwan.
E-mail: canon@ntu.edu.tw

poor, and only about 17% patients will survive to discharge,[1,2] despite vigorous resuscitation. Measures to prevent in-hospital arrests or reduce resuscitation have recently been advocated.[4]

Previous studies have shown as many as 84% of unexpected arrests may be preceded by significant pathophysiologic alterations,[5] and at least 18% of the arrests are retrospectively considered potentially avoidable.[6] The concept of the medical emergency team/rapid response team (MET/RRT)[4] was therefore developed for early detection and timely management of patients with acute deterioration. The risk factors for in-hospital arrest have been identified and activation criteria to alert the MET/RRT have been formulated.[7] As the effectiveness of MET/RRTs has been demonstrated, more institutions have become aware of the significance of early intervention for patients with deteriorating conditions.[8] Deployment of the MET/RRT has become one of the main goals for improving health care quality in the "100,000 Live Campaign" proposed by the Institute of Healthcare Improvement.[9]

Most MET/RRTs use a set of predetermined, largely objective criteria, which any hospital personnel can use to identify patients at risk. The criteria for alerting the MET/RRT have been proposed by experts[4] or formulated by a quasi-experimental study.[7] There have been few reports on their incidence and outcome in Taiwan, especially in an institutional setting in a medical center with more than 2000 beds. Since 2005, our institution has implemented a clinical alert system (CAS) that applies modified MET/RRT criteria to alert the staff for management. Here, we describe our experience and report the incidence of clinically abnormal events in this institution, and their possible association with patient outcome.

Patients and Methods

This was a hospital-based, prospective, observational investigation conducted at the National Taiwan University Hospital (NTUH), which is a 2400-bed university-affiliated tertiary referral medical center in northern Taiwan. This study was conducted as a part of the CAS, which is regarded as an equivalent to MET/RRT in our institution. Since the CAS mandated the staff to report clinically abnormal events and submit case report forms to the administrative and patient safety structures of the institution, the Institutional Review Board waived the necessity of written informed consent.

The CAS was implemented at NTUH in November 2005. Similar to the concept of MET/RRTs, the CAS was expected to reduce unexpected in-hospital cardiopulmonary arrests and improve the outcome of patients on the general ward. Criteria for reporting clinical abnormalities, as shown in Table 1, were derived from previously described screening criteria,[4,10] and were finally determined after a consensus meeting of experts from the institution before the implementation of the CAS. All of the general wards of NTUH, except for the pediatric wards, were included in the CAS. Patients

Table 1. Definitions of clinically abnormal events for the clinical alert system

Event	Definition
Desaturation	SpO_2 < 90% shown by pulse oximetry, or apparent cyanosis if SpO_2 not available
Tachycardia/bradycardia	Heart rate > 120/min or < 50/min
Tachypnea/bradypnea	Respiratory rate > 30/min or < 6/min
Hypotension	Systolic blood pressure < 90 mmHg or > 220 mmHg
Coma	New onset of loss of consciousness not responding to stimulation, regardless of duration
Seizures	New onset of any seizures
Cardiac arrhythmia	New onset of arrhythmia
Chest pain	New onset of chest pain with cold sweats
Oliguria	Urine output < 4 mL/kg in 8 hours
Other condition	Any condition when the staff feel worried

younger than 18 years of age or with a "do-not-resuscitate" order were excluded. Using the criteria, staff of the participating wards screened the patients at a frequency of no less than once every 8 hours. Once the staff detected any abnormal event, they were mandated to report to the senior physicians responsible for the patients. Meanwhile, they were asked to complete the CAS case report form and submit it to the Center of Quality Management of NTUH. The senior physicians then came to the bedside in response to the call, evaluated the patients and made suggestions, as well as helped the staff in further decision-making, investigations and intervention. The Center of Quality Management followed up the patients until discharge. To study the incidence and significance of the detected events, data were retrieved from the CAS case report form, including demographic data, department and ward, checked CAS criteria, timing of report and response, and names of staff submitting the report or receiving the call. Data collection was undertaken over a 14-month period. The investigators checked all observations and reports of adverse events such as death, in-hospital resuscitation, and transfer to the intensive care unit (ICU).

Data were entered, processed and analyzed with SPSS version 12 (SPSS Inc., Chicago, IL, USA) for Windows. Results were expressed as mean ± standard deviation for continuous variables, and numbers and percentages for categorical variables. Differences between groups were evaluated with the *t* test or χ^2 test depending on the distribution of data. Multivariate analysis of patient outcome was performed with Cox's proportional hazard method, and relative risk (RR) and 95% confidence intervals were reported where appropriate. A p value < 0.05 was considered statistically significant.

