

Characteristics and outcomes of children receiving intensive care therapy within 12 hours following a medical emergency team event

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The identification and prevention of deterioration in patients are key health care priorities.¹ Rapid response teams, or medical emergency teams (MET), have become standard practice to provide immediate assessment and early management of deteriorating patients. The introduction of rapid response teams has reduced morbidity and mortality.²⁻⁶ However, in the current era, as paediatric intensive care mortality decreases^{7,8} and cardiorespiratory arrests remain infrequent,⁹ other outcome metrics may be more suitable.

The need for ventilation and vasoactive therapies in a paediatric intensive care unit (PICU) is an important outcome and is associated with increased hospital mortality and health care costs.¹⁰⁻¹² However, there are few contemporary data regarding demographic, clinical or MET-related predictors for such adverse outcomes or data regarding subsequent intensive care therapy (ICT) and outcomes.

Accordingly, we conducted a retrospective study of MET events in a quaternary paediatric hospital in order to describe the demographic, clinical and MET characteristics of children who deteriorate following a MET event. The aims were to describe the characteristics and outcomes of children who have a MET event and investigate predictors of the need for ICT within 12 hours of a MET event. For MET events that resulted in admission to intensive care, we aimed to compare outcomes between children who did and did not receive ICT. Lastly, we aimed to describe the frequency of vital signs measurements and abnormalities in the 6 hours before the MET event.

Methods

We conducted a retrospective study of children who experienced a MET event at the Royal Children's Hospital, Melbourne, from July 2017 to March 2019. Children less than 18 years old and admitted to an inpatient hospital ward at the time of the MET event were included.

ABSTRACT

Objectives: To describe characteristics and outcomes of children requiring intensive care therapy (ICT) within 12 hours following a medical emergency team (MET) event.

Design: Retrospective cohort study.

Setting: Quaternary paediatric hospital.

Patients: Children experiencing a MET event.

Measurements and main results: Between July 2017 and March 2019, 890 MET events occurred in 566 patients over 631 admissions. Admission to intensive care followed 183/890 (21%) MET events. 76/183 (42%) patients required ICT, defined as positive pressure ventilation or vasoactive support in intensive care, within 12 hours. Older children had a lower risk of requiring ICT than infants aged < 1 year (age 1–5 years [risk difference, –6.4%; 95% CI, –11% to –1.6%; $P = 0.01$] v age > 5 years [risk difference, –8.0%; 95% CI, –12% to –3.8%; $P < 0.001$]), while experiencing a critical event increased this risk (risk difference, 16%; 95% CI, 3.3–29%; $P = 0.01$). The duration of respiratory support and intensive care length of stay was approximately double in patients requiring ICT (ratio of geometric means, 2.0 [95% CI, 1.4–3.0] v 2.1 [95% CI, 1.5–2.8]; $P < 0.001$) and the intensive care mortality increased (risk difference, 9.6%; 95% CI, 2.4–17%; $P = 0.01$). Heart rate, oxygen saturation and respiratory rate were the most commonly measured vital signs in the 6 hours before the MET event.

Conclusions: Approximately one-fifth of MET events resulted in intensive care admission and nearly half of these required ICT within 12 hours. This group had greater duration of respiratory support, intensive care and hospital length of stay, and higher mortality. Age < 1 year and a critical event increased the risk of ICT.

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The Royal Children's Hospital is a 360-bed quaternary referral centre. The MET service includes an intensive care registrar, an intensive care nurse and a paediatric registrar for inpatient MET events. A description of the MET service is provided in the Online Appendix. Admission to the PICU is at the discretion of the attending paediatric intensivist. The PICU is a 24-bed unit with dedicated cardiac and general units. In April 2016, a hospital-wide, integrated electronic medical record (EMR) was implemented (Epic Systems). An electronic MET documentation tool was completed by the MET intensive care staff (Online Appendix) and checked for completion by the PICU MET leadership group. We defined ICT as the need for positive pressure ventilation or vasoactive support in the PICU within 12 hours of the MET event.

