A prospective before-and-after trial of a medical emergency team

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ABSTRACT

Objective: To determine the effect on cardiac arrests and overall hospital mortality of an intensive care-based medical emergency team.

Design and setting: Prospective before-and-after trial in a tertiary referral hospital.

Patients: Consecutive patients admitted to hospital during a 4-month "before" period (May–August 1999) ($n = 21\,090$) and a 4-month intervention period (November 2000 – February 2001) ($n = 20\,921$).

Main outcome measures: Number of cardiac arrests, number of patients dying after cardiac arrest, number of postcardiac-arrest bed-days and overall number of in-hospital deaths.

Results: There were 63 cardiac arrests in the "before" period and 22 in the intervention period (relative risk reduction, RRR: 65%; $P < 0.001$). Thirty-seven deaths were attributed to cardiac arrests in the "before" period and 16 in the intervention period (RRR: 56%; $P = 0.005$). Survivors of cardiac arrest in the "before" period required 163 ICU bed-days versus 33 in the intervention period (RRR: 80%; $P < 0.001$), and 1353 hospital bed-days versus 159 in the intervention period (RRR: 88%; $P < 0.001$). There were 302 deaths in the "before" period and 222 in the intervention period (RRR: 26%; $P = 0.004$).

Conclusions: The incidence of in-hospital cardiac arrest and death following cardiac arrest, bed occupancy related to cardiac arrest, and overall in-hospital mortality decreased after introducing an intensive care-based medical emergency team.

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MOST HOSPITALS have cardiac arrest teams that respond to in-hospital cardiac arrests using modern technology and standardised protocols. However, survival to hospital discharge in patients with in-hospital cardiac arrests has remained stable at between 14.7% (United States) and 16.7% (United Kingdom) for 30 years.[1] As several studies of in-hospital cardiac arrests suggest that signs of clinical and physiological instability may precede the arrest,[2-4] introducing an intensive care-based hospital-wide preventive approach (a medical emergency team [MET]) might decrease the incidence of cardiac arrests and, consequently, hospital mortality. We tested this hypothesis by conducting a prospective trial comparing these outcome measures before and after introducing a MET.

METHODS

Hospital

The Austin and Repatriation Medical Centre comprises two major teaching hospital campuses (affiliated with the University of Melbourne), one for acute-care and the other for longer-term, less seriously ill patients. The acute-care campus, where our study was conducted, admits about 60 000 patients per year and has 21 intensive care unit (ICU) beds. About 1700 patients are admitted to our ICU each year.

Cardiac arrest procedure

The hospital's cardiac arrest team (coronary care nurse, cardiology registrar, ICU registrar and anaesthesia registrar) is activated via the switchboard operator, who calls for "*Respond Blue to Ward X*" via the internal public address and paging communication system. All wards are equipped with resuscitation trolleys with resuscitation drugs and defibrillators. All cardiac arrests are recorded, and the information is entered into a computerised database. The coronary care team also separately records cardiac arrests, and the switchboard operators record all Code Blue calls. During our study, a dedicated research nurse separately collected cardiac arrest information. All these sources were used for verification of data accuracy.

Medical emergency team

The MET system was structured so that any member of the hospital staff could activate it. The MET included the duty intensive care fellow and a designated intensive care nurse. If available, the receiving medical registrar was encouraged to attend. An ICU consultant was available from 08:00 until 20:00, and attended if requested. After hours, an intensive care consultant was available within 15–30 minutes for attendance if required.

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See also page 313

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The criteria for MET activation (Box 1) were displayed prominently in each ward. The MET was activated by a pager call and by a public announcement internal communication call "*Medical emergency team to Ward X*". The MET carried an emergency pack with drugs and equipment for resuscitation and endotracheal intubation.