Results

During the 14-month study period, there were 76,527 admissions to the general wards of NTUH, which comprised 642,179 bed-days. A total of 2050 events were reported in 1640 admissions. The incidence of clinically abnormal events was 3.19 per 1000 bed-days in 2.14% of admissions.

The relevant data and distribution of clinically abnormal events are summarized in Table 2 and are also shown in Figure 1. The most commonly reported abnormal events were abnormal heart rate (36.5%), followed by desaturation (26.7%), abnormal respiratory rate (24.5%), and abnormal blood pressure (23.1%). One hundred and sixty-five (8%) events were reported as "other" events, including "worrying" conditions (36 episodes), massive gastrointestinal bleeding (26 episodes),

Table 2. Summary of reported clinically abnormal events in 1640 patients

Variable	*n* (%)
Total number of events	2050
Events	
Desaturation	548 (26.7)
Abnormal heart rate	749 (36.5)
Abnormal respiratory rate	503 (24.5)
Abnormal blood pressure	473 (23.1)
Coma	385 (18.8)
Seizures	83 (4.0)
Arrhythmia	151 (7.4)
Chest pain	82 (4.0)
Oliguria	280 (13.7)
Others	165 (8.0)
Time	
8 a.m.–4 p.m.	847 (41.3)
4 p.m.–12 p.m.	760 (37.1)
12 p.m.–8 a.m.	443 (21.6)
Place/wards	
Medical	1310 (63.9)
Surgical	475 (23.2)
Oncology	122 (6.0)
Gynecological	59 (2.9)
Others	84 (4.1)
Reporter	
Nurse	1361 (66.4)
Resident	751 (36.6)
Responder	
Senior resident	1744 (85.1)
Attending physician	259 (12.6)
Others	47 (2.3)

respiratory distress (13 episodes), limb weakness (7 episodes), hypercapnia (7 episodes), hemoptysis (5 episodes), suspected sepsis (5 episodes), and various other conditions that accounted for no more than three episodes each, such as abdominal pain, metabolic acidosis, acute myocardial infarction, severe anemia, chills, electrolyte disturbance, fever, hyperglycemia, hypothermia and intracranial hemorrhage. Most of the events were reported between 8 a.m. and 4 p.m., and accounted for 41.3% of the reports. Most of the events were detected on the medical wards (63.9%), followed by surgical wards (23.2%). Nurses (66.4%) contributed most of the reports, while senior residents (85.1%) contributed most of the responses to the calls. Figure 2 shows the trend in alert numbers during the study period. There was a gradual increment in alert calls, and the number of alerts in the last 2 months was higher than that in the first 2 months (399 *vs.* 279 episodes).

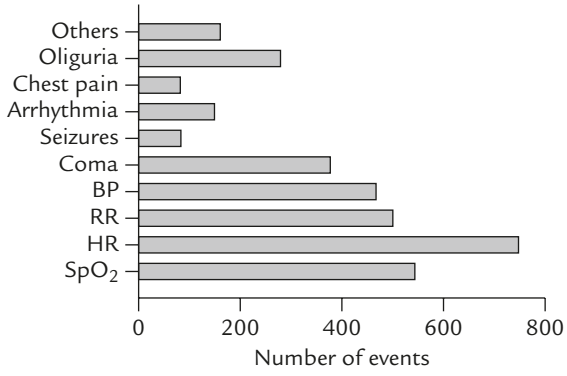

Figure 1. Distribution of clinically abnormal events reported to the clinical alert system in 1640 patients. A total of 2050 events were detected.

Of the 2505 events, 62 (3.0%) were followed by cardiopulmonary arrest that required resuscitation on the general ward, while 513 (25.0%) of the events were managed by a transfer of the patients to the ICU. The interval between the first detected abnormal event and hospital discharge was 25 ± 28 days (range, 1–215 days). Of the 1640 patients, 432 (26.3%) died within 30 days after the first report of a clinical abnormality, while 558 (34%) died at hospital discharge. The results of multivariate analysis using the Cox proportional hazard method are summarized in Table 3. It shows that oxygen desaturation (RR = 1.715; $p < 0.001$), abnormal respiratory rate (RR = 1.652; $p < 0.001$), abnormal blood pressure (RR = 1.460; $p = 0.001$), coma (RR = 1.918; $p < 0.001$), and oliguria (RR = 1.424; $p = 0.024$) were independent significant risk factors for 30-day mortality. We further analyzed the mortality difference between patients who were subsequently transferred to the ICU (513 patients) and those who were not (1127 patients). The difference was not significant (30% *vs.* 26%, $p = 0.297$ by log-rank test).

