Hospital outcomes associated with introduction of a two-tiered response to the deteriorating patient

Steven A Frost, Amanda Chapman, Anders Aneman, Jack Chen, Michael J Parr and Ken Hillman

ABSTRACT

Background: Liverpool Hospital introduced the medical emergency team system in 1990 and it has recently been adopted at a national and international level. New South Wales, Australia, has introduced a standardised rapid response system in over 250 acute-care hospitals: the two-tiered (clinical review call [CRC] and rapid response call [RRC]) "between the flags" (BTF) program.

Objectives: To describe the effect of the introduction of a two-tiered response to the deteriorating patient on the number of RRCs, cardiac arrests and hospital deaths.

Methods: Our study was undertaken at an 850-bed teaching hospital in the south-west of Sydney, Australia, with about 80 000 hospital admissions each year. Rates of RRCs, cardiac arrests and all hospital deaths (with and without not-for-resuscitation orders) were compared before the introduction of the BTF program (2009) and after implementation, until June 2013. The rates of CRCs after implementation were measured. Changes in the reasons for RRCs were also compared for the 12-month period before and the 36 months after the introduction of the BTF program.

Results: The monthly rate of RRCs before introduction of the program was 18.8 per 1000 hospital admissions (95% CI, 17.8–19.8 per 1000 admissions) and was estimated to increase by 4% after program implementation (95% CI, 3.2%–4.7%; $P < 0.001$). The rate of CRCs increased by 13.2% (95% CI, 10.9%–15.6%) during the study period. The cardiac arrest rate before implementation of clinical review was 1.1 per 1000 admissions (95% CI, 0.9–1.3 per 1000 admissions) and after implementation was estimated to have changed by 1% (95% CI, −1.9 to 3.9; $P = 0.48$). The hospital death rate before implementation of the BTF program was 10.8 per 1000 admissions (95% CI, 10.1–11.5 per 1000 admissions), and after implementation was estimated to increase by 2% (95% CI, 1.2%–3%, $P < 0.001$). The reasons for RRCs before and after the introduction of the BTF program did not change (all P values > 0.2), apart from the "worried" criterion, that decreased from 30% to 17% of all calls after implementation ($P < 0.001$).

Conclusion: After introduction of the BTF program, there was a progressive increase in documented CRCs and an increase in RRCs. There was no decrease in cardiac arrests or hospital deaths. RRCs based on objective physiological criteria increased. More research is needed to evaluate two-tiered response systems.

Crit Care Resusc 2015; 17: 77–82

Hospitalised patients who have adverse events such as unexpected death or cardiac arrest often show signs of deterioration before the event.[1,2] In an attempt to avoid such adverse events, early identification and timely treatment is undertaken in many hospitals throughout the world in the form of a rapid response system (RRS).[3] Liverpool Hospital, in southwestern Sydney, Australia was a pioneer of rapid response systems when it introduced the medical emergency team (MET) system in 1990.[4]

The rapid response team (RRT) of specially trained medical and nursing staff quickly responds to abnormalities in vital signs of patients, specific conditions and staff concern in much the same way as a cardiac arrest team would, but at an earlier stage of physiological instability.[5] While there is considerable variability in the exact levels of clinical signs used to identify the deterioration of patients for activation of the RRT, the basic combination of serious vital signs and observational abnormalities have changed little in over 20 years. A standardised RRS, known as "between the flags" (BTF), was introduced into over 250 acute hospitals throughout New South Wales, Australia, in 2010.[6] Before the introduction of the BTF system, not all hospitals in NSW had an RRS and many still relied on cardiac arrest teams to respond to patients who deteriorated in hospital. As part of this system change, a two-tiered response was established. The first tier was a new addition to the traditional MET system, and reflected less urgent criteria (see Table 1). In response to a patient who met the first-tier criteria, the home or admitting team (in most cases a registrar or resident) would be required to review the patient in a clinical review call (CRC). A rapid response call (RRC) (the second tier) would still be responded to by appropriately trained advanced life support staff when the calling criteria were more serious (Table 1).

