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Original Article

Associations between patient and system characteristics and MET review within 48 h of admission to a teaching hospital: A retrospective cohort study

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A B S T R A C T

The Medical Emergency Team (MET) has enhanced the recognition and response to clinical deterioration in acute healthcare. However, patients reviewed by the MET are at increased risk of in-hospital death. Identifying patients at risk of deterioration may improve patient outcomes.

Aim: To identify patient demographic, medical characteristics and healthcare systems and processes at the time of admission (baseline), associated with Medical Emergency Team (MET) review within 48 h (MET-48 h) of admission.

Methods: Single-site, year-long, retrospective cohort comprising patients admitted for at least 24 h, using routinely collected hospital data. A three-stage modelling approach was used to identify baseline factors associated with MET-48 h

Results: The study included 15,695 patients with mean age 62.1 years (SD 19.6), male (53.5%), born in Australia or New Zealand (60.9%) and 51.6% held a low-income concession card. A total of 4.3% of patients received a MET review within 48 h of admission. Variables independently associated with MET-48 h in a fully adjusted logistic model included age of 80 years or more (OR = 1.37); ≥3 previous emergency admissions (OR = 1.59); Charlson Comorbidity Index 1 or 2 (OR = 1.47), or ≥ 3 (OR = 1.99); history of alcohol-related behaviour concerns (OR = 2.04), chronic heart failure (OR = 1.48); chronic obstructive pulmonary disease (OR = 1.35); admission for colorectal (OR = 2.66) or upper gastro-intestinal (OR = 1.94) surgery, respiratory or tracheostomy (OR = 2.24); immunology and infections (OR = 1.90); emergency admission (OR = 1.36); admission at night (OR = 1.74), or summer (OR = 1.41)

Conclusions: This is the first study to demonstrate the potential to predict clinical deterioration using data that is readily accessible at the time of admission to hospital.

1. Introduction

Rapid response systems (RRSs) were developed to support the recognition and response to clinical deterioration, in order to decrease the high mortality associated with adverse events such as in-hospital cardiac arrest and unplanned Intensive Care Unit (ICU) admissions [1]. RRSs are organisation-wide systems and consist of four parts [2]. First, the afferent limb which comprises the recognition of deterioration and activation of the response system; second, a Rapid Response Team (RRT) to respond to deteriorating patients; third, an administration limb consisting of the day-to-day resourcing and management of the RRS; and finally, a governance limb for monitoring and quality improvement of the RRS [2]. In Australia, the most common model of RRT is the Medical Emergency Team (MET) [3,4], an ICU-specialist led response team, summonsed in response to pre-defined single -parameter criteria for recognising clinical deterioration [2,4].

Although the effectiveness of RRSs has been questioned [5,6], in three meta-analyses RRSs were associated with a decrease in in-hospital cardiac arrests and, to a lesser extent, hospital mortality [7–9]. However, the MET is a reactive approach to recognising and responding to clinical deterioration, is resource intensive and often under-funded, and patients reviewed by the MET are at high risk of in-hospital death [10–12]. This reactive approach may also encourage ward-based clinicians to defer care decisions and abdicate responsibility for patient care [6,13].

Earlier recognition of deterioration may further improve patient outcomes [14,15], and experts have recommended that the focus of researchers and clinicians shifts to predicting and preventing clinical deterioration [11,16]. A better understanding of risk factors for clinical deterioration will assist clinicians to identify high-risk patients and enable proactive, informed clinical care decisions to be made before deterioration occurs. MET review records are currently the earliest,

