Crisis resource management, simulation training and the medical emergency team

Stuart Gillon, Sam Radford, Richard Chalwin, Michael DeVita, Ruth Endacott and Daryl Jones

Principles of the medical emergency team

Recently there has been increased focus on improved detection and management of deteriorating patients in Australian hospitals.[1] Several studies have revealed that about 10% of hospital admissions are associated with adverse events, many of which are unrelated to the patient's underlying medical condition.[2-8] Other studies have shown that, in the period leading up to the development of such events, there are objective signs of deterioration, such as derangement in the patient's vital signs or increased oxygen requirements.[9-12] In response to these observations, Lee and colleagues developed the medical emergency team (MET) model for responding to clinical deterioration.[13]

The MET is activated by hospital ward staff when a patient fulfils objective criteria for deterioration that are primarily based on vital signs.[14] In addition, there is typically a criterion for activation based on staff concern alone. The MET is summoned when there is a mismatch between the acute needs of a deteriorating patient and the ward resources available to assess and treat this deterioration.[14,15]

About two-thirds of Australian hospitals with intensive care units report having a MET or MET equivalent, and several studies report increased use of the service with time.[16] Common conditions associated with MET calls include heart failure, sepsis and arrhythmias.[17]

A recent study of 39 Australian MET services revealed that regular ICU consultant involvement in the MET was infrequent,[18] confirming registrar perceptions of an earlier survey.[19] In 7/39 teams, the most senior member did not have skills in advanced airway management.[18] Furthermore, existing evidence suggests that few systems have dedicated resources, implying that the task of responding to MET calls is often added to the role of caring for ICU patients.[18] In addition, there may be variable support for the concept of the MET principle, given that a third of ICU-equipped hospitals report not having a MET or MET equivalent.[16] Combined, these observations suggest that the typical apprentice model applied for teaching how to assess and manage critically ill patients in the ICU appears not to be applied during management of MET patients. In addition, it suggests that training of MET staff may need to be tailored to individuals' experience level and skill set, and that criteria

ABSTRACT

- Recently there has been increased focus on improved detection and management of deteriorating patients in Australian hospitals. Since the introduction of the medical emergency team (MET) model there has been an increased role for intensive care unit staff in responding to deterioration of patients in hospital wards. Review and management of MET patients differs from the traditional model of ward patient review, as ICU staff may not know the patient. Furthermore, assessment and intervention is often time-critical and must occur simultaneously. Finally, about 10% of MET patients require intensive care-level interventions to be commenced on the ward, and this requires participation of non-ICU-trained ward staff.

- To date, the interventions performed by MET staff and approaches to training responders have been relatively under investigated, particularly in the Australian and New Zealand context. In this article we briefly review the principles of the MET and contend that activation of the MET by ward staff represents a response to a medical crisis. We then outline why MET intervention differs from traditional ward-based doctor–patient encounters, and emphasise the importance of non-technical skills during the MET response. Finally, we suggest ways in which the skills required for crisis resource management within the MET can be taught to ICU staff, and the potential benefits, barriers and difficulties associated with the delivery of such training in New Zealand and Australia.

for MET staff to escalate care to ICU and other consultants may also be needed.

There is currently no agreed model for training medical team leaders in management of MET calls. International models for training MET members[20] may not apply to typical health care systems in New Zealand and Australia.[16,18,21] A training approach applicable to regional rapid response systems must take into account the variability in seniority and skill set of the medical team leader. It should also consider the tasks required in managing a MET patient, and the multiple communication episodes involving MET members, ward staff, the patient and the patient's relatives.

Table 1. Comparison of features and outcomes of a traditional ward patient–doctor encounter with that seen during MET review

	Traditional ward patient–doctor encounter	Patient–doctor encounter during MET review
Time-critical	Relatively infrequently	Very often
Time over which information must be obtained	Relatively slowly	Often very quickly
Patient stability during consultation	Relatively stable	Often unstable
Typical chronology of process	Serial: sequential history, examination, investigations, treatment	Parallel: simultaneous assessment and management
Major aim early in consultation	To establish a differential diagnosis	To re-establish normal physiology
Number of clinicians present	Relatively few initially; may involve serial referrals	Often more than five at initial consultation; some referral subsequently
Need for team leader and staff coordination	Relatively unimportant	Of crucial importance
Use of equipment during consultation	Relatively infrequently	Very often
Requirement for non-technical skills	Somewhat important	Extremely important
Requirement for ICU-level therapies	Very infrequent	In about 10% of cases
In-hospital mortality	< 5%	About 25%

ICU = intensive care unit. MET = medical emergency team.

What is a crisis and how does it apply to the MET model?

The *Oxford English Dictionary* defines "crisis" as "a time of intense difficulty or danger", "a time when a difficult or important decision must be made" and "the turning point of a disease when important changes take place, indicting either recovery or death".[22] Patients subject to a MET response or fulfilling MET criteria have an in-hospital mortality rate of about 25%,[23-25] and about 10% will require admission to the ICU.[23,24] It is not surprising, therefore, that the requirement for a MET response has been described as a crisis,[21] as the patient is at risk of imminent harm[15] or death.[26] In all circumstances, there is a "disparity between what care a patient is receiving and what care he or she requires emergently".[15]

The physiological instability that defines the typical MET patient results in a situation that is substantially different from the routine ward-based doctor–patient encounter (Table 1). The traditional medical approach to problem-solving (Figure 1a) is not sufficient for crisis management, as it involves the *sequential* or *serial* acquisition of information,

and the primary aim is to formulate a differential diagnosis and then institute a management plan. Such a traditional response may also involve serial review by increasingly senior and more specialised medical staff.