Demographic and clinical characteristics at the time of the first MET event were collected, including age, sex, admission weight, and hospital admission diagnosis, based on International Classification of Diseases, tenth revision (ICD-10) classification and collapsed into broader categories. The Paediatric Index of Mortality 3 (PIM3) score¹³ and PICU admission diagnoses¹⁴ were collected from the PICU database.¹⁵ Characteristics of each MET event, including duration, time of day, location/admission unit, indication, diagnosis and interventions, were recorded. Critical events at the time of the MET event⁴ were recorded, including cardiac arrest, endotracheal intubation, bag valve mask ventilation, reversal of analgo-sedation, > 40 mL/kg of fluid resuscitation, hypo- or hypernatraemia (serum sodium < 125 mmol/L or > 155 mmol/L), hypoglycaemia (blood glucose < 2 mmol/L) or acidaemia (pH < 7.1). In-hours MET events were those occurring between Monday and Friday from 7:30 to 17:30.

For PICU admissions, respiratory support (non-invasive and invasive mechanical ventilation), mechanical ventilation, extracorporeal membrane oxygenation, continuous renal replacement therapy, PICU and hospital length of stay, and mortality data were recorded and compared between children who required ICT and those who did not. Vital sign data in the 6 hours preceding the MET event were analysed. Vital sign abnormalities were defined as values outside of normal range for age on hospital observation charts.

Statistical analysis

Frequency and percentages are presented for categorical patient demographics, clinical characteristics of MET events and vital signs data. The symmetry of continuous data was assessed by visual inspection. Mean and standard deviation (SD) are presented for symmetrically distributed data, while skewed data are described using median and interquartile range (IQR).

Univariate analyses were performed on all MET events to identify potential determinants requiring ICT. Age, sex,

duration from hospital admission to MET event, time of day, surgery and PICU discharge in the previous 72 hours and the occurrence of a critical event at the time of the MET event (selected a priori) were analysed and presented as risk difference with 95% confidence interval (CI). ICT and outcomes were analysed for PICU admissions comparing patients requiring ICT within 12 hours of the MET event with those who did not need ICT. The risk of mortality and intensive care support during the PICU admission were analysed using a generalised linear model for the binomial distribution. Risk difference and 95% CI are presented. A linear regression was performed on the log transformed values for skewed data. The ratio of geometric means and 95% CI are presented. Due to repeated measures from the same patient, standard errors allowing for clustering effects were calculated using the robust "information sandwich" method. Where MET events occurred within 6 hours of a prior MET event, vital signs data related to the first of these MET events were analysed. The analysis was performed using Stata version 16.1 (StataCorp). The Royal Children's Hospital Human Research Ethics Committee provided approval to conduct the study (HREC 37189A).

Results

Over the study period there were 95 082 hospital admissions (Online Appendix, supplementary table 1). There were 890 MET events in 566 patients across 631 hospital admissions. A flow diagram of hospital and PICU admissions is shown in the Online Appendix, supplementary figure 1, and the frequency of hospital admissions with multiple MET events are presented in the Online Appendix, supplementary table 2. The demographic characteristics of children at the time of their first MET event are described in Table 1.

MET event characteristics and outcomes

The median time from hospital admission to the first MET event was 51 hours (IQR, 14–176 hours), and 30% of all MET events were in-hours (Table 1 and Table 2). The most common indications were desaturation (296, 33%), staff concern (232, 26%) and tachypnoea (229, 26%). There were five cardiac arrests and seven respiratory arrests. Seventy-three MET events (8%) had one or more critical event, with 95 critical events in total (Online Appendix, supplementary table 3).