1: Criteria for initiation of a MET call*

If one of these is present call 7777 and ask for the MET

- Staff member is worried about the patient
- Acute change in heart rate to < 40 or > 130 beats/min
- Acute change in systolic blood pressure to < 90 mmHg
- Acute change in respiratory rate to < 8 or > 30 breaths/min
- Acute change in pulse oximetry saturation to < 90%, despite oxygen administration
- Acute change in conscious state
- Acute change in urine output to < 50 mL in 4 hours.

*Criteria were listed on a large red poster placed prominently in all wards.

Study design

All patients admitted to the hospital were considered as participants. The study design was that of a prospective before-and-after intervention trial, with three periods:

- A 4-month "before" period (1 May 1999 – 31 August 1999) during which the outcome measures were studied under the normal operating conditions of the hospital.
- A preparation and education period (1 September 1999 – 31 August 2000) to introduce the MET. During this period, extensive and repeated presentations and discussions were held with all members of the medical, nursing and paramedical staff. The MET was then implemented (1 September 2000), and a run-in period of 2 months was allowed.
- A 4-month "after" or intervention period (1 November 2000 – 28 February 2001) during which the outcome measures were studied under the new (availability of a MET) operating conditions of the hospital.

To assess the effect of seasonal variation, we obtained data on cardiac arrests and hospital deaths for the same 4 months of the year as the intervention period 2 years before introduction of the MET (November 1998 – February 1999).

Outcome measures

- The number of cardiac arrests (primary outcome measure);
- The number of patients who died from cardiac arrest;
- The number of in-hospital deaths;
- The number of ICU bed-days occupied by survivors of cardiac arrest; and
- The number of hospital bed-days occupied by survivors of cardiac arrest.

Cardiac arrest was defined as the sudden onset of all of the following:

- Lack of palpable pulses;
- No detectable blood pressure;
- Unresponsiveness; and
- Documented initiation of basic life support.

All patients electronically recorded as admitted to the acute-care campus were included in the denominator for the study. As surgical and medical patients might be affected differently, patients were identified as surgical (operation performed during the admission) or medical (no operation performed) and analysed separately.

The primary reason for the MET call and the time of day of the call were listed for each patient. ICU and hospital bed-days were obtained from the ICU and hospital electronic databases, and the number of in-hospital deaths was obtained from the hospital electronic admission and discharge database. Patients transferred to the long-term care campus were considered as discharged from the acute-care campus.

Ethical approval

We obtained approval from the Austin and Repatriation Medical Centre Ethics Committee to implement the MET and to collect data related to the study. The need for informed consent was waived because consent to receive care according to hospital emergency protocols was considered implicit for each admission.

Statistical analysis

A computerised statistical package (Statview) was used for data analysis

2: Hospital population, patients having major surgery* and types of surgery, before and after introducing the medical emergency team (MET). Data are number of patients or procedures (95% CI), unless otherwise indicated

	Before MET (1/5/99 – 31/8/99)	After MET (1/11/00 – 28/2/01)
Medical admissions	8 974 (8 834–9 114)	8 377 (8 239–8 516)
Surgical admissions	12 116 (11 976–12 256)	12 544 (12 405–12 683)
Patients receiving major surgery	1 127 (1 065–1 189)	1 067 (1 006–1 128)
Men	660 (628–692)	613 (582–644)
Women	467 (434–500)	454 (422–484)
Mean age (years)	60.7 (59.5–61.9)	60.2 (59–61.4)
Patients > 75 years	315 (286–344)	281 (253–309)
Major surgical procedures	1 369 (1 301–1 437)	1 313 (1 246–1 380)
Cardiac surgery	188 (163–213)	141 (119–163)
Thoracic surgery	142 (120–164)	117 (97–137)
General surgery	288 (259–317)	318 (288–348)
Orthopaedic surgery	253 (225–281)	285 (256–314)
Vascular surgery	160 (137–183)	132 (111–153)
Neurosurgery	147 (125–169)	111 (92–130)
Plastic surgery	77 (61–93)	84 (67–101)
Other (includes liver transplantation)	114 (94–134)	125 (104–146)

*Major surgery is defined as any surgery requiring a hospital stay > 48 hours.

and descriptive statistics.[5] Fisher's exact test was used for comparisons between the "before" and "after" periods, and the χ^2 test was used for three-way comparison of the "before" period, the "after" (intervention) period, and the additional seasonal control period.

