Introduction of the medical emergency team (MET) system: a cluster-randomised controlled trial

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Summary

Background Patients with cardiac arrests or who die in general wards have often received delayed or inadequate care. We investigated whether the medical emergency team (MET) system could reduce the incidence of cardiac arrests, unplanned admissions to intensive care units (ICU), and deaths.

Methods We randomised 23 hospitals in Australia to continue functioning as usual (n=11) or to introduce a MET system (n=12). The primary outcome was the composite of cardiac arrest, unexpected death, or unplanned ICU admission during the 6-month study period after MET activation. Analysis was by intention to treat.

Findings Introduction of the MET increased the overall calling incidence for an emergency team (3·1 *vs* 8·7 per 1000 admissions, p=0·0001). The MET was called to 30% of patients who fulfilled the calling criteria and who were subsequently admitted to the ICU. During the study, we recorded similar incidence of the composite primary outcome in the control and MET hospitals (5·86 *vs* 5·31 per 1000 admissions, p=0·640), as well as of the individual secondary outcomes (cardiac arrests, 1·64 *vs* 1·31, p=0·736; unplanned ICU admissions, 4·68 *vs* 4·19, p=0·599; and unexpected deaths, 1·18 *vs* 1·06, p=0·752). A reduction in the rate of cardiac arrests (p=0·003) and unexpected deaths (p=0·01) was seen from baseline to the study period for both groups combined.

Interpretation The MET system greatly increases emergency team calling, but does not substantially affect the incidence of cardiac arrest, unplanned ICU admissions, or unexpected death.

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Introduction

Unexpected deaths and cardiac arrests that occur in hospitals[1–3] are often preceded by warning signs.[4,5] Similarly, unplanned admissions to intensive care units (ICU) are commonly foretold by abnormalities in patients' vital signs without appropriate action being undertaken.[6,7] These findings suggest that some of these adverse outcomes might be preventable.

A hospital-wide approach to the management of patients at risk of unexpected deaths and cardiac arrests, by early recognition of deterioration and early resuscitation, has been developed to reduce the number of unexpected deaths, cardiac arrests, and unplanned ICU admissions.[8] This approach is based on the medical emergency team (MET) system, which includes staff education, the introduction of MET calling criteria, increased awareness of the dangers of physiological instability, and immediate availability of a MET. The MET quickly responds to abnormalities in patients' vital signs, specific conditions, and staff concerns in much the same way as a cardiac arrest team would, but at an earlier stage of physiological instability.

The rationale behind this approach is that early intervention in response to physiological instability might prevent further deterioration in many patients. In studies that have had restricted analysis (by being small, using historical controls, or using unrandomised comparisons), operation of a MET system has been associated with a reduction in unplanned ICU admissions,[9] cardiac arrests, and deaths.[10–12] To rigorously assess the MET system, we undertook a cluster-randomised controlled trial in 23 hospitals in Australia and investigated the effectiveness of the system in hospitals of various sizes and organisational characteristics.

Methods

Participating hospitals and procedures

We identified potential participating hospitals using the Australian Hospital and Health Services Yearbook.[13] Public hospitals with more than 20 000 estimated admissions every year, with an ICU and emergency department, and that did not already have a MET, were eligible for participation. The director of the ICU or emergency department was contacted and invited to participate. Approval to participate was obtained from all the hospitals' human research ethics committees.

Outcome and process measures were obtained in all hospitals for a baseline period of 2 months. Halfway through the baseline period, an independent statistician (who had no other involvement in the study) randomly assigned hospitals to receive standardised MET implementation or to be controls. Randomisation was concealed from the project investigators and participating hospitals, and was stratified by teaching or non-teaching status and blocked by the number of hospital beds with a group size of four using SAS version 6.12.

During the next 4 months, an educational strategy was undertaken to prepare hospitals for the introduction of the MET system (implementation period). The control hospitals did not receive any education about the MET at

any stage. Data collection continued during the implementation period. At the end of this period, the MET system was activated in the intervention hospitals only and made available hospital-wide for the next 6 months (study period). Apart from the obtaining of approval from the hospital ethics committee and the hospital management, and an undertaking by the resuscitation committee to maintain normal functioning of the cardiac arrest team, the study was not publicised in the control hospitals. Management and resuscitation committees of the control hospitals agreed that the operation of their cardiac arrest teams would continue unchanged during the implementation and study periods. Process and outcome data were obtained in all hospitals for the 6-month study period. Before the project began, all data collectors were trained at the coordinating centre with a standardised data collection manual. During the study, three data audits were done to ensure the accuracy of data. These data audits targeted the accuracy of the study data with reference to source documentation, outcomes of the study, and accuracy of the automated optical scanning data entry.