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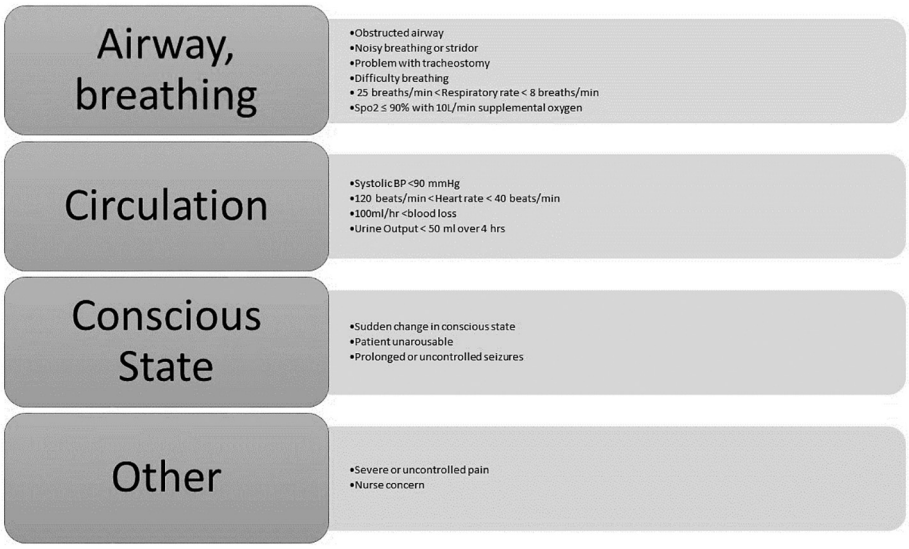

Fig. 1. Medical Emergency Team criteria at the study site

reliable, evidence-based indication of clinical deterioration events in acute care patients. Most MET reviews take place within the first 48 h of an admission [17]. Therefore identifying patient and admission characteristics that have important associations with MET review within 48 h and are readily accessible to clinicians at the time of admission, is a first step towards proactive, preventative care for patients at increased risk of clinical deterioration.

1.1. AIM

The aim of this study was to identify: i) patient demographic characteristics; ii) patient medical characteristics; and iii) factors related to the healthcare system and processes present at the time of admission to hospital that are associated with clinical deterioration in the first 48 h using routinely collected hospital data.

2. Methods

2.1. Study design

This was a retrospective cohort study, using routinely collected hospital data for the period January 1 to December 31, 2016.

2.2. Ethics approval

Approval was received from the Human Research Ethics Committee at the study site (LNR/16/Austin/562), and Deakin University (2017–041), prior to study commencement. The requirement to obtain consent from participants was waived according to local and national policy regulations.

2.3. Setting

The setting was the major acute care campus of a three-campus health network in the northern suburbs of Melbourne, Australia. The hospital is a university affiliated 560 bed teaching hospital, with a 22-bed intensive care unit, and approximately 80,000 admissions per year, roughly one-third of which are multi-day (> 24 h) stays. The hospital provides tertiary level medical and surgical services, as well as state-wide liver transplant, spinal cord injury and respiratory support services.

2.4. Participants

Eligible patients with a hospital admission during the study period were identified from hospital records. Patients were the unit of analysis. For patients with more than one admission in the study period, we selected the last admission within the study period. As we could not identify patients who had admissions prior to the study period, selecting the last admission ensured that only the most recent admission was used for all patients in the study.

2.5. Eligibility criteria

Adults patients (≥18 years old), with an inpatient length of stay > 24 h, and admitted under any of the 23-acute medical or surgical hospital services between January 1 to December 31, 2016 were included. Patients who required critical organ support and were directly admitted to a critical care setting (ICU/HDU/PACU/CCU) from the Emergency department were excluded. Paediatric and psychiatry unit admissions were also excluded.

2.6. Study variables

The primary study outcome was (MET) review within 48 h of admission (MET-48 h). The secondary outcome was MET review within 7 days of admission (MET-7 days). The RRS at the study site is well-established, and has been the subject of several previous studies [18–24]. The organisation's criteria for recognising clinical deterioration are shown in Fig. 1.

Factors potentially associated with MET reviews were clustered into three groups. First, *patient demographics* comprising gender (male/female), age (years), private health insurance (yes/no), low-income concession status (yes/no), country of birth, preferred language (English/other), requirement for an interpreter (yes/no), relationship status and residence in the suburbs serviced by the study site (yes/no). Second, *clinical information* including primary diagnosis at hospital admission, defined according to the International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification (ICD-10-AM) [25]; comorbid health, measured using the Charlson Comorbidity Index and Score for Risk Adjustment [26]; and the number of previous admissions to the hospital in a patient's lifetime. Third, *system and process factors* including type of admission (scheduled, emergency, transfer from another care setting); the funding source; and the calendar date and time that were used to

generate season, day of the week, and hour of admission. The last three system and process factors indicate healthcare system conditions such as nursing and medical shifts.