RESULTS

Box 2 shows the number and distribution of medical and surgical admissions during the period before and after the MET was introduced. There were no significant differences.

Cardiac arrests (Box 3)

In the "before" period, there were 8974 medical admissions, compared with 8377 in the intervention period. There were 33 cardiac arrests among medical patients in the "before" period, compared with 11 in the intervention period (relative risk reduction [RRR], 66%; $P=0.002$).

There were 12 116 surgical admissions in the "before" period, compared with 12 544 in the intervention period. The number of cardiac arrests in surgical patients decreased from 30 to 11 (RRR, 63%; $P=0.003$). Therefore, the total reduction in the number of cardiac arrests was from 63 to 22 (RRR, 65%; $P<0.001$). None of the patients suffering a cardiac arrest and receiving treatment had "do not resuscitate" orders explicitly written in the patient progress notes.

In the same 4-month period (seasonal control period) 2 years before the introduction of the MET, there were 51 cardiac arrests, which was not significantly different from the number of cardiac arrests in the "before" period ($P=0.3$), but significantly different from the number in the intervention period ($P=0.001$). Monthly cardiac arrest data during these periods are presented in Box 4.

Reasons for MET calls

In the intervention period, there were 99 MET calls triggered by different, and sometimes multiple, criteria for physiological instability ("worried about the patient", 46; haemoglobin desaturation on pulse oximetry, 37; change in conscious state, 28; low systolic blood pressure, 35; heart rate change, 20; respiratory rate change, 18; and oliguria, 2).

The MET attended each call within a mean (SD) period of 4.5 (2.2) minutes, and was in attendance for a mean (SD) period of 19 (18) minutes. Different units within the hospital activated the MET in a relatively uniform way (Box 5), but the MET was significantly more frequently activated during the evening (48 calls from 16:00 to midnight versus 31 from 08:00 to 16:00 versus 20 from midnight to 08:00; $P<0.001$).

MET procedures and outcomes

The MET initiated and completed a variety of therapeutic, investigational and procedural interventions (Box 6). Of the 99 MET calls, 18 resulted in an emergency ICU or high dependency unit (HDU) admission, with a total of 109 days and 18 days spent in ICU and HDU, respectively. The ICU/HDU stay for these patients ranged from 1 to 31 days, with 10 patients staying for 3 days or less.

Of the 24 patients who died after a MET call, 10 were designated "not for resuscitation" before the call, and two were so designated after the MET call. Three patients had a cardiac arrest at the time of the MET call and died during the call. The other nine patients, who were for full resuscitation, died a median of 19 days after the call (range, 2–57 days). Considering "not for resuscitation" orders and cardiac arrests separately, survival after a MET call was 89.6%, and none of the patients who were for full resuscitation died within 24 hours of a MET call.