In contrast, during MET review, an integrated and *parallel* model is required — one that prioritises correction of deranged physiology, emphasises simultaneous assessment and management, and promptly assembles a team of appropriate responders (Figure 1b). As with other crises, effective performance of multiple simultaneous tasks requires the coordinated efforts of a team of clinicians rather than an individual. Successful teamwork relies on agreed team objectives and defined roles for each member.[27] However, achieving clarity of team function is problematic in the MET environment, for several reasons.

Firstly, the wide range of clinical conditions that instigate MET calls generates variable *initial* priorities. For example, in a surgical patient who develops tachycardia and hypotension 6 hours after laparotomy, exclusion of haemorrhage will be the primary objective. In contrast, in a medical patient who is admitted with urosepsis and presents with

Figure 1a. Traditional ward-based patient–doctor encounter showing *serial* assessment and management, with a primary aim of establishing a differential diagnosis
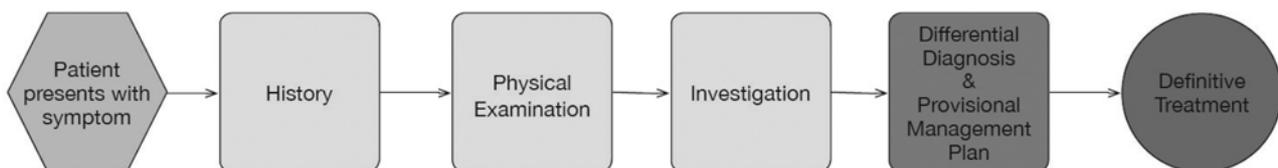
Figure 1b. Model for management of MET-based patient–doctor encounter showing *parallel* processes of simultaneous assessment and management by the team, with a primary aim of establishing physiological stability
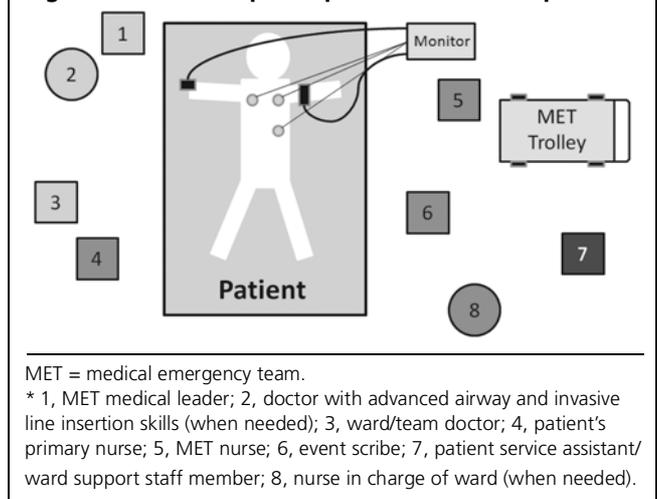
MET = medical emergency team.
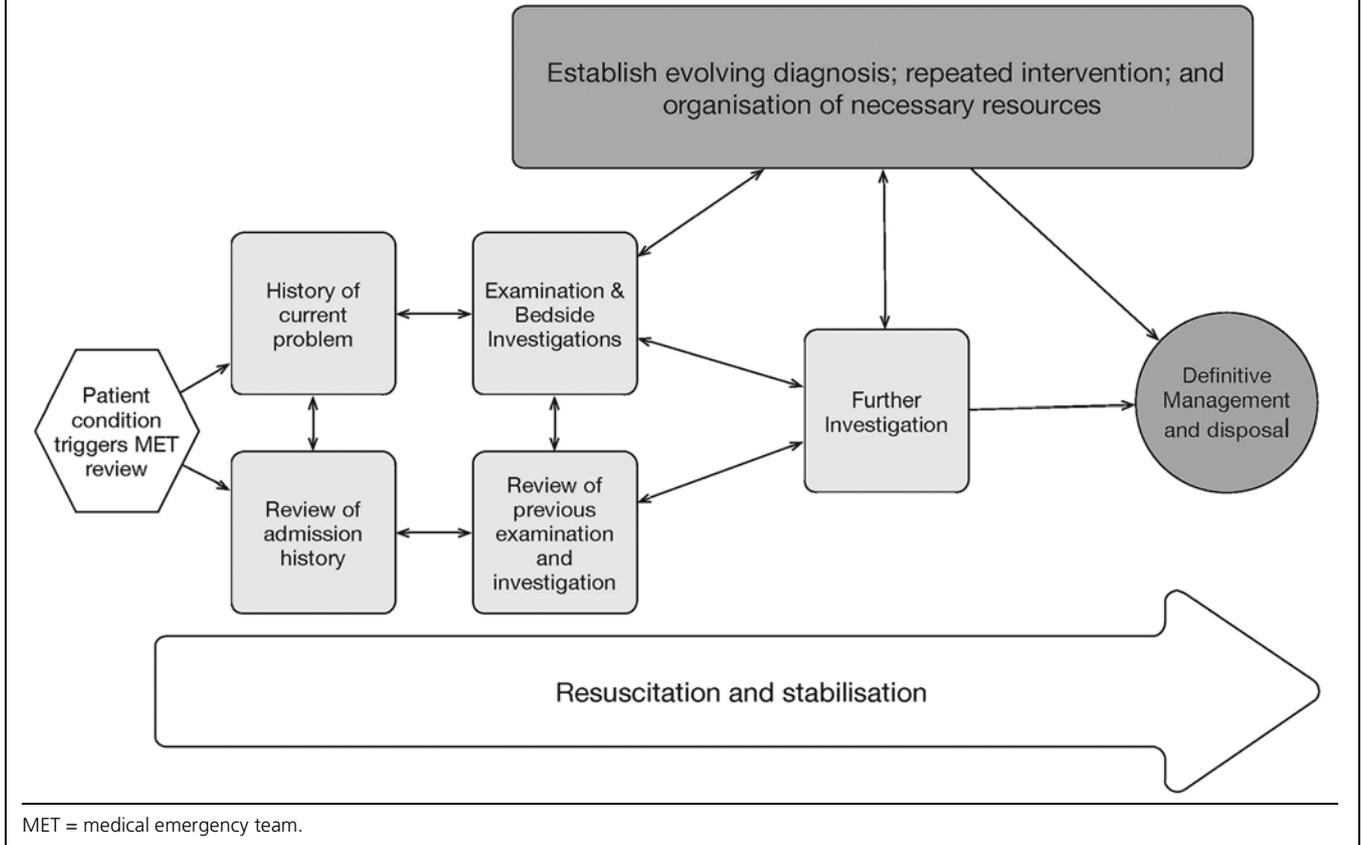
similarly deranged physiology, a quite different set of issues and priorities will be generated. The tasks required of each MET member and the order in which these tasks are conducted may therefore vary between MET activations, even if the physiological trigger is the same. Furthermore, the *ultimate* or *end* objective of the MET response may vary significantly: in 10% of patients, therapy will be escalated to ICU-level care,[23] while in up to 30%, aggressive intervention may be deemed futile or inappropriate and end-of-life care planning may be implemented.[28] Accordingly, the ultimate aim may be to restore physiological normality or to provide comfort care, and patient disposition may vary considerably between cases. Such undifferentiated scenarios differ from situations such as a failed-intubation algorithm, where the approach and ultimate aim is relatively uniform between cases.