3. Data sources and management

The demographic, clinical and systems data used in this study were routinely collected by Victorian health services as part of the Victorian Admitted Episodes Dataset (VAED) [27]. Healthcare services report these data to the state government to enable service evaluation and funding decisions. Information is initially entered into an individual's health record by clinicians and hospital clerks contemporaneously, then extracted and coded by professional coders following hospital separation. Details of MET reviews were documented separately by members of the MET in an electronic database.

Data were extracted and collated from the health service's databases by an experienced data analyst employed by the hospital. Records from different sources were matched using the unique patient identification code and the unique admission episode identification code. The administrative nature of the dataset meant that we had no missing data in clinical or system and process variables. There was a small proportion of patients with no demographic data (see Table 1) which were missing due to lack of collection at the point of care. A small proportion (~5%) of MET reviews were not recorded due to clinician workloads, other pressing patient care priorities.

3.1. Statistical analysis

The primary outcome was MET review within 48 h of admission for patients in acute wards. The secondary outcome was MET review within 7 days of admission.

We used classification and regression trees (CART) with MET-48 h as the outcome to categorise numerical predictors or categorical factors with multiple levels. Variables were grouped as follows: age (18–24, 25–59, 60–79, 80 +); relationship status (widowed or not); Charlson Comorbidity Index (0, 1 or 2, ≥ 3), number of emergency admissions in the preceding 12 months (0, 1 or 2, ≥ 3), admission diagnostic group collapsed from 37 to 10 groups, admission source (residential care, other [private residence or acute transfer]), admission funding source (public, private insurance, or other [self-funded, transport accidents, occupational accident, or war veterans]); day of the week (weekday [Monday to Friday], Saturday, Sunday); admission time (7:00 am-9:59 am, 10:00 am-11:59 pm, 12:00 am-6:59 am); shown in Tables 2 and 3. The admission date was used to classify the season (Summer [Dec 21- Mar 20], Autumn [Mar 21 – Jun 20], Winter [Jun 21 – Sep 20], Spring [Sep 21 – Dec 20]).

Due to the large number of variables of interest, a three-stage modelling approach was used. In the first stage, univariate logistic regressions were fitted to identify factors associated with MET-48 h ($p < .20$). In the second stage, the identified variables were grouped (patient demographic, patient clinical, healthcare system and process factors) and a logistic regression model fitted for each group. Finally, a fully adjusted logistic regression model was fitted with all the factors selected in the second stage ($p < .20$). Age and gender were included in all multivariate models. The same approach was repeated for the secondary outcome (MET-7 days). Analyses were conducted using IBM SPSS version 23 [28] and SAS Enterprise Miner version 14.3 [29].

4. Results

A total of 22,241 admissions in 15,695 patients meeting the eligibility criteria occurred during the study period. Of these, 12,209 had a single admission in the study period, while 3486 patients had multiple admissions, of which we selected the last admission in the study period.

The mean age at admission was 62.1 years (SD 19.6), and 53.5% were male. Most held a low-income concession card (51.6%) and only 29.6% were privately insured. The majority were born within Australia or New Zealand (60.9%) (Table 1). Most identified English as their

Table 1
Characteristics of the patient cohort at the time of admission.

