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Patient physiological status at the emergency department-ward interface and emergency calls for clinical deterioration during early hospital admission

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PATIENT PHYSIOLOGICAL STATUS AT THE EMERGENCY DEPARTMENT - WARD INTERFACE AND EMERGENCY CALLS FOR CLINICAL DETERIORATION DURING EARLY HOSPITAL ADMISSION

Running title: ED-ward interface and clinical deterioration

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Author contributions: JCo, JCu and DJ conceived the study, designed the trial, and obtained research funding. JCo, JCu, DJ and DP supervised the conduct of the trial and data collection. JCo analysed the study data. JCo and JCu provided statistical advice. JCo drafted the manuscript, and all authors contributed substantially to its revision. JCo takes responsibility for the paper as a whole.

ABSTRACT

Aims: to examine the relationship between physiological status at the emergency department -ward interface and emergency calls (medical emergency team or cardiac arrest team activation) during the first 72 hours of hospital admission.

Background: Ward adverse events are related to abnormal physiology in emergency department however the relationship between physiology at the emergency department-ward interface and ward adverse events is unknown.

Design: descriptive, exploratory design

Methods: the study involved 1980 patients at three hospitals in Melbourne Australia: i) 660 randomly selected adults admitted via the emergency department to medical or surgical wards during 2012 and who had an emergency call; and ii) 1320 adults without emergency calls matched for gender, triage category, usual residence, admitting unit and age.

Results/Findings: the median age was 78 years and 48.8% were males. The median time to the first emergency call was 18.8 hours and ≥1 abnormal parameters were documented in 34.9% of patients during the last hour of ED care and 47.1% of patients during first hour of ward care. Emergency calls were significantly more common in patients with heart rate and conscious state abnormalities during the last hour of emergency care and abnormal oxygen saturation, heart rate or respiratory rate during the first hour of ward care. Medical emergency team afferent limb failure occurred in 55.3% patients with medical emergency team activation criteria during first hour of ward care.

Conclusion: The use of physiological status at the emergency department-ward interface to guide care planning and reasons for and outcomes of medical emergency team afferent limb failure are important areas for future research.

Keywords: emergency nursing; patient safety; risk management; rapid response teams

SUMMARY STATEMENT

Why is this research or review needed?

- Many countries are using emergency department length of stay of 4-6 hours as a quality of care indicator
- There are concerns that moving patients quickly through emergency departments will result in increased numbers of physiologically unstable patients transferred to hospital wards
- There is a clear relationship between physiological abnormality in the emergency department and subsequent ward adverse events but the relationship between physiological status at the emergency department -ward interface and ward safety is unknown

What are the key findings?

- Abnormal physiological observations at the emergency department -ward interface were common and were documented in one in three patients leaving the emergency department and one in two patients arriving on ward
- Relationships between physiological abnormalities and risk of emergency calls for clinical deterioration
- One in two patients with parameters fulfilling medical emergency team activation criteria during first one hour of ward care experienced medical emergency team afferent limb failure.

How should the findings be used to influence policy/practice/research/education?

- The utility of physiological status at the transition between the emergency department and inpatient wards to guide care planning, particularly frequency of nursing and medical assessments warrants further analysis
- The reasons why nurses do and do not activate medical emergency team for patients who fulfil activation criteria and outcomes of medical emergency team afferent limb failure are important areas for future research.

INTRODUCTION

Many countries including Australia have introduced time-driven Emergency Department (ED) performance indicators, particularly ED length of stay (LOS) targets of 4-6 hours (Geelhoed and de Klerk 2012, Baggoley *et al*. 2011, Department of Health 2010). An area of concern is that shorter ED LOS will result in increased numbers of physiologically unstable patients transferred to hospital wards, which may lead to increased emergency calls for clinical deterioration such as cardiac arrest team or Medical Emergency Team (MET) activation during the early stage of hospital admission (Considine *et al*. 2014). Although implementation of METs has decreased cardiac arrests and ICU admissions in ward patients (DeVita *et al*. 2004, Jones *et al*. 2011, Bellomo *et al*. 2003), the in-hospital mortality of patients who have an MET review is as high as 34% (Buist *et al*. 2002, Casamento *et al*. 2008, Calzavacca *et al*. 2010) making MET activation a high risk patient event (Jones *et al*. 2012).

Studies of emergency calls for clinical deterioration in patients admitted to medical or surgical wards from the ED show that as many as one-quarter of hospital wide emergency

calls are in patients admitted to medical or surgical wards via ED during the first 24 hours of emergency admission (Considine *et al*. 2014). Up to half of emergency calls for clinical deterioration occurring during the first 24 hours of emergency admission were in the first 8 hours (Berkovits *et al*. 2013).

Background

Several studies have investigated the relationship between physiological status in ED and patient outcomes, such as hospital admission (Burch *et al*. 2008), in-hospital death (Groarke *et al*. 2008, Burch *et al*. 2008) need for critical care admission (Groarke *et al*. 2008) and emergency calls in the early stages of hospital admission (Considine *et al*. 2015a, Considine *et al*. in press). Predictors of hospital admission include systolic blood pressure ≤100 mm Hg, pulse rate >130 beats per minute, respiratory rate >30 breaths per minute, temperature >38.5^{0}Celcius and altered conscious state (Burch *et al*. 2008). Predictors of in hospital death were include systolic blood pressure ≤100 or ≥200 mm Hg, respiratory rate >30 breaths per minute and altered conscious state (Burch *et al*. 2008). Known predictors of unplanned ICU admission in patients admitted to hospital through the ED are older age, male sex, higher acuity triage category and a history of comorbid conditions (Frost *et al*. 2009). Clinical factors evident on ED arrival predictive of critical care admission (ICU and CCU) in patients triaged as low to moderate acuity were chief complaints of nausea, vomiting and diarrhoea on ED arrival; heart rate or temperature abnormalities at triage; and respiratory rate or heart rate abnormalities at first ED nursing assessment (Considine *et al*. 2009).

A study comparing matched patients who did and did not require an emergency call within 72 hours of admission to a hospital ward from the ED showed that the emergency call patients were more likely to have physiological abnormalities fulfilling hospital MET activation criteria during ED care (36.7% vs 23.8%; p<0.001) (Considine *et al*. 2015a). Further, emergency call patients had more in-hospital deaths (16.5% vs 3.6%, p<0.001), more ICU admissions (11.8% vs 0.7%, p<0.001) and longer hospital length of stay (median = 8 days vs 5 days, p<0.001) than patients who did not require an emergency call (Considine *et al*. 2015a). Specifically, tachypnoea (AOR=2.69, 95%CI: 1.78 - 4.07) or hypotension (AOR=1.43, 95%CI: 1.00 - 2.03) fulfilling MET activation criteria during ED care were associated with increased risk of emergency call within 72 hours of admission (Considine *et*

al. 2015a). Similarly, respiratory rate at triage and heart rate before ward transfer were predictors of MET activation within 24 hours of transfer from ED to hospital wards (Mora *et al*. in press). For each breath per minute increase in respiratory rate (OR 1.07, 95%CI: 1.02 - 1.12) or beat per minute increase in heart rate (OR=1.02, 95% CI: 1.002 - 1.030) increased the risk of MET activation during the first 24 hours of hospital admission (Mora *et al*. in press). Again, patients with MET activation within 24 hours of admission, had greater mortality than like patients who did not require a MET call (21% vs 6%, p = 0.0003).