The two-tier system involves increased patient review by the primary admitting medical or surgical team by activating a CRC, as well as responding to the patient at an earlier stage, with the aim of preventing further deterioration and reducing the

number of more urgent RRCs. The two-tiered system has been operating at Liverpool Hospital since the introduction of the BTF system midway through 2010. Before the introduction of the BTF program, the MET system only responded to patients who show signs of serious clinical deterioration. The aim of our study was to investigate trends in clinical review, RRCs, cardiac arrests and hospital deaths (with and without not-for-resuscitation [NFR] orders) after the introduction of the BTF program.

Methods

Subjects and setting

Our observational study was undertaken at an 850-bed teaching hospital in the south-west of Sydney, Australia, that has about 80 000 hospital admissions each year. The emergency department (ED) is a major trauma centre and has about 35 000 presentations each year. The hospital has 29 intensive care unit beds with about 2500 admissions annually. Other specialised services of the hospital include cardiothoracic surgery, neurosurgery, cardiac catheterisation with a dedicated coronary care unit, paediatric medicine and surgery, specialist haematology services with bone marrow transplantation and cancer therapies. Ethics approval was given by the human research ethics committee of the Local Health Districts. Data for this study were collected between January 2009 and June 2013.

Implementation of the BTF program

A standard adult general observation chart with the CRC and RRC criteria was introduced at Liverpool Hospital in January 2010. Training of medical, nursing and allied health staff in the use of the new ward-based observation chart was undertaken over 2 months until March 2010. At the end of May 2010, all areas, except paediatrics, maternity and critical care areas, started using the CRC criteria. Standard paediatric observation charts and clinical review were introduced to the paediatric unit in early December 2010. The rollout of standard maternity observation charts and associated maternity-specific CRC criteria did not start until the end of March 2012.

Statistical analysis

Comparison of the rates of CRCs, RRCs, cardiac arrests and hospital deaths (per 1000 hospital admissions) were undertaken using Poisson regression, as suggested by Armitage and colleagues.[7] A Poisson error distribution was used to estimate all 95% confidence intervals,[8] and the linear 3-monthly trend was assessed by using a natural logarithmic transformation of rates to estimate percentage change and 95% CIs. Comparisons of the change in frequency of reason for activation of the RRT before and after the introduction of the BTF program were undertaken using a χ^2 or Fisher exact test.

Data collection and outcomes of interest

Data used in this study were collected by a dedicated hospital coordinator who obtains the details of RRCs and CRCs from the hospital switchboard. The details are logged and transferred to an electronic record. Cardiac arrest calls are defined as events during which the RRT was activated owing to a cardiac arrest or the RRT subsequently performed cardiopulmonary resuscitation or defibrillation. All non-inpatient calls were excluded from our analysis (such as visitors or hospital staff). The number of monthly admissions and all deaths within the hospital (with and without NFR orders) were supplied by the clinical information department.

Activation of RRC and CRC

The RRC, through the use of specific calling criteria, activates a specialised critical care team to assess and, if required, treat patients who show early signs of deterioration in hospital (Table 1).[4,5] In contrast, a CRC is activated for less serious clinical signs (Table 1). The BTF program included the addition of high systolic blood pressure, and low Spo_2 being added to the RRC criteria.

Results

During and after implementation of the BTF program, the rate of cardiac arrests and proportion of deaths after cardiac arrest did not change, but hospital deaths increased (Table 2). During the same period, the rates of CRCs and RRCs increased (Table 2 and Figure 1).

The average rate of CRCs during the first 12-month period following the introduction of the BTF program was 34.7 calls per 1000 hospital admissions and during the second and third 12-month period, these rates were 67.7 and 94.9 calls per 1000 hospital admissions, respectively (Table 2). The rates of CRCs were estimated to have increased by 13.2% for each 3-month period between July 2010 and June 2013 ($P < 0.001$) (Table 2). The proportion of patients who did not survive initial resuscitation by the RRT for cardiac arrest was 54% before the introduction of the BTF program and ranged between 48% and 59% after program implementation ($P = 0.69$). The proportion of hospital deaths with NFR orders are also shown in Table 2; no changes in these rates were seen during the study period ($P = 0.743$). Plots of the trends in the monthly rates of CRCs, RRCs, hospital deaths and cardiac arrests after introduction of the BTF program are shown in Figure 1.

