ORIGINAL ARTICLE

Reduction of paediatric in-patient cardiac arrest and death with a medical emergency team: preliminary results

J Tibballs, S Kinney, T Duke, E Oakley, M Hennessy

Arch Dis Child 2005;**90**:1148–1152. doi: 10.1136/adc.2004.069401

See end of article for authors' affiliations

Correspondence to: Associate Prof. J Tibballs, Intensive Care Unit, Royal Children's Hospital, Flemington Road, Parkville, Melbourne, Victoria, Australia 3052; james.tibballs@rch.org.au

Accepted 23 March 2005

Aims: To determine the impact of a paediatric medical emergency team (MET) on cardiac arrest, mortality, and unplanned admission to intensive care in a paediatric tertiary care hospital.

Methods: Comparison of the retrospective incidence of cardiac arrest and death during 41 months before introduction of a MET service with the prospective incidence of these events during 12 months after its introduction. Comparison of transgression of MET call criteria in patients who arrested and died before and after introduction of MET.

Results: Cardiac arrest decreased from 20 among 104 780 admissions (0.19/1000) to 4 among 35 892 admissions (0.11/1000) (risk ratio 1.71, 95% CI 0.59 to 5.01), while death decreased from 13 (0.12/1000) to 2 (0.06/1000) during these periods (risk ratio 2.22, 95% CI 0.50 to 9.87). Unplanned admissions to intensive care increased from 20 (SD 6) to 24 (SD 9) per month. The incidence of transgression of MET call criteria in patients who arrested decreased from 17 to 0 (risk difference 0.16/1000, 95% CI 0.09 to 0.24), and in those who died, decreased from 12 to 0 (risk difference 0.11/1000, 95% CI 0.05 to 0.18) after introduction of MET.

Conclusions: Introduction of a medical emergency team service was coincident with a reduction of cardiac arrest and mortality and a slight increase in admissions to intensive care.

The medical emergency team (MET), a concept to prevent unexpected in-hospital cardiac arrest, was developed for adults at Liverpool Hospital, Sydney in the 1990s[1] after recognition that cardiac arrest was often preceded by warning signs and symptoms.[2–4] While there have been several reports of the efficacy of MET services in adult hospitals,[5–10] no report of the impact of a MET service in a paediatric hospital has been published.

The outcome of cardiac arrest in children is dismal,[11] but since it is usually the culmination of prolonged hypoxaemia or hypotension, or both, there may be sufficient time to intervene and prevent it.

Review of adverse events by the Patient Safety Committee (PSC) at The Royal Children's Hospital (RCH), Melbourne suggested that it was necessary to radically change provision of urgent medical assistance on wards. Perceived reasons for unexpected cardiac arrest and death were inability of medical and nursing staff at all levels to recognise serious illness, lack of empowerment of junior staff to obtain assistance, delay in calling for and arrival of assistance, lack of readily available medical staff, or a combination of these reasons.

METHODS

A MET service was commenced in September 2002. RCH is a specialised paediatric hospital serving a population of approximately 6 million inhabitants, of whom approximately 1.5 million are children, in southern Australia. All medical and surgical paediatric services are provided including emergency care, trauma, and cardiac surgery. It offers extra-corporeal membrane oxygenation and organ transplantation. It has an emergency retrieval service for the whole of the states of Victoria and Tasmania and for southern New South Wales.

This analysis is a quality assurance exercise conducted under statutory immunity granted to the PSC such that approval of the hospital ethics committee was not required. We excluded non-inpatients, infants in the neonatal and paediatric intensive care units, patients for whom a decision not to resuscitate had been established, those receiving palliative care, and those who had arrests under anaesthesia.

STATA 7 (StatCorp, College Station, TX) was used to analyse results. Differences in risk of arrest and death before and after MET introduction were subjected to a two-sample test of proportion. Differences in admissions to ICU were subjected to *t* test.

Pre-MET (Code Blue)

Prior to our MET service, a ''Code Blue'' service operated in ward areas for management of cardiorespiratory arrest by a team of doctors and nurses from the intensive care unit (ICU). During the period April 1999 to August 2002, contemporaneous records of cardiac arrest had been maintained in a format devised by representatives of the European Resuscitation Council, American Academy of Pediatrics, and the American Heart Association (''Utstein guidelines'').[12] These served as retrospective controls.