The primary outcome for the study was the composite outcome of the incidence (events divided by number of eligible patients admitted to the hospital during the study period) of: cardiac arrests without a pre-existing not-for-resuscitation (NFR) order, unplanned ICU admissions, and unexpected deaths (deaths without a pre-existing NFR order) taking place in general wards. A general ward included any inpatient ward within the study hospitals. The coronary care unit was regarded as a general ward, as was a high-dependency unit that was not under the supervision of an intensive care specialist. The ICUs, ICU-supervised high-dependency units, operating theatres, postoperative recovery areas, and emergency departments were not regarded as general wards. Secondary outcomes consisted of: cardiac arrests without a pre-existing NFR order, unplanned ICU admissions, and unexpected deaths.

A cardiac arrest was defined as when a patient had no palpable pulse. An unplanned ICU admission was defined as any unscheduled admission to the ICU from a general ward. Unexpected deaths encompassed all deaths without a pre-existing NFR order, including those with a preceding cardiac arrest. If a patient had more than one event during their hospital stay, only one event was included in the composite measure. We excluded events in patients younger than 14 years, patients who died on arrival to hospital, or patients who had not been formally admitted to hospital.

A standardised education and implementation strategy was used to introduce the MET into every intervention hospital. This strategy included education of clinical (medical and nursing) staff about the calling criteria, the importance of these criteria in identification of patients at risk, the need to call quickly if these criteria were met, and how to call the MET. We educated participating staff by using lectures, a MET videotape, and booklets, but we did not educate them on the treatment of critically ill or unstable patients. Once MET implementation was complete, we provided reminders about the MET system and how to call it by attaching the list of calling criteria to all identification badges of hospital staff and prominently displaying posters with the list of calling criteria throughout the intervention hospitals.

The MET calling criteria are shown in the panel. Staff awareness of the introduction of the MET system was maintained by the use of regular reminders until the first day of the study period, after which awareness and education became the responsibility of the individual hospitals. The staff designated to form the MET varied between participating centres because of local circumstances. The study protocol required that the MET should be at least the equivalent of the pre-existing cardiac arrest team and should consist of at least one doctor and a nurse from the emergency department or ICU.

***Panel:* MET calling criteria**

Airway
If threatened

Breathing
All respiratory arrests
Respiratory rate <5 breaths per min
Respiratory rate >36 breaths per min

Circulation
All cardiac arrests
Pulse rate <40 beats per min
Pulse rate >140 beats per min
Systolic blood pressure <90 mm Hg

Neurology
Sudden fall in level of consciousness
(fall in Glasgow coma scale of >2 points)
Repeated or extended seizures

Other
Any patient you are seriously worried about that does not fit the above criteria

Statistical analysis

With the assumption of an average 20 000 admissions per year per hospital, the detection of a 30% reduction in the incidence of the composite primary outcome (from 3% to 2·1%) with 90% power would need 18 hospitals with a 6-month follow-up. We used the method of Kerry and Bland to account for clustering when the sample size was calculated.[14] The intraclass correlation coefficient used for the sample size calculation (0·00127) was obtained from a non-randomised study of three hospitals.[9]

A weighted *t* test was used to assess cluster-level differences in event incidence.[14,15] Individual level

differences were assessed using the Rao-Scott χ^2 test in categorical variables and the adjusted *t* test for continuous variables.[16] Multiple linear regression (analytically weighted by admission numbers during the study period) was used to adjust for stratification by teaching hospital status at randomisation and other differences in hospital (cluster-level) characteristics (including baseline outcome variables).[17] A multilevel logistic regression model was used to adjust for individual (sex, age) and cluster (bed number, teaching status) differences.[18] A post-hoc exploratory analysis, using a paired weighted *t* test, was undertaken to examine the incidence difference between baseline and the study period.