Admission to the PICU followed 183/890 (21%) MET events (171 hospital admissions), of which 76/183 (42%) received ICT within 12 hours of the MET event, while 707 (79%) remained on the ward (Online Appendix, supplementary figure 1). The first MET event prompted admission to the PICU in 121/171 (71%) hospital admissions. The median time from hospital admission to these 121 first METS events was 42 hours (IQR, 13–199 hours). Age,

Table 1. Patient demographic and clinical characteristics of all children at the time of their first medical emergency team (MET) event during the study period (n = 566)

Baseline Clinical Characteristics	Values
Age (years), median (IQR)	2.5 (0.5–9.4)
Age groups	
< 1 year	197 (35%)
1–5 years	162 (29%)
> 5 years	207 (37%)
Weight z-score, mean (SD), n = 559	–0.7 (1.9)
Sex, male	327 (58%)
Primary hospital diagnoses	
Cardiac conditions/congenital heart disease	130 (23%)
Lower respiratory tract infections	75 (13%)
Neurological conditions/seizures	62 (11%)
Respiratory/airway conditions	54 (10%)
Sepsis	33 (6%)
Malignancy	42 (7%)
Metabolic or genetic conditions	41 (7%)
Other	129 (23%)
Time from hospital admission to first MET (hours), median (IQR)	51 (14–176)

IQR = interquartile range; SD = standard deviation.

hospital admission diagnoses, MET event characteristics and intensive care supports/outcomes are summarised for each MET event by destination in Table 3 and by PICU admission diagnoses in the Online Appendix, supplementary table 4.

Predictors of the need for ICT

For 890 MET events, we found that the risk of receiving ICT within 12 hours of a MET event was lower in older children compared with infants aged < 1 year (age 1–5 years [risk difference, –6.4%; 95% CI, –11% to –1.6%; $P = 0.01$] v age > 5 years [risk difference, –8.0%; 95% CI, –12% to –3.8%; $P < 0.001$]) (Table 4). A critical event at the time of the MET event increased the risk of receiving ICT within 12 hours (risk difference, 16%; 95% CI, 3.3–29%; $P = 0.01$). Recent prior surgery and PICU discharge were associated with less risk of receiving ICT within 12 hours (risk difference, –5.5% [95% CI; –9.3% to –1.7%; $P = 0.005$] v –4.6% [95% CI; –8.5% to –0.7%; $P = 0.02$] respectively). We found no evidence that sex, time from hospital admission or whether the MET event occurred in-hours affected the risk of ICT.

PICU admission and ICT

Respiratory support and invasive mechanical ventilation were administered in the PICU for 144/890 (16%) and 70/890 (7.9%) of all MET events respectively. The risk of

death in the PICU for patients requiring ICT within 12 hours of a MET event was 9.6% (95% CI, 2.4–17%; $P = 0.01$) higher than for patients who did not require ICT (Table 5). The percentage of PICU admissions requiring respiratory support, mechanical ventilation and continuous renal replacement therapy for these two groups and their differences are also presented in Table 5. The duration of respiratory support, mechanical ventilation and length of stay, both in PICU and the hospital, for both groups are presented in Table 6. On average, the duration of respiratory support and PICU length of stay in the ICT group was twice that in the no ICT group ($P < 0.001$).

Vital sign abnormalities in the 6 hours before the MET

Of 890 MET events, 833 (94%) were examined for vital signs. Heart rate, oxygen saturation and respiratory rate were recorded five times or more for almost two-thirds of these 833 MET events within the previous 6 hours (Online Appendix, supplementary table 5). This

increased to about 80% for MET events that received ICT within 12 hours, and to 81%, 85% and 76% for heart rate, oxygen saturation and respiratory rate respectively. Overall, blood pressure was recorded five times or more for 20% of the MET events, but it was not recorded at all for a further 20%. Two or more abnormal readings of heart rate, oxygen saturation and respiratory rate were recorded in 148/800 (19%), 144/798 (18%) and 138/797 (17%) MET events respectively in the 6 hours before a MET event (Online Appendix, supplementary table 6).