Records of patients for whom ''Code Blue'' had been initiated for cardiac arrest were analysed to determine if MET call criteria (box 1) had been transgressed within the previous six hours. The call criterion ''doctor or nurse worried by patient's condition'' was interpreted as fulfilled when there had been increased frequency of nursing observations, transfer to a high dependency area where pulse oximetry or electrocardiographic monitoring was provided, or notification by nurses to medical staff of concern about the patient's condition.

MET service development, introduction, and operation

The Resuscitation Committee of RCH developed the MET and its call criteria which, although adapted from adult studies, were more complex and included several domains: oxygenation, clinical signs of respiratory distress, age related

Abbreviations: ED, emergency department; ICU, intensive care unit; MET, medical emergency team; PSC, Patient Safety Committee; RCH, Royal Children's Hospital

Box 1: Criteria for activation of medical emergency team

Any *one* or more of:

- 1 Nurse or doctor *worried* about clinical state
- 2 Airway threat
- 3 Hypoxaemia:
  - SpO_2 <90% in any amount of oxygen
  - SpO_2 <60% in any amount of oxygen (cyanotic heart disease)
- 4 Severe respiratory distress, apnoea, or cyanosis
- 5 Tachypnoea:

Age	Respiratory rate/min
Term–3 months	>60
4–12 months	>50
1–4 years	>40
5–12 years	>30
12 years+	>30

- 6 Tachycardia or bradycardia:

Age	Bradycardia (beats/min)	Tachycardia (beats/min)
Term–3 months	<100	>180
4–12 months	<100	>180
1–4 years	<90	>160
5–12 years	<80	>140
12 years+	<60	>130

- 7 Hypotension:

Age	BP (systolic mm Hg)
Term–3 months	<50
4–12 months	<60
1–4 years	<70
5–12 years	<80
12 years+	<90

- 8 Acute change in neurological status or convulsion
- 9 Cardiac or respiratory arrest

- Some of the values for respiratory rate, heart rate, and blood pressure are outside the normal ranges for age: they represent concerning levels that may indicate serious illness, and that require expert review
- It is also important to look for worsening trends in vital signs and report these
- If a child fulfils any of these criteria, notify the treating medical team and the MET service (via switchboard)

abnormal recordings of heart rate, respiratory rate, and blood pressure, changes in neurological status, respiratory or cardiac arrest, and general clinical impression (worried). These criteria were displayed prominently on posters in wards.

A uniform response was adopted rather than a two-tiered system of response such as one for ''cardiac arrest'' and another for ''urgent assistance''. MET calls were regarded as potential cardiac arrests.

Instigation of MET was announced to medical officers by mail in early September 2002 along with a hospital-wide educational campaign. Daytime and night-time informal open teaching fora for nurses and medical staff were held and additional educational sessions offered. Sick Child Workshops were introduced to reinforce the clinical features of serious illness and the MET call criteria. The number of places for doctors and nurses in Advanced Paediatric Life Support courses was increased. A series of Clinical Practice Reviews for medical, nursing, and allied health staff were held in early September, November, and early December (2002) when the rationale and criteria for MET were presented and illustrative cases were reviewed. This educational period was regarded as preliminary to MET operation and as a transition period from the era of ''Code Blue''. Its duration in advance was not specified, but by early December 2002 the need for intensive training had abated, representing an educational transition period of three months.

The composition of MET was initially five members comprising an ICU doctor (consultant/registrar), ICU nurse, emergency department (ED) senior doctor and nurse, and a medical registrar. However, after six months, the emergency nurses withdrew on realisation that four personnel were sufficient.

MET was initiated by calling the hospital switchboard on an emergency number. Telephonists were instructed to regard calls for any type of medical assistance as a MET call. Telephonists then: (1) issued a loud-speaker MET call (for example, ''MET ward X''); (2) paged MET team members via beepers and personal data screens in ICU; and (3) telephoned ICU directly advising staff of a call and location.

At the scene, the MET provided immediate medical treatment as required, then communicated with the admitting bed-card unit members to formulate further treatment, and completed a standard MET data sheet which was collected by the investigators. To prevent discouragement of junior staff, particularly nurses, to make calls, MET members were instructed not to make adverse comments on the appropriateness or otherwise of calls and to adopt a supportive attitude.

