

Prospective controlled trial of effect of medical emergency team on postoperative morbidity and mortality rates*

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Objective: To determine whether the introduction of an intensive care unit-based medical emergency team, responding to hospital-wide preset criteria of physiologic instability, would decrease the rate of predefined adverse outcomes in patients having major surgery.

Design: Prospective, controlled before-and-after trial.

Setting: University-affiliated hospital.

Patients: Consecutive patients admitted to hospital for major surgery during a 4-month control phase and during a 4-month intervention phase.

Interventions: Introduction of a hospital-wide intensive care unit-based medical emergency team to evaluate and treat inpatients deemed at risk of developing an adverse outcome by nursing, paramedical, and/or medical staff.

Measurements and Main Results: We measured incidence of serious adverse events, mortality after major surgery, and mean duration of hospital stay. There were 1,369 operations in 1,116 patients during the control period and 1,313 in 1,067 patients during the medical emergency team intervention period. In the control period, there were 336 adverse outcomes in 190 patients

(301 outcomes/1,000 surgical admissions), which decreased to 136 in 105 patients (127 outcomes/1,000 surgical admissions) during the intervention period (relative risk reduction, 57.8%; $p < .0001$). These changes were due to significant decreases in the number of cases of respiratory failure (relative risk reduction, 79.1%; $p < .0001$), stroke (relative risk reduction, 78.2%; $p = .0026$), severe sepsis (relative risk reduction, 74.3%; $p = .0044$), and acute renal failure requiring renal replacement therapy (relative risk reduction, 88.5%; $p < .0001$). Emergency intensive care unit admissions were also reduced (relative risk reduction, 44.4%; $p = .001$). The introduction of the medical emergency team was also associated with a significant decrease in the number of postoperative deaths (relative risk reduction, 36.6%; $p = .0178$). Duration of hospital stay after major surgery decreased from a mean of 23.8 days to 19.8 days ($p = .0092$).

Conclusions: The introduction of an intensive care unit-based medical emergency team in a teaching hospital was associated with a reduced incidence of postoperative adverse outcomes, postoperative mortality rate, and mean duration of hospital stay. (Crit Care Med 2004; 32:916–921)

Adverse outcomes (AOs) appear common among patients admitted to hospital (1). A review of 30,121 medical records in New York State showed that AOs affected close to 4% of all admissions. Of these events, 13.6% led to death (2). A similar review of 14,000 Australian medical records (3) revealed similar findings showing that AOs are a worldwide problem.

Much skepticism was expressed in response to these provocative findings, especially because of the retrospective nature of the studies (4). Nonetheless,

although the true prevalence remains unknown, AOs might be particularly common after major surgery (4–11). A 15,000-patient review of surgical adverse events in Colorado and Utah found an incidence of 14.1% among patients undergoing lower extremity bypass grafting, 18.9% among those undergoing abdominal aortic aneurysm repair, and 12.3% among those undergoing cardiac surgery. It remains unclear, however, whether these AOs are the inevitable consequence of performing major surgery in older and sicker patients or whether some of these AOs are preventable (12–17).

We hypothesized that some AOs might be preventable and that a systematic rapid-intervention intensive care-based program (the medical emergency team approach, or MET) would decrease the number of AOs, the number of deaths, and mean duration of hospital stay of surgical patients.

We tested this hypothesis by conducting a prospective controlled trial compar-

ing these outcome measures before and after the introduction of the MET.

METHODS

We obtained Institutional Review Board approval for the implementation of the MET and for the collection of data related to the study. The need for informed consent was waived by the Institutional Review Board.

The study was conducted from May 1, 1999, until March 1, 2001.

The Hospital

The Austin & Repatriation Medical Center is a teaching hospital of the University of Melbourne. It has two campuses located in the northeast of Melbourne, a city with a population of close to 4 million. One campus (400 beds) receives all acute admissions and the other more chronic, less severely ill admissions. The acute care campus admits approximately 60,000 patients per year and is the campus where this study was conducted. The acute care campus has 21 intensive care unit

*See also p. 1071.