The second major impediment to coordinated team function during MET review relates to the ad-hoc nature of each MET call, resulting in different responders on the team at different times of day, on different days of the week, and in different locations. Thus, there are limited opportunities for team building, particularly in large hospitals. MET membership is usually drawn from several professional disciplines, and the perspective of each member is influenced by his or

Figure 2. Potential participants in a MET response*

MET = medical emergency team.
* 1, MET medical leader; 2, doctor with advanced airway and invasive line insertion skills (when needed); 3, ward/team doctor; 4, patient's primary nurse; 5, MET nurse; 6, event scribe; 7, patient service assistant/ward support staff member; 8, nurse in charge of ward (when needed).

1

her training and experience.[18,29] For such disparate individuals to function effectively as a team, they need to complete a number of formative steps[30] wherein interpersonal relationships evolve, boundaries are agreed to and a team structure or hierarchy is established. A lack of team cohesion is particularly problematic during the MET response, as ward-based staff may be unfamiliar with requirements for commencing ICU-type therapies at the bedside.

A further barrier to effective team functioning relates to the complex, time-pressured nature of the MET scenario, difficulties in acquiring and analysing important information, and subsequent decision making. Availability of information may range from sparse (in recently admitted patients) to overwhelming (in those with prolonged admission). Furthermore, available information may be biased by assumptions and labels attached to the patient by previous practitioners. MET patients may deteriorate not only due to progression of the original diagnosis, but also as a result of iatrogenic complications or an entirely unrelated disease process. Management of the medical crisis often requires the pooling of cognitive resources of multiple people, frequently from several disciplines. The optimal team possesses a shared awareness of the situation and a shared decision-making process that may provide some protection against the inherent risk of error related to the time-critical, high-stakes environment.[27,30]

Additional sources of stress arise from the fact that many MET calls occur out of hours,[31] when staffing is lowest. Furthermore, team members typically have other responsibilities for continuous patient care that must be put on hold to respond to the call.[32] There are no data on whether this potential conflict of priorities affects behaviour or decision making, but it seems logical that there is a strong potential for interruptions to arise during the MET response.