The strong relationship between abnormal physiological states during ED care and subsequent adverse events on the ward raise questions about whether or not the patient was stable enough for transfer from the ED to the wards. Intra-hospital transfer is recognised a period of high patient risk for critically ill patients (Australasian College for Emergency Medicine (ACEM) *et al*. 2015). There are studies of intra-hospital transfer of patients from ED to inpatient wards from a handover perspective (Ong and Coiera 2011, Venkatesh *et al*. 2015) but no studies of the transfer process and particularly patient assessment during this time. Whether patient physiological status at this critical juncture of movement from ED to hospital wards has a relationship with emergency calls for clinical deterioration in the early stages of admission and could be used to plan care on the ward remains unknown.

THE STUDY

Aim

The aim of this study was to examine the relationship between physiological status at the ED-ward interface and emergency calls for clinical deterioration during the first 72 hours of hospital admission via the ED. The ED-ward interface was defined as the last hour of ED care and first hour of ward care. This period was chosen because observations of practice highlight this as a period of intensive activity related to patient flow and meeting ED and hospital performance targets. During this time, there is tension between ensuring physiological stability and patient safety and patient movement to maintain ED and hospital function. At all sites there were policies mandating physiological observations on admission to clinical areas, including wards but there were no formal policies mandating physiological observations when leaving a clinical area, including the ED. Emergency calls for clinical deterioration were defined as a Medical Emergency Team (MET) or cardiac arrest team (CAT) activation. Time of hospital admission was defined as the time the patient left the ED.

The specific research questions were as follows:

i) What were the timing and outcomes of emergency calls for clinical deterioration during the first 72 hours of hospital admission via the ED?

ii) What were the characteristics of physiological assessment and the frequency of abnormal physiological parameters during the last hour of ED care and first hour of ward care?

iii) Was there a relationship between abnormal physiological parameters during the last hour of ED care or first hour of ward care with subsequent emergency calls for clinical deterioration?

iv) What was the frequency of MET afferent limb failure in patients who had physiological parameters fulfilling MET activation criteria documented during first hour of ward care?

The timing of emergency calls during the first 72 hours of hospital admission were categorised as follows:

- no emergency call
- early emergency call occurring during the first 4 hours of admission,
- intermediate emergency call occurring between 4.1-24 hours of admission and
- late emergency call occurring between 24.1-72 hours of admission.

The time points for emergency calls were chosen based on the methodologies of other single site studies that have examined emergency calls within 24 (Mora *et al*. in press, Considine *et al*. 2014) and 72 hours (Considine *et al*. 2014) of admission in similar patient cohorts. Early emergency calls occurring within 4 hours of admission to the ward were deliberately included for two reasons. First, the majority of initial care planning and interventions for new patients admitted to wards occurs during this period of time. Second, there have been suggestions that performance targets requiring shorter ED LOS will result in increased numbers of unstable patients transferred to hospital wards. A high incidence of early calls could be seen as further evidence of this phenomenon.

Normal physiological parameters were defined as respiratory rate 12-22 breaths / minute, oxygen saturation ≥95%, heart rate 60-100 beats per minute, systolic blood pressure 90-140 mmHg, alert conscious state and temperature 35.0-37.8^{0}C (Considine *et al*. 2009). MET afferent limb failure was defined as failure to make an emergency call in patients fulfilling

hospital MET activation criteria (Trinkle and Flabouris 2011). Afferent limb failure was an area of focus of this study as it is recognised as a patient safety performance indicator (Trinkle and Flabouris 2011).

Design

A descriptive, exploratory design was used to address the research aims. This study was a secondary analysis of data from a case-control study that aimed to examine the relationship between MET or cardiac arrest team (CAT) call within 72 hours of emergency admission and physiological status in the emergency department (ED) (Considine *et al*. 2015a).

Setting

The study was conducted at three hospitals in metropolitan Melbourne. The number of admissions via the ED per year is approximately 23268 Hospital A, 26012 at Hospital B and 30413 at Hospital C (National Health Performance Agency 2013). At all hospitals, deteriorating ED patients were managed by ED clinicians within their own resources. Ward patients who meet predefined criteria for clinical deterioration or who have a cardio-respiratory arrest are immediately attended by the MET or cardiac arrest team. In all organisations, the MET or cardiac arrest team comprised the usual major components of a rapid response system: afferent and efferent limbs (DeVita *et al*. 2010). The afferent limb or the method of detecting patients at risk of serious adverse events and calling for help (DeVita *et al*. 2010) was based on a single parameter trigger approach whereby patients had to fulfil only one of the predefined criteria for clinical deterioration for MET to be activated. The efferent limb or team that responds to calls for assistance (DeVita *et al*. 2010), comprised an intensive care doctor, specialist critical care nurse, medical staff from the parent medical team when the MET was activated. In the case of the cardiac arrest team, support from an anaesthetist and coronary care nurse is added. ED patient assessment data were entered into an electronic ED information system at Hospital A and hand written onto paper charts that are later scanned into the patient's electronic medical record at Hospitals B and C. On the wards at all sites, paper based charts were used that were later scanned into the patient's electronic medical record.

Sample

This study used data 1980 patients from a case-control study that examined the relationship between MET or CAT call within 72 hours of emergency admission and physiological status

in the ED (Considine *et al*. 2015a). There were 660 randomly selected adults admitted via the ED to non-monitored medical or surgical wards during 2012 and who had an emergency call for clinical deterioration within 72 hours of admission and 1320 adults matched for gender, ED triage category, place of usual residence, admitting unit and age in whom an emergency call did not occur. Patients aged less than 18 years, patients transferred from the ED to a ward with continuous monitoring (such as intensive care unit, high dependency unit, coronary care unit (CCU), neurosurgery, cardiac surgery and thoracic surgery wards) and patients admitted to short stay units or observation wards, mental health and maternity wards were excluded. SPSS Version 21.0 (IBM Corporation 2012) was used to undertake random selection. Patients were then categorised into four groups based on the timing of their emergency call for clinical deterioration as described above: no call, early call (0-4 hours after admission), intermediate call (4.1 – 24 hours after admission) and late call (24.1 – 72 hours after admission).