RESULTS

Pre-MET cardiac arrest and death

In the 41 month pre-MET era, of 166 ''Code Blue'' calls, 28 were for in-hospital cardiac arrest. Five were for children who arrested outside hospital and arrived in ED receiving resuscitation, and one was for an adult visitor. All of these six died. Of the remaining 22 in-patients, two arrests occurred in the operating theatre and were excluded from analysis because under conditions of surgery and anaesthesia we could not fairly compare their status against our MET call criteria.

Thus, in the pre-MET era there were 20 children who had an in-hospital cardiac arrest. Their mean age was 3.6 (SD 5.1) years (range 2 weeks to 17 years). The conditions predisposing to cardiac arrest were: nine post-cardiac surgery, four septic shock, three lung diseases, two upper airway obstruction, one metabolic disorder, and one hypovolaemic shock. Arrest occurred in 17 patients who had transgressed MET call criteria and in three patients who had not transgressed call

Table 1 Incidence of cardiac arrests and death (per 1000 admissions)

	Code Blue 41 months 104 780 admissions	MET 12 months 35 892 admissions	
Total			Risk ratio (95% CI)
Cardiac arrest	20 (0.1908)	4 (0.1114)	1.71 (0.59 to 5.01), p=0.320
Death	13 (0.1241)	2 (0.0557)	2.22 (0.50 to 9.87), p=0.279
Transgressing MET criteria			Risk difference (95% CI)
Cardiac arrest	17 (0.1622)	0 (0.0000)	0.16 (0.09 to 0.24), p=0.016
Death	12 (0.1145)	0 (0.0000)	0.11 (0.05 to 0.18), p=0.043
Not transgressing MET criteria			Risk ratio (95% CI)
Cardiac arrest	3 (0.0286)	4 (0.1114)	0.26 (0.06 to 1.15), p=0.055
Death	1 (0.0095)	2 (0.0557)	0.17 (0.02 to 1.89), p=0. 102

CI, confidence interval; NS, not significant.

criteria within six hours prior to arrest. A total of 13 patients died either at the time of arrest or within 24 hours. Of these deaths, 12 occurred in patients who had transgressed MET call criteria and one in a patient who had not. A total of 104 780 patients were admitted to wards during the period, yielding a cardiac arrest rate of 0.1908/1000 admissions and a death rate of 0.1241/1000 admissions.

Educational-transitional period

During the three month transitional period from ''Code Blue'' to MET, there were four cardiac arrests among four children, all of whom died. All had transgressed cardiovascular and respiratory MET criteria, including one child with septic shock and three infants with cardiac failure, of whom two had been receiving inotropic infusions.

Cardiac arrest and death after introduction of MET

During the 12 months of MET service there were four cardiac arrests in three children (two children died) (table 1) but none had transgressed MET criteria. One child with bacterial endocarditis arrested twice with sudden cardiac dysrhythmia with no antecedent signs or symptoms during ECG and oximetry monitoring; one child with complex congenital heart disease arrested (but survived intact) during presumed vagal stimulation on insertion of a nasogastric tube; another child with acute lymphatic leukaemia arrested suddenly with no antecedent symptoms or signs and in whom a post-mortem examination revealed cerebral haemorrhage. The total number of admissions to wards during the period was 35 892 which gives a cardiac arrest rate of 0.1114/1000 admissions and a death rate of 0.0557/1000 admissions.

Changes in risks of cardiac arrest and death

The risk of cardiac arrest was 0.1908/1000 admissions before MET, reducing to 0.1114/1000 admissions with MET: a risk ratio of 1.71 (95% CI 0.59 to 5.01, p = 0.32). The risk of death before MET was 0.1241/1000 admissions, reducing to 0.0557/1000 admissions with MET: a risk ratio of 2.22 (95% CI 0.50 to 9.87, p = 0.28).

The risk of transgression of MET call criteria among those who arrested before introduction of MET was 0.1622/1000 admissions, reducing to 0/1000 admissions after introduction of MET, yielding a risk difference of 0.1622 (95% CI 0.0851 to 0.2394, p = 0.0158). The risk of transgression of MET call criteria among those who died was 0.1145/1000 admissions before MET, reducing to 0/1000 admissions after introduction of MET, with a risk difference of 0.1145 (95% CI 0.0497 to 0.1793, p = 0.0426).