The outcome-specific intraclass correlation coefficient and design factor (DEFT)[19] were reported; these are measures used to adjust sample size in cluster-randomised trials.[20] The intraclass correlation coefficients and their 95% CIs were derived from the null multilevel logistic regression model with no independent variables. The design factor value of the intervention effects (MET *vs* control) were calculated from the survey estimator logistic regression with the intervention effect only. This design factor value is the ratio of the SE of the intervention effect from the model with adjustment for the cluster effect to the SE of the intervention effect from the model ignoring the cluster effect. A p value of less than 0·05 was regarded as significant. All statistical analyses were undertaken with Stata version 8.2 on an intention-to-treat basis.[21]

Role of the funding source

The sponsor of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The writing committee had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

23 hospitals were randomised to receive introduction of a MET system or to be controls (figure). Hospital and patient characteristics in the MET and control hospitals were similar during the baseline period; they were also comparable with respect to the baseline period incidence of primary and secondary outcomes (table 1).

During the study period, the overall rate of calls for the cardiac arrest team or MET was significantly higher in intervention hospitals than in control hospitals (p=0·0001; table 2). Calls not associated with events were more common in MET hospitals than in controls (table 2). In the control hospitals, about half the total calls were not associated with a cardiac arrest or unexpected death, whereas in MET hospitals more than 80% of calls were not associated with a cardiac arrest or death (p<0·0001). Of 194 calls not associated with an event, six (3%) resulted in an NFR order at the time of the call in the control hospitals, compared with 106 (8%) of 1329 calls in the MET hospitals (p=0·048). No significant difference was recorded in the overall rate of deaths of patients with NFR between the control and MET hospitals (8·91 *vs* 9·32 per 1000 admissions, p=0·797).

In patients with documented MET calling criteria in association with cardiac arrest or unexpected death, the call rate was similar in MET and control hospitals. However, the call rate was higher in MET hospitals before unplanned ICU admissions (p=0·001). Of 611 patients who had unplanned ICU admissions in MET hospitals during the study period, about 50% had documented calling criteria more than 15 min before the event. Of these patients, 95 (30%) had an emergency team called before their unplanned ICU admission. In patients without a documented NFR order, a record of blood pressure, heart rate, and respiratory rate in the 15-min period before an event was absent in 3657 (62%) cases, incomplete in 1122 (19%) cases, and complete in 1120 (19%) cases.

The webtable shows incidences of the primary and secondary outcomes for all study hospitals. Table 3 shows incidences of the primary and secondary outcomes in the MET and control hospitals during the study period. We recorded no significant differences between the MET and control hospitals for any outcome.