Discussion

Key findings

In this retrospective study in a single-centre, quaternary hospital, we found that about one in five MET events required PICU admission, and 42% of those required ICT within 12 hours of the MET event. Congenital heart disease and lower respiratory infections were the most common admission diagnoses. Desaturation, staff concern and tachypnoea were the most common indications and 30% of the events were in-hours. Patients with MET events who received ICT within 12 hours had about double the duration of respiratory support, double the PICU length of

Table 2. Medical emergency team (MET) characteristics and outcomes for all MET events (n = 890)

Characteristic/outcome	Number (%)
Number of MET events per admission (631 admissions)	
1	491 (78%)
2	87 (14%)
3	28 (4%)
4	11 (2%)
≥ 5	14 (2%)
MET in-hours	264 (30%)
MET indication	
Desaturation	296 (33%)
Staff concern	232 (26%)
Tachypnoea	229 (26%)
Tachycardia	174 (20%)
Seizures	82 (9%)
Decreased consciousness	80 (9%)
Airway threat	76 (9%)
Hypotension	43 (5%)
Respiratory arrest	7 (0.8%)
Cardiac arrest	5 (0.6%)
Bradycardia	67 (8%)
Other	110 (12%)
MET interventions	
Critical care advice	389 (44%)
Low flow oxygen	97 (11%)
High flow nasal cannula	94 (11%)
Fluid bolus	81 (9%)
Bag valve mask ventilation	42 (5%)
Non-invasive ventilation	39 (4%)
MET events with ≥ 1 critical event	73 (8%)
MET duration (minutes)	
5	85 (10%)
10	203 (23%)
15	214 (24%)
20	145 (16%)
≥ 25	199 (22%)
Unknown	44 (5%)
MET outcomes	
Remained on ward	707 (79%)
Admitted to PICU	107 (12%)
Admitted to PICU + ICT*	76 (9%)

ICT = intensive care therapy; PICU = paediatric intensive care unit. * MET events that led to PICU admission and either positive pressure ventilation or vasoactive therapy within 12 hours of the MET event.

stay and higher mortality compared with those admitted to the PICU who did not receive ICT. Critical events during the MET event had an increased risk of requiring ICT within 12 hours of the MET event, whereas the risk was reduced in older children and those who had surgery or were discharged from the PICU in the previous 72 hours. Heart rate, oxygen saturation rate and respiratory rate were the most commonly measured vital signs. Less than 20% of the vital signs were outside the normal range two or more times in the 6 hours preceding a MET event.

Comparisons to other studies

Our findings highlight characteristics and predictors of rapid clinical deterioration following a MET event. The implementation of rapid response teams has been shown to reduce hospital cardiac arrests and deaths,^{2,12} but less is known regarding clinical deterioration. Bonafide and colleagues¹⁰ showed deterioration to be eight-fold more common than cardiorespiratory arrests and was associated with increased hospital mortality. The PICU admission rate in our study (about 20%) was lower than in a North American multicentre study, where 53% of patients required PICU admission.⁹ However, the rate of ventilatory support was reported as 6.1%, similar to our rate of 7.9% for mechanical ventilation (16% including non-invasive ventilation). It is difficult to draw much from such comparisons due to differences in PICU admission criteria and health care systems.

Predictors of deterioration following a MET event in children

Children aged < 1 year and the presence of a critical event at the time of the MET event predicted clinical deterioration. Previous studies of MET events, from our institution⁴ and others,¹² show that MET events most commonly occur in infants. Infants may be more likely to deteriorate quickly due to underlying conditions such as congenital heart disease or respiratory infections. It may be that identification of abnormal physiology in this age group is

Table 3. Characteristics and outcomes of medical emergency team (MET) events, by destination and therapy within 12 hours of the MET event