Data collection

Study data were collected by retrospective medical record audit. Patient characteristics and assessment of physiological status during the last hour of ED care and first hour of ward care were collected for each patient. For patients who had an emergency call, the type and outcome of emergency calls were also collected. For the purposes of this paper, physiological status refers to assessment of one or more of the following parameters: respiratory rate, oxygen saturation, heart rate, systolic blood pressure, conscious state, temperature and pain score. A complete set of physiological observations was defined as assessment of respiratory rate, oxygen saturation, heart rate, blood pressure, temperature and conscious state as per the Australian Commission on Safety and Quality in Health Care criteria (Australian Commission on Safety and Quality in Health Care (ACSQHC) 2010).

Ethical considerations

The study was approved by the Human Research and Ethics Committees at the three study sites and Deakin University.

Data analysis

Data were analysed using SPSS 22.0. Descriptive statistics were used to summarise the study data. As data were not normally distributed (according to the Kolmogorov–Smirnov test),

medians and interquartile ranges (IQRs) are presented and between-group comparisons were performed using Chi Square test. Statistical significance was indicated by $p < 0.05$.

Reliability and validity

To ensure consistency of data collection, a project specific data collection tool and detailed data dictionary were developed and piloted by the research team. Data were collected by one research nurse per site; the three research nurses had specific training in the use of the tool and data dictionary by members of the research team (JCo).

RESULTS

Emergency call characteristics and outcomes

There were 1980 patients included in the study; the median age was 78 years (IQR = 63 to 85) and 48.8% were males (n=1014). In patients who had an emergency call (n=660), the median time from leaving the ED to the first emergency call was 18.8 hours (IQR 7.3 to 37.9); 15.4% were early calls (n=102), 43.5% were intermediate calls (n=287) and 41.1% were late calls (n=271).

The median time to emergency calls was 1.6 hours (IQR = 0.7 to 2.9) for early calls (n=102), 12.2 hours (IQR 7.8 to 17.9) for intermediate calls (n=287) and 42.3 hours (IQR 31.4 to 54.4) for late calls (n=271). The majority of patients (87.2%, n=576/660) remained on the ward immediately following an emergency call, 8.6% (n=57/660) were transferred to ICU and 2.3% (n=15/660) died.

Overall, the in-hospital mortality was 7.9% (n=156/1980). The in-hospital mortality was 3.5% (47/1320) in patients with no emergency call. For patients with emergency calls, the in-hospital mortality was 18.6% (19/102) in patients with early emergency calls, 19.8% (57/287) in patients with intermediate emergency calls and 12.2% (33/271) in patients with late emergency call. A limitation of medical treatment order was in place on ED discharge for 22.0% (n=436) patients and 22.9% (n=100) of these patients died in hospital. When patients with limitation of medical treatment orders were excluded, the in-hospital mortality was 0.9% (10/1074) for patients with no emergency call, was 9.0% (6/67) in patients with early emergency calls, 10.0% (21/207) in patients with intermediate emergency calls and 9.8% (19/194) in patients with late emergency calls.

Physiological assessment during last hour of ED care

During the last hour of ED care, 84.6% of patients (n=1676/1980) had documentation of at least one physiological parameter. The median number of parameters documented was 4 (IQR = 1 to 6). The frequency of documentation of specific parameters in the last hour of ED care is shown in Figure 1. A complete set of physiological observations (Australian Commission on Safety and Quality in Health Care (ACSQHC) 2010) occurred in 15.0% (n=297/1980) of all patients; 14.4% (n=190) of patients with no call; 12.5% of (n=34) patients with early calls; 17.1% (n=24) of patients with intermediate calls; and 23.5% (n=49) of patients with late calls (χ^2 = 8.448, p=0.038).

During the last hour of ED care, 34.9% (n=691/1980) of patients had one or more parameters that were abnormal, but these did not necessarily fulfil hospital MET activation criteria. The most common abnormal parameters were systolic blood pressure (32.6%), heart rate (19.1%) and conscious state (15.1%) (Table 2). Subsequent emergency calls on the ward were less common in patients with abnormal systolic blood pressure and more common in patients with heart rate and conscious state abnormalities during the last hour of emergency care (Table 2). Patients with abnormal systolic blood pressure and abnormal conscious state had lower proportion of early calls compared with late and intermediate calls; and patients with abnormal heart rate had a higher proportion of intermediate calls when compared with early and late calls (Table 2).

Physiological assessment during first hour of ward care

At least one physiological parameter was documented in 94.6% of patients (n=1873/1980) during the first hour of ward care. The median number of parameters measured was 6 (IQR = 5 to 7). The frequency of documentation of specific parameters is shown in Figure 2. During the first hour of ward care, a complete set of physiological observations (Australian Commission on Safety and Quality in Health Care (ACSQHC) 2010) occurred in 53.7% (n=1064) of all patients; 53.2% (n=702) of patients with no calls; 54.9% of (n=56) patients with early calls; 60.6% (n=174) of patients with intermediate calls; and 48.7% (n=132) of patients with late calls (χ^2 = 8.456, p=0.037).

During the first hour of ward care, 47.1% of patients (n=932) had one or more parameters that were abnormal, but not necessarily fulfilling hospital MET activation criteria. The most common abnormal parameters were systolic blood pressure (28.3%), oxygen saturation

(16.7%) and heart rate (16.4%) (Table 3). Patients with abnormal oxygen saturation, heart rate and respiratory rate during the first hour of ward care were significantly more likely to require an emergency call during the first 72 hours of admission (Table 3). When timing of emergency call was examined, patients with abnormal oxygen saturation had lower proportion of early calls compared with late and intermediate calls. Patients with abnormal heart rate or respiratory rate had a higher proportion of intermediate calls when compared with early and late calls (Table 3).

Medical Emergency Team afferent limb failure

Using physiological observations from the first hour of ward care, we examined the frequency of documentation of parameters fulfilling hospital MET activation criteria (Table 1) and the subsequent incidence of MET afferent limb failure. During the first hour of ward care, 9672 parameters were measured in 1980 patients. Of these, 201 parameters fulfilled hospital MET activation criteria in 188 patients. The majority of patients had a single documented parameter fulfilling MET activation criteria. Only seven patient had two parameters that fulfilled MET activation criteria; three patients had three parameters fulfilling MET activation criteria (Table 4). Afferent limb failure occurred in 53.7% of documented parameters fulfilling MET activation criteria (n=108/201). At a patient level, afferent limb failure occurred in 55.3% (n=104/188) patients with MET activation criteria.

Afferent limb failure occurred in 50-58.8% of occurrences of hypotension, altered conscious state, hypoxaemia, tachycardia and bradycardia and 38.9% of occurrences of tachypnoea (Table 4). The majority of emergency calls for hypotension (71.4%) and tachypnoea (72.7%) were early calls; the majority of calls for tachycardia were intermediate calls (60.0%); and calls for altered conscious state and hypoxaemia tended to be spread across the time points studied (Table 4).