In-hospital deaths

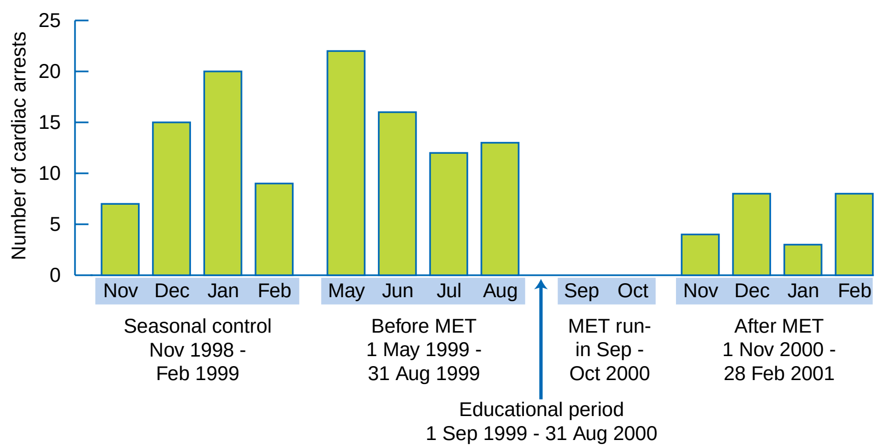
There were 37 in-hospital deaths related to cardiac arrests in the "before" period and 16 in the intervention period (RRR for cardiac arrest deaths, 56%; $P=0.008$). There were a total of 302 inpatient deaths

3: Changes in number of cardiac arrests, bed-days and mortality, before and after introducing the medical emergency team (MET)

	Before MET	After MET	Difference (95% CI)	Relative risk ratio (95% CI)
No. of cardiac arrests	63	22	41 (23–59)	0.35 (0.22–0.57)
Deaths from cardiac arrest	37	16	21 (7–35)	0.43 (0.26–0.70)
No. of days in ICU after cardiac arrest	163	33	130 (110–150)	0.20 (0.13–0.33)
No. of days in hospital after cardiac arrest	1353	159	1194 (1119–1269)	0.11 (0.09–0.13)
Inpatient deaths	302	222	80 (37–123)	0.74 (0.70–0.79)

ICU = intensive care unit.

4: Number of cardiac arrests in the study periods



5: Proportion of medical emergency team (MET) calls from the different hospital units

General surgery	21%
Neurology	13%
Cardiology	9%
Nephrology	8%
Cardiothoracic surgery	8%
Othopaedic surgery	6%
Spinal	6%
Plastic surgery	4%
Oncology	4%
General medicine	3%
Other (vascular surgery, thoracic medicine, haematology, neurosurgery, liver transplant)	18%

in the "before" period compared with 222 deaths in the intervention period (RRR, 26%; $P=0.004$) (Box 3). In the same 4-month period 2 years before the introduction of the MET, there were 275 deaths ($P=0.27$ compared with the "before" period; $P=0.018$ compared with the intervention period).

Bed-days

After cardiac arrest, and in the absence of any change in the cardiac arrest treatment protocol, survivors in the "before" period required a total of 163 ICU bed-days and 1353 hospital bed-days, and survivors in the intervention period required 33 ICU bed-days (RRR, 80%; $P<0.001$) and 159 hospital bed-days (RRR, 88%; $P<0.001$) (Box 3).

DISCUSSION

We found that the incidence of in-hospital cardiac arrests decreased by two-thirds after the introduction of a MET. This reduction, in both medical and surgical patients, is internally consistent and suggests a widespread impact, irrespective of admission diagnosis. It is also consistent with previous observations that between 50% and 84% of in-hospital cardiac arrests are preceded by physiological instability.[2-4,6,7] By appropriately responding to physiological instability, most in-hospital cardiac arrests can be prevented.

With the MET there was also a more than 50% reduction in the number of cardiac arrest-related deaths, and a reduced number of postcardiac-arrest bed-days. For our institution, this would mean a yearly decrease of close to 3500 bed-days. This suggests that a MET is associated with major cost savings and increased hospital efficiency.

Our institution was able to continue to implement and sustain the MET system after the study period by adding one dedicated MET fellow to the intensive care staff allocation. This staff member responds to MET calls and collects data, making possible continuing education and auditing.

Introduction of the MET was associated with a 26% reduction in overall hospital mortality (three lives/1000 admissions). To our knowledge, this is the first before-and-after study of any intervention that shows an impact on all-cause hospital mortality. This effect was only partly accounted for by the impact of the MET on cardiac arrests. The MET might, therefore, confer other benefits, such as increasing awareness of the consequences of physiological instability. It is also possible that the educational program to introduce the MET had an impact on the care of acutely unwell patients.