Demographic characteristics	Mean (SD)	Median (25,75)	*N* = 15,695 (%)	Clinical characteristics	Median (min,max)
Age (years)	62.14 (19.61)	65 (49,78)		Charlson Comorbidity Index	1 (0,13)
Male n(%)			8400 (53.5)		
^Has Private Health Insurance			4651 (29.6)	No. admissions previous year (total)	0 (0,56)
^Low-income concession			8105 (51.6)	No. emergency admissions previous year	0 (0,18)
Country of Birth				No. planned admissions previous year	0 (0,54)
Australia & New Zealand			9559 (60.9)	Healthcare System and Process Factors	n (%)
[Indigenous]			[113 (0.7)]	Admission Day	
Pacific Islands			83 (0.5)	Monday	2618 (16.7)
UK and Ireland			750 (4.8)	Tuesday	2531 (16.1)
North & Western Europe			242 (1.5)	Wednesday	2556 (16.3)
South & East Europe			2932 (18.7)	Thursday	2450 (15.6)
Africa & Mid-East			791 (5.0)	Friday	2402 (15.3)
Asia			1014 (6.5)	Saturday	1646 (10.5)
America			109 (0.7)	Sunday	1492 (9.5)
Missing			215 (1.4)	Admission source	
Preferred language				Residential Care	572 (3.6)
English			13,754 (87.6)	Private residence	1438 (91.7)
Other			1686 (10.8)	Acute transfer	736 (4.7)
Missing			255 (1.6)	^Funding Source	
Interpreter required			1083 (6.9)	Public insurer (Medicare)	11,364 (72.4)
Relationship Status				Private insurer	3647 (23.2)
Married			7989 (50.9)	Veteran's affairs	349 (2.2)
Never Married			3640 (23.2)	Transport Accident Commission	123 (0.8)
Widowed			2021 (12.9)	Workcover	73 (0.5)
Defacto			591 (3.8)	Other	139 (1.0)
Divorced			563 (3.6)		
Separated			342 (2.2)		
Missing			549 (3.5)		
Residence in the suburbs serviced by the study site			12,481 (79.5)		

^Note: private health insurance status, concession status, and the hospital funding source were included as indicators of socio-economic and demographic characteristics of the patients. As all admissions took place in a publicly-funded hospital, equal care is provided to all patients.

Table 2
Univariate associations between MET-48 h and patient demographic characteristics and healthcare system and process factors.

Demographic Variable	Category	n(%)	nMET (%)	OR (95%CI)	P
Gender	Male	8400 (53.5)	348 (4.14)	1	0.379
	Female	7295 (46.5)	323 (4.43)	1.07 (0.92,1.25)	
Age	18–24	685 (4.4)	22 (3.21)	1.07 (0.68,1.67)	0.000
	25–59	5697 (36.6)	172 (3.02)	1	
	60–79	5825 (37.1)	259 (4.45)	1.49 (1.23,1.82)	
	80 +	3488 (22.2)	218 (6.25)	2.14 (1.75,2.63)	
Widowed	No	13,125 (83.6)	520 (3.96)	1	0.000
	Yes	2021 (12.9)	122 (6.04)	1.56 (1.27,1.91)	
Low-income concession	No	7590 (48.4)	280 (3.69)	1	0.000
	Yes	8105 (51.6)	391 (4.82)	1.32 (1.13,1.55)	
Private health insurance	Yes	4651 (29.6)	192 (4.13)	1	0.571
	No	11,043 (70.4)	478 (4.33)	1.03 (0.94,1.12)	
Interpreter required	No	14,385 (91.7)	595 (4.14)	1	0.019
	Yes	1083 (6.9)	61 (5.63)	1.38 (1.05,1.81)	
Residence in the suburbs serviced by the study site	No	3214 (20.5)	112 (3.48)	1	0.013
	Yes	12,481 (79.5)	559 (4.48)	1.3 (1.06,1.6)	

System and process variable	Category	n(%)	nMET (%)	OR (95%CI)	P
Transferred from residential care	No	15,123 (96.4)	620 (4.1)	1	0.000
	Yes	572 (3.6)	51 (8.92)	2.29 (1.7,3.09)	
Admission funding	Public	11,364 (72.4)	487 (4.29)	1	0.017
	Private	3647 (23.2)	141 (3.87)	0.9 (0.74,1.09)	
	Other	684 (4.4)	43 (6.29)	1.5 (1.09,2.07)	
Emergency Admission	No	4890 (31.2)	137 (2.8)	1	0.000
	Yes	10,805 (68.8)	534 (4.94)	1.8 (1.49,2.18)	
Admission Day	Weekday	12,557 (80.0)	505 (4.02)	1	0.002
	Saturday	1646 (10.5)	78 (4.74)	1.19 (0.93,1.52)	
	Sunday	1492 (9.5)	88 (5.9)	1.5 (1.18,1.89)	
Admission Time	0700–0959	2280 (14.5)	58 (2.54)	1	0.000
	1000–2359	10,757 (68.5)	464 (4.31)	1.73 (1.31,2.28)	
	2400–0659	2658 (17.0)	149 (5.61)	2.28 (1.67,3.1)	
Admission Season	Autumn	4163 (26.5)	150 (3.6)	1	0.020
	Winter	3968 (25.3)	187 (4.71)	1.32 (1.06,1.65)	
	Spring	4400 (28.0)	179 (4.07)	1.13 (0.91,1.42)	
	Summer	3164 (20.2)	155 (4.9)	1.38 (1.1,1.73)	