Finally, the members of the MET may not have all of the necessary technical skills to manage all MET interventions, such as endotracheal intubation.[18] Thus, the therapies that can be offered by the MET may

Table 2. Knowledge and technical skill requirements for clinical staff participating in medical emergency teams

System	Knowledge	Technical skill/task
Airway	Airway assessment and anatomy Signs of obstruction Intubation/securing airway Safe use of different airway devices Management of tracheostomy tubes	Jaw thrust/chin lift Oral suction using Yankauer sucker Insertion of oropharyngeal airway Insertion of nasopharyngeal airway Changing of tracheostomy tube Insertion of ETT
Breathing	Assessment of patient with hypoxia, hypercarbia or respiratory distress Knowledge of different oxygen delivery systems	Examination of respiratory system Bag-valve mask ventilation Insertion of intercostal catheter Prescribing non-invasive ventilation

Circulation	Management algorithms for basic and advanced life support
	Assessment and management of:
	  Hypotension
	  Arrhythmias
	  Volume status
	  Peripheral perfusion
	  Hypertension
		Examination of cardiovascular system
		Insertion of venous cannulae
		Insertion of arterial cannula
		Taking of ABG (single stab)
		Appropriate CVC insertion
		Performance of CPR
		Performance of safe defibrillation
		Fluid administration

Neuromuscular	Assessment of: Consciousness Delirium Focal neurology Pain Dermatomes/myotomes	Examination of nervous system Lumbar puncture Assessment of epidural blockade Assessment of spinal sensory and motor level Joint examination
Gastrointestinal	Assessment of acute abdominal pain	Examination of abdomen Insertion of NGT

Renal	Assessment of patient with:
	  Oliguria
	  Acute renal failure
	  Chronic renal failure
		Insertion of urinary catheter

Investigations	Universal precautions for sample collection
	Risks and benefits of transporting unstable patient for imaging (eg, CT, MRI)
	MRI safety principles
	Differential diagnoses for laboratory abnormalities
		Bedside interpretation of test results:
		  Blood tests
		  Other pathology tests
		  Imaging
		Preparing and monitoring of unstable patient for safe transport

Prescribing	Indications, contraindications and potential side effects of a broad range of medications Altered pharmacology in the acutely unwell patient	Titration of vasoactive medications Safe preparation and administration of intravenous medications Blood product administration

ABG = arterial blood gas. CPR = cardiopulmonary resuscitation. CT = computed tomography. CVC = central venous catheter. ETT = endotracheal tube. MET = medical emergency team. MRI = magnetic resonance imaging. NGT = nasogastric tube.

Box 1. Definitions of non-technical skills and crisis resource management[27]

Non-technical skills

The cognitive, social and personal resource skills that complement technical skills and contribute to safe and efficient task performance.

Cockpit (crew/crisis) resource management

A management system that makes use of all available resources — equipment, procedures and people — to promote safety and enhance efficiency of (flight deck) operations.

Table 3. The ANTS taxonomy for non-technical skills used in crisis resource management*

Categories	Elements
Task management	Planning and preparing
	Prioritising
	Providing and maintaining standards
	Identifying and utilising resources
Team working	Coordinating activities with team members
	Exchanging information
	Using authority and assertiveness
	Assessing capabilities
	Supporting others
Situation awareness	Gathering information
	Recognising and understanding
	Anticipating
Decision making	Identifying options
	Balancing risk and selecting options
	Re-evaluating

ANTS = Anaesthetists' Non-technical Skills. * Adapted from Fletcher et al[57] and Reader et al[58] with permission.

differ between hospitals (and even between shifts in the same hospital). Accordingly, training may need to be tailored to the skill sets of MET members. In situations in which the clinical scenario requires skills or knowledge that are beyond the capabilities of the MET members, the crisis continues until new resources are obtained to match the needs. Ideally, team members should recognise these situations and have a plan, agreed in advance, to assemble the necessary resources (Figure 2, Table 2). An a priori acknowledgement of the MET skill set establishes realistic expectations of MET capability, and permits an agreed plan to assemble resources when such scenarios are encountered.

Thus, while effective MET performance requires personnel with knowledge of pathophysiology and pharmacology of acute illness and competence in practical skills of critical care, the delivery of such skills in a ward-based medical crisis may require additional expertise. Traditional critical care training focuses on *what* should be done (technical skills) rather than *how* it should be done (non-technical skills [NTS]), and a traditional educational approach may lead to poor performance during crisis, even in highly skilled staff.[33-36] To understand how ICU registrars may be best trained for the crisis environment of the MET, it is useful to examine the experience of other professional groups exposed to high-pressure, time-critical situations outside their "usual" environment.

Non-technical skills and Crisis Resource Management

In-depth analysis of human performance in high-stakes situations was pioneered and refined by the aviation industry when human factors (rather than equipment failure) were found to be the most common cause of serious accidents.[37-40] Suboptimal performance among highly trained pilots was not always the result of lack of knowledge or deficiency in technical ability, but often due to shortcomings in communication, leadership, situational awareness, decision making and/or teamwork. These so-called "non-technical skills" became a key component of

pilot training and were integrated into everyday operations with the introduction of a system known as cockpit resource management (CRM).[41,42] Training in NTS was subsequently introduced into numerous other industries, and the word "cockpit" in CRM was replaced with "crisis" (crisis resource management) to reflect a move away from aviation while retaining the original principles (Box 1).