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Supported, in part, by a grant from the Quality Improvement Branch of the Acute Health Care section of the Victorian Department of Human Services.

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DOI: 10.1097/01.CCM.0000119428.02968.9E

(ICU) beds, which admit approximately 1,700 patients per year. The ICU operates according to the "closed" ICU model where only ICU physicians can prescribe treatment. The medical center has a strong academic tradition with two research institutes (immunology and oncology) located within its campus. In essence, it is very similar to most large tertiary institutions in developed countries.

Preintervention Emergency Response Structure

Before the introduction of the MET, the hospital emergency response system was based on the traditional cardiac arrest team concept. Cardiac arrest team members carry pagers, which are activated during the "code blue" call. All wards are equipped with resuscitation trolleys containing resuscitation drugs and defibrillators. The cardiac arrest team includes a cardiology fellow, an intensive care fellow, a coronary care nurse, and the receiving medical unit fellow. This cardiac arrest response system remained unaltered throughout the study.

The Medical Emergency Team

Any member of hospital clinical staff (nurses, physiotherapists, social workers, speech therapists, residents, members of senior medical staff) could activate the MET. The MET included the duty intensive care fellow (who was also responsible for other ICU duties) and a designated intensive care nurse. If available, the receiving medical fellow was encouraged to attend. An ICU specialist was available and would attend, if requested, from 8 am until 8 pm. After hours, an intensive care specialist was available within 15–30 mins for attendance if required. The criteria for MET activation (Table 1) were available in the form of a large red poster, which was displayed prominently in each ward. The MET was activated by a pager call and by a public announcement internal communication call saying "medical emergency team to ward X." Members of the MET carried an emergency pack with drugs and equipment needed for resuscitation and endotracheal intubation. After a MET call, if the patient was not admitted to ICU, the MET visit was considered a formal

consult, the parent unit was contacted, and concerns, advice, and suggestions were verbally communicated and recorded in the patient's chart.

Study Design

The study design was that of a prospective, controlled, before-and-after intervention trial.

All patients admitted to hospital who had major surgery were considered as participants. Major surgery was defined as any operation associated with a hospital stay >48 hrs.

Study Principle

The principle underlying intervention with the MET was that physiologic instability identifies surgical patients who are at risk of AOs. The assessment and care of these patients should be implemented as rapidly as possible before further deterioration and should be provided by an ICU team with appropriate resuscitation skills.

Study Periods

The "before" period was a 4-month period (control period) during which the outcome measures were studied under the normal operating conditions of the hospital.

This period was followed by a preparation and education period to allow the introduction of the MET. During this period, the concept of the MET was presented in the form of lectures and tutorials to all nursing staff and paramedical personnel (physiotherapists and speech therapists). Extensive and repeated presentations and discussions were held with all members of medical staff. Objections were raised and addressed at these meetings. The MET was then implemented, and a run-in period of 2 months was allowed. This was done to ensure that there were no logistic or political problems with its implementation and that the hospital and all members of staff would become familiar with its use.

The "after" period was the following 4-month period (intervention period) during which the outcome measures were studied under the new (availability of MET) operating conditions of the hospital.

Subjects

Analysis included all subjects who had inpatient surgery during the study period and who remained in hospital for ≥ 48 hrs after surgery. The 48-hr limit was used to exclude patients having day surgery or minor procedures who were not expected to be at risk of serious adverse events.

Design

Demographic and logistic data were collected at inclusion (age, gender, surgical specialty of admission, ward, scheduled or unscheduled status of surgery, planned ICU admission). Following inclusion, all patients were followed up to either death or hospital discharge. During follow-up, outcome data (length of hospital stay, survival, and development of predefined postoperative severe adverse events) were obtained.

Definition of Adverse Outcomes

Specific criteria were used to define postoperative AOs (Table 2) as previously described (11).