The reasons for activation of the RRT before and after introduction of the BTF program are shown in Table 3. The

Table 1. Rapid response team and clinical review activation criteria

Rapid response criteria	Clinical review criteria
Threatened airway	RR 5–10 or 25–30 breaths/min
↓GCS > 2 points, only responds to P on AVPU, sudden ↓ LOC	Heart rate 40–50 or 120–140 beats/min
RR < 5 or > 30 breaths/min (was 35 breaths/min before BTF started)	Systolic blood pressure 90–100 or 180–200 mmHg
Heart rate < 40 or > 140 beats/min	Spo_2 90%–94%
Systolic blood pressure < 90 or > 200 mmHg	↓AVPU assessment from A to V, or new onset of confusion
Repeated or prolonged seizures	Temperature < 35.5°C or > 38.5°C
Staff concerned	Concern by any staff member
Spo_2 < 90%	**Additional clinical review criteria**
Cardiac arrest	↑Oxygen requirement
Respiratory arrest	Poor peripheral circulation
Additional rapid response criteria	Excess or ↑ blood loss
Deterioration not reversed within 1 h of clinical review	Low urine output < 100 mL/4 h or < 0.5 mL/kg/h (via IDC) for 4 h
↑Oxygen requirement to maintain oxygen saturation > 90%	Polyuria, urine output > 200 mL/h/2 h (in absence of diuretics)
Patient deteriorates further before, during or after clinical review	Greater than expected fluid loss from a drain
Pao_2 < 60 or $Paco_2$ > 60 or pH < 7.2 or BE < –5	New, increasing or uncontrolled pain (including chest pain)
$Pvco_2$ > 65 or pH < 7.2	Blood glucose level < 4 mmol/L or > 20 mmol/L with no ↓ in LOC
Low urine output < 200 mL/8 h or < 0.5 mL/kg/h (via IDC) for 8 h	Ketonaemia > 1.5 mmol/L or ketonuria 2+ or more
Blood glucose level < 4 mmol/L or > 20 mmol/L with ↓ LOC	Concern by patient or family member
Lactate ⩾ 4 mmol/L	
Serious concern by any patient or family member	

GCS = Glasgow coma scale. AVPU = alert, voice, pain, unresponsive scale. BTW = between the flags. RR = respiratory rate. IDC = indwelling catheter. LOC = level of consciousness. BE = base excess.

reasons for activation of the RRT before and after the introduction of the BTF program did not change (all *P* values > 0.2), apart for the "worried" criterion, which decreased from 30% in the 12-month period before implementation to between 16% and 17% after implementation ($P < 0.001$). The new criteria for RRCs (low Spo2 and high systolic blood pressure), introduced with the BTF program (see Table 1), together made up between 15.2% and 15.9% of the reasons for RRCs between July 2010 and June 2013 (see Table 3).

Discussion

We have been able to show a rapid increase in the number of CRCs, increasing over time with no decrease in the number of RRCs, after the introduction of the BTF program. Importantly, there was no reduction in cardiac arrests or hospital deaths over the same period. There was a decrease in the number of calls from staff who were concerned about their patient. We presume these calls were mainly from nursing staff and it could be concluded that, because they had greater access to the first-tier CRC, staff did not have to make RRCs for the "worried" criterion. Apart from this, the introduction of the CRC appeared to have had little effect on the reasons for staff activating the RRT. Patients still deteriorated for much the same reasons as before the BTF program was introduced and, despite widespread use of the new system in our hospital, the two-tiered response has had no effect on patient outcomes or urgent responses.

RRSs have been estimated to reduce mortality and cardiac arrest rates in hospitals with such a system by about 30% when compared with hospitals without such systems to respond to deteriorating patients.[3,9] However, there are still questions about the sensitivity, specificity and utility of the criteria used to trigger RRCs. Poor sensitivity of all track-and-trigger systems has been identified as a particularly important issue.[10] There is an inference that the sensitivity could be improved by lowering the triggering levels and including many more criteria, as occurred during the introduction of the BTF program (Table 1). In fact, our results show that increasing the sensitivity resulted in many first-tier CRCs, with no reduction in the number of more urgent RRCs. Moreover, there was no reduction in hospital death and cardiac arrest rates after the BTF program was introduced. In other words, the introduction of the BTF program, even though it increased the number of false positive results

Table 2. Rates of clinical review calls, rapid response calls, cardiac arrests and deaths, January 2009 to June 2013