MET activity

In 12 months of MET operation, 184 calls were made compared with 49 per 12 months in the pre-MET period (ratio 3.9:1). Of these, 20 involved visitors or staff in the hospital. The staff making calls, the reasons for calls, and the destination of patients is given in table 2. Interventions by MET are provided in table 3.

Changes in clinical practice

One MET call lead to specification of individual MET criteria for selected patients discharged from the recovery room of the operating theatre. Another patient who died in the transition period had been a recent ICU patient and had been discharged at a time when transgressing MET criteria. Subsequently, all patients leaving ICU have specified MET criteria and are reviewed on the ward by ICU staff in the evening of the day of discharge.

Admissions to and mortality in intensive care

Unplanned admissions to ICU from wards increased from a mean of 20 (SD 6) per month to 24 (SD 9) (p = 0.074), representing an increase from 17.3% to 21.3% of total ICU admissions. Seventy seven patients were admitted to ICU

Table 2 Callers, reasons, and dispositions from MET calls

Caller (%)		Reason for call (%)		Disposition (%)	
Nurse	62	Hypoxaemia	47	Intensive care	47
Doctor	10	Respiratory distress	39	Reviewed on ward	24
Nurse and doctor	17	''Worried''	27	No revision on ward	21
Other	11	Airway threat	27	Other transferral	8
		Altered neurological status	20		
		Tachycardia	14		
		Tachypnoea	13		
		Bradycardia	7		
		Cardiac arrest	2		
		Hypotension	2		

Table 3 Action taken during MET calls

Action	(%)
Advice only	23
Oxygen	30
Basic airway support (alone)	18
Bag-valve-mask ventilation	21
Endotracheal intubation +/− ventilation	8
External cardiac compression	2
DC shock	0.6
Venous cannulation	16
Central venous cannulation	2
Intraosseous cannulation	0.6
Resuscitation fluids	17
Resuscitation drugs	4

Other treatments: drugs (bronchodilators, adrenaline aerosol, antibiotics, sedatives, naloxone, flumazenil, sedatives, opiates), blood tests, *x* rays, echocardiography, MRI, oesophageal pacing, pericardial tap.

after MET calls. Of these, four died in ICU and eight died after discharge during palliation. Deaths among ICU patients admitted unplanned from the wards decreased from 66/809 (8.2%) pre-MET to 15/287 (5.2%) post-MET. The incidence of death among all admissions to ICU was 5.7% (266/4666) pre-MET and 4.8% (65/1344) after MET was introduced.

DISCUSSION

Several adult hospitals have introduced MET with beneficial effects. The most recent study[9] showed a 17% decrease in cardiopulmonary arrest from 6.5 to 5.4 per 1000 admissions. Another ''before and after'' trial showed a relative risk reduction of 65% for cardiac arrest, 56% for death at cardiac arrest, and 26% for hospital deaths.[5 10] It has been claimed that if this was applied nationally it would reduce Australian hospital deaths by 6000 per annum.[13] In another hospital[6] the incidence of unexpected cardiac arrests reduced from 3.77/1000 hospital admissions to 2.05/1000, which after adjustment for case mix was associated with a 50% reduction. Validity was challenged on the inability to separate the effects of education and instigation of MET.[14] At another hospital,[8] the incidence of in-hospital death decreased slightly from 0.74% to 0.65% and the incidence of cardiorespiratory arrest decreased slightly from 0.08% to 0.07% but with a significant decrease in unplanned ICU admissions. Another study of arrest and death between one hospital with a MET service and two others without MET did not reveal differences.[7]

In comparison, although clinically important reductions of cardiac arrest and death were observed in our ''before and after'' study, these were not statistically significant. This probably reflects a relatively small incidence of paediatric cardiac arrest, a small MET sample size after introduction of MET, and the fact that paediatric arrest may occur without warning. In our institution, before MET, the incidence of cardiac arrest was one twentieth of that reported in an adult hospital.[6]

The key feature of our MET service is empowerment of any nurse or paramedical personnel to request urgent medical assistance without necessarily consulting with seniors or doctors, and empowerment of any doctor to request assistance without consulting with peers or seniors. Potentially, this organisational change could lead to conflict between MET and bed-card unit members, but this was uncommonly experienced, and possibly averted by mandatory consultation of MET members with bed-card unit members to decide further management, after immediate treatment was provided.