Outcome Measures

The primary outcome measure for the trial was the incidence of AOs. The secondary outcome measures were as follows:

1. The percentage of patients affected by AOs
2. The incidence of in-hospital deaths
3. The incidence of individual AOs
4. The mean duration of hospital stay

For each MET intervention, the primary reason and time of day for the MET call were obtained. Using a standardized data collection tool, demographic, clinical, intervention, and outcome information were obtained for each MET call. All patients were followed up to discharge from hospital and AOs recorded.

Statistical Analysis

A computerized statistical package was used for data analysis (Statview, Abacus, Berkeley, CA) and descriptive statistics. Comparisons of nominal data between the two study periods were performed using Fisher's exact test. For nonnormally distributed continuous data, such as length of stay, the Mann-Whitney was used. A $p < .05$ was considered statistically significant.

RESULTS

Effect on Number of AOs and Patients Affected

During the control period, 1,116 patients received 1,369 operations com-

Table 1. Criteria for initiation of medical emergency team (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 mm Hg
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 hrs

Table 2. Specific criteria used to define postoperative serious adverse events

SAE	Definition
AMI	All of the following findings: chest pain, ECG changes, and at least one elevated CK concentration
PE	Clinical suspicion of PE and a high probability V/Q scan
Acute pulmonary edema	Clinical suspicion of acute pulmonary edema and formal radiological confirmation of acute pulmonary edema
Respiratory failure	The need to reinstitute mechanical ventilation in the ICU
Stroke	Clinical symptoms and neurologic examination suggestive of a stroke with formal radiological confirmation by CT and/or MR scanning
Severe sepsis	Clinical suspicion of infection + hypotension (systolic BP <90 mm Hg) + at least one positive blood culture
Acute renal failure	Acute need for continuous renal replacement therapy
Emergency admission to ICU	Unscheduled admission to the ICU during the postoperative period due to a clinical complication
Death	Cessation of life indicated by the absence of heartbeat and respiration

SAE, serious adverse event; AMI, acute myocardial infarction; ECG, electrocardiogram; CK, creatine kinase; PE, pulmonary embolism; V/Q, ventilation/perfusion ratio; ICU, intensive care unit; CT, computed tomography; MR, magnetic resonance; BP, blood pressure.

pared with 1,067 patients who received 1,313 operations in the intervention (MET) period. The demographic features and surgical specialty distribution of these patients are presented in Table 3.

During the control period, there were 336 AOs, which affected 190 patients (301 events/1,000 patients and 170 affected patients/1,000 admissions). During the intervention period, after the introduction of the MET service, there were 136 AOs, which affected 105 patients (127 events/1,000 patients and 98 patients affected/1,000 admissions) (relative risk reduction, 57.8%; $p < .0001$). These changes were due to decreases in the incidence of each and every AO (Table 4). Furthermore, emergency ICU admissions were also reduced from 89 to 48 (relative risk reduction, 44.4%; $p = .001$).

Activation of the MET During the Intervention Period

During the intervention period, there were 52 MET calls for surgical patients. All surgical units triggered such activation of the MET because of physiologic instability (Fig. 1) or clinical concern. The MET attended each call within a mean period of 1.7 ± 2.6 mins. It was in attendance at the patient's bedside for a mean period of 40 ± 39 mins. There was a trend toward more frequent activation of the MET in the evening ($p = .12$). A nurse (81.6%) initiated most MET calls. Surgical residents or fellows made the MET call the rest of the time (18.4%). The MET initiated and completed a variety of therapeutic, investigational, and procedural interventions (Table 5).

The MET and "Not for Resuscitation" Orders

On five occasions, the MET was activated for patients who had documented

Table 3. Demographic features and surgical specialty of study patients

	Control	MET
Gender, M/F, %	58.4/41.6	57.4/42.6
Age, yrs	60.7 ± 19.7	60.1 ± 19.5
Scheduled postoperative ICU admission, %	21.7	19.8
Cardiac, %	14.9	11.7
Thoracic, %	10.2	9.3
General, %	21.3	24
Orthopedic, %	19.4	21.8
Vascular, %	10.5	8.4
Neurosurgical, %	10.8	9.4
Plastic, %	4.6	5.3
Other, %	13.4	9.7

MET, medical emergency team; M, male; F, female; ICU, intensive care unit.

