on the Response to Acutely Deteriorating Patients

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Introduction: The Deteriorating Patient

An aging population, increasingly complex surgical procedures and yet shorter inpatient stays has led to much a greater proportion of significantly ill patients within the in-patient population [1]. Such patients may benefit from input from critical care, hence the need for expansion of critical care beyond the traditional physical boundaries of high dependency and intensive care units [1]. Thus, in the United Kingdom the levels of care are now defined as follows [1].

- Level 0: Patients whose needs can be met through normal ward care in an acute hospital
- Level 1: Patients at risk of their condition deteriorating, or those recently relocated from higher levels of care, whose needs can be met on an acute ward with additional advice and support from the critical care team
- Level 2: Patents requiring more detailed observation or intervention including support for a single failing organ system or postoperative care and those 'stepping down' from higher levels of care
- Level 3: Patients requiring advanced respiratory support alone or basic respiratory support together with support of at least two organ systems. This level includes all complex patients requiring support for multi-organ failure.

Deterioration in a patient's condition can occur at any stage, although may be more likely during the onset of illness, during surgical or medical interventions, and during recovery from critical illness. The timely detection of such deterioration and the delivery of remedial measures remains a challenge

Sub-optimal Care

Outcome is a complex function of age, surgical or medical status, elective or emergency presentation, co morbidities, physiological reserve, nature of severity of acute illness, and quality of care. The quality of care and the early identification of severity of illness and effective management ought to be in the control of clinicians [2]. However, there is a substantial and consistent body of evidence suggesting that management of airway, breathing, circulation, oxygen therapy, and monitoring before admission to intensive care units (ICUs) has been sub-optimal [3]. A large proportion of patients are referred to intensive care late in the clinical course of their illness, many having suffered cardiac arrest [4]. Frustratingly, observation charts often show clear evidence of deterioration, which might have triggered earlier action [5].

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The reasons for such sub-optimal care have been identified as serious deficiencies in communication between acute medical and critical care services, lack of awareness by medical staff of the worsening condition of their patients [6], failure to seek timely advice, and lack of knowledge and skills [3] of staff to recognize and react appropriately. A significant number of admissions to critical care could have been avoided by timely referral and intervention by critical care staff. One study estimated that this sub-optimal care may have contributed to one third of the deaths that occurred [3]. Acutely deteriorating patients experience a mismatch of resources to needs and hospitals have been encouraged to implement a response based system based on an afferent limb 'crisis detection', a 'response triggering' mechanism, and an *efferent limb*, a 'rapid response team' or similar [7]. Studies comparing events and outcomes with or without involvement of a 'Patient At Risk Team' showed early advice and active management may prevent the need for cardiopulmonary resuscitation (CPR) and may improve outcomes [8].

'Track and Trigger' Mechanisms

There is evidence to show that a majority of adverse events (deaths, cardiac arrests and unplanned ICU admission) is preceded by documented abnormal physiology, the commonest being decrease in Glasgow Coma Score, hypotension [4], and change in respiratory rate [8].

One might think early identification of patients at risk, both before admission and after discharge from the ICU, may facilitate early treatment and decrease mortality [9]. A NCEPOD (National Confidential Enquiry into Patient Outcome and Death) report (a nationwide audit from the UK) suggested that the majority (66 %) of patients who have been in hospital for more than 24 hours prior to ICU admission had exhibited physiological instability for more than 12 hours [5]. Others have shown a significant increase in mortality as the number of abnormal physiological variables increase [10].

In pre-critical care settings, physiological 'track and trigger' warning systems are used to identify patients who are at risk of deteriorating clinically. These are usually derived from routine vital sign observations and if implemented properly should be a tool to ensure early recognition of clinical worsening and the initiation of timely intervention from appropriately experienced medical staff. Such systems include periodic observation of pre-set physiological parameters and pre-determined response criteria. The types of track and trigger and response algorithm vary, and include, e.g., Patient at Risk (PAR) score [8], (Modified) Early Warning Score (MEWS) [11], Assessment Score for Sick patient Identification and Step-up in Treatment (ASSIST) [12], and locally devised scores.