It is important to consider our study's limitations. First, this trial was not double blind, or placebo-controlled or randomised. It is not possible to have a double-blind MET intervention, and introducing "sham" intervention as placebo was ethically untenable, and "contamination" (so-called Hawthorne effect) would have been inevitable. Finally, a traditional, patient randomisation study of the MET would be ethically, scientifically and logistically impossible in a single hospital.

Our favourable findings may have been due to a high incidence of cardiac arrests in the control period or an abnormally low seasonal incidence in the intervention period. Australian data show a cardiac arrest incidence ranging from 36 to 51 per 10 000 admissions.[2,8] In the "before" period, there were 30 cardiac arrests per 10 000 hospital admissions, and there was no statistically significant seasonal variation in the incidence of cardiac arrests in our hospital. Furthermore, the 4-month MET intervention period included, by chance, 3 months immediately after the start of the working year for new interns (a possible seasonal bias against the MET), whereas the control period did not.

The reduction in cardiac arrests was not due to "reclassification" of cardiac arrests into MET calls. There were three true cardiac arrests which occurred dur-

6: Number of interventions and procedures implemented by the Medical Emergency Team

Interventions	
Nasopharyngeal/oropharyngeal suctioning and additional oxygen	21
Administration of IV fluid bolus	18
Administration of IV frusemide bolus	11
Initiation of non-invasive positive pressure ventilation by mask	9
Nebulised salbutamol	8
Temporary ventilation by bag and mask	6
Suctioning of tracheostomy tube	6
Initiation of IV glyceryltrinitrate infusion	6
Administration of anticonvulsants	5
Administration of IV vasopressors	5
Insertion of a Guedel airway	4
Administration of IV morphine	4
Insertion of a urinary catheter	4
Cardioversion	3
Administration of IV β blockers or digoxin	3
Administration of IV naloxone	2
Transfer to operating room with ongoing resuscitation	2
Administration of IV metoclopramide	2
Administration of IV ranitidine	2
Administration of IV insulin or glucose	2
Insertion of new tracheostomy tube	1
Insertion of minitracheostomy tube	1
Acute transfusion of red cells	1
Administration of dexamethasone	1
Administration of intravenous magnesium	1
Administration of atropine	1
Removal of central venous catheter	1
Acute investigations	
Chest x-ray	14
Electrocardiogram	16
Computed tomography scan	4
Arterial blood gases	36
Urea, creatinine, electrolytes and liver function tests	40
Invasive procedures	
IV line insertion	18
Arterial line insertion	5
Endotracheal intubation	3
Central venous catheter insertion	3

IV = intravenous.

ing a MET intervention, and these arrests were counted as such. Furthermore, most of the interventions were technically "simple", suggesting that timely intervention (within minutes rather than hours) at the time of deterioration might also decrease the complexity of care required. Together with the dominance of the "worried" criterion for activation of the MET, this also suggests that some relatively simple acute interventions may appear too technically demanding to junior medical or nursing staff, or that such staff might lack the experience to recognise that these interventions are needed immediately.

Similarly, it is possible that our overall in-hospital mortality was high during the "before" period and was simply restored to standard levels by the MET, or fell because of seasonal variation. In Australia, data from other large hospitals show an overall crude mortality rate between 138 and 184 deaths per 10 000 admissions.[8] Our crude mortality rate in the "before" period was 143 deaths per 10 000 admissions, and there was no statistically significant seasonal variation in in-hospital mortality.