Table 4. Incidence of severe adverse events (SAEs) in the two study groups

Type of SAE	Control Period, No. (%)	MET Period, No. (%)	Significance (p)
Respiratory failure	75 (6.7)	15 (1.4)	<.0001
Stroke	19 (1.7)	4 (0.3)	.0026
Severe sepsis	18 (1.6)	4 (0.3)	.0044
ICU readmission	33 (2.9)	20 (1.8)	NS
Acute RRT	27 (2.4)	2 (0.02)	.0001
AMI	22 (1.9)	15 (1)	NS
PE	5 (0.04)	1 (0.01%)	NS

MET, medical emergency team; ICU, intensive care unit; NS, not significant; RRT, renal replacement therapy; AMI, acute myocardial infarction; PE, pulmonary embolism.

"not for cardiopulmonary resuscitation" orders. All of these patients eventually died. On two occasions, the MET call precipitated a reevaluation of the goals of care and led to "not for cardiopulmonary resuscitation" orders. One of these patients subsequently died and the other was discharged from hospital to a palliative care facility.

In-Hospital Outcome of MET Interventions

There were ten in-hospital deaths (19.2% mortality rate) among MET-

treated patients. However, after exclusion of patients with "not for cardiopulmonary resuscitation" orders, in-hospital survival after a MET call was 89.4%. Only one of the "for full resuscitation" patients died within 24 hrs of a MET call. This patient had a cardiac arrest several days after cardiac surgery and died despite open chest cardiac massage in the ward. The cardiac arrest occurred in the 2 mins between the MET call being made and the team's arrival. Eight patients (15.4%) were transferred from the ward to ICU fol-

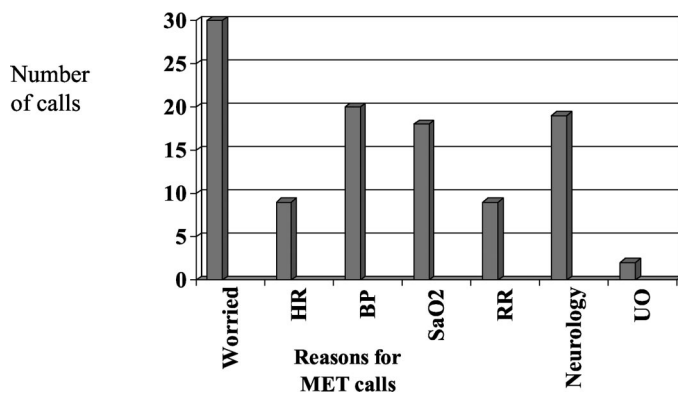


Figure 1. Histogram summarizing the criteria, which triggered medical emergency team (MET) calls during the intervention period. For some MET calls several criteria were present at the same time. *Worried* indicates that the person triggering the call was concerned about the patient's status; *neurology* indicates a change in conscious state. *SaO₂*, presence of hemoglobin desaturation on pulse oximetry; *BP*, blood pressure; *HR*, heart rate; *RR*, respiratory rate.

lowing a MET call. Four of these patients eventually died, making up 80% of post-MET call deaths.

Surgical Patients' Mortality Rate and Hospital Stay With the MET

There were 73 inpatient deaths during the control period (pre-MET) compared with 45 deaths during the intervention period (post-MET; relative risk reduction, 36.6%; $p = .0178$). Duration of hospital stay decreased from a mean of 23.8 ± 56.5 days to a mean of 18.9 ± 35.3 days ($p = .0092$). This decrease in duration of hospital stay translated into a saving of approximately 4,000 hospital bed days during the study period.