DISCUSSION

This study had four major findings. First, early calls within the first four hours of hospital admission were uncommon (15.4% of calls) and the period of highest risk for an emergency call seems to be between 7 and 38 hours. Second, there was variability in physiological assessment and high frequency of abnormal physiological observations at the ED-ward interface. Third, there were clear relationships between physiological abnormalities at the

ED-ward and risk of emergency calls for clinical deterioration. Finally, one in two patients with parameters fulfilling MET activation criteria experienced afferent limb failure.

Published studies of emergency calls in ward patients following hospital admission via the ED report that approximately 1% of patients admitted from ED to non-critical care areas will have an emergency call for clinical deterioration within 24 hours of hospital admission (Considine *et al*. 2014, Mora *et al*. in press) and 3.3% of patients have an emergency call within 72 hours of hospital admission (Considine *et al*. 2014). The median time to emergency call in our study was 18.8 hours which is shorter than the 36 hours and 59 hours reported in studies by Considine *et al*. respectively (2014, 2012). The reason for this difference is unclear. Both Considine *et al*. (2014, 2012) studies were single site studies, but our study included three hospitals so the differences in results may be from cultural differences in recognising and responding to deterioration between sites.

Inconsistent physiological assessment at the ED-ward may increase the risk of unrecognised clinical deterioration. A complete set of physiological observations (Australian Commission on Safety and Quality in Health Care (ACSQHC) 2010) was documented in only 15% of patients during the last hour of ED care and 53.7% of patients during first hour of ward care. Other studies of documentation of physiological observations report that complete vital signs occur in 72% of patients (Bleyer *et al*. 2011). However the study by Bleyer *et al*. (2011) had a sample of over one million individual vital sign measures in 27,722 patients and vital signs were entered electronically into the hospital data system and based on physician orders. In our study, physiological observations were measured according to the clinical judgement of nurses and the outcome of interest was in-hospital mortality rather than emergency calls for clinical deterioration.

The variability in parameters documented and lack of completeness of physiological observations (Australian Commission on Safety and Quality in Health Care (ACSQHC) 2010) is concerning given that all three sites had a single parameter trigger MET system with activation reliant on measurement of respiratory rate, oxygen saturation, heart rate, blood pressure and conscious state. Poor measurement and documentation of physiological observations, particularly preceding adverse events such as cardiac arrest, unplanned intensive care admission or unexpected death are well reported in other studies.(Chen *et al*. 2009, Cretikos *et al*. 2008, Fieselmann *et al*. 1993, Hillman *et al*. 2005, Hillman *et al*. 2001,

McGain *et al*. 2008, Chellel *et al*. 2001, Skrifvars *et al*. 2006) It may be argued that the risk of unrecognised clinical deterioration increases as a consequence of incomplete assessment. This notion is reinforced by our finding that patients with early emergency calls were significantly less likely to have a complete set of physiological observations (Australian Commission on Safety and Quality in Health Care (ACSQHC) 2010) when compared with patients with intermediate or late calls and that physiological abnormalities were not detected during last hour of ED care because they were not measured.

Second, abnormal physiological observations were common in patients admitted to wards from the ED. In our study, one in three patients leaving the ED and one in two patients arriving on the ward had at least one abnormal physiological parameter documented that did not necessarily fulfil hospital MET activation criteria. The high frequency of physiological abnormalities in hospital patients is supported by other studies. One or more abnormal observations are reported in 15% to 80% of hospital patients (Ashworth 2002, Goldhill and McNarry 2004, Considine *et al*. in press) and at any point in time 3% to 14% of ward patients (Bucknall *et al*. 2013, Shearer *et al*. 2012, Buist *et al*. 2004, Guinane *et al*. 2013, Tirkkonen *et al*. 2014) and 2% to 15% of ED patients (Hosking *et al*. 2014, Considine *et al*. 2015b) fulfil hospital or local MET activation criteria. This study is the first to highlight that abnormal physiological parameters, that have not yet reached MET activation criteria, are present in many patients during transport from the ED to the wards.

These findings raise questions about nurses' mental models or illness scripts of clinical deterioration that shape their recognition of and response to, abnormal physiological assessment findings. Mental models and illness scripts are cognitive structures that hold clinically relevant descriptions of typical patients and consequences of patient problems and act as organisers of information in memory (Schmidt *et al*. 1990, Custers 2015). It may be that some nurses have normalised abnormal physiological parameters by virtue of repeated exposure to patients with abnormal physiological observations. In EDs, it is common for nurses to manage undiagnosed, undifferentiated and unstable patients in the absence of a formal MET system. In contrast, MET is well established in ward settings and MET activation criteria is central to ward nurses' clinical practice. Mandatory MET activation in the context of single parameter calling criteria would also strongly reinforce ward nurses' schemas of recognising and responding clinical deterioration. Thus ED nurses' recognition of and response to, abnormal physiology are unlikely to be consistent with ward nurses' mental

models and illness scripts of clinical deterioration which are more likely to be defined by MET criteria and escalation protocols (Cioffi *et al*. 2009, Cioffi 2000). The proposition that ED nurses may not respond as early to deviations from normal vital sign parameters due to their specific mental model of deterioration requires further investigation to determine whether true differences exist and to identify the most appropriate systems for recognising clinical deterioration in ED patients.

Third, physiological abnormalities at the ED-ward interface were associated with increased risk of emergency calls for clinical deterioration during first 72 hours of admission. Specifically heart rate and conscious state abnormalities during the last hour of ED care and oxygen saturation, heart rate and respiratory rate abnormalities during the first hour of ward care posed an increased risk of emergency call. The relationship between physiological abnormalities in the ED and serious adverse events is supported by other studies (Jones *et al*. 2004, Burch *et al*. 2008, Groarke *et al*. 2008). Hypotension in the ED has been associated with in-hospital death (Burch *et al*. 2008, Jones *et al*. 2006, Sikorski *et al*. 2004). Tachycardia and tachypnoea on ED arrival have been associated with in-hospital death (Burch *et al*. 2008) and tachycardia and tachypnoea on ED arrival or in the early stages of emergency care have been associated with increased risk of critical care unit admission (Considine *et al*. 2009). Further, tachypnoea or hypotension fulfilling MET activation criteria during ED care have been associated with increased risk of emergency calls for clinical deterioration during early hospital admission. The relationship between physiological abnormalities during the last hour of ED care and emergency calls for clinical deterioration during first 72 hours of admission warrants further investigation. It is acknowledged that not all patients had all parameters measured during the last hour of ED care so prospective studies than can ensure data completeness are needed to further our understanding of whether physiological abnormalities during ED care can be used to inform nursing surveillance during ward based care.