To evaluate the effect of the CAS on patient mortality, we compared patient outcomes at 30 days after the first events were reported with those at hospital discharge. Compared with the 30-day mortality rate of the first 2 months (35.4%), the

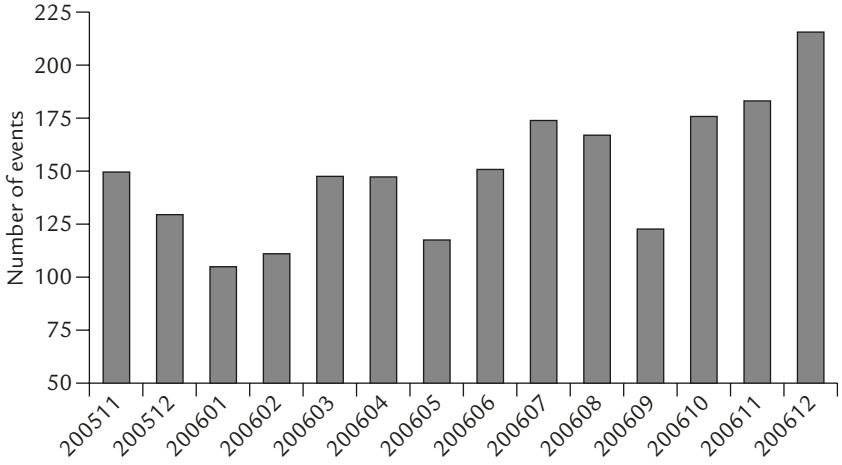

Figure 2. Distribution of clinically abnormal events according to the months during the implementation of the clinical alert system. A total of 2050 events were detected.

Table 3. Multivariate analysis of clinically abnormal events and mortality in 1640 patients

Events	Mortality among those with events (%)	Mortality among those without events (%)	RR	95% CI	*p*
Desaturation	38.5	21.9	1.715	1.392–2.112	<0.001
Abnormal HR	28.1	25.3	1.216	0.996–1.483	0.055
Abnormal RR	36.3	23.2	1.652	1.335–2.043	<0.001
Abnormal BP	30.9	24.9	1.460	1.179–1.808	0.001
Coma	38.5	23.4	1.918	1.544–2.383	<0.001
Seizures	22.7	26.5	0.842	0.500–1.417	0.52
Arrhythmia	28.6	26.1	1.075	0.758–1.524	0.69
Chest pain	23.4	26.5	0.686	0.419–1.123	0.13
Oliguria	25.4	26.5	1.424	1.047–1.936	0.024
Others	27.8	26.2	1.274	0.918–1.768	0.15

mortality rate 1 year after implementation of the CAS was significantly reduced to 20.5% (log-rank test, $p = 0.001$); the in-hospital mortality rate was also significantly reduced from 42.4% to 29.5% (log-rank test, $p < 0.001$).

Discussion

We estimated the incidence of clinical abnormalities on the general ward and showed that patients reported with abnormalities had a high in-hospital mortality rate. Several types of these events were significantly associated with poor outcome.

Unexpected in-hospital cardiopulmonary arrest on the general ward remains a serious patient safety issue, as patients are usually considered stable upon admission to the ward. In addition to programs to intensify the resuscitation skills of staff, measures for early detection of physiologic deterioration have been advocated and have become subjects of research interest. The prevalence and sensitivity of MET criteria have been investigated previously, and such criteria have been shown to be able to single out patients with elevated mortality, as compared to the rest of the hospital population.[11] This suggests that routine use of simple physiologic tests can be of help in the identification of patients at risk. Organizations such as the Institute for Healthcare Improvement[9] have included an RRT as one of the interventions for improving healthcare quality. In 2005, a cluster-randomized controlled trial showed that the MET system greatly increases emergency team calling, but their results showed that implementation of the MET did not substantially affect the incidence of cardiac arrest, unplanned ICU admission, or unexpected death.[12] Nevertheless, a consensus conference on METs has been held[8] and guidelines for the uniform reporting of data for METs has also recently been published.[13]