preferred language (87.6%); approximately 7% required an interpreter. Most were married (50.9%) and lived in the suburbs serviced by the study site (79.5%). Nearly half of the patients had never had a prior hospital admission (46.4%), and most were admitted from a private residence (91.7%). Admissions were spread relatively evenly from Monday to Friday (15.3–16.7%) with fewer occurring on Saturday (10.5%) and Sunday (9.5%). There was a small difference between the number of patients with private health insurance ($n = 4651$, 29.6%), and the number whose admission was funded by private insurance ($n = 3647$, 23.3%).

Approximately one in twelve (8.1%, $n = 1273$) patients received a MET review at any time during their admission. MET review took place within 48-h in 671 patients (4.3%), within 72-h in 810 patients (5.2%), and within 1-week of admission in 1035 patients (6.6%). In the same period 93 patients (0.6%) experienced a cardiac arrest call, of which 31 took place within 48 h of admission.

4.1. Univariate associations with MET review within 48 h

Several demographic variables had significant univariate associations with MET-48 h (Table 2), including age, being widowed, holding a low-income concession card, requiring an interpreter, and living in the suburbs serviced by the study site. All the system and process variables were associated with MET-48 h (Table 2), including transfer from residential care, admission funding, emergency admissions, and admission time, day and season. Most of the clinical variables were associated with MET-48 h (Table 3). These clinical variables included prior emergency hospital admissions, Charlson Comorbidity Score, a comorbid diagnosis of alcohol or smoking related behavioural changes, history of acute myocardial infarction (AMI) or chronic heart failure (CHF), malignancy, chronic obstructive pulmonary disease (COPD), diabetes with end-organ damage, moderate to severe renal or liver disease, and admission diagnostic groups. Five demographic variables, fourteen clinical variables, and all six system and process variables were selected from the univariate logistic regression models ($p < .20$). Sixteen of these (1 demographic, 8 clinical, 7 system and process) remained following sub-group logistic regressions (Table S1).

4.2. Factors associated with MET review within 48 h in the fully adjusted logistic model

Ten factors were associated ($P < .05$) with MET-48 h in the fully adjusted analysis (Table 4). The odds of having a MET review significantly increased for those patients with: an age > 80 years (OR = 1.37); three or more emergency admissions in the preceding year (OR = 1.59); alcohol-related behaviour (OR = 2.04); a Charlson Comorbidity score of 1 or 2 (OR = 1.47) or ≥ 3 (OR = 1.99); a past history of CHF (OR = 1.48) or COPD (OR = 1.35); an admission diagnosis of colorectal surgery (OR = 2.66), respiratory or tracheostomy (OR = 2.24), upper gastro-intestinal (GI) surgery (OR = 1.94) or immunology and infections (OR = 1.90); an emergency admission (OR = 1.36); an admission at night (OR = 1.74), in winter (OR = 1.25) or summer (OR = 1.41). Due to the low prevalence of the MET reviews (4.3%) odds ratios can be interpreted as risk ratios [30].

4.3. Factors associated with MET review within 7 days in a fully adjusted logistic model

Results for the analysis of MET-7 days are reported in tables S2-S5 (supplementary data). The variables selected for the final MET-7 days

Table 3
Univariate associations between MET-48 h and patient clinical characteristics.