Blood pressure and conscious state abnormalities during first hour of ward care were also associated with increased risk of emergency calls for clinical deterioration during first 72 hours of admission with strong trends for statistical significance; further assessment of these parameters with a larger sample size is warranted. Our results show that abnormalities of three of the six parameters examined had a statistically significant relationship with risk of emergency calls for clinical deterioration during first 72 hours of admission emphasising that

abnormalities in the first set of physiological observations on the ward can be used to guide nursing surveillance and care planning during the early stages of admission.

Finally, 1 in 10 patients had at least one parameter that fulfilled hospital MET activation criteria during the first hour of ward care and afferent limb failure occurred in more than half of those patients. This finding raises questions about practices and processes of care during early admission to the ward. It is well within the scope of practice of nurses to measure and interpret physiological data and escalate care of patients who are deteriorating. Thus, the reason for nurses' failure to interpret and escalate care as appropriate warrants further investigation. One possible explanation for this finding is that the complexity of nursing practice is distracting nurses from focusing on physiological status during this vulnerable time for patients. Australian data shows that nurses perform on average, 72 tasks per hour and change tasks every 55 seconds (Westbrook *et al*. 2011). Nurses spend 37% of their time with patients and 25% of their activities are related to direct patient care (Westbrook *et al*. 2011). Indirect care (reviewing results, planning care, washing hands, reviewing documentation, returning equipment), documentation and professional communication comprise 42-47% of nurses' activities (Westbrook *et al*. 2011, Chaboyer *et al*. 2008). Patient outcomes are optimised when nurses spend more time with patients (Duffield *et al*. 2011, Aiken *et al*. 2002), however, observations of clinical practice suggest that much of the complexity of nursing care is driven by compliance with accreditation standards rather than safety orientated patient-centred care.

MET afferent limb failure is well documented (Hillman *et al*. 2005, DeVita *et al*. 2010, Sandroni and Cavallaro 2011, Trinkle and Flabouris 2011) and reported rates of afferent limb failure vary from 23% to 50% (Trinkle and Flabouris 2011, Hillman *et al*. 2005). Notably the MERIT study, Australia's only randomised controlled trial of MET systems, showed that despite fulfilling MET calling criteria in the 15 minutes preceding specific adverse events, there was no MET activation in 30% of patients who had a cardiac arrest; 51% of patients who required unplanned ICU admission; and 50% of patients who died unexpectedly (Hillman *et al*. 2005). In our study, afferent limb failure occurred in two thirds of patients with hypotension and when an emergency call was activated, is was usually made within the first 4 hours. This finding is similar to Quach *et al*. (2008) who found delayed MET occurred in 39% patients with hypotension and there was a median delay of 5 hours.

Afferent limb failure occurred in 58% of patients with altered conscious state and 50% of patients with tachycardia or bradycardia. Further, when an emergency call was made for conscious state or heart rate derangement, almost half were delayed by more than 24 hours. Downey *et al*. (2008) found that delayed MET activation occurred in 35% of patients with altered conscious state with a median delay of 16 hours and in 24% of patients with arrhythmias (defined as heart rate to greater than 120 or less than 40 beats / minute) with a median delay of 13 hrs. We also found that afferent limb failure occurred in more than one third of patients with tachypnoea and when emergency calls were made, the majority were within the first 4 hours and all occurred within 24 hours. Quach *et al*. (2008) report that 50% of patients with respiratory distress (respiratory rate less than 8 or more than 30 breaths per minute and, or oxygen saturation less than 90% despite oxygen therapy) had a delayed MET call with a median delay of 12 hours.

Limitations

There are several limitations that should be considered when interpreting the study findings. Study limitations include a retrospective design and use of organisational data; however, data collection was performed by research nurses who had specific training and were guided by a data dictionary to optimise data reliability. Physiological observation data were collected from patient records so it is impossible to understand the accuracy of measurement of physiological data. There were differences in the frequency and types of parameters assessed during the last hour of emergency care and first hour of ward care. The larger amount of missing data during the last hour of emergency care is a possible confounder and may explain differences in the findings from ED versus ward data. The focus of this study was patients admitted to medical or surgical wards and study design excluded patients admitted to environments with continuous physiological monitoring. Therefore, the study results may not be generalisable to all hospital patients admitted via the ED or to other practice settings that receive patients from ED. Patients were selected from three sites minimising the possibly of selection bias however our results may not be generalisable to other organisations with different processes for measuring and recording physiological data and recognising and responding to clinical deterioration. Finally, detailed assessment of the reasons for and outcomes of, afferent limb failure were beyond the scope of this study but warrant further investigation in future research.

CONCLUSION

In this case control study involving 3 hospitals and 1980 patients we found that documentation of physiological observations at the ED-ward interface was incomplete in the majority of patients. Abnormal physiological parameters at the ED-ward interface were common and predicted subsequent emergency calls. The utility of physiological status at the transition between the ED and inpatient wards to guide care planning, particularly frequency of nursing and medical assessments warrants further analysis. Half of patients who had physiological parameters fulfilling MET activation criteria during the first hour of ward care experienced MET afferent limb failure. The reasons for and outcomes of MET afferent limb failure is an important area for future research.

Author Contributions:

All authors have agreed on the final version and meet at least one of the following criteria (recommended by the ICMJE*):

1) substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data;

2) drafting the article or revising it critically for important intellectual content.

* http://www.icmje.org/recommendations/

REFERENCES

Aiken, L.H., Clarke, S.P., Sloane, D.M., Sochalski, J. & Silber, J.H. (2002) Hospital Nurse Staffing and Patient Mortality, Nurse Burnout and Job Dissatisfaction. *Journal of the American Medical Association*, **288**(16), 1987-1993.

Ashworth, S. (2002) A prelude to outreach: prevalence and mortality of ward patients with abnormal vital signs. *15th Annual Congress of the European Society of Intensive Care Medicine*, **28 S1**, S21.

Australasian College for Emergency Medicine (ACEM), Australian and New Zealand College of Anaesthetists (ANZCA) & College of Intensive Care Medicine of Australia and New Zealand (CICM) (2015) PS52 Minimum Standards for Intrahospital Transport of Critically Ill Patients. Australian and New Zealand College of Anaesthetists, Melbourne, Victoria

Australian Commission on Safety and Quality in Health Care (ACSQHC) (2010) National Consensus Statement: essential elements for recognising and responding to clinical deterioration. Australian Commission on Safety and Quality in Health Care,, Sydney.

Retrieved 31 August 2015 from http://www.safetyandquality.gov.au/our-work/recognising-and-responding-to-clinical-deterioration/implementing-r-and-r-systems/the-national-consensus-statement/.

Baggoley, C., Owler, B., Grigg, M., Wellington, H., Monaghan, M. & Hartley-Jones, J. (2011) Expert Panel Review of Elective Surgery and Emergency Access Targets under the National Partnership Agreement on Improving Public Hospital Services. Report to the Council of Australian Governments. Retrieved 31 August 2015 from https://www.coag.gov.au/node/44, Canberra.