	Before BTF	BTF implementation	After implementing BTF				
Events	Jan–Dec 2009	Jan–Jun 2010	Jul 2010–Jun 2011	Jul 2011–Jun 2012	Jul 2012–Jun 2013	Quarterly change, % (95% CI)	*P**
Monthly hospital admissions†	6803 (264)	6977 (388)	6944 (300)	5833 (518)	6024 (243)	–1.1 (–1.5 to –0.8)	< 0.001
CRCs†	NA	NA	34.7 (33.4–36)	67.7 (65.6–69.5)	94.9 (92.6–97.2)	13.2 (10.9 to 15.6)	< 0.001
RRCs†	18.8 (17.8–19.8)	18.5 (17.2–19.8)	22.6 (21.6–23.6)	28.0 (26.8–29.3)	31.3 (30–32.6)	3.9 (3.2 to 4.7)	< 0.001
CAs†	1.1 (0.9–1.3)	0.8 (0.6–1.1)	0.9 (0.7–1.1)	1.0 (0.8–1.2)	1.2 (1–1.5)	1.0 (–1.9 to 3.9)	0.480
Deaths†	10.8 (10.1–11.5)	9.0 (8.1–10)	10.5 (9.8–11.2)	13.4 (12.6–14.3)	13.4 (12.6–14.3)	2.1 (1.2 to 3)	< 0.001
Deaths after CA, %	54.0 (39.7–71.9)	64.7 (40.5–98.0)	52.1 (36.7–71.9)	58.8 (42.0–80.1)	48.3 (34.8–65.3)	–1.0 (–5.6 to 3.8)	0.691
Deaths with NFR, %	45.9 (40.9–51.4)	61.6 (53.9–70.1)	67.3 (61.9–73)	50.4 (45.9–55.2)	63.7 (57.6–70.2)	–0.5 (–3.5 to 2.6)	0.743

BTF = between the flags program. CRC = clinical review call. NA = not applicable. RRC = rapid response call. CA = cardiac arrest. NFR = not for resuscitation. * Trend test of rates after implementation of CR. † Rates are shown as number/1000 hospital admissions/month, shown as mean with 95% CI, except monthly hospital admissions, shown as mean with SD.

(patients identified who will not then suffer adverse events such as cardiac arrest or unexpected death), did not have an impact on the number of false negative results. Nor did the added criteria decrease the numbers of seriously ill and deteriorating patients requiring an RRC. Of further interest is that even though the number of RRCs increased during the study period, our adverse outcomes did not decrease, which is not consistent with the observed "dose–response" rate of RRT activation that has been observed in many settings.[11]

A potential consequence of these data is that the workload of the admitting teams of patients identified by the clinical review system may have increased significantly; for example, during the final month of our study period, there had been 721 CRCs. Our study did not directly measure the workload of admitting teams before and after

Figure 1. Rates of clinical review calls, rapid response calls, hospital deaths and cardiac arrests after implementation of the "between the flags" program (July 2010 to June 2013).