The importance of NTS in health care was recognised by anaesthetists,[43] who developed the first formal medical NTS training course. Anaesthesia crisis resource management (ACRM), which focused on perioperative emergencies, was piloted in 1990.[44] The use of NTS training in health care has since been endorsed by the United States Institute of Medicine[45] and the US Agency for Healthcare Research and Quality[46] as a means of improving patient safety. The NTS model has subsequently been adapted to emergency situations in obstetrics,[47-49] paediatrics,[50] emergency medicine,[51] critical care[52] and prehospital care,[53] and has been applied in cardiac arrest teams[54] and, recently, the MET.[35] Additional models that focus on a less hierarchical and more "roles and goals"-based approach have also been developed.[55]

To implement NTS in health care teams effectively, lessons learned in aviation need to be adapted to the hospital environment.[56] Although the core components of NTS identified by the aviation industry are broadly applicable to health care personnel, the cockpit and the ward are not comparable domains. Data from critical incident reports,

surveys, theoretical models and observations of real and simulated crises have therefore been used to develop NTS principles specific to health care. One such health care-specific classification, the Anaesthetists' NTS (ANTS) behavioural marker system (Table 3),[57] has been used as a basis for assessment and training of NTS in the operating theatre[57] and intensive care[58] environments.

The major domains of CRM include task management, team working, situational awareness and decision making (Table 3). The individual elements of NTS are not novel and do not serve as a rigid system in which to operate. Instead, they are a set of ideals that, when implemented effectively, create a climate for optimal team performance. Outlining these ideals and integrating them into the ethos of the team provides a framework within which members can be trained and assessed, and establishes a commonly understood system by which to operate.

What are the potential benefits of CRM training for the MET?

Recognising the importance of NTS to the MET has a number of advantages for education and training. Any approach would need to consider the ad-hoc assembly of the team, and which members would require more intensive CRM training. Application of NTS and CRM principles might allow the development of predefined roles and responsibilities of the MET members (Table 2).[20,55] The term Crisis Team Training has been used to describe this "roles and goals" team-training approach. It differs from CRM in that the staff roles are more predefined. This approach may reduce the workload of the team leader and overcome some of the problems resulting from ad-hoc and infrequent team assembly.[55] Such roles would require some flexibility, depending on team composition, level of experience and the skill set of the assembled team members. A MET may be expected to have a minimum of four, but as many as eight, staff members, depending on staff availability, patient acuity and the time of day (Figure 2). Such training would also emphasise the importance of the ward staff handing over to the arriving MET in a standardised manner.[59]

Principles of CRM training would also teach MET members *how to* manage a MET call, which would complement the technical skills or roles outlined above. Appreciation of the need for NTS would permit development of resources to teach such skills, and might guide the development of a curriculum for both technical skills and NTS (Table 2). The use of CRM in the MET model, and indeed in clinician training, is still relatively new, and outsiders should anticipate the need to go through the same evolution as occurred in the aviation industry, rather than expecting instant solutions. Thus, for example, NTS might be either delivered as a discrete module or incorporated partly in the MET and partly in other domains of ICU training (eg, difficult intubation, management of the bleeding patient, advanced cardiac life support). A longer-term goal may be to incorporate components of NTS into all aspects of undergraduate and postgraduate clinician training.

Standardising MET management may also reduce undesirable practice variation by allowing standardisation of equipment, assessment and intervention, as well as handover and communication. It may also assist the development of guidelines or protocols for common conditions encountered during MET review.[17]

Issues surrounding implementation and teaching of non-technical skills

Introduction of NTS to a particular clinical domain first requires evaluation of the specific non-technical issues encountered in that area of practice.[56] This may take the form of evidence-based analyses (such as critical incident reports), questioning techniques (such as focus groups) and observational techniques (of either real or simulated events).[27] While no complete analysis of the non-technical needs of the MET within the Australian health care system has yet been conducted, a wealth of information is available from evaluation of related areas of care, including resuscitation teams,[33,54,60] emergency medicine,[61] anaesthesia[56,57] and intensive care medicine.[52,58] Although these resources provide an initial reference point, there may be a need to more clearly understand the roles and responsibilities of each of the MET members.

To date, teaching of NTS principles has primarily been delivered in specialty-specific courses, many of which follow the format of the original ANTS course (ACRM), combining didactic teaching of NTS principles with immersive simulation exercises.[62] Simulation, as an educational concept, is now considered an integral component of training in acute medical specialties.[63] Simulation allows trainees to learn and develop skills in an environment that reflects reality, with no risk to patients and the opportunity for instruction and feedback from experienced practitioners.[64] The term simulation encompasses a range of educational tools, from easily disseminated computer-based scenarios[65] to simplistic role play to fully immersive simulation with highly technical mannequins in realistic clinical environments. Regardless of the level of technology, high-fidelity (realistic) simulation with clearly defined rubrics is considered important for achieving sustained learning.[66]

Adult learners develop new skills through repeated experience[62] with simulation, allowing repeated exposure to both common and rare clinical scenarios. If conducted well and accompanied by structured and constructive feedback,

simulation has been shown to improve trainee performance and confidence when faced with a similar situation again, and is found to be both beneficial and enjoyable by participants.[50,67] Conducting simulation in a team context allows the opportunity for team building and development of interpersonal skills.

Despite the theoretical benefits of team training using simulation for teaching NTS, there are several barriers and risks associated with the process. The lack of consultant-level involvement in MET calls or even MET services is a significant potential barrier to teaching all relevant skills, including NTS. The lack of participation of intensive care consultants in MET events is a lost opportunity for leadership and coaching of NTS in clinical practice. A major obstacle to applying NTS for MET training is the novelty of this field to intensive care medicine. As relatively few intensivists would have trained in an environment of mannequin-based simulation training, they may lack comfort, experience and expertise in this domain.