Our findings within a single institution might not apply to other hospitals. Institution-specific heuristics and unique administrative features may have enhanced the impact of the MET approach. However, our institution has all the organisational, structural and logistic features of a typical tertiary referral hospital. Another possibility is that our implementation of a MET may have differed from that of other institutions,[9-11] but whether implementation has an impact on its efficacy is not known. We believe that our approach is simple and low cost. It is also possible that the decrease in cardiac arrests was secondary to some other improvements in patient care between the "before" and "after" periods. However, there were no changes in the structure, referral pattern or activity of our hospital, with the total number of admissions during the two study periods remaining essentially unchanged (< 1% change in the denominator for the study outcomes). Furthermore, there were no changes in "not for CPR" policy, hospital admission policy, discharge practices or surgical casemix during the study. We are also not aware of any improvements or advances in medical or surgical treatment that could explain a greater than 60% reduction in cardiac arrests and a 25% reduction in overall mortality.

Another recent study showing a possible beneficial effect of a MET[9] had several methodological shortcomings.[12] Despite other indirect supportive evidence,[10,11,13-17] the MET approach has not yet been adopted by most hospitals in Australia or elsewhere, and controversy continues concerning its safety and effectiveness.[8,12]

In conclusion, introducing an ICU-based MET in a teaching hospital decreased the incidence of and deaths from cardiac arrests, postcardiac-arrest bed-days, as well as overall mortality. Further testing of this approach is now needed in a variety of hospital and geographical settings.

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COMPETING INTERESTS

None identified.

REFERENCES

1. Saklayen M, Liss H, Markert R. In-hospital cardiopulmonary resuscitation. *Medicine* 1995; 74: 163-175.
2. Buist MD, Jarmolowski E, Burton PR, et al. Recognising clinical instability in hospital patients before cardiac arrest or unplanned admission to intensive care. *Med J Aust* 1999; 171: 22-25.
3. Franklin C, Mathew J. Developing strategies to prevent in-hospital cardiac arrest: analyzing responses of physicians and nurses in the hours before the event. *Crit Care Med* 1994; 22: 244-247.
4. Shein RMH, Hazday N, Pena M, et al. Clinical antecedents to in-hospital cardiopulmonary arrest. *Chest* 1990; 98: 1388-1392.
5. Statview [computer program], version 4. Berkeley, Calif: Abacus Concepts Inc, 1996.
6. 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: 125-131.
7. Smith AF, Wood J. Can some in-hospital cardiorespiratory arrests be prevented? A prospective survey. *Resuscitation* 1998; 37: 133-137.
8. Bristow P, Hillman KM, Chey T, et al. Rates of in-hospital arrests, deaths, and intensive care admissions: the effect of a medical emergency team. *Med J Aust* 2000; 173: 236-240.
9. Buist M, 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: 387-390.
10. Lee A, Bishop G, Hillman K, Daffum K. The medical emergency team. *Anaesth Intensive Care* 1995; 23: 183-186.
11. Hurihan F, Bishop G, Hillman KM, et al. The medical emergency team: a new strategy to identify and intervene in high-risk patients. *Clin Intensive Care* 1995; 6: 269-272.
12. Smith GB, Nolan J. Medical emergency teams and cardiac arrests in hospital. Results may have been due to education of ward staff. *BMJ* 2002; 324: 1215.
13. Goldhill DR, White SA, Sumner A. Physiological values and procedures in the 24 hours before ICU admission from the ward. *Anaesthesia* 1999; 54: 529-534.
14. McQuillan P, Pilkington S, Allan A, et al. Confidential inquiry into quality of care before admission to intensive care. *BMJ* 1998; 316: 1853-1858.
15. Hillman KM. Redefining resuscitation. *Aust N Z J Med* 1998; 28: 759-760.
16. Daly FFS, Sidney KL, Fatovich DM. The medical emergency team (MET): a model for the district general hospital. *Aust N Z J Med* 1998; 28: 795-798.
17. Henderson SO, Ballestreros D. Evaluation of a hospital-wide resuscitation team: does it increase survival for in-hospital cardiopulmonary arrest? *Resuscitation* 2001; 48: 111-116.

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