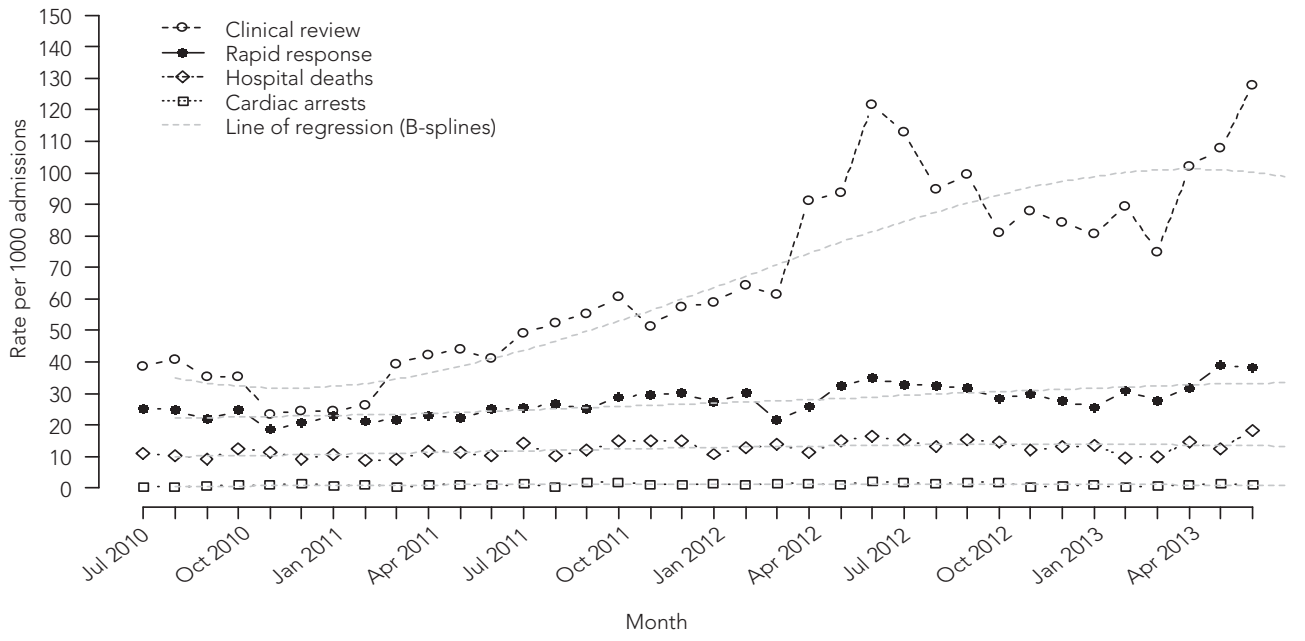

Table 3. Reason for rapid response call before and after implementation of clinical review

Reason for rapid response calls, *n* (%)	Before BTF	After implementing BTF			
	Jul 2009–Jun 2010	Jul 2010–Jun 2011	Jul 2011–Jun 2012	Jul 2012–Jun 2013	*P*
Airway threatened	12 (0.8%)	9 (0.5%)	14 (0.7%)	14 (0.6%)	0.708
Systolic blood pressure < 90 mmHg	341 (22.1%)	398 (21.4%)	436 (22.6%)	493 (21.9%)	0.851
Cardiac arrest	72 (4.7%)	70 (3.8%)	83 (4.3%)	90 (4.0%)	0.605
Decreased GCS > 2	288 (18.7%)	342 (18.4%)	333 (17.2%)	385 (17.1%)	0.497
Heart rate < 40 beats/min	20 (1.3%)	31 (1.7%)	39 (2.0%)	37 (1.6%)	0.433
Heart rate > 140 beats/min	140 (9.1%)	191 (10.3%)	193 (10.0%)	224 (10.0%)	0.689
Respiratory arrest	9 (0.6%)	7 (0.4%)	10 (0.5%)	8 (0.4%)	0.684
Repeat or prolonged seizure	49 (3.2%)	55 (3.0%)	42 (2.2%)	59 (2.6%)	0.275
Respiratory rate < 5 breaths/min	7 (0.5%)	6 (0.3%)	5 (0.3%)	6 (0.3%)	0.721
Respiratory rate > 36 breaths/min*	141 (9.1%)	157 (8.4%)	165 (8.5%)	204 (9.1%)	0.830
Worried	463 (30.0%)	298 (16.0%)	317 (16.4%)	382 (17%)	< 0.001
Spo2 < 90%†	NA	237 (12.7%)	90 (9.8%)	187 (8.3%)	–
Systolic blood pressure > 200†	NA	59 (3.2%)	104 (5.4%)	161 (7.2%)	–
Total rapid response calls	*1542*	*1860*	*1931*	*2250*	–

CR = clinical review. GCS = Glasgow coma scale. * From July 2010, increased respiratory rate calling criteria for activation of the rapid response team was decreased to 30 breaths per min. † Low SpO_2 and high systolic blood pressure calling criteria were introduced in July 2010.

the introduction of the two-tiered system, so further research is needed to solve this potential problem. If the workload has increased among admitting teams, economically, a two-tiered system could be increasing costs with no demonstrated benefit in terms of reducing adverse events. For example, a rough estimate of the clinical cost (assuming that most clinical reviews are undertaken by junior medical staff, and on average require 30 minutes) is that clinical reviews might cost a hospital $20 000 each month, and about $250 000 annually (not including added diagnostic costs). This potential increase in cost, when applied to the 250 hospitals included in the introduction of the BTF program throughout NSW, climbs to $6 million annually. Such an estimate does not account for the routine work that must be done by admitting teams, so a more rigorous analysis is needed as part of future research. Moreover, the introduction of the clinical review has not decreased the workload of the RRT. It is also important that the effect on other aspects of patient care is evaluated. The significant extra burden on junior medical staff, already under extreme pressure, may compromise other aspects of care, such as ordering and following up investigations, performing procedures, admitting and discharging patients, and communication and handovers, as well as discussing issues with patients and relatives.