In addition, costs of training may be prohibitive, particularly for high-end immersive simulation, which requires medical equipment, a mannequin, personnel, simulation programming and facilities. For this reason, simulator equipment may need to be centralised as a shared resource. However, centralisation creates a geographic barrier to attendance by trainees and requires their removal from the workplace for training, with an associated need for back-fill. An alternative to centralised immersive simulation is less intensive, in-situ simulation that is run in the hospital setting.[68] But a barrier to this strategy is the requirement for motivated and appropriately trained facilitators, without whom simulation is at best wasteful and at worst detrimental to clinician confidence.[69] The feasibility of engaging personnel from aviation and other industries who are familiar with CRM principles might need to be explored.

Thus, while simulation has the potential to impart NTS and facilitate strong individual and team performance within the MET, without clear learning objectives and motivated staff, it risks being expensive and detrimental to staff morale. There is a need to assess the elements of a CRM and simulation training model as it is applies to the MET, and then develop studies to assess the effectiveness of such programs on team performance as well as patient-centred outcomes. Attempts to demonstrate effectiveness of these educational techniques in the field of anaesthesia have proven challenging.[43,70]

Conclusion

With the advent and promulgation of the MET model of care, advanced intensive care trainees in New Zealand and Australia will increasingly be involved in assessing and managing deteriorating ward patients. The clinical, environmental and interprofessional interactions encountered in MET review differ from traditional doctor–patient encounters not only for ward patients but also for ICU patients. There is a need to further assess the technical and non-technical skills required to provide optimal MET review, and to develop evidence-based, centralised, hospital-specific strategies to teach and implement them.

Author details

Stuart Gillon, Intensive Care Registrar[1]
Sam Radford, Consultant Intensive Care Specialist[1]
Richard Chalwin, Staff Specialist,[2] and Senior Clinical Lecturer[3]
Michael DeVita, Professor of Internal Medicine[4,5]
Ruth Endacott, Director,[6] and Professor of Critical Care Nursing[7]
Daryl Jones, Consultant Intensive Care Specialist,[1] Adjunct Associate Professor,[8] and Adjunct Senior Research Fellow[9]

1 Department of Intensive Care, Austin Health, Melbourne, VIC, Australia.
2 Department of Intensive Care, Lyell McEwin Hospital, Adelaide, SA, Australia.
3 Discipline of Acute Care Medicine, University of Adelaide, Adelaide, SA, Australia.
4 Frank H Netter School of Medicine, Quinnipiac, CT, USA.
5 St Vincent's Medical Center, Bridgeport, CT, USA.
6 Centre for Health and Social Care Innovation, Faculty of Health, Education and Society, University of Plymouth, Plymouth, UK.
7 Monash University, Melbourne, VIC, Australia.
8 Department of Intensive Care, University of Melbourne, Melbourne, VIC, Australia.
9 Department of Epidemiology and Preventive Medicine, Monash University, Melbourne, VIC, Australia.
daryl.jones@austin.org.au

References

1 Australian Commission on Safety and Quality in Health Care. National consensus statement: essential elements for recognising and responding to clinical deterioration. Sydney: ACSQHC, 2010. http://www.safetyandquality.gov.au/wp-content/uploads/2012/01/national_consensus_statement.pdf (accessed Jul 2012).

2 Thomas EJ, Studdert DM, Burstin HR, et al. Incidence and types of adverse events and negligent care in Utah and Colorado. *Med Care* 2000; 38: 261-71.

3 Andrews LB, Stocking C, Krizek T, et al. An alternative strategy for studying adverse events in medical care. *Lancet* 1997; 349: 309-13.

4 Wilson RM, Runciman WB, Gibberd RW, et al. The Quality in Australian Health Care Study. *Med J Aust* 1995; 163: 458-71.

5 Davis P, Lay-Yee R, Briant R, et al. Adverse events in New Zealand public hospitals I: occurrence and impact. *N Z Med J* 2002; 115: U271.

6 Davis P, Lay-Yee R, Briant R, et al. Adverse events in New Zealand public hospitals II: preventability and clinical context. *N Z Med J* 2003; 116: U624.

7 Vincent C, Neale G, Woloshynowych M. Adverse events in British hospitals: preliminary retrospective record review. *BMJ* 2001; 322: 517-9.

8 Baker GR, Norton PG, Flintoft V, et al. The Canadian Adverse Events Study: the incidence of adverse events among hospital patients in Canada. *CMAJ* 2004; 170: 1678-86.

9 Hodgetts TJ, Kenward G, Vlackonikolis I, et al. Incidence, location and reasons for avoidable in-hospital cardiac arrest in a district general hospital. *Resuscitation* 2002; 54: 115-23.

10 McQuillan P, Pilkington S, Allan A, et al. Confidential inquiry into quality of care before admission to intensive care. *BMJ* 1998; 316: 1853-8.

11 Hayward RA, Hofer TP. Estimating hospital deaths due to medical errors: preventability is in the eye of the reviewer. *JAMA* 2001; 286: 415-20.

12 Schein RM, Hazday N, Pena M, et al. Clinical antecedents to in-hospital cardiopulmonary arrest. *Chest* 1990; 98: 1388-92.