Track and trigger systems may be classified as follows [13]:

- Single parameter system: Periodic observation of selected vital signs which are compared with a simple set of criteria with predefined thresholds, with a response algorithm being activated when any criterion is met
- Multiple parameter system: Response algorithm requires more than one criterion to be met or differs according to the number of criteria met
- Aggregate scoring system: Where weighted scores are assigned to physiological values and compared with predefined trigger thresholds
- Combination system: Involving single or multiple parameter systems in combination with aggregate weighted scoring systems

Single parameter systems have been used extensively in the Medical Emergency Team (MET) approach adopted in Australia [14]. In the UK, most hospitals favor using the weighted aggregate scoring system [13] and these are usually some form of modified early warning system. In the USA, the Rapid Response Team concept uses track and trigger systems as a key component of the Institute of Healthcare Improvement 100,000 Lives Campaign [15].

Being a single parameter system, the MET has been shown to be simpler and more reproducible than the ASSIST and the MEWS but does not enable monitoring of clinical progress [13]. MEWS is more complex, taking into account urine output and relative changes in blood pressure; ASSIST is a simplified version of MEWS with only four parameters and an age-constant; both ASSIST and MEWS allow monitoring of clinical progress, and are representative of the wide range of track and trigger systems in use [13].

Systematic reviews have shown that the variety of published track and trigger systems in use have little rigorous evidence of validity [16]. Sensitivities and positive predictive values were unacceptably low but they had acceptable specificity and negative predictive values. The low sensitivity may be partly due to the rapid deterioration of patients, infrequent non-standardized measurement of physiology and varying trigger thresholds. Sensitivities can be improved by reducing these thresholds but at the cost of specificity and potentially increased workload.

In the absence of level 1 evidence, those considering introduction of a track and trigger system may seek a mechanism that is tailored to their local needs [16]. It is important to bear in mind that track and trigger systems should only be used as an adjunct to clinical judgment and staff must be trained and supported to use them [13].

Role of Critical Care Outreach Services

A proposal to extend critical care outside the physical walls of the ICU resulted in the evolution of critical care 'outreach'. Outreach has three essential objectives [1]:

1. To avert or facilitate ICU admission by identifying deteriorating patients in a timely manner and intervene to ensure the best outcome.
2. To enable discharges by supporting the continued recovery of the discharged patient.
3. To share critical care skills with staff in the ward and impart appropriate training and awareness.

The graded response strategies for an identified deteriorating patient in medical, surgical and emergency wards would be as follows. First, initiation of a ward level response by increased frequency of physiological monitoring, second an urgent call to a team with primary medical responsibility for the patient, and third the involvement of a dedicated hospital team competent in acute medicine and critical care.

A predominantly nurse led Critical Care Outreach Team (CCOT) runs in the UK, although often with physician or physiotherapist support. Alternative models have more integral physician membership, such as the Patient At Risk Team (PART) in the UK [8], METs [14] in Australia and Rapid Response teams in the USA [15]. Similar team services are now rapidly emerging across Europe. The first Consensus Conference [7] on METs, held in the USA in 2005, concluded that hospitals should implement the MET approach.

Two good quality cluster-randomized controlled trials (RCTs) with level 1+ evidence show conflicting outcomes of the outreach/response team concept. The MERIT study [17] by Hillman et al. was conducted in Australia using a MET with a single parameter track and trigger system; the study included 23 hospitals over a period of six months. These investigators showed a significant increase in call out to the MET after the introduction of the system, but no difference in the incidences of cardiac arrest, unplanned ICU admissions or unexpected deaths.

The other study [18], also a cluster-RCT, was set in an acute hospital in England using a nurse lead CCOT with a multiple parameter track and trigger system making up the PAR score [8]. The results showed significant reduction in hospital mortality with involvement of CCOT but a non-significant increase in hospital length of stay.

A prospective large cohort study [19] of adult patients was performed by Chan et al. in a tertiary hospital at Kansas City Missouri where standard activation criteria for a Rapid Response Team were used. The study did not show any reduction in hospital wide cardiac arrest or mortality rates after implementation of the Rapid Response Team. However, other work has indicated an improvement in survival to discharge from hospital and reduced readmission rates to critical care with the introduction of CCOT [20].

A large observational study by Gao et al. in England [21] showed a reduction in the number of patients undergoing