Bellomo, R., Goldsmith, D., Uchino, S., Buckmaster, J., Hart, G., Opdam, H., Silverster, W., Doolan, L. & Gutteridge, G. (2003) A prospective before-and-after trial of a medical emergency team. *Medical Journal of Australia,* **179**(6), 283 - 287.

Berkovits, A.S., Parker, J.R., Comeau, S., Patel, T.Y. & Berkeley, R.P. (2013) Emergency Department Vital Signs are Not Predictive of Rapid Response Assessment Team Activation and Early Clinical Deterioration After Arrival on a Medical Floor. *Annals of Emergency Medicine,* **62**(4, Supplement), S21-S22.

Bleyer, A.J., Vidya, S., Russell, G.B., Jones, C.M., Sujata, L., Daeihagh, P. & Hire, D. (2011) Longitudinal analysis of one million vital signs in patients in an academic medical center. *Resuscitation,* **82**(11), 1387-1392.

Bucknall, T.K., Jones, D., Bellomo, R., Staples, M. & for the RESCUE Investigators (2013) Responding to medical emergencies: System characteristics under examination (RESCUE). A prospective multi-site point prevalence study. *Resuscitation,* **84**(2), 179-183.

Buist, M., Bernard, S., Nguyen, T.V., Moore, G. & Anderson, J. (2004) Association between clinically abnormal observations and subsequent in-hospital mortality: a prospective study *Resuscitation,* **62**(2), 137-141.

Buist, M., Moore, G.E., Bernard, S.A., Waxman, B.P. anderson, J.N. & Nguyen, T.V. (2002) Effects of a medical emergency team on reduction of incidence of and mortality from unexpected cardiac arrests in hospital: preliminary study. *British Medical Journal,* **324**(7334), 387-90.

Burch, V.C., Tarr, G. & Morroni, C. (2008) Modified early warning score predicts the need for hospital admission and inhospital mortality. *Emergency Medicine Journal,* **25**(10), 674-678.

Calzavacca, P., Licari, E., Tee, A., Mercer, I., Haase, M., Haase-Fielitz, A., Jones, D., Gutteridge, G. & Bellomo, R. (2010) Features and outcome of patients receiving multiple Medical Emergency Team reviews. *Resuscitation,* **81**(11), 1509-1515.

Casamento, A.J., Dunlop, C., Jones, D.A. & Duke, G. (2008) Improving the documentation of medical emergency team reviews. *Critical Care and Resuscitation*, **10**(1), 24-29.

Chaboyer, W., Wallis, M., Duffield, C., Courtney, M., Seaton, P., Holzhauser, K., Schluter, J. & Bost, N. (2008) A comparison of activities undertaken by enrolled and registered nurses on medical wards in Australia: an observational study. *International Journal of Nursing Studies*, **45**(9), 1274-1284.

Chellel, A., Fraser, J., Fender, V., Higgs, D., Buras-Rees, S., Hook, L., Mummery, L., Cook, C., Parsons, S. & Thomas, C. (2001) Nursing observations on ward patients at risk of critical illness. *Nursing Times*, **98**(46), 36-39.

Chen, J., Hillman, K., Bellomo, R., Flabouris, A., Finfer, S. & Cretikos, M. (2009) The impact of introducing medical emergency team system on the documentations of vital signs. *Resuscitation*, **80**(1), 35-43.

Cioffi, J. (2000) Recognition of patients who require emergency assistance: A descriptive study. *Heart & Lung*, **29**(4), 262-268.

Cioffi, J., Conwayt, R., Everist, L., Scott, J. & Senior, J. (2009) 'Patients of concern' to nurses in acute care settings: A descriptive study. *Australian Critical Care*, **22**(4), 178-186.

Considine, J., Charlesworth, D. & Currey, J. (2014) Characteristics and outcomes of patients requiring rapid response system activation within 24 hours of emergency admission. *Critical Care and Resuscitation*, **16**(3), 184 - 189.

Considine, J., Jones, D., Pilcher, D. & Currey, J. (in press) Patient physiological status during emergency care and rapid response team or cardiac arrest team activation during early hospital admission. *European Journal of Emergency Medicine*, accepted 06/01/2016.

Considine, J., Jones, D., Plicher, D. & Currey, J. (2015a) Factors associated with clinical deterioration in the first 72 hours of emergency admission: a retrospective case control study. *13th International Conference for Emergency Nurses.* Brisbane Exhibition and Convention Centre: Brisbane, Australia.

Considine, J., Lucas, E. & Wunderlich, B. (2012) The uptake of an early warning system in one Australian Emergency Department: a pilot study. *Critical Care and Resuscitation*, **14**(2), 135-141.

Considine, J., Rawet, J. & Currey, J. (2015b) The effect of a staged, emergency department specific, rapid response system on reporting of clinical deterioration. *Australasian Emergency Nursing Journal,* **18**(4), 218-226.

Considine, J., Thomas, S. & Potter, R. (2009) Predictors of critical care admission in emergency department patients triaged as low to moderate urgency *Journal of Advanced Nursing,* **65**(4), 818-827.

Considine, J., Trotter, C. & Currey, J. (in press) Nurses' documentation of physiological observations in three acute care settings. *Journal of Clinical Nursing*, accepted 07/08/2015.

Cretikos, M.A., Bellomo, R., Hillman, K., Chen, J., Finfer, S. & Flabouris, A. (2008) Respiratory rate: the neglected vital sign. *Medical Journal of Australia,* **188**, 657–659.

Custers, E.J. (2015) Thirty years of illness scripts: Theoretical origins and practical applications. *Medical Teacher,* **37**(5), 457-462.

Department of Health (2010) A&E Clinical Quality Indicators Implementation Guidance. Department of Health, London, pp. Retrieved 20 August 2015 from http://webarchive.nationalarchives.gov.uk/20130107105354/http:/www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_122868.

DeVita, M.A., Braithwaite, R.S., Mahidhara, R., Stuart, S., Foriada, M. & Simmons, R.L. (2004) Use of the medical emergency team responses to reduce hospital cardiopulmonary arrests. *Quality and Safety in Health Care,* **13**, 251-4.

DeVita, M.A., Smith, G.B., Adam, S.K., Adams-Pizarro, I., Buist, M., Bellomo, R., Bonello, R., Cerchiari, E., Farlow, B., Goldsmith, D., Haskell, H., Hillman, K., Howell, M., Hravnak, M., Hunt, E.A., Hvarfner, A., Kellett, J., Lighthall, G.K., Lippert, A., Lippert, F.K., Mahroof, R., Myers, J.S., Rosen, M., Reynolds, S., Rotondi, A., Rubulotta, F. & Winters, B. (2010) 'Identifying the hospitalised patient in crisis'-A consensus conference on the afferent limb of Rapid Response Systems. *Resuscitation,* **81**(4), 375-382.