These results should be considered in the context of potential limitations. First, our study is observational and does not allow strong conclusions about a causal relationship between the introduction of the BTF system and changes in our outcomes of interest. For example, changes in patient illness acuity over time may have accounted partially for the observed relationship between the introduction of a two-tiered system and the number of RRCs, and the study was conducted in a single centre that has a mature RRS as a result of being in place for over two decades. Therefore, results may not be generalisable to other hospitals. It may be that widespread implementation of a simpler, less expensive system to respond to the deteriorating patient may achieve the same results as a more complicated, resource-intensive system. There may have been other reasons why the two-tiered system had no impact on cardiac arrest rates but resulted in an increase in hospital death rates. For example, an increase in the number of patients identified by clinical review for limitation of treatment would result in higher inhospital mortality with no change in cardiac arrests rates. Our hospital's ICU had an increase in predicted hospital mortality, and an increase in withdrawal and limitation of treatment among patients admitted via the ED, during the period of our study. These changes alone may indicate changes in the hospital population for the period before and after the introduction of the BTF system. More research is necessary to identify these effects.

Conclusion

We have shown that after the introduction of the BTF program, the program has achieved its aim of being widely used, as seen by the increasing number of CRCs. However, there has been no measurable improvement in patient outcome or a decrease in seriously ill patients needing an RRC as a result of the patient being identified and responded to at an earlier time. Further work needs to be done on whether there are subtle improvements in patient care as a result of earlier clinical review taking place, or even if there is an as-yet-unmeasured decline in patient care.

Competing interests

None declared.

Author details

Steven A Frost, RN,[1] Lecturer[2,3]
Amanda Chapman, RN[1]
Anders Aneman, Senior Staff Specialist[1,3]
Jack Chen, Research Fellow[3,4]
Michael J Parr, Director of Intensive Care[1,3]
Ken Hillman, Professor of Intensive Care[1,3,4]

1 Intensive Care Liverpool Hospital, Sydney, NSW, Australia.
2 University of Western Sydney, Sydney, NSW, Australia.
3 South Western Sydney Clinical School, University of New South Wales, Sydney, NSW, Australia.
4 Simpson Centre for Health Services Research, Australian Institute of Health Innovation, Sydney, NSW, Australia.

Correspondence: s.frost@uws.edu.au

References

1 Hillman KM, Bristow PJ, Chey T, et al. Antecedents to hospital deaths. *Intern Med J* 2001; 31: 343-8.
2 Kause J, Smith G, Prytherch D, et al. A comparison of antecedents to cardiac arrests, deaths and emergency intensive care admissions in Australia and New Zealand, and the United Kingdom — the ACADEMIA study. *Resuscitation* 2004; 62: 275-82.
3 Chan PS, Jain R, Nallmothu BK, et al. Rapid response teams: a systematic review and meta-analysis. *Arch Intern Med* 2010; 170: 18-26.
4 Lee A, Bishop G, Hillman KM, Daffurn K. The medical emergency team. *Anaesth Intensive Care* 1995; 23: 183-6.
5 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.
6 Clinical Excellence Commission. Between the flags: keeping patients safe. http://www.cec.health.nsw.gov.au/programs/between-the-flags (accessed Jan 2015).
7 Armitage P, Berry G, Matthews JNS. Statistical methods in medical research. 4th ed. Oxford: Blackwell, 2002.
8 Breslow NE, Day NE. Statistical methods in cancer research. Lyon: International Agency for Research on Cancer, 1980.
9 Chen J, Flabouris A, Bellomo R, et al. Baseline hospital performance and the impact of medical emergency teams: modelling vs. conventional subgroup analysis. *Trials* 2009; 10: 117.
10 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: 667-79.
11 Jones D, Bellomo R, DeVita MA. Effectiveness of the Medical Emergency Team: the importance of dose. *Crit Care* 2009; 13: 313. ❑