Characteristic/outcome	MET destination		
	Ward	PICU no ICT with- in 12 hours	PICU ICT within 12 hours
Total number of MET events	707	107	76
Age (years), median (IQR)	3.0 (0.7–11.0)	1.6 (0.3–5.3)	0.8 (0.2–4.3)
PIM 3, median (IQR)	na	1.3 (1.2–1.9)	3.2 (1.2–3.9)
Primary hospital diagnoses			
Cardiac conditions/congenital heart disease	169 (24%)	34 (32%)	20 (26%)
Lower respiratory tract infections	85 (12%)	21 (20%)	18 (24%)
Neurological conditions/seizures	69 (10%)	10 (9%)	1 (1%)
Respiratory/airway conditions	78 (11%)	9 (8%)	9 (12%)
Sepsis	33 (5%)	7 (7%)	4 (5%)
Malignancy	54 (8%)	5 (5%)	4 (5%)
Metabolic or genetic conditions	62 (9%)	10 (9%)	4 (5%)
Other	157 (22%)	11 (10%)	16 (21%)
Pre-MET events			
Surgery up to 72 hours before MET	129 (18%)	15 (14%)	6 (8%)
PICU discharge up to 72 hours before MET	135 (19%)	24 (22%)	8 (11%)
MET characteristics			
In-hours	215 (30%)	27 (25%)	22 (29%)
Time from hospital admission to MET (h), median (IQR)*	95 (24–327)	56 (17–229)	78 (17–356)
MET events with ≥ 1 critical event	47 (7%)	9 (8%)	17 (22%)
Intensive care support and outcomes			
Respiratory support/NIV	na	69 (64%)	75 (99%)
Duration of respiratory support/NIV, h	na	49 (21–126)	105 (43–220)
Mechanical ventilation	na	24 (22%)	46 (61%)
Duration of mechanical ventilation (h), median (IQR)	na	67 (31–95)	107 (36–189)
ECMO	na	0 (0.0%)	4 (5.3%)
CRRT	na	3 (2.8%)	7 (9.2%)
PICU LOS (h), median (IQR)	na	68 (39–117)	128 (67–265)
PICU mortality	na	1 (0.9%)	8 (10.5%)
Hospital LOS (days), median (IQR)	17 (7–49)	16 (7–48)	27 (12–61)

CRRT = continuous renal replacement therapy; ECMO = extracorporeal membrane oxygenation; ICT = intensive care therapy; IQR = interquartile range; LOS = length of stay; na = not applicable; NIV = non-invasive ventilation; PICU = paediatric intensive care unit; PIM 3 Paediatric Index of Mortality. * MET event leading to PICU admission where appropriate.

most challenging. Interestingly, in this study, recent surgery and PICU discharge were associated with reduced risk of clinical deterioration contrary to previous reports.⁴ These findings could be explained by improved processes for elective postoperative PICU admission, postoperative care and post-PICU discharge follow-up.

Implications of findings

Our study provides additional data indicating the high risk nature of MET events in children, particularly the very young and those experiencing a severe event and their consequences. Understanding risk factors for adverse

Table 4. Potential predictors of intensive care therapy (ICT) within 12 hours of a medical emergency team (MET) event*

Explanatory variable	Risk difference (%) (95% CI)	P
Age groups, years		
< 1	Reference group	
1–5	–6.4% (–11% to –1.6%)	0.01
> 5	–8.0% (–12% to –3.8%)	< 0.001
Sex, male	1.7% (–1.9% to 5.2%)	0.36
Time from hospital admission to MET, h [†]	0.2% (–0.2% to 0.6%)	0.39
In-hours MET	–0.3% (–4.3% to 3.7%)	0.89
Critical events ^{‡,§}	16% (3.3 to 29%)	0.01
Surgery up to 72 hours before MET	–5.5% (–9.3% to –1.7%)	0.005
PICU discharge up to 72 before MET	–4.6% (–8.5% to –0.7%)	0.02

PICU = paediatric intensive care unit. * All METs ($n = 890$); METs requiring ICT ($n = 76$). † Time is log₂ transformed. ‡ 07:30–17:30 hours Monday–Friday. § Cardiac arrest, bag valve mask ventilation, endotracheal intubation, reversal of analgesia/sedation, > 40 mL/kg of fluid resuscitation, hypo- or hypernatraemia (serum sodium < 125 mmol/L or > 155 mmol/L, hypoglycaemia (blood glucose < 2 mmol/L) or acidosis (pH < 7.1).