Clinical variable	Category	n(%)	nMET (%)	OR (95%CI)	P
Emergency admissions in the prior year	None	10,790 (68.7)	398 (3.69)	1	0.000
	1 or 2	3910 (24.9)	187 (4.78)	1.31 (1.1,1.57)	
	3+	995 (6.4)	86 (8.64)	2.47 (1.94,3.15)	
Charlson Comorbidity Index Score	0	7672 (48.9)	204 (2.66)	1	0.000
	1 or 2	5054 (32.2)	249 (4.93)	1.9 (1.57,2.29)	
	3+	2969 (18.9)	218 (7.34)	2.9 (2.38,3.53)	
Co-morbid alcohol-related behavioural diagnosis	No	15,310 (97.5)	639 (4.17)	1	0.000
	Yes	385 (2.5)	32 (8.31)	2.08 (1.44,3.01)	
Co-morbid smoking-related behavioural diagnosis	No	15,150 (96.5)	629 (4.15)	1	0.000
	Yes	545 (3.5)	42 (7.71)	1.93 (1.39,2.67)	
Past History of:					
Acute myocardial infarction	No	15,226 (97.0)	641 (4.21)	1	0.022
	Yes	469 (3.0)	30 (6.4)	1.55 (1.07,2.27)	
Cancer – Leukaemia, lymphoma or localised solid tumour	No	14,726 (93.8)	616 (4.18)	1	0.027
	Yes	696 (6.2)	55 (5.68)	1.38 (1.04,1.83)	
Cancer – Metastatic tumour	No	14,690 (93.6)	612 (4.17)	1	0.010
	Yes	1005 (6.4)	59 (5.87)	1.43 (1.09,1.89)	
Cerebrovascular Disease	No	15,036 (95.8)	638 (4.24)	1	0.343
	Yes	659 (4.2)	33 (5.01)	1.19 (0.83,1.7)	
Chronic Heart Failure	No	14,695 (93.6)	568 (3.87)	1	0.000
	Yes	1000 (5.1)	103 (10.3)	2.86 (2.29,3.56)	
Chronic obstructive pulmonary disease	No	14,895 (94.9)	578 (3.88)	1	0.000
	Yes	800 (5.1)	30 (6.4)	3.26 (2.58,4.11)	
Dementia	No	15,390 (98.1)	652 (4.24)	1	0.091
	Yes	305 (1.9)	19 (6.23)	1.5 (0.94,2.4)	
Diabetes – no complications	No	14,365 (91.5)	609 (4.24)	1	0.467
	Yes	1330 (8.5)	62 (4.66)	1.1 (0.85,1.44)	
Diabetes with end-organ damage	No	13,733 (87.5)	535 (3.9)	1	0.000
	Yes	1962 (12.5)	136 (6.93)	1.84 (1.51,2.23)	
Human immuno-deficiency virus	No	15,683 (99.9)	670 (4.27)	1	0.496
	Yes	12 (0.1)	1 (8.33)	2.04 (0.26,15.8)	
Mild liver disease	No	14,965 (95.3)	639 (4.27)	1	0.882
	Yes	730 (4.7)	32 (4.38)	1.03 (0.71,1.48)	
Moderate-severe liver disease	No	15,517 (98.9)	651 (4.2)	1	0.000
	Yes	178 (1.1)	20 (11.24)	2.89 (1.8,4.63)	
Hemiplegia	No	15,233 (97.1)	646 (4.24)	1	0.222
	Yes	462 (2.9)	25 (5.41)	1.29 (0.86,1.95)	
Peripheral vascular disease	No	15,409 (98.2)	660 (4.28)	1	0.717
	Yes	286 (1.8)	11 (3.85)	0.89 (0.49,1.64)	
Moderate to severe renal disease	No	14,577 (92.9)	580 (3.98)	1	0.000
	Yes	1118 (7.1)	91 (8.14)	2.14 (1.7,2.69)	
Connective tissue disease	No	15,590 (99.3)	668 (4.28)	1	0.474
	Yes	105 (0.7)	3 (2.86)	0.66 (0.21,2.08)	
Peptic ulcer disease	No	15,588 (99.3)	665 (4.27)	1	0.496
	Yes	107 (0.7)	6 (5.61)	1.33 (0.58,3.05)	
Admission Diagnosis	All other surgery (reference)	4732 (30.2)	125 (2.64)	1	0.000
	Respiratory or Tracheostomy	1774 (11.3)	165 (9.3)	3.78 (2.98,4.8)	
	Colorectal surgery	278 (1.8)	20 (7.19)	2.86 (1.75,4.66)	
	Immunology and infections	712 (4.5)	48 (6.74)	2.66 (1.89,3.75)	
	Clinical cardiology	740 (4.7)	45 (6.08)	2.39 (1.68,3.39)	
	Oncology, radio or chemotherapy	652 (4.2)	33 (5.06)	1.96 (1.33,2.91)	
	Gastroenterology	476 (3.0)	24 (5.04)	1.96 (1.25,3.06)	
	Upper GI surgery	680 (4.3)	34 (5)	1.94 (1.32,2.86)	
	Orthopaedic surgery	1502 (9.6)	55 (3.66)	1.4 (1.01,1.93)	
	All other medical	4107 (26.2)	118 (2.87)	1.09 (0.84,1.41)	