Downey, A.W., Quach, J.L., Haase, M., Haase-Fielitz, A., Jones, D. & Bellomo, R. (2008) Characteristics and outcomes of patients receiving a medical emergency team review for acute change in conscious state or arrhythmias. *Critical Care Medicine,* **36**(2), 477-481.

Duffield, C., Diers, D., O'Brien-Pallas, L., Aisbett, C., Roche, M., King, M. & Aisbett, K. (2011) Nursing staffing, nursing workload, the work environment and patient outcomes. *Applied Nursing Research,* **24**(4), 244-255.

Fieselmann, J., Hendryx, M., Helms, C. & Wakefield, D. (1993) Respiratory rate predicts cardiopulmonary arrest for internal medicine inpatients. *Journal of General Internal Medicine,* **8**(7), 354-360.

Frost, S.A., Alexandrou, E., Bogdanovski, T., Salamonson, Y., Parr, M.J. & Hillman, K.M. (2009) Unplanned admission to intensive care after emergency hospitalisation: Risk factors and development of a nomogram for individualising risk. *Resuscitation,* **80**(2), 224-230.

Geelhoed, G.C. & de Klerk, N.H. (2012) Emergency department overcrowding, mortality and the 4-hour rule in Western Australia. *Medical Journal of Australia,* **196**(2), 122-126.

Goldhill, D.R. & McNarry, A.F. (2004) Physiological abnormalities in early warning scores are related to mortality in adult inpatients. *British Journal of Anaesthesia,* **92**(6), 822-824.

Groarke, J.D., Gallagher, J., Stack, J., Aftab, A., Dwyer, C., McGovern, R. & Courtney, G. (2008) Use of an admission early warning score to predict patient morbidity and mortality and treatment success. *Emergency Medicine Journal,* **25**(12), 803-806.

Guinane, J., Bucknall, T., Currey, J. & Jones, D. (2013) Missed medical emergency team activations: tracking decisions and outcomes in practice. *Critical Care and Resuscitation,* **15**(4), 266-272.

Hillman, K., Chen, J., Cretikos, M., Bellomo, R., Brown, D., Doig, G., Finfer, S. & Flabouris, A. (2005) MERIT study investigators: Introduction of the medical emergency team (MET) system: a cluster-randomised controlled trial. *Lancet,* **365**, 2091 - 2097.

Hillman, K.M., Bristow, P.J., Chey, T., Daffurn, K., Jacques, T., Norman, S.L., Bishop, G.F. & Simmons, G. (2001) Antecedents to hospital deaths. *Internal Medicine Journal,* **31**(6), 343-348.

Hosking, J., Considine, J. & Sands, N. (2014) Recognising clinical deterioration in Emergency Department patients. *Australasian Emergency Nursing Journal,* **17**(2), 59-67.

IBM Corporation (2012) IBM SPSS (Statistical Package for Social Sciences) Statistics Version 21.0. IBM Corporation,, Armonk, NY.

Jones, A.E., Aborn, L.S. & Kline, J.A. (2004) Severity of Emergency Department hypotension predicts adverse hospital outcome. *Shock,* **22**(5), 410-414.

Jones, A.E., Yiannibas, V., Johnson, C. & Kline, J.A. (2006) Emergency Department hypotension predicts sudden unexpected in-hospital mortality: a prospective cohort study. *Chest,* **130**(4), 941-946.

Jones, D.A., DeVita, M.A. & Bellomo, R. (2011) Rapid-Response Teams. *New England Journal of Medicine,* **365**(2), 139-146.

Jones, D.A., Dunbar, N.J. & Bellomo, R. (2012) Clinical deterioration in hospital inpatients: the need for another paradigm shift. *Medical Journal of Australia,* **196**(2), 97-100.

McGain, F., Cretikos, M., Jones, D., Van Dyk, S., Buist, M.D., Opdam, H., Pellegrino, V., Robertson, M.S. & Bellomo, R. (2008) Documentation of clinical review and vital signs after major surgery. *Medical Journal of Australia,* **189** 380-383.

Mora, J.C., Schneider, A.G., Robbins, R., Bailey, M., Bebee, B., Hsiao, Y.-F.F., Considine, J., Jones, D. & Bellomo, R. (in press) Epidemiology of early Rapid Response Team activation after emergency department admission. *Australasian Emergency Nursing Journal*, Accepted 31/03/2015. Available on line 11/06/2015.

National Health Performance Agency (2013) My Hospitals Commonwealth of Australia. Retrieved 31 August 2015 from http://www.myhospitals.gov.au/ Canberra

Ong, M. & Coiera, E. (2011) A systematic review of failures in handoff communication during intrahospital transfers. *Joint Commission Journal on Quality and Patient Safety* **37**(6), 247-84.

Quach, J.L., Downey, A.W., Haase, M., Haase-Fielitz, A., Jones, D. & Bellomo, R. (2008) Characteristics and outcomes of patients receiving a medical emergency team review for respiratory distress or hypotension. *Journal of Critical Care*, **23**(3), 325-331.

Sandroni, C. & Cavallaro, F. (2011) Failure of the afferent limb: A persistent problem in rapid response systems. *Resuscitation,* **82**(7), 797-798.

Schmidt, H.G., Norman, G.R. & Boshuizen, H.P. (1990) A cognitive perspective on medical expertise: Theory and implications. *Academic Medicine,* **65**(10), 611-621.

Shearer, B., Marshall, S., Buist, M.D., Finnigan, M., Kitto, S., Hore, T., Sturgess, T., Wilson, S. & Ramsay, W. (2012) What stops hospital clinical staff from following protocols? An analysis of the incidence and factors behind the failure of bedside clinical staff to activate the rapid response system in a multi-campus Australian metropolitan healthcare service. *BMJ Quality and Safety*, **21**(7), 569-575.

Sikorski, T., Black, L., Ho, E. & Mills, T. (2004) Survival in posttraumatic hypotension. *Annals of Emergency Medicine*, **44**(4), S128-S129.

Skrifvars, M., Nurmi, J., Ikola, K., Saarinen, K. & Caster, M. (2006) Reduced survival following resuscitation in patients with documented clinically abnormal observations prior to in-hospital cardiac arrest. *Resuscitation*, **70**(2), 215-222.

Tirkkonen, J., Olkkola, K.T., Huhtala, H., Tenhunen, J. & Hoppu, S. (2014) Medical emergency team activation: performance of conventional dichotomised criteria versus national early warning score. *Acta Anaesthesiologica Scandinavica*, **58**(4), 411-419.

Trinkle, R.M. & Flabouris, A. (2011) Documenting Rapid Response System afferent limb failure and associated patient outcomes. *Resuscitation*, **82**(7), 810-814.

Venkatesh, A.K., Curley, D., Chang, Y. & Liu, S.W. (2015) Communication of vital signs at Emergency Department handoff: opportunities for improvement. *Annals of Emergency Medicine*, **66**(2), 125-130.