See Lancet Online for webtable

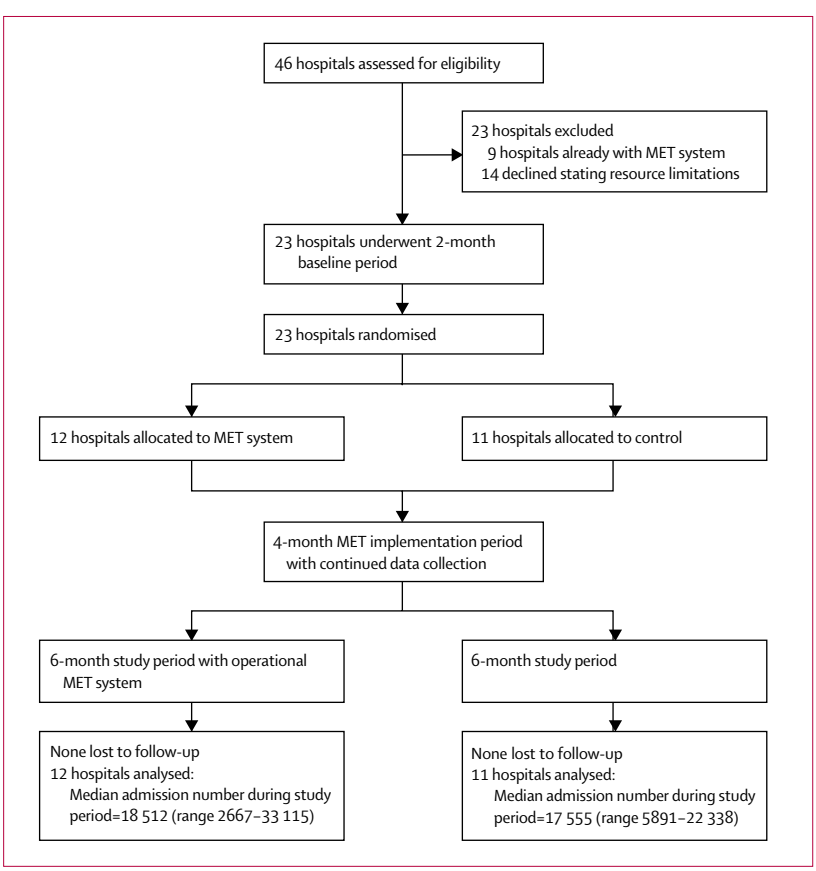

Figure: **Trial profile**

	Control hospitals (n=11)	MET hospitals (n=12)
Hospital characteristics		
Teaching hospital	8	9
Non-teaching hospital	3	3
Median bed number (IQR)	315 (229–400)	364 (182–457)
Metropolitan location	9	9
Non-metropolitan location	2	3
Patient characteristics		
Number	56 756	68 376
Median admission number per hospital (IQR)	5856 (2784–4946)	6494 (2812–7961)
Mean age (years, SD)	56·9 (20·8)	55·4 (19·9)
Number of male individuals (%)	26 775 (47%)	33 965 (50%)
Number of patients with an event*		
Primary outcome	7·07	6·58
Cardiac arrests†	2·60	1·60
Unplanned ICU admission	5·29	4·96
Unexpected death†	1·61	1·65

*Crude rate per 1000 admissions. †Excludes events with pre-existing NFR orders.

Table 1: **Study characteristics and outcomes during 2-month baseline period**

Incidence of cardiac arrests and unexpected deaths fell significantly from the baseline to the study period in all hospitals combined. There was no significant difference in the change over time between the two groups of hospitals (table 4).

Discussion

We undertook a cluster-randomised controlled trial to study the effects of the introduction of a MET system on the composite incidence of unexpected deaths, cardiac arrests, and unplanned ICU admissions. Introduction of such a system did not significantly reduce the incidence of our study outcomes. Possible explanations for our findings are that the MET system is an ineffective intervention; the MET is potentially effective but was inadequately implemented in our study; we studied the wrong outcomes; control hospitals were contaminated as a result of being in the study; the hospitals we studied were unrepresentative; or our study did not have adequate statistical power to detect important treatment effects.

Previous studies have suggested that the MET system could reduce the incidence of unplanned ICU admissions, cardiac arrests, and deaths.[9,10,12] The notable limitations of previous studies have been the use of historical controls and the absence of randomisation. By comparison, our study was a prospective cluster-randomised trial and so should have provided a reliable estimate of the treatment effect of a MET system. However, by contrast with many medical interventions studied in randomised trials, the implementation of a MET system is complex and the results of our study will have been affected by the effectiveness of our implementation strategy. Although we used a comprehensive educational strategy up to the point of activation of the MET, MET implementation could have been improved by continuation of this process throughout the study period. We used an educational

	Control hospitals	MET hospitals	p*
Mean calling rate per hospital per 1000 admissions (SD)†	3·1 (1·3)	8·7 (3·5)	0·0001
Mean number of calls not associated with an event per 1000 admissions (SD)†	1·2 (0·8)	6·3 (2·4)	<0·0001
Number of calls not associated with an event (% of total calls)†	194/528 (37%)	1329/1886 (70%)	<0·0001
Number of calls not associated with a cardiac arrest or unexpected death (% of total calls)†	253/528 (48%)	1587/1886 (84%)	<0·0001
Number of calls (% of event type)			
Cardiac arrests	236/246 (96%)	244/250 (98%)	0·359
Unplanned ICU admission	54/568 (10%)	209/611 (34%)	0·001
Unexpected deaths (not related to cardiac arrest)	5/29 (17%)	4/48 (8%)	0·420
Events with documented MET criteria present >15 min before event (% of event type)			
Cardiac arrests	109/246 (44%)	76/250 (30%)	0·031
Unplanned ICU admission	314/568 (55%)	313/611 (51%)	0·596
Unexpected deaths (not related to cardiac arrest)	16/29 (55%)	24/48 (50%)	0·660
Number of calls (% of events with documented MET criteria present >15 min before event)			
Cardiac arrests	104/109 (96%)	72/76 (95%)	0·874
Unplanned ICU admission	27/314 (9%)	95/313 (30%)	0·009
Unexpected deaths (not related to cardiac arrest)	4/16 (25%)	2/24 (8%)	0·231
Events with documented MET criteria present <15 min before event (% of event type)			
Cardiac arrests	130/246 (53%)	115/250 (46%)	0·664
Unplanned ICU admission	121/568 (21%)	219/611 (36%)	0·090
Unexpected deaths (not related to cardiac arrest)	10/29 (34%)	12/48 (25%)	0·473
Number of calls (% of events with documented MET criteria present <15 min before event)			
Cardiac arrests	124/130 (95%)	112/115 (97%)	0·545
Unplanned ICU admission	28/121 (23%)	112/219 (51%)	0·049
Unexpected deaths (not related to cardiac arrest)	4/16 (25%)	2/12 (17%)	0·298