model included all the variables identified for MET-48 h and some additional co-morbid conditions, including cancer, dementia, and liver disease. The strength of the associations, as measured by the odds ratios, was essentially unchanged, although some factors became significant in the MET-7 days analysis due to the increase in power because of the larger incidence of MET reviews within 7-days compared to 48-h (6.6% vs 4.3%).

5. Discussion

The aim of this study was to identify patient and admission characteristics that have important associations with clinical deterioration, and are readily accessible to clinicians at the time of admission. The study included 15,695 patients, representative of an acute inpatient population of a tertiary referral hospital. MET review within 48 h of admission was selected as a surrogate outcome indicating clinical deterioration. One in twelve patients received a MET review at any time during their admission; half of which occurred during the first 48 h.

Several patient clinical characteristics and healthcare system factors were independently associated with MET review within 48 h of the admission. Some factors (previous emergency hospital admissions; Charlson Comorbidity Score; history of COPD or CHF) were associated with a 50% increase in the risk of a MET review, while others (Charlson score ≥ 3, admission for colorectal surgery, respiratory disease or a tracheostomy) had double the risk of a MET review within 48 h. In addition, the risk of MET review was increased for patients admitted after midnight (midnight-0700) and in both summer and winter seasons. No demographic characteristics were independently associated with MET review. The same variables were associated with MET reviews within 7 days of admission.

Table 4
Fully adjusted logistic regression model for MET-48 h.

Variable	Category	OR (95%CI)	P
Gender	Female	1.11 (0.95,1.31)	0.185
Age	18–24	1.32 (0.83,2.09)	0.063
	25–59	1	
	60–79	1.2 (0.97,1.47)	
	80 +	1.37 (1.08,1.73)	
Emergency admissions in the prior year	None	1	0.002
	1 or 2	1.05 (0.87,1.27)	
	3 +	1.59 (1.22,2.05)	
Charlson Comorbidity Index Score	0	1	0.000
	1 or 2	1.47 (1.19,1.82)	
	3 +	1.99 (1.55,2.57)	
Co-morbid alcohol-related behavioural diagnosis	Yes	2.04 (1.37,3.03)	0.000
Past History of:	Chronic Heart Failure	1.48 (1.12,1.94)	0.005
	AMI	1.48 (0.99,2.22)	0.058
	COPD	1.35 (1.02,1.79)	0.035
	Moderate to severe renal disease	1.3 (1,1.71)	0.053
Admission Diagnosis	All other surgery (reference)	1	0.000
	Colorectal surgery	2.66 (1.62,4.37)	
	Respiratory or Tracheostomy	2.24 (1.71,2.93)	
	Upper GI surgery	1.94 (1.31,2.87)	
	Immunology and infections	1.9 (1.33,2.71)	
	Oncology, radio or chemotherapy	1.46 (0.96,2.21)	
	Gastroenterology	1.36 (0.85,2.15)	
	Orthopaedic surgery	1.21 (0.87,1.68)	
	Clinical cardiology	1.01 (0.67,1.51)	
	All other medical	0.82 (0.63,1.06)	
Transferred from residential care	Yes	1.36 (0.98,1.87)	0.064
Admission funding	Public	1	0.041
	Private	0.86 (0.71,1.05)	
	Other	1.37 (0.98,1.92)	
Emergency admission	Yes	1.36 (1.09,1.69)	0.006
Admission day	Weekday	1	0.183
	Saturday	1.06 (0.83,1.36)	
	Sunday	1.26 (0.98,1.6)	
Admission time	0700–0959	1	0.001
	1000–2359	1.33 (0.99,1.77)	
	2400–0659	1.74 (1.26,2.39)	
Admission season	Autumn	1	0.011
	Winter	1.25 (1,1.56)	
	Spring	1.04 (0.83,1.3)	
	Summer	1.41 (1.12,1.78)	