Studies that have estimated the incidence of acute physiologic deterioration in inpatients on general wards are still scarce, although some have reported the high incidence of antecedent physiologic abnormalities in patients with in-hospital cardiopulmonary arrest. Pathophysiologic alterations preceding cardiopulmonary arrest have been shown to be common, accounting for 84%, within 8 hours of arrest.[5] Significant physiologic deterioration seems to be common in the hours before a cardiac arrest on the wards of Finnish hospitals[14] and in medical ICUs in Taiwan.[15] In a recent prospective study, Buist et al showed that the incidence of clinically abnormal events was 8.9% for inpatients.[16] Gao et al systematically reviewed 36 papers using the physiologic track and trigger warning systems,[17] and found that the sensitivity and positive predictive value were poor, probably owing to the nature of the physiology monitored, or to the choice of trigger threshold. In one study in a single institution that had implemented the rapid

response system 16 years previously, the incidence of MET calls for crisis events was 53.8 crisis events per 1000 patient admissions.[6] Nevertheless, the true incidence of clinically abnormal events may remain underestimated. In our study, we showed that only 2.14% of the admissions to the general wards were found to have abnormal events, according to the screening criteria of the CAS. The incidence was lower than that reported by Buist et al.[16] It is possible that some physiologic deterioration was not detected and the CAS may not be sufficiently sensitive to identify patients at risk. One of the reasons is that the CAS relies on the action of routine screening by staff, but it seems impossible that they can continuously monitor or evaluate patients' conditions. Some authors have advocated the use of continuous physiologic monitoring on the general ward for patients with a high risk of death from medical or surgical conditions,[18] but the benefits and effectiveness remain to be assessed.

We showed that the in-hospital mortality of patients with clinically abnormal events was high. In our institution, the CAS mandated staff to report to senior physicians; therefore, most of the patients should have received substantial medical attention and probable interventions to avoid deterioration. It is therefore reasonable to suggest that the mortality of these patients might have been higher if no such system was in place in our institution. However, the fact that the interval between the first detection of physiologic deterioration and hospital discharge (25 ± 28 days) was so long suggests that patients with detected events may have had a protracted and complicated hospital course, which had contributed to their poor outcome. As more institutions are implementing MET/RRTs, a prospective study of the natural course of patients with clinically abnormal events would not be ethical. A mature rapid response system has shown that 18% of cardiopulmonary arrests were potentially avoidable.[6] An integrated monitoring system for early warning of patient deterioration has been proposed.[18] To further improve patient outcome, the institution should stress both detection and management of physiologic deterioration of patients on the general wards. We compared the events reported in the opening 2 months and the last 2 months. There were more alerts in the last 2 months, which might reflect improved monitoring or vigilance. Our data were derived mainly from the case report forms, which lack the content of post-call management; therefore, we did not analyze the difference in post-call management between the two periods.

It might be speculated that earlier transfer to the ICU is helpful for improving patient outcome. However, based on our data, we are unable to reach this conclusion because of the lack of randomization in this system. In our analysis, the difference in mortality in patients who were subsequently transferred to the ICU and those who were not was not significant. Explanations for this finding may include a selection bias for ICU admission for sicker patients, lack of ICU bed vacancies, and the effect of timely management on the general wards. We speculate that timely management and resuscitation might be more important than transfer to the ICU for CAS-positive patients. The overall mortality rate in NTUH was about 4% during the study period, which was much lower than the mortality rate of patients meeting the CAS criteria. To assess the effectiveness of the CAS in reducing the incidence of cardiopulmonary arrests, unscheduled admission to the ICU and hospital mortality, a matched case-control study might be required, but this is different from our study design. We hope that in the future, a matched case-control study can be performed to answer this question.

Although the CAS is supposed to mandate the staff to report patients with deterioration to senior physicians, we did not have any data on compliance with this regulation. There is a possibility of inconsistent implementation of the system on individual wards, which may lead to under-reporting of clinical abnormalities. This study did not analyze the management by senior physicians in response to calling, therefore, we do not know the adequacy of post-calling management. Our institution is a tertiary referral acute care medical center, with a substantial proportion of patients with active malignancy and chronic illness, and therefore

generalization of our findings regarding the incidence of abnormal events may be difficult. The rapid response system, as stated in the Consensus Conference on Medical Emergency Teams in 2006, may comprise four components, including afferent (event detection and response triggering), efferent (crisis response), patient safety/process improvement, and governance/administrative components.[8] In the efferent component, the consensus suggests that a response team should be considered and provide hospital-wide response to calls. In our institution, however, the CAS stresses the afferent component, and the efferent component relies on individual senior physicians who evaluate and manage patients at the bedside in response to a call from primary care staff. It is therefore not clear if the management in each response was adequate. Our study focused on the incidence and significance of the events. Whether implementation of the CAS can reduce unexpected in-hospital resuscitation or unexpected death requires further investigation. Furthermore, because the CAS might be regarded more as a warning system than as a management measure in our institution, there might be a lack of correlation between the alert problem and cause of death. Information concerning the cause of death was incomplete and might have been confounded by subsequent events during the hospital stay. To assess whether death is predictable or avoidable, one must use subjective criteria, and a panel of experts is required for further analysis. We hope, in the future, that we will be able to achieve this goal.