13 Lee A, Bishop G, Hillman KM, et al. The medical emergency team. *Anaesth Intensive Care* 1995; 23: 183-6.

14 Jones DA, DeVita M, Bellomo R. Current concepts: rapid-response teams. *N Engl J Med* 2011; 365: 139-46.

15 DeVita MA, Bellomo R, Hillman K, et al. Findings of the First Consensus Conference on Medical Emergency Teams. *Crit Care Med* 2006; 34: 2463-78.

16 Jones D, George C, Bellomo R, et al. Introduction of medical emergency teams in Australia and New Zealand: a multi-centre study. *Crit Care* 2008; 12: R46.

17 Jones D, Duke G, Green J, et al. Medical emergency team syndromes and an approach to their management. *Crit Care* 2006; 10: R30.

18 ANZICS-CORE MET Dose Investigators. Rapid response team composition, resourcing and calling criteria in Australia. *Resuscitation* 2012; 83: 563-7.

19 Jacques T, Harrison GA, McLaws ML. Attitudes towards and evaluation of medical emergency teams: a survey of trainees in intensive care medicine. *Anaesth Intensive Care* 2008; 36: 90-5.

20 DeVita MA, Schaefer J, Lutz J, et al. Improving medical emergency team (MET) performance using a novel curriculum and a computerized human patient simulator. *Qual Saf Health Care* 2005; 14: 326-31.

21 DeVita MA, Hillman K, Bellomo R, editors. Medical emergency teams: implementation and outcome measurement. New York: Springer, 2006: preface, 80-90.

22 Pearsall J, editor. Concise Oxford English dictionary. Revised 10th ed. New York: Oxford University Press, 2002.

23 Calzavacca P, Licari E, Tee A, et al. Features and outcome of patients receiving multiple medical emergency team reviews. *Resuscitation* 2010; 81: 1509-15.

24 Casamento AJ, Dunlop C, Jones DA, et al. Improving the documentation of medical emergency team reviews. *Crit Care Resusc* 2008; 10: 24-9.

25 Buist MD, 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: 387-90.

26 Buist M, Bernard S, Nguyen TV, et al. Association between clinically abnormal observations and subsequent in hospital mortality: a prospective study. *Resuscitation* 2004; 62: 137-41.

27 Flin R, O'Conner P, Crichton M. Safety at the sharp end: a guide to non-technical skills. Farnham, UK: Ashgate Publishing, 2007.

28 Jones DA, Bagshaw SM, Barrett J, et al. The role of the medical emergency team in end of life care: a multicenter, prospective, observational study. *Crit Care Med* 2012; 40: 98-103.

29 Ummenhofer W, Amsler F, Sutter PM. Team performance in the emergency room: assessment of inter-disciplinary attitudes. *Resuscitation* 2001; 49: 39-46.

30 St Pierre M, Hofinger G, Buerschaper C. The key to success: teamwork. In: Crisis management in acute care settings. Berlin: Springer, 2008: 131-45.

31 Jones D, Bates S, Warrillow S, et al. Circadian pattern of activation of the medical emergency team in a teaching hospital. *Crit Care* 2005; 9: R303-6.

32 Joyce C, McArthur C. Rapid response systems: have we met the need? *Crit Care Resusc* 2007; 9: 127-8.

33 Rousek JB, Hallbeck MS. The ergonomics of "code blue" medical emergencies: a literature review. *IIE Trans Healthc Syst Eng* 2011; 1: 197-212.

34 Hunziker S, Tschan F, Semmer NK, et al. Human factors in resuscitation: lessons learned from simulator studies. *J Emerg Trauma Shock* 2010; 3: 389-94.

35 Murray AW, DeVita MA, Schaefer JJ. Personnel resources for crisis response. In: De Vita MA, Hillman K, Bellomo R, editors. Textbook of rapid response systems: concept and implementation. New York: Springer, 2011.

36 Marsch SC, Müller C, Marquardt K, et al. Human factors affect the quality of cardiopulmonary resuscitation in simulated cardiac arrests. *Resuscitation* 2004; 60: 51-6.

37 US Federal Aviation Administration. Crew resource management training. AC-120-51E. Jan 2004.

38 UK Civil Aviation Authority. Crew resource management (CRM) training. CAP-737. Nov 2006.

39 Stephenson JC. CRM training for ADF aeromedical staff. *J Mil Veterans Health* 2008; 16: 21-6.

40 Australian Civil Aviation Safety Authority. Human factors (HF) and non-technical skills (NTS) training for regular public transport (RPT) operations. CAAP-SMS-3(0). Jan 2009.

41 Helmreich RL, Foushee HC. Why CRM? Empirical and theoretical bases of human factors training. In: Kanki BG, Helmreich RH, Anca JM, editors. Crew resource management. 2nd ed. London: Academic Press, 2010.

42 CRM Standing Group of the Royal Aeronautical Society. Crew resource management. London: RAS, 1999.

43 Gaba DM. Crisis resource management and teamwork management in anaesthesia. *Br J Anaesth* 2010; 105: 3-6.

44 Gaba DM, Howard SK, Fish KJ, et al. Simulation-based training in anesthesia crisis resource management (ACRM): a decade of experience. *Simul Gaming* 2001; 32: 175-93.