Table 5. Estimated risk of specified therapies and mortality in the paediatric intensive care unit (PICU) in patients requiring intensive care therapy (ICT) versus no ICT within 12 hours of the medical emergency team (MET) event ($n = 183$)

Therapy and outcome	Risk (%)		Risk difference (95% CI)	P
	PICU no ICT within 12 hours	PICU ICT with- in 12 hours		
Total number of MET events	107	76		
Respiratory support*	64%	99%	34% (24–44%)	< 0.001
Mechanical ventilation	22%	61%	38% (25–51%)	< 0.001
CRRT	2.8%	9.2%	6.4% (–0.8% to 14%)	0.08
PICU mortality	0.9%	10.5%	9.6% (2.4–17%)	0.01

CRRT = continuous renal replacement therapy; PICU = paediatric intensive care unit. * Respiratory support refers to all non-invasive and invasive ventilation.

Table 6. Duration of specified therapies and outcomes for medical emergency team (MET) events leading to paediatric intensive care unit (PICU) admission, intensive care therapy (ICT) versus no ICT within 12 hours of the MET event ($n = 183$)

Therapy and outcome	Ratio of geometric means (95% CI)	P
Respiratory support, h* ($n = 144$)	2.0 (1.4–3.0)	< 0.001
Mechanical ventilation, h [†] ($n = 70$)	1.5 (0.9–2.8)	0.14
PICU LOS, h	2.1 (1.5–2.8)	< 0.001
Hospital LOS, days	1.4 (1.0–2.1)	0.05

LOS = length of stay. * Respiratory support refers to all non-invasive ventilation; cases with no respiratory support excluded. † Cases with no mechanical ventilation excluded.

outcomes following a MET event is important to optimally recognise populations at risk. We aimed to investigate vital signs abnormalities in the 6 hours before the MET event. We were able to describe the frequency of vital signs and abnormalities only. Not all children had an equal number of vital signs recordings and, therefore, comparisons were not possible. Neither absolute number nor proportion of abnormal signs were suitable and, therefore, only descriptive analyses are presented. Using automated physiological signals to assist clinicians in detecting deterioration early or predicting adverse outcomes is worthy, but a suitable method is required.

Further research

Key components of identifying deteriorating patients include the right physiological predictors, at the right time, signalled to the right responder with the lowest “false alarm” rate.¹⁶ Recognising changes in physiology before a MET event, using vital signs trends, in the era of abundant electronic data is central to this. There has been considerable uptake of early warning scores with rapid response teams in paediatrics,¹⁷ as they can indicate deterioration early.¹⁸ Although early warning scores can identify need for intensive care,^{19,20} broad, hospital-wide processes are required to optimally recognise

deterioration, beyond merely a score.²¹ Mandating MET events based on physiological triggers does not always achieve improved outcomes.²² Electronic medical records have assisted in MET activation and reduce ICU admission, length of stay and mortality.^{23,24} Real-time physiological data for assisting clinicians to recognise clinical deterioration in hospital are promising.

Strength and limitations

The strength of this study is the use of point-of-care, clinician-entered, EMR-embedded MET data. Completion and accuracy of electronic MET forms were checked by MET clinical leads and we used previously defined outcome metrics. However, there are some limitations. We did not examine the effect of multiple MET events, but comparative analyses were performed allowing for clustering at the patient level. Summarised data were presented based on MET outcome destination; therefore, some repeated measurements occurred. Nevertheless, this was infrequent for children admitted to the PICU (160 children in 171 hospital admissions for 183 MET events). Furthermore, we did not compare characteristics, risk factors or outcomes based on the MET indication because of multiple indications. Therefore, grouping by pathophysiological process was not feasible. No specific criteria for PICU admission exist, thus, it is somewhat subjective. However, MET calling criteria thresholds are standardised on vital signs charts in Victoria. Electronic MET forms may have had inaccuracies, but checking was performed and incomplete data were updated using medical records.

Conclusions

Admission to the PICU occurred in 21% of MET events and 9% of all events required ICT within 12 hours. Infants aged < 1 year and those experiencing a critical event at the time of the MET event were at greater risk of needing ICT. Those requiring ICT had longer duration of respiratory support and of PICU and hospital length of stay, and higher mortality compared with those admitted to the PICU alone.

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Competing interests

No relevant disclosures.

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