Data are mean (SD) or number (%). p values exclude events with pre-existing NFR orders apart from unplanned ICU admissions. Unplanned ICU admission excludes instances with immediate preceding cardiac arrest but includes those with pre-existing NFR orders. *Derived from the Rao-Scott χ^2 test. Values for calling incidence per hospital and number of calls not associated with an event per 1000 admissions are derived from the weighted t test. †Calculation based on all events. All other indicators only included the first event per admission.

Table 2: **Calling incidence and rate of documentation of MET criteria in control and MET hospitals during study period**

	Control	MET	p	Difference (95% CI)*	Adjusted p	Adjusted odds ratio (95% CI)	ICC (95% CI)	DEFT
Primary outcome	5·86	5·31	0·804	−0·264 (−2·449 to 1·921)	0·640	0·98 (0·83 to 1·16)	0·0666 (0·0525 to 0·0841)	4·018
Cardiac arrest†	1·64	1·31	0·306	−0·208 (−0·620 to 0·204)	0·736	0·94 (0·79 to 1·13)	0·0196 (0·0065 to 0·0707)	1·511
Unplanned ICU admission	4·68	4·19	0·899	−0·135 (−2·330 to 2·060)	0·599	1·04 (0·89 to 1·21)	0·0951 (0·0757 to 0·1191)	4·258
Unexpected death†	1·18	1·06	0·564	−0·093 (−0·423 to 0·237)	0·752	1·03 (0·84 to 1·28)	0·0205 (0·0061 to 0·0663)	1·457

Outcome data are crude rate per 1000 admissions. ICC= intraclass correlation coefficient. *Difference weighted by number of hospital admissions during study period. †Excludes events with pre-existing NFR orders.

Table 3: **Primary and secondary outcomes during study period**

strategy that was focused on the education of staff to recognise patients at risk of unexpected deaths and cardiac arrests and to call the MET as soon as such patients were identified.

Although our educational approach was successful by increasing the emergency team calling incidences in the MET hospitals, rates could have been raised further by a sophisticated, broad-based, and continued educational approach using academic detailing, educationally influential opinion leaders, or timely reminders. More sophisticated interventions are an important area for future study. The low rate of MET calls preceding unplanned ICU admissions and unexpected deaths when MET criteria were documented suggests that MET implementation in our study could have been improved. However, we do not know whether better implementation would have increased the number of MET calls or whether an increased number of calls would have changed the negative outcome that we recorded.

Additionally, we sought to implement change and measure improvement over a short period. In this respect, our study emphasises the restrictions inherent to such studies in a dynamic health-care environment. By comparison, similar complex interventions such as the introduction of trauma systems have taken up to 10 years before any effect on mortality has been detected.[22,23] Whether the MET system might improve outcome over an extended period is unknown and extended term study of MET systems is needed.

Our ability to show that the MET system improved outcome would have also depended on the quality of care provided by the participating hospitals, because if hospitals already had effective systems to manage deteriorating patients in general wards, the MET implementation might not improve outcome. In our study, only up to half the patients had MET calling criteria documented before an adverse event, and many patients had incomplete or absent records in the period preceding cardiac arrest, death, or unplanned ICU admission. It is unlikely that a patient could be admitted from the general ward to the ICU as an unplanned admission without fulfilling the MET calling criteria, and so it seems safe to assume that virtually all these patients would have fulfilled the MET calling criteria. Although these data are not a definitive measure of the quality of ward care, they do not suggest that such quality of care was especially good in the study hospitals, and this seems to be an unlikely explanation for the negative outcome we recorded.