Although there were 165 events reported as "other" conditions, the number of each type of condition was, however, not large enough to analyze. Some of the "worrying" conditions were actually not physiologic deterioration, but the patient might have shown alterations in their general condition that warranted reporting to the CAS. Some of the conditions might have been of similar importance to the predetermined criteria for predicting deterioration of patients, and further modification of the CAS criteria is warranted.

In conclusion, a substantial proportion of inpatients on the general ward will develop significant clinically abnormal events, most of which are changes in vital signs and respiratory function. These patients have a high in-hospital mortality rate. Vigorous detection and further management of the events is highly recommended.

Acknowledgments

The authors thank Miss Li-Ching Chen, Department of Nursing, National Taiwan University Hospital, for her assistance with data collection and management. None of the authors declare any conflict of interest.

References

1. Peberdy MA, Kaye W, Ornato JP, et al. Cardiopulmonary resuscitation of adults in the hospital: a report of 14720 cardiac arrests from the National Registry of Cardiopulmonary Resuscitation. *Resuscitation* 2003;58:297–308.
2. Huang CH, Chen WJ, Ma MH, et al. Factors influencing the outcomes after in-hospital resuscitation in Taiwan. *Resuscitation* 2002;53:265–70.
3. Jacobs I, Nadkarni V, Bahr J, et al. Cardiac arrest and cardiopulmonary resuscitation outcome reports: update and simplification of the Utstein templates for resuscitation registries. A statement for healthcare professionals from a task force of the international liaison committee on resuscitation. *Resuscitation* 2004;63:233–49.
4. Hillman K, Parr M, Flabouris A, et al. Redefining in-hospital resuscitation: the concept of the medical emergency team. *Resuscitation* 2001;48:105–10.
5. Schein RM, Hazday N, Pena M, et al. Clinical antecedents to in-hospital cardiopulmonary arrest. *Chest* 1990;98:1388–92.
6. Galhotra S, DeVita MA, Simmons RL, et al. Mature rapid response system and potentially avoidable cardiopulmonary arrests in hospital. *Qual Saf Health Care* 2007;16:260–5.
7. Hodgetts TJ, Kenward G, Vlachonikolis IG, et al. The identification of risk factors for cardiac arrest and formulation of activation criteria to alert a medical emergency team. *Resuscitation* 2002;54:125–31.
8. Devita MA, Bellomo R, Hillman K, et al. Findings of the first consensus conference on medical emergency teams. *Crit Care Med* 2006;34:2463–78.
9. Berwick DM, Calkins DR, McCannon CJ, et al. The 100,000 lives campaign: setting a goal and a deadline for improving health care quality. *JAMA* 2006;295:324–7.
10. Buist MD, Moore GE, Bernard SA, et al. Effects of a medical emergency team on reduction of incidence of and mortality

from unexpected cardiac arrests in hospital: preliminary study. *BMJ* 2002;324:387–90.
11. Bell MB, Konrad D, Granath F, et al. Prevalence and sensitivity of MET-criteria in a Scandinavian University Hospital. *Resuscitation* 2006;70:66–73.
12. Hillman K, Chen J, Cretikos M, et al. Introduction of the medical emergency team (MET) system: a cluster-randomised controlled trial. *Lancet* 2005;365:2091–7.
13. Cretikos M, Parr M, Hillman K, et al. Guidelines for the uniform reporting of data for Medical Emergency Teams. *Resuscitation* 2006;68:11–25.
14. Nurmi J, Harjola VP, Nolan J, et al. Observations and warning signs prior to cardiac arrest. Should a medical emergency team intervene earlier? *Acta Anaesthesiol Scand* 2005;49:702–6.
15. Chou CH, Jerng JS, Shih CL, et al. Clinical antecedents to cardiopulmonary resuscitation in the medical intensive care unit: a retrospective study. *Thoracic Medicine* 2006;21: 239–46.
16. Buist M, Bernard S, Nguyen TV, et al. Association between clinically abnormal observations and subsequent in-hospital mortality: a prospective study. *Resuscitation* 2004;62: 137–41.
17. Gao H, McDonnell A, Harrison DA, et al. Systematic review and evaluation of physiological track and trigger warning systems for identifying at-risk patients on the ward. *Intensive Care Med* 2007;33:667–9.
18. Tarassenko L, Hann A, Young D. Integrated monitoring and analysis for early warning of patient deterioration. *Br J Anaesth* 2006;97:64–8.