DISCUSSION

Our study shows that the introduction of an ICU-based medical emergency team service was associated with decreased adverse outcomes, mortality rate, and mean duration of hospital stay among surgical patients in a teaching hospital. These findings have potential public health implications with regard to the safety and quality of postoperative care and require discussion.

Effect of the MET on AOs

The MET was associated with a >50% decrease in the incidence of AOs in surgical patients. This reduction affected all individual AOs and achieved significance in most. These findings are consistent with previous observations in American, Australian, and British hospitals showing that some AOs are

preceded by physiologic instability (4, 6, 9, 18, 19). They are also consistent with previous uncontrolled (20–23) and more recent (24) reports of the possible effectiveness of a MET-based approach to critical illness prevention. These observations support the notion that many postoperative AOs can be prevented.

The effect on AOs and the decrease in the number of patients affected ($n = 73$) were only partly accounted for by the number of patients who received a MET intervention ($n = 47$). The introduction of a MET might, therefore, have led to other changes in hospital care that accounted for the reduction in hospital morbidity and mortality rates. One such change might be increased awareness of the consequences of physiologic instability. Such awareness is inevitably associated with the implementation of the MET.

Effect of the MET on Mortality

The introduction of the MET was associated with a 36.6% reduction in postoperative hospital mortality rate (23 lives/1,000 surgical admissions). Although studies of specific interventions such as β -blockade have also shown a significant benefit in selected operative cases (25), to our knowledge this is the first controlled study of any postoperative intervention that suggests a possible impact on all-cause postoperative mortality rate across the full range of patients and operative procedures.

Table 5. Interventions implemented by the medical emergency team

Nasopharyngeal/oropharyngeal suctioning and additional oxygen	16
Administration of iv fluid bolus	7
Administration of iv furosemide bolus	6
Initiation of iv/topical glyceryltrinitrate	6
Initiation of NIPPV by mask	5
Temporary ventilation by bag and mask	4
Administration of iv morphine	3
Administration of iv vasopressors	3
Nebulized β -agonist	2
Administration of anticonvulsants	2
Acute transfusion of red cells	2
Administration of iv metoclopramide	2
Administration of iv ranitidine	1
Administration of iv naloxone	1
Administration of iv amiodarone	1
Suctioning of tracheostomy tube	1
Acute investigations	
CR	9
ECG	9
CT scan	3
ABG	8
U&Es/LFT/FBES	7
Procedures	
iv catheter insertion	7
Insertion of a urinary catheter	4
Endotracheal intubation	2
Arterial catheter insertion	1
Central venous catheter insertion	1
Cardioversion	1
Insertion of a Guedel airway	1
Insertion of minitracheostomy tube	1

iv, intravenous; NIPPV, noninvasive positive pressure ventilation; CR, chest radiograph; ECG, electrocardiogram; CT, computerized tomography; ABG, arterial blood gases; U&Es/LFTs, urea, creatinine, and electrolytes and liver function tests; FBE, full blood examination.

Effect of the MET on Bed Days

By reducing the number of postoperative AOs, the MET was associated with a reduction in the mean duration of hospital stay for surgical patients, which was equivalent to a yearly decrease of close to 12,000 bed days. This finding suggests that the MET was associated with major cost savings and increased efficiency of hospital care.

General Critique and Limitations of the Study

Design. The limitations of this study should be carefully considered. First, it was not double-blinded, placebo-controlled, or randomized. However, it is not possible to double-blind intervention by the MET. Furthermore, introducing "sham" intervention as placebo was considered ethically untenable. Even if this had been done, "contamination" (so-called Hawthorne effect) would have been

inevitable. We consider a traditional patient randomization-based study of the MET ethically, scientifically, and logistically impossible in a single hospital. It might be possible to perform a cluster randomization-based study where hospitals rather than individuals would be randomized to have or not to have MET-based intervention. Such a study, however, would pose extraordinary organizational challenges.