Our study was ambitious in design, scope, and intervention. It included a wide range of tertiary, metropolitan, and non-metropolitan hospitals in different states across Australia. As implementation of the MET system changes the delivery of emergency care within a hospital, randomisation of hospitals rather than patients was the most appropriate way of assessing the system. The fact that both control and MET hospitals improved their adverse outcome rate during the study could have reduced our ability to record a positive treatment effect. Possible explanations for this finding include seasonal variation or increased awareness of patient safety, causing systematic change in the delivery of health care in Australia. We carefully prevented contamination of hospitals in the control group, in particular the control hospitals received no specific training in the recognition of patients at risk of unexpected deaths and

Outcome	Control hospitals				MET hospitals				Control and MET hospitals combined			
	Baseline	Study	Weighted difference	p	Baseline	Study	Weighted difference	p	Baseline	Study	Weighted difference	p
Primary outcome	7·07	5·86	−1·41	0·030	6·58	5·31	−0·39	0·612	6·82	5·57	−0·85	0·089
Cardiac arrest*	2·61	1·64	−0·98	0·004	1·60	1·31	−0·44	0·171	2·08	1·47	−0·68	0·003
Unplanned ICU admission	5·29	4·96	−0·53	0·280	4·68	4·19	−0·02	0·976	5·12	4·42	−0·23	0·577
Unexpected death*	1·61	1·18	−0·68	0·040	1·65	1·06	−0·31	0·132	1·63	1·11	−0·48	0·010

Outcome data are crude rate per 1000 admissions. *Excludes events with pre-existing NFR orders. Differences are weighted by number of hospital admissions during study period. p values for weighted differences are derived from the paired weighted *t* test. If the change in outcomes from baseline to study periods are compared (ie, the change over time in control hospitals vs change over time in MET hospitals), p values for weighted differences are: primary outcome, p=0·297; cardiac arrest, p=0·190; unplanned ICU admission, p=0·508; unexpected death p=0·288. p values for change over time are derived from the weighted *t* test.

Table 4: **Primary and secondary outcomes during baseline and study periods**

cardiac arrests, but hospital safety in general and the MET system in particular were reported in the media during the study period, which could have affected operation of the control hospitals.[24]

Our data provide evidence that the cardiac arrest teams in control hospitals did operate as METs to some extent. In particular, nearly half the calls to cardiac arrest teams in the control hospitals were made without a cardiac arrest or unexpected death. Whether ICU staff in control hospitals worked as informal medical emergency teams is unknown since we did not record the incidence of direct calls for ICU assistance when these direct calls were independent to calls to the cardiac arrest team. Furthermore, we do not know whether cardiac arrest teams or ICU staff act as informal METs in hospitals outside of our study, which makes it difficult to determine the generalisability of our results to other hospitals or health-care systems. Even in Australian hospitals, the external validity of our results could be restricted only to hospitals with similar characteristics to those in our study.

The point estimate for the treatment effect of the MET system was a reduction in the composite adverse event rate of 0·264 events per 1000 hospital admissions; the 95% CIs (–2·264 to 1·921 in the adverse event rate per 1000 admissions) are consistent with anything between a large positive effect and a large negative effect. On the basis of data available when we planned the study, the incidence rate for the primary outcome was estimated at 30 in 1000 admissions.[9] However, the actual rate in the control arm was 5·7 in 1000 admissions. Moreover, the interhospital variability and intraclass correlation coefficient were substantially higher than anticipated, which further reduced our ability to show a difference between the two groups of hospitals. The incidence rates and variance observed in our study provide reliable data on which to base the design of future studies. Although these findings could be specific to our study, we estimate that more than 100 hospitals might be needed to show the 30% difference in the composite outcome we sought. To show or exclude lesser positive or negative effects of a MET system would require the study of many more than 100 hospitals, and this raises the possibility that it might not be practicable to obtain such evidence. Since previous studies have reported that the MET system reduces the incidence of cardiac arrests, deaths, and unplanned ICU admissions, we chose to study these outcomes. Whether the MET has beneficial or detrimental effects on other important outcomes remains unknown.

Our study could have important implications for clinicians and policy makers. Even in the MET hospitals that knew they were part of a clinical trial, monitoring, documentation, and response to changes in vital signs were not adequate. These findings suggest the need for improved intensive monitoring of patients in general wards; frequent and rigorous documentation of patients' condition; and increased attention to education to ensure a timely response by appropriately trained clinicians.

In conclusion, we successfully undertook a cluster-randomised trial to examine the effects of MET introduction. The MET did not greatly improve our study outcomes. However, we show that prospective assessment of system change is feasible in acute care and we provide important new incidence data and insights into the procedural issues confronting such assessment. In view of the overwhelming evidence that many seriously ill patients receive inadequate care in hospitals worldwide, further research should be undertaken and our results can assist the design and management of other such studies.

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Conflict of interest statement
We declare that we have no conflict of interest.

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