Westbrook, J.I., Duffield, C., Li, L. & Creswick, N.J. (2011) How much time do nurses have for patients? A longitudinal study quantifying hospital nurses' patterns of task time distribution and interactions with health professionals. *BMC Health Services Research*, **11**(1), 319.

Table 1: Medical Emergency Team activation criteria per site

	Hospital A	Hospital B	Hospital C
Bradypnoea (breaths/ minute)	• RR < 8	• RR < 8	• RR < 6
Tachypnoea (breaths/ minute)	• RR >30	• RR > 25	• RR > 36
Hypoxaemia (SpO_2 %)	• SpO_2 <90% on oxygen	• SpO_2 <90% on oxygen	• SpO_2 <90% on oxygen
Bradycardia (beats/ minute)	• HR < 50	• HR < 40	• HR < 40
Tachycardia (beats/ minute)	• HR >130	• HR > 120	• HR > 140
Hypotension (mmHg)	• SBP < 90	• SBP < 90	• SBP < 90
Altered conscious state	• Acute change in conscious state	• Sudden change in conscious state, patient cannot be roused	• Drop of >2 GCS points or seizure
Staff concern	✓	✓	✓

RR = respiratory rate; SpO_2 = oxygen saturation; HR = heart rate; SBP = systolic blood pressure; GCS = Glasgow Coma Score

Table 2: Normal versus abnormal physiological parameters documented during last hour of ED care and timing of emergency calls for clinical deterioration

Parameter	Frequency of documentation of parameter		Emergency call <72 hours of admission		p*	Timing of emergency calls: Early emergency call (0 - 4h)		Intermediate emergency call (4.1 - 24h)		Late emergency call (24.1 - 72h)	
	n	%	n	%		n	%	n	%	n	%
Systolic blood pressure											
• Normal	764	67.4	281	36.8	0.039	45	16.1	126	44.8	110	39.1

• Abnormal	370	32.6	113	30.5		22	19.4	47	41.6	44	39.0
Heart rate												
• Normal	906	80.8	284	31.3	<0.001	38	13.4	124	43.6	122	43.0
• Abnormal	215	19.2	99	46.0		26	26.3	40	40.4	33	33.3
Conscious state												
• Normal	634	84.9	198	31.2	0.002	42	21.2	85	42.9	71	35.9
• Abnormal	113	15.1	56	49.6		10	17.8	23	41.1	23	41.1
Oxygen saturation												
• Normal	962	87.4	325	33.8	0.313	57	17.5	140	43.1	128	39.4
• Abnormal	139	12.6	53	38.1		9	17.0	25	47.2	19	35.8
Respiratory rate												
• Normal	989	88.5	329	33.3	0.098	52	15.8	138	42.0	139	42.2
• Abnormal	128	11.5	52	40.6		11	21.2	28	53.8	13	25.0
Temperature												
• Normal	490	95.0	172	35.1	0.960	29	16.9	78	45.3	65	37.8
• Abnormal	26	5	9	34.6		3	33.4	3	33.3	3	33.4

* p = comparison of emergency calls for normal vs abnormal parameters, Chi Square test

Abnormal parameters: respiratory rate <12 or >22 breaths / minute ; oxygen saturation <95%; heart rate <60 or > 100 beats per minute; systolic blood pressure <90 or > 140mmHg; conscious state responsive to voice, pain or unresponsive; and temperature <35.0 or > 37.8^{0}C (Considine et al. 2009)

Table 3: Normal versus abnormal physiological parameters documented during first hour of ward care and timing of emergency calls for clinical deterioration

Parameter	Frequency of documentation of parameter		Emergency call <72 hours of admission		p*	Timing of emergency calls: Early emergency call (0 - 4h)		Intermediate emergency call (4.1 - 24h)		Late emergency call (24.1 - 72h)	
	n	%	n	%		n	%	n	%	n	%
Systolic blood pressure											
• Normal	1419	71.7	491	34.6	0.057	71	14.5	219	44.6	201	40.9
• Abnormal	561	28.3	169	30.1		31	18.3	68	40.2	70	41.5
Oxygen saturation											

• Normal	1650	83.3	522	31.6	<0.001	78	14.9	230	44.1	214	41.0
• Abnormal	330	16.7	138	41.8		24	17.4	57	41.3	57	41.3
Heart rate											
• Normal	1695	85.6	530	31.3	<0.001	72	13.6	224	42.3	234	44.1
• Abnormal	285	16.4	130	45.6		30	23.0	63	48.5	37	28.5
Respiratory rate											
• Normal	1783	90.1	575	32.2	0.002	73	12.7	249	43.3	253	44.0
• Abnormal	197	9.9	85	43.1		29	34.1	38	44.7	18	21.2
Conscious state											
• Normal	1894	95.7	623	32.9	0.051	93	14.9	275	44.2	255	40.9
• Abnormal	86	4.3	37	43.0		9	24.3	12	32.4	16	43.3
Temperature											
• Normal	1916	96.8	635	33.1	0.323	94	14.8	275	43.3	266	41.9
• Abnormal	64	3.2	25	39.1		8	32.0	12	48.0	5	20.0

* p = comparison of emergency calls for normal vs abnormal parameters, Chi Square test

Abnormal parameters: respiratory rate <12 or >22 breaths / minute ; oxygen saturation <95%; heart rate <60 or > 100 beats per minute; systolic blood pressure <90 or > 140mmHg; conscious state responsive to voice, pain or unresponsive; and temperature <35.0 or > 37.8^{0}C (Considine et al. 2009)

Table 4: Physiological parameters fulfilling MET activation criteria documented during first hour of ward care, frequency of MET afferent limb failure, and timing of emergency calls for clinical deterioration

Parameter	Measures fulfilling MET activation criteria (n=1980)		MET afferent limb failure		**Timing of emergency calls in patients with MET activation criteria**					
					Early emergency call (0 - 4h)		Intermediate emergency call (4.1 - 24h)		Late emergency call (24.1 - 72h)	
	n	%	n	%	n	%	n	%	n	%
• MET criteria: Hypotension	34	1.7	20	58.8	10	71.4	2	14.3	2	14.3

• MET criteria: decreased consciousness	87	4.4	49	58.0	10	26.3	12	31.6	16	42.1
• MET criteria: Hypoxaemia	46	2.3	24	52.2	7	31.8	6	27.3	9	40.9
• MET criteria: Tachycardia	10	0.5	5	50.0	1	20.0	3	60.0	1	20.0
• MET criteria: Bradycardia	6	0.3	3	50.0	1	33.3	1	33.3	1	33.3
• MET criteria: Tachypnoea	18	0.9	7	38.9	8	72.7	3	27.3	0	0.0

MET = Medical Emergency Team; Afferent limb failure = failure to escalate the MET despite the presence of documented MET criteria