45 Institute of Medicine, USA. To err is human. Building a safer health system. Washington, DC: National Academy Press, 2000: 137.

46 Pizzi LT, Goldfarb NI, Nash DB. Crew resource management and its applications in medicine. In: Shojania KG, Duncan BW, McDonald KM, Wachter RM, editors. Making health care safer: a critical analysis of patient safety practices. Rockville, MD: Agency for Healthcare Research and Quality, 2001. (Evidence Report/Technology Assessment No. 43; AHRQ Publication 01-E058.) http://www.ahrq.gov/clinic/ptsafety/pdf/ptsafety.pdf (accessed Jul 2012).

47 Birch L, Jones N, Doyle PM, et al. Obstetric skills drills: evaluation of teaching methods. *Nurse Educ Today* 2007; 27: 915-22.

48 Crofts JF, Ellis D, Draycott TJ, et al. Change in knowledge of midwives and obstetricians following obstetric emergency training: a randomised controlled trial of local hospital, simulation centre and teamwork training. *BJOG* 2007; 114: 1534-41.

49 Strachan B, Crofts J, James M, et al. Proof of principle study of the effect of individual and team drill on the ability of labour ward staff to manage acute obstetric emergencies. The SaFE Study. http://www.haps2.bham.ac.uk/publichealth/psrp/documents/SaFE_Final_Report_Aug_2008.pdf (accessed Mar 2012).

50 Molyneux M, Lauder G. A national collaborative simulation project: paediatric anaesthetic emergencies. *Paediatr Anaesth* 2006; 16: 1302.

51 Carne B, Kennedy M, Gray T. Review article: crisis resource management in emergency medicine. *Emerg Med Australas* 2012; 24: 7-13.

52 Bion JF, Abrusci T, Hibbert P. Human factors in the management of the critically ill patient. *Br J Anaesth* 2010; 105: 26-33.

53 Hearns S, Shirley PJ. Retrieval medicine: a review and guide for UK practitioners. Part 2: safety in patient retrieval systems. *Emerg Med J* 2006; 23: 943-7.

54 Andersen PO, Jensen MK, Lippert A, et al. Identifying non-technical skills and barriers for improvement of teamwork in cardiac arrest teams. *Resuscitation* 2010; 81: 703-11.

55 DeVita MA, Schaefer J, Lutz J, et al. Improving medical crisis team performance. *Crit Care Med* 2004; 32 (2 Suppl): S61-5.

56 Flin R, Maran N. Identifying and training non-technical skills for teams in acute medicine. *Qual Saf Health Care* 2004; 13 Suppl 1: i80-4.

57 Fletcher G, Flin R, McGeorge P, et al. Anaesthetists' non-technical skills (ANTS): evaluation of a behavioural marking system. *Br J Anaesth* 2003; 90: 580-8.

58 Reader T, Flin R, Lauche K, et al. Non-technical skills in the intensive care unit. *Br J Anaesth* 2006; 96: 551-9.

59 Tasota FJ, Clontz A, Shatzer M. What's the 4-1-1 on "the first five"? *Nursing* 2010; 40: 55-7.

60 Cooper S, Cant R, Porter J, et al. Rating medical emergency teamwork performance: development of the Team Emergency Assessment Measure (TEAM). *Resuscitation* 2010; 81: 446-52.

61 Hicks CM, Bandiera GW, Denny CJ. Building a simulation-based crisis resource management course for emergency medicine, phase 1: results from an interdisciplinary needs assessment survey. *Acad Emerg Med* 2008; 15: 1136-43.

62 Foot C. Simulation for team crisis management training in critical care medicine — where have we been, where are we now and where are we going? *Aust Anaes* 2007: 87-93.

63 Nimmo GR, Shippey B, Fluit L. Intensive care and simulation — a guide. *Care Crit Ill* 2008; 24: 4-8.

64 Salas E, Wilson KA, Burke CS, et al. Using simulation-based training to improve patient safety: what does it take? *Jt Comm J Qual Patient Saf* 2005; 31: 363-71.

65 Foot C, Steel L, Campher D. Medical crisis management: improving performance under pressure. York, UK: Erudite Medical, 2011: 4.

66 Cook DA, Hatala R, Brydges R, et al. Technology-enhanced simulation for health professions education: a systematic review and meta-analysis. *JAMA* 2011; 306: 978-88.

67 Issenberg SB, McGaghie WC, Petrusa ER, et al. Features and uses of high-fidelity medical simulations that lead to effective learning: a BEME systematic review. *Med Teach* 2005; 27: 10-28.

68 Endacott R, Scholes J, Cooper S, et al. Identifying patient deterioration: using simulation and reflective interviewing to examine decision making skills in a rural hospital. *Int J Nurs Stud* 2012; 49: 710-7.

69 Rudolph JW, Simon R, Dufresne RL, Raemer DR. There's no such thing as "non-judgmental" debriefing: a theory and method for debriefing with good judgment. *Simul Healthc* 2006; 1: 49-55.

70 Nishisaki A, Keren R, Nadkarni V. Does simulation improve patient safety?: self-efficacy, competence, operational performance, and patient safety. *Anesthesiol Clin* 2007; 25: 225-36. ❏