Interestingly, the comorbid conditions CHF and COPD were independently associated with MET review, even after adjusting for the Charlson Comorbidity Index. An even larger number of comorbid conditions were associated with MET within 7 days. These associations suggest that the risk of deterioration increases with the presence of particular comorbid conditions, as well as the overall comorbid disease burden.

The results of this study are consistent with previous studies that have reported that clinical deterioration is associated with comorbid disease, and [12,31,32] and with emergency admissions and inter-hospital transfers [12,33,34]. Previous studies have reported associations between general medicine, cardiothoracic, neurosurgery and stroke patients and clinical deterioration [12,33,34], however, in this study these patient groups had the lowest risk. The findings of this study also conflict with previous research reporting independent associations between age and clinical deterioration, [12,32,35,36] which were not evident in this study. In addition, the authors know of no previous study that has identified the importance of factors such as the day and time of admission in clinical deterioration.

This is the first study to demonstrate the potential to use information that is readily accessible at the time of admission to predict clinical. Previous studies have used variables such as physiological measurements or blood pathology, which are not immediately available at the time of admission [37,38], subsets of admissions such as medical patients [38,39], or predicted deterioration that occurs subsequent to another event such as discharge from ICU [40]. Understanding the important patient demographic and clinical characteristics associated with MET review is the first step to clinicians' prospectively identifying patients at increased risk of clinical deterioration. In the future this knowledge may allow proactive care interventions, or inform decisions about staffing and bed allocations. Additionally, although this study did not directly measure factors such as staffing conditions, it is clear that both admission time and date are associated with an increased risk of deterioration, suggesting seasonal and diurnal variation in healthcare systems and processes. This is an area that warrants further research.

The strengths of this study include using a large, high-quality data set collected in a hospital with a mature rapid response system. The data included in this study were collected contemporaneously during the admission, extracted retrospectively, and were limited to those that were routinely collected. The result was few missing data and variables that are readily accessible to clinicians at the time of hospital admission. A consecutive sample covering the full 12 moths of the year, ensured that the sample was representative of the study population. The mature RRS at the study site meant that the application of MET criteria and recording of MET reviews was consistent.

As a single-site study, with several highly-specialised referral services, the results of this study may have limited generalisability. However, it highlights the importance of medical history, admission diagnosis and the time and date of an admission in predicting MET review. The majority (> 95%) of MET reviews at the study site are recorded accurately, however systematic differences to those not recorded are possible. It is also possible that characteristics such as

patient age, diagnosis and comorbidities influence clinician behaviour and decisions, and alter the outcomes. Designing a study to take these limitations, such as potential clinician behaviour, into consideration would be extremely difficult and may even adversely impact patient care.

Future research should focus on validating these results in other conditions, both within the study setting and in external settings. Ultimately, this study shows that there is potential for clinicians to use variables present at the time of admission to stratify patients according to the risk of clinical deterioration.

6. Conclusions

This was the first study to demonstrate the potential to use information that is readily accessible at the time of admission to predict clinical deterioration. In this single-site cohort study several factors including previous emergency hospital admissions; Charlson Comorbidity Index score; history of chronic cardiac or respiratory illness; and admission diagnosis, time of day, and season were each independently associated with MET review within 48 h. These results enable the development of quality improvement strategies to prospectively identify patients with a high risk of clinical deterioration, and opportunities to enhance pre-MET clinical care.

Conflicts of interest

There are no competing interests to declare.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejim.2019.05.021.

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