Unlike others,[14] we believe it is unnecessary to separate the effects of education and provision of emergency services with MET. Indeed, we believe twin processes of MET and education on serious illness are inextricably linked. We established a coordinated programme of education for medical, nursing, and paramedical staff in the recognition of serious illness, using MET call criteria as reference values. We believe that these interventions were an integral part of the process of introduction of MET and it is this process which contributed to reduction in unexpected cardiac arrests.

Although four arrests and deaths occurred during the three month transitional-education programme, they are not a failure of MET, but rather a reflection that education and behavioural change takes time. A similar period of transition (2 months) and a much longer preceding educational period (12 months) were described in the introduction of an adult MET service.[5 10] In that study, cardiac arrests during a 12 month educational period and during a two month transitional period were not considered in the initial analysis of the service, but in later correspondence[15] it was revealed that unexpected cardiac arrest decreased to levels commensurate with those observed during MET, thus supporting our contention that education about serious illness is as important as provision of emergency services by MET.

Nearly one half of all patients subject to a MET call were admitted to ICU and unplanned admissions increased by an average of 4 per month. This increase contrasts with an adult service which observed a decrease in ICU admissions.[8] We suspected that some MET calls made would be for relatively trivial matters, but this was not the case. In approximately 80% of cases treatment was given, and in approximately 20% only advice was given.

It is conceivable that one effect of MET may be to reduce death on wards and allow it to happen in ICU, but our observations suggest otherwise. The risk of ward death reduced from 0.12/1000 admissions to 0.06/1000 admissions, while death in all ICU patients also decreased, from 5.7% to 4.8%. These observations suggest that introduction of MET is effective in reducing unexpected cardiac arrest and mortality outside ICU and moreover does not contribute to ICU mortality.

Our study identified significant reductions in transgression of MET call criteria among patients who arrested and died before and after MET introduction, but this is subject to errors involved in retrospective analysis. It could be argued that reduction in MET transgression was partly dependent on MET criteria. We do not know the true incidence of transgression of MET call criteria among all patients and the sensitivity, specificity, and predictive power of the criteria have not yet been validated, and need research. However, it appears that we have chosen our call criteria appropriately: approximately 85% (17/20) of children in the Code Blue era who suffered cardiac arrest had transgressed MET criteria while in the MET era, a minority of calls (20%) did not warrant intervention apart from advice on ongoing management.

Establishment of a MET service may de-skill ward staff in the management of cardiac arrest. Rotation of junior medical and nursing staff through critical care areas and the integration of educational strategies within MET may offset this. Some MET members reported a disadvantage compared with the Code Blue service in that they did not know what situation was to be encountered until arrival at the scene. However, this is a relatively minor and unavoidable complication of providing preventative medical assistance.

Although this quality assurance study suggests improvement in performance, a prospective controlled study is required before a firm conclusion about the efficacy of a paediatric MET service can be made. Nonetheless, introduction of a MET service was co-incident with significant reduction of cardiac arrest and death among patients transgressing our MET call criteria.

What is already known on this topic

- A medical emergency team (MET) responds quickly to transgressions of specified physiological call criteria
- MET services have reduced the incidence of unexpected cardiopulmonary arrest and death in several adult hospitals

What this study adds

- A MET service operated successfully in a paediatric hospital using age related and other physiological call criteria
- MET reduced the incidence of unexpected cardiorespiratory arrest and mortality

ACKNOWLEDGEMENTS

We thank Hayley Salter for provision of admission data, Bradley Carter for assistance with statistical analysis, and Dr Karen Dunn for valuable comments on the manuscript.

Authors' affiliations

J Tibballs, Intensive Care Unit, Royal Children's Hospital, Melbourne, Australia
S Kinney, Intensive Care Unit, Royal Children's Hospital, Melbourne, Australia
T Duke, Intensive Care Unit and Department of Paediatrics, Royal Children's Hospital, Melbourne, Australia
E Oakley, Emergency Department, Royal Children's Hospital, Melbourne, Australia
M Hennessy, Mackinnon School of Nursing, Royal Children's Hospital, Melbourne, Australia

Competing interests: none declared

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