If patients were not admitted to ICU, the MET visit was treated as a formal consult. This raises issues of medical liability and comanagement, which might have specific and variable medicolegal implications in different countries. We experienced no problems in relation to such issues.

Morbidity. Our favorable findings might have been due to a high rate of morbidity in the control period. However, a large body of data points to the contrary (1–12, 26–29).

Mortality. Similarly, it is possible that our overall in-hospital surgical mortality rate was high during the control period and was simply restored to acceptable levels by the MET. Unfortunately, only limited data are available for comparison. On the other hand, a recent study (29) reported the mortality rate for several standard operations among 2.5 million patients between 65 and 99 yrs of age in the United States over the last 5 yrs. This enabled us to use our medical records database and ICD-9 coding to compare our institutional mortality rate for most of these operations in the previously mentioned age groups over the last 5 yrs with the mortality rate reported for the best performing hospitals in the United States (so-called very high-volume hospitals). This comparison suggests that, in terms of surgical mortality rate, the institution under study compared favorably with the performance standards of U.S. hospitals. Accordingly, we consider it unlikely that our institution would have an excess of AOs compared with similar institutions worldwide.

Applicability, Reproducibility, and Implications. We studied the MET within a single institution. Its findings might not apply to other hospitals. However, our institution has all the organizational, structural, logistic, and clinical performance features of a typical tertiary referral hospital in a developed country. Furthermore, a recently published study further supports the wider applicability of the MET concept (24). It is possible that

other institutions would have insufficient manpower to meet the additional workload created by the MET or that the size of the institution would not allow such a rapid presence at the bedside. Clearly, this would depend on the number of calls per day or on the degree of proximity between the ICU and surgical wards. We found it possible to meet such demands with relative ease from 8 am until 6 pm in the presence of daytime staffing levels, but it was quite demanding at times during the night with less medical staff available. It is possible that our doctors and nurses did not recognize signs of imminent AOs that would be easily identified by other physicians or nurses in other hospitals and, when they did, failed to act appropriately. Available data from the United States and other developed countries, however, do not support this notion (1–12, 24, 26–29).

It is possible that the decrease in AOs was secondary to seasonal fluctuations or some other improvements in postoperative care. However, there were no changes in the structure, seasonal referral pattern, or activity of our hospital.

The incidence of AOs during the control period may appear surprisingly high. However, a 15,000-patient chart review of the incidence of surgical adverse events in Colorado and Utah shows almost identical problems (5). For specific AOs reported in the that study (5) such as pulmonary embolism (2.3%), acute myocardial infarction (2.1%), and stroke (1.2%), the similarities are striking. Finally, there was a marked reduction in the use of renal replacement therapy. This could be explained by variability in the criteria for initiating such therapy. However, our unit follows explicit and previously published criteria (30) for the initiation of renal replacement therapy, which did not change during the study period.

We only studied surgical patients for logistic reasons. In medical patients (>8,000 admissions) we were only able to monitor the incidence of cardiac arrests and found that they decreased significantly (31). Finally, we are unable to comment on the denominator (number of patients who had significant deviations from physiologic stability and for whom no MET call was issued) and on how many such deviations resulted in no clinically important adverse outcomes. Further research is warranted in this field to better understand the epidemiology and

The introduction of an intensive care unit-based medical emergency team was associated with a decreased number of adverse outcomes and deaths among patients receiving major surgery in a tertiary hospital.

outcome of physiologic instability in surgical patients.

CONCLUSIONS

The introduction of an ICU-based MET was associated with a decreased number of AOs and deaths among patients receiving major surgery in a tertiary hospital. It also appeared to reduce the duration of hospital stay associated with such surgery. If widely introduced, the MET approach might prevent many AOs and save many lives and bed days among hospital patients. Further testing of this approach is now needed in a variety of hospital and geographical settings.

ACKNOWLEDGMENTS

We thank our Medical Records Department, our ICU nurses, and our ICU fellows for their assistance with this project.

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