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Missed Opportunities in Use of Medical Emergency Teams Prior to In-Hospital Cardiac Arrest

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Abstract

Background—Hospitals often employ Medical Emergency Teams (MET) to respond to patients with acute physiological decline so as to prevent deaths from in-hospital cardiac arrest (IHCA). We determined the frequency of missed opportunities for MET evaluation, defined as no MET evaluation prior to IHCA despite evidence of severe vital sign abnormalities 1 hour preceding cardiac arrest.

Methods—Within Get With The Guidelines-Resuscitation, we identified 21,913 patients from 274 hospitals with IHCA on general inpatient or telemetry floors who would be eligible for a MET evaluation prior to IHCA. We determined the proportion of patients with missed opportunities for MET evaluation, defined as no MET evaluation before IHCA despite at least one severe vital sign abnormality (pulse >150 or <30, respiratory rate >35 or <8, systolic blood pressure <80, and oxygen saturation <80%) 1, 2, and 4 hours before IHCA. The relationship between a hospital's proportion of missed opportunities for MET evaluation and its risk-standardized rate of survival to discharge for IHCA (derived using hierarchical linear regression models) was then evaluated.

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Results—Overall, few (3814 [17.4%]) patients with IHCA had a preceding MET evaluation, and the odds of a MET evaluation varied by >80% across hospitals (median: 14.6% [IQR: 9.1% to 22.2%]; median odds ratio, 1.82). Vital sign data were available for 13,115 (72.5%) of the 18,099 patients without MET evaluation. Of these patients, 5243 (40.0%), 4078 (31.1%), and 1767 (13.4%) had at least one severe vital sign abnormality 1, 2, and 4 hours before IHCA, respectively. Hospitals with the highest proportion of unevaluated patients despite severe vital sign abnormalities 2 and 4 hours preceding cardiac arrest had the lowest IHCA survival rate (correlation of -0.14 [$P=0.04$] and -0.16 [$P=0.01$], respectively).

Conclusions—Although MET teams are designed to prevent IHCA, many patients with severe vital sign abnormalities prior to IHCA did not have a MET evaluation, and hospitals with higher rates of unevaluated patients had lower IHCA survival. These findings suggest missed opportunities to efficiently use MET teams in current practice.

Introduction

In-hospital cardiac arrest (IHCA) occurs frequently in the U.S., affecting 200,000 people annually,¹ and is associated with a low survival rate of approximately 20%.² Given the poor prognosis once patients progress to cardiac arrest, medical emergency teams (MET),³⁻⁴ also known as rapid response teams,⁵ have been designed to respond to patients with acute physiological decline⁶⁻⁷ outside of intensive care units by ordering tests, initiating invasive treatments and therapies, and transferring patients to appropriate levels of critical care. However, few studies of MET teams have examined the extent to which patients with IHCA are evaluated by a MET team prior to cardiac arrest, and among those without evaluation, whether severe abnormalities in vital signs are present and could have prompted a MET evaluation.

In theory, MET teams have the potential to reduce the incidence and severity of IHCA and improve survival.⁸ However, results from MET studies have been mixed, and prior meta-analyses and systematic reviews of studies in adults have found variable results on whether MET teams reduce hospital-wide mortality.⁹⁻¹¹ This discordance between the theoretical advantage of MET teams and the results of clinical studies could be, in part, due to inefficient use of MET teams by hospitals. If the majority of patients with IHCA are not evaluated by a MET team prior to their arrest, and if many of these patients display severe derangements of vital signs at least 1 hour beforehand, this would represent missed opportunities in optimizing the benefits of MET team deployment.

To address this gap in knowledge, we linked data from the cardiac arrest and MET databases within Get With The Guidelines (GWTG)-Resuscitation, a large national registry for IHCA. We examined how often IHCA occurred without a preceding MET evaluation and, among those without MET evaluation, the frequency of severely abnormal vital signs at least 1, 2, and 4 hours prior to cardiac arrest. In addition, we examined whether hospitals with a higher proportion of patients without MET evaluation prior to IHCA despite vital sign abnormalities had lower survival rates for their patients with IHCA. Clarifying the extent to which MET teams are underused may identify potential missed opportunities to further optimize their use in hospitals.

Methods

Data Source

Get With the Guidelines®-Resuscitation (GWTG-Resuscitation), formerly the National Registry of Cardiopulmonary Resuscitation, is a large prospective quality-improvement registry of in-hospital cardiac arrests. Its design has been previously described in detail.¹² In brief, trained quality-improvement hospital personnel enroll all patients with cardiac arrest (defined as the absence of a palpable central pulse, apnea, and unresponsiveness) and without do-not-resuscitate orders who undergo cardiopulmonary resuscitation. Cases are identified by various methods within hospitals, including any of the following: centralized collection of cardiac arrest flow sheets, reviews of hospital paging system logs, and routine checks of code carts, pharmacy tracer drug records, and hospital billing charges for resuscitation medications.¹² The registry uses standardized Utstein-style definitions for patient variables and outcomes to facilitate uniform reporting across hospitals.¹³⁻¹⁴ Data accuracy is further ensured by rigorous certification of hospital staff and use of standardized software with data checks for completeness and accuracy.

Study Population

We derived the study cohort from hospitals that submitted data on adults 18 years of age or older to GWTG-Resuscitation between January 1, 2000, and December 31, 2014. Since our study examined whether a patient with IHCA had a preceding MET evaluation within 24 hours, we linked the registry's cardiac arrest and MET databases and then restricted our analyses to those hospitals that submitted data on both MET evaluations and IHCA. To ensure that IHCA events at these hospitals would have a MET evaluation documented, we further restricted analyses to include only IHCA events occurring after the date of the first MET evaluation at each hospital, which yielded 61,980 IHCAs.

As MET teams typically evaluate patients on only general inpatient and telemetry floors, we additionally excluded 41,702 patients from intensive care units, emergency rooms, and procedural and operative areas where MET teams would not be expected to respond. Since we were interested in examining IHCA outcomes, we excluded 401 patients with missing data on survival. Finally, we included 2036 patients who had a MET evaluation on a general or telemetry floor, were transferred by the MET team to an intensive care unit, and subsequently had an IHCA within 48 hours of transfer, to assign credit for the MET team response. Our final study cohort comprised 21,913 patients with IHCA at 274 hospitals (Figure 1).

Study Exposure

The main exposure of interest was whether a patient with IHCA had a preceding MET evaluation. Among patients without a MET evaluation, we examined whether patients had severe abnormal vital signs 1, 2, and 4 hours prior to IHCA. We used stringent definitions for six vital sign abnormalities that are typical triggers for MET team activation: heart rate >150 or < 30 beats per minute, respiratory rate > 35 or < 8 breaths per minute, systolic blood pressure < 80 mm Hg, and oxygen saturation level of < 80%.

Statistical Analysis

We first determined the proportion of patients with IHCA with and without a preceding MET evaluation. Baseline differences between patients with and without MET evaluation were then evaluated using X^2 tests for categorical variables and Student's t-tests for continuous variables.

To assess whether a MET team evaluation may have been warranted, we next examined whether patients without a MET evaluation had severe vital sign abnormalities (as detailed above) at least 1, 2, and 4 hours prior to cardiac arrest. In addition, we examined each patient's Modified Early Warning Score (MEWS) at one hour prior to cardiac arrest. The MEWS score assigns points of 0 to 3 for abnormalities in systolic blood pressure, heart rate, respiratory rate, temperature, and consciousness level (Supplementary Appendix eTable 1), with a MEWS score of > 4 denoting a high risk for death.¹⁵ For our analysis, we were only able to calculate the MEWS score based on the first 3 criteria, as information on temperature and consciousness level are not consistently captured within GWTG-Resuscitation.

Next, we conducted a series of hospital-level analyses and restricted the study sample to the 237 hospitals with at least 20 IHCA cases to provide more reliable estimates of hospitals' MET use among patients with IHCA. First, we examined hospital variation in the proportion of IHCA with a preceding MET evaluation by constructing a hierarchical regression model and quantifying the median odds ratio (MOR).¹⁶⁻¹⁸ The MOR represents the average odds of evaluation by a MET team for 2 statistically identical patients with an IHCA (i.e., similar demographics, comorbidities, and cardiac arrest characteristics) in one randomly selected hospital compared with another randomly selected hospital. The MOR is derived from the variance estimate of the random intercept from a hierarchical model, and is always 1 or greater. A MOR of 1 indicates no hospital variation in MET team evaluation prior to IHCA, whereas a MOR of 1.50 indicates that the odds of a preceding MET evaluation for a patient with IHCA are, on average, 50% higher in one randomly selected hospital compared with another.

Next, to assess the impact of not evaluating patients with severe vital sign abnormalities, we examined the correlation between a hospital's proportion of patients without MET evaluation but with abnormal vital signs 1, 2, and 4 hours prior to IHCA and the hospital's risk-standardized survival rate for IHCA. To accomplish this, we first computed risk-standardized survival rates for each hospital in the study cohort using a previously validated model.¹⁹ In brief, this methodology uses multivariable hierarchical regression models to account for eighteen key predictors of IHCA survival. Risk-standardization ensures similar case-mix severity to facilitate comparisons of IHCA outcomes across hospitals. We then computed Pearson correlation coefficients between a hospital's proportion of patients without MET evaluation but with abnormal vital signs 1, 2, and 4 hours prior to IHCA and the hospital's risk-standardized survival rate for IHCA.

For each analysis, we evaluated the null hypothesis at a 2-sided significance level of 0.05 and calculated 95% confidence intervals (CIs) using robust standard errors. All analyses were performed using SAS version 9.2 (SAS Institute, Cary, North Carolina) and R version 2.10.0 (R Foundation for Statistical Computing, Vienna, Austria).²⁰

The institutional review board of the Mid America Heart Institute approved the study and waived the requirement for informed consent. The authors are solely responsible for the design and conduct of the study, all analyses, the drafting and editing of the paper, and its final contents. Dr. Chan was supported by funding (K23HL102224 and R01HL123980) from the National Heart Lung and Blood Institute.

Results

Of 21,913 patients with IHCA, 3,814 (17.4%) patients were evaluated by a MET team prior to their cardiac arrest and 18,099 (82.6%) were not evaluated. The rate of MET evaluation prior to IHCA has increased modestly over the study period, from 14.3% for 2006-2007 to 18.1-19.5% for 2012-2014 (see Supplementary Appendix eFigure 1). Table 1 summarizes characteristics of the two groups. Overall, the mean age was 68.5 ± 15.2 , 42.9% were women, and 24.2% were of black race. Patients evaluated by a MET team prior to IHCA were younger and more frequently of female sex and black race. Moreover, those evaluated by a MET team were more likely to have respiratory insufficiency, hypotension, a metabolic or electrolyte abnormality, sepsis, cancer, and hepatic insufficiency at the time of their cardiac arrest and were more likely to have pulseless electrical activity as their initial cardiac arrest rhythm.

Vital sign data were available for 13,115 (72.5%) of the 18,099 patients without MET evaluation. Of these patients, 5243 (40.0%) had at least one severe vital sign abnormality 1 hour before their IHCA. In addition, 4078 (31.1%) had at least one severe vital sign abnormality at least 2 hours prior to cardiac arrest, and 1767 (13.4%) at least 4 hours prior (Table 2). At each time point, hypoxia with an oxygen saturation of $<80\%$ was the most common abnormality, followed by hypopnea (respiratory rate of <8) and hypotension (systolic blood pressure of <80) (Table 3). As a MEWS score of ≥ 4 portends a high risk of death, we also found that 14.2% without a MET evaluation had a MEWS score of ≥ 4 at least 1 hour before IHCA (Table 4).

Characteristics of the 237 hospitals with at least 20 cases of IHCA are summarized in Table 5. A majority (54.0%) of hospitals had a residency program (23.6% with residents and fellows and 30.4% with residents only), 53% of hospitals had a bed capacity of 200-499 beds, and the sites were distributed throughout the U.S. There was significant variation in the rate of MET evaluation prior to IHCA, with a median rate of 14.6% (interquartile range: 9.1% to 22.2%; range: 0.0% to 50.0%; Figure 2) and a MOR of 1.82, indicating an 82% average difference in the odds of 2 identical patients with IHCA having a preceding MET evaluation at one randomly selected hospital as compared with another. However, there was no association between hospital academic status, bed size, or geographical location and a hospital's rate of MET evaluation prior to IHCA, although there was a mild trend for non-teaching hospitals and hospitals located in the South to have higher rates of missed opportunities for MET evaluation despite evidence of severely abnormal vital signs at 1 hour prior to IHCA (see Table 5).

Across hospitals, not evaluating patients with a MET team despite severely abnormal vital signs prior to IHCA was associated with lower IHCA survival. There was an inverse

correlation between a hospital's proportion of patients without MET evaluation but with severely abnormal vital signs at 2 and 4 hours prior to IHCA and the hospital's risk-standardized survival rate for IHCA (Pearson correlation coefficients of -0.14 [$P=0.04$] and -0.16 [$P=0.01$], respectively), but this relationship was not observed for the 1 hour threshold (correlation of -0.11; $P=0.11$) prior to IHCA (Figure 3).

Discussion

In a large national registry, we found that more than 80% of patients are not evaluated by a MET team prior to their IHCA. Of those without a MET evaluation, two in five patients had severely abnormal vital signs at least 1 hour beforehand, which could have prompted a MET evaluation, and more than 1 in 8 had a MEWS vital sign score that portended a high risk for cardiac arrest and death. Notably, there was substantial hospital variation in the proportion of patients evaluated by a MET team, and hospitals with a high proportion of unevaluated patients, despite evidence of acute physiological decline, had lower survival rates for their patients with IHCA. Collectively, our findings provide important insights into whether MET teams are efficiently used in routine practice and illuminate potential missed opportunities in activating MET teams to respond to high risk patients.

Prior studies of MET teams have primarily focused on the effect of MET team implementation on rates of IHCA and mortality. These studies have yielded mixed results, and recent meta-analyses of MET team studies on adult inpatients have found significant heterogeneity on the impact of MET teams on hospital mortality rates.^{9, 11} Although the results of some MET team studies suggest they may be some effect on hospital mortality, the null finding in other studies also may be due, in part, to poor implementation of MET teams.

To date, few studies have examined missed opportunities in MET team activation. One single-center study found that among 188 patients with IHCA, only 20 (10.6%) occurred in non-intensive care unit patients with documented evidence of severely abnormal vital signs that could have prompted a MET team activation but did not.²¹ That study, however, reflected the experience of a single motivated institution and may not be generalizable to other hospitals. The multi-center MERIT trial found that only 30% of cardiac arrest patients (76/250) in hospitals randomized to a MET team had a MET evaluation >15 minutes prior to their IHCA, but the study did not report results for other time intervals.²² Our study extends the findings of prior studies by examining the frequency of MET team activations in over 21,000 patients with IHCA across 274 hospitals throughout the U.S, evaluated different time thresholds for MET activation (1, 2, and 4 hours), and assessed the impact of these gaps in care on patient outcomes. We found that only 1 in 7 patients were evaluated by a MET team prior to their IHCA, and that this rate varied substantially across hospitals from 0% to 50%. Indeed, the odds of MET evaluation among two identical patients varied, on average, by over 80% in one randomly selected hospital versus another randomly selected hospital. These findings suggest that use of MET teams is highly variable across hospitals with even the hospitals most aggressively using MET teams doing so in less than half of their patients who subsequently experience an IHCA.

One potential explanation for why many patients were not evaluated by a MET team prior to IHCA is because these patients declined acutely (i.e., within minutes) or did not have any physiological warning signs to prompt a MET evaluation. We examined this possibility by determining the proportion of patients without a MET evaluation who exhibited severely abnormal vital signs at least 1, 2, and 4 hours prior to their arrest. We used more stringent criteria for defining vital sign abnormalities than is traditionally used for MET team activation to ensure that our reported rates represented significant departures from normal physiology (e.g., systolic blood pressure of <80). Our findings suggest there were numerous missed opportunities to activate a MET team, as 2 in 5 patients with IHCA and without a MET evaluation had severely abnormal vital signs at least one hour prior to their IHCA.

We also found that higher rates of missed opportunities for MET evaluation despite severely abnormal vital signs at 2 and 4 hours prior to an IHCA were associated with lower rates of survival for that hospital's cardiac arrest patients. Interestingly, we did not find a significant relationship when we examined a hospital's rate of no MET activation despite severely abnormal vital signs at 1 hour prior to cardiac arrest. This may be because there are other competing demands during the first hour in a patient with acute physiological decline (e.g., notifying primary medical or surgical team, discussions with nursing supervisor regarding transfer of care, or family meetings regarding goals of care and code status), and therefore the relationship at the 1-hour threshold may have been confounded by other indicators of good patient care and communication.

Nevertheless, there is a critical need to better understand how to optimize activation and use of MET teams, especially given that nearly all hospitals throughout the U.S. have devoted resources to them. Despite the Institute of Healthcare Improvement's promotion of their adoption, it is possible that MET teams have not been as successful in achieving their stated goals of reducing hospital mortality because of their imprecise implementation.²³ Although we found that the proportion of IHCAs with a preceding MET evaluation has increased modestly from 14% to 18-19% over the past decade, many patients remain unevaluated despite evidence of acute physiological decline. Further research is needed to assess whether hospitals need to standardize the training of MET team and nursing staff members to maximize their effectiveness and efficiency. Moreover, hospitals may wish to conduct prospective root cause analyses to examine the reasons why a MET team is not activated, despite abnormal vital signs preceding an IHCA and provide immediate feedback to all staff involved (nurses and MET team members) to better understand how best to decrease missed opportunities for MET team use. This type of feedback strategy has been shown to improve outcomes in other aspects of IHCA care (e.g. debriefing after an acute resuscitation²⁴) and will be critical to optimizing use of MET teams.

Our study should be interpreted in the context of the following limitations. First, GWTG-Resuscitation is a quality-improvement registry, so our findings may not represent the experience of non-registry hospitals. To the extent that this is true, the rate of missed opportunities in MET activation among non-registry hospitals could be higher as these hospitals may not have ongoing quality improvement initiatives in resuscitation care. Second, we did not have data for all the components of the MEWS risk score (such as temperature and consciousness); therefore, the rate of an abnormal MEWS score 4 is

likely higher than the 14% rate that we found, which underscores that significant acute physiological decline was still detectable in many patients in this study using only 3 of the 5 variables in this score. Third, we did not have more detailed information on hospitals (e.g., cancer or geriatric hospitals), which may have explained some of the hospital variation in rates of missed opportunities for MET evaluation. Nonetheless, lack of this information is not likely to have affected the main objective of our hospital-level analysis—the correlation between a hospital's rate of missed opportunities for MET evaluation and its risk-standardized survival rate for patients with IHCA as our risk-standardized survival analyses accounted for patients' malignancy status and age. Fourth, we did not have data on all hospitalized patients (i.e., those with and without IHCA) with severely abnormal vital signs, so we could not globally assess MET team efficiency among total hospital admissions. Our assessment of use of MET teams was limited to an examination of patients who progressed to IHCA and thus do not represent IHCA incidence, but rather the proportion of patients experiencing an IHCA who would have been potential candidates for MET team evaluation. Moreover, we did not have specific details on hospital MET teams (e.g., composition) and therefore were unable to assess whether certain types of MET teams were more consistent in responding to patients with acute physiological decline.

In conclusion, we found that most patients with IHCA in hospitals that had MET teams were not evaluated by a MET team prior to their cardiac arrest, and the rate of MET team evaluation prior to IHCA varied substantially across hospitals. Many patients without a preceding MET evaluation had signs of acute physiological decline prior to IHCA, suggesting missed opportunities for use of MET teams, and hospitals with the highest rates of missed opportunities in such patients had the lowest survival rate for their patients with IHCA. Our findings suggest opportunities to optimize the use of MET teams across hospitals in order to improve resuscitation care and outcomes.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1. Derivation of the Study Cohort

*Analyses restricted to study hospitals with at least 20 cases of in-hospital cardiac arrest (IHCA)

Figure 2. Hospital Variation in IHCA Patients with Preceding MET Team Evaluation

The odds that two identical patients with IHCA were evaluated by a MET team varied by over 80% (median odds ratio of 1.82) between two randomly selected hospitals in the study cohort

Figure 3. Correlation Between a Hospital's Rate of Missed Opportunities for MET Team Evaluation prior to IHCA and its Risk-Standardized Survival Rate (RSSR) for IHCA

Hospitals with higher rates of missed opportunities (no MET evaluation prior to IHCA despite evidence of severely abnormal vital signs) had lower survival rates for its patients with IHCA.

A: Relationship between a hospital's proportion of patients with no MET evaluation despite severely abnormal vital signs ≥ 1 hours prior to IHCA and its RSSR for IHCA

B: Relationship between a hospital's proportion of patients with no MET evaluation despite severely abnormal vital signs ≥ 2 hours prior to IHCA and its RSSR for IHCA

C: Relationship between a hospital's proportion of patients with no MET evaluation despite severely abnormal vital signs ≥ 4 hours prior to IHCA and its RSSR for IHCA

Table 1
Baseline Characteristics of Patients, Stratified by MET Evaluation Prior to IHCA

	Total n = 21,913	MET Evaluation n = 3814	No MET Evaluation n = 18,099	P value
<i>Demographics</i>				
Age				< 0.001
Mean $\pm$ standard deviation	68.5 $\pm$ 15.2	66.5 $\pm$ 15.6	68.9 $\pm$ 15.1	
Median (inter-quartile range)	70.0 (59.0, 80.0)	68.0 (56.0, 78.0)	71.0 (59.0, 81.0)	
Male Sex	12,515 (57.1%)	2061 (54.0%)	10,454 (57.8%)	< 0.001
Race				< 0.001
White	20,686 (69.1%)	2474 (64.9%)	12,542 (69.3%)	
Black	7106 (23.7%)	1073 (28.1%)	4239 (23.4%)	
Other	723 (2.4%)	111 (2.9%)	417 (2.3%)	
Unknown	1440 (4.8%)	156 (4.1%)	901 (5.0%)	
<i>Pre-Existing Conditions</i>				
Respiratory insufficiency	7302 (33.3%)	1776 (46.6%)	5526 (30.5%)	< 0.001
Renal insufficiency	7495 (34.2%)	1347 (35.3%)	6148 (34.0%)	0.11
Diabetes mellitus	7410 (33.8%)	1128 (29.6%)	6282 (34.7%)	< 0.001
Hypotension	3330 (15.2%)	1195 (31.3%)	2135 (11.8%)	< 0.001
Heart failure this admission	4116 (18.8%)	651 (17.1%)	3465 (19.1%)	0.002
Heart failure prior to admission	5277 (24.1%)	794 (20.8%)	4483 (24.8%)	< 0.001
MI this admission	2277 (10.4%)	395 (10.4%)	1882 (10.4%)	0.94
MI prior to admission	3172 (14.5%)	450 (11.8%)	2722 (15.0%)	< 0.001
Metabolic/electrolyte abnormality	2780 (12.7%)	698 (18.3%)	2082 (11.5%)	< 0.001
Sepsis	3131 (14.3%)	752 (19.7%)	2379 (13.1%)	< 0.001
Pneumonia	3132 (14.3%)	574 (15.0%)	2558 (14.1%)	0.14
<i>Pre-Existing Conditions</i>				
Metastatic malignancy	3411 (15.6%)	683 (17.9%)	2728 (15.1%)	< 0.001
Baseline depression in CNS function	2258 (10.3%)	357 (9.4%)	1901 (10.5%)	0.03
Hepatic insufficiency	1489 (6.8%)	358 (9.4%)	1131 (6.2%)	< 0.001
Acute CNS non-stroke event	1336 (6.1%)	266 (7.0%)	1070 (5.9%)	0.01
Acute stroke	779 (3.6%)	148 (3.9%)	631 (3.5%)	0.23
Major trauma	426 (1.9%)	75 (2.0%)	351 (1.9%)	0.91
<i>Characteristics of arrest</i>				
Initial cardiac arrest rhythm				< 0.001
Asystole	8416 (38.4%)	1064 (27.9%)	7352 (40.6%)	
PEA	10409 (47.5%)	2340 (61.4%)	8069 (44.6%)	
Ventricular Fibrillation	1841 (8.4%)	189 (5.0%)	1652 (9.1%)	
Pulseless VT	1247 (5.7%)	221 (5.8%)	1026 (5.7%)	
Day and Time of Arrest				0.002
Weekday (7:00am - 10:59pm)	9834 (44.9%)	1788 (46.9%)	8046 (44.5%)	
Weeknight (11:00pm - 6:59am)	4658 (21.3%)	739 (19.4%)	3919 (21.7%)	
Weekend	7421 (33.9%)	1287 (33.7%)	6134 (33.9%)	

	Total n = 21,913	MET Evaluation n = 3814	No MET Evaluation n = 18,099	P value
Event Location				< 0.001
General inpatient floor	10114 (46.2%)	892 (23.4%)	9222 (51.0%)	
Telemetry unit	9763 (44.6%)	886 (23.2%)	8877 (49.0%)	
Transferred by MET team from general or telemetry unit to ICU	2036 (9.3%)	2036 (53.4%)	0 (0.0%)	

Abbreviations: CNS, central nervous system; IHCA, in-hospital cardiac arrest; ICU, intensive care unit; MET, medical emergency team; MI, myocardial infarction; PEA, pulseless electrical activity; VT, ventricular tachycardia

Table 2
Timing of Severely Abnormal Vital Signs

The proportion of patients without a MET evaluation and with severely abnormal vital signs at 1, 2, and 4 hour prior to in-hospital cardiac arrest are summarized.

Timing of Abnormal Vital Signs	N (%)
No Abnormal Vital Signs	7291 (55.6)
Occurring at < 1 hour	581 (4.4)
Occurring between 1 to <2 hours	1165 (8.9)
Occurring between at 2 to <3 hours	1186 (9.0)
Occurring between at 3 to <4 hours	1125 (8.6)
Occurring between 4 hours	1767 (13.5)
Total: 13,115	
Cumulative Frequency of Vital Sign Abnormality	N (%)
Abnormal vital signs 1 hour	5243 (40.0)
Abnormal vital signs 2 hours	4078 (31.1)
Abnormal vital signs 4 hours	1767 (13.4)

Table 3
Vital Sign Abnormalities at Each Time Threshold Before In-Hospital Cardiac Arrest*

Hypoxia was the most common severely abnormal vital sign at each time threshold, followed by hypopnea and hypotension.

	HR <30	HR >150	RR <30	RR >35	Systolic BP <80	O2 sat <80%
1 hour	1016 (7.7%)	61 (0.5%)	1988 (15.2%)	354 (2.7%)	1882 (14.3%)	3816 (29.1%)
2 hours	735 (5.6%)	43 (0.3%)	1439 (11.0%)	237 (1.8%)	1376 (10.5%)	2971 (22.7%)
4 hours	253 (1.9%)	20 (0.2%)	507 (3.9%)	85 (0.6%)	422 (3.2%)	1324 (10.1%)

Abbreviations: BP, blood pressure; HR, heart rate; O2 sat, oxygen saturation; RR, respiratory rate.

* Denominator for each table cell is the 13,115 patients with no MET evaluation prior to in-hospital cardiac arrest and with information on vital signs

Table 4
Modified Early Warning Score (MEWS) at 1 hour Prior to Cardiac Arrest*

The distribution of MEWS score for patients without a MET evaluation prior to in-hospital cardiac arrest is summarized.

MEWS Score at 1 Hour	N (%)
0	749 (6.9)
1	4226 (39.1)
2	2614 (24.2)
3	1695 (15.7)
4	865 (8.0)
5	416 (3.8)
6	157 (1.5)
7	61 (0.6)
8	27 (0.3)
9	7 (0.06)
10	1 (0.01)
Cumulative MEWS	N (%)
4	1534/10,818 (14.2)
5	669/10,818 (6.5)

* A MEWS score was not available for 2297 patients, either because only vital signs < 1 hour preceding cardiac arrest was submitted or because a complete set of vital signs was not available to generate a MEWS score

Table 5
Association Between Hospital Factors and MET Evaluation Rates

There was no association between hospital characteristics and a hospital's rate of MET evaluation prior to IHCA, but there was a mild trend for non-teaching hospitals and hospitals located in the South to have higher rates of missed opportunities for MET evaluation.

	Hospitals with 20 IHCAs n = 237	Proportion of IHCA Evaluated by MET	Rate of Missed Opportunities for MET Evaluation	
			1 hour*	P
Teaching Status				0.90
Major teaching (residents and fellows)	56 (23.6%)	16.7% ± 12.2%	31.8% ± 20.0%	0.79
Minor teaching (residents only)	72 (30.4%)	15.9% ± 9.6%	37.3% ± 24.7%	
Non-teaching (no trainees)	109 (46.0%)	16.2% ± 10.2%	41.5% ± 27.4%	
Hospital Bed Number				0.86
< 200	59 (24.9%)	15.6% ± 10.4%	39.3% ± 30.8%	
200 to 499	125 (52.7%)	16.6% ± 10.5%	37.0% ± 23.6%	
500	53 (22.4%)	16.4% ± 11.7%	38.5% ± 22.9%	0.09
Census Location				
North Mid Atlantic	36 (15.2%)	15.7% ± 11.2%	38.7% ± 30.1%	
South Atlantic	73 (30.8%)	16.4% ± 11.3%	39.2% ± 25.3%	
North Central	46 (19.4%)	15.2% ± 7.9%	39.3% ± 23.2%	
South	41 (17.3%)	16.9% ± 11.2%	43.8% ± 27.1%	
Mountain / Pacific	41 (17.3%)	17.7% ± 11.3%	28.0% ± 17.5%	

* Missed opportunities were defined as no MET team evaluation despite evidence of severely abnormal vital signs 1 hour prior to IHCA

Abbreviations: IHCA, in-hospital cardiac arrest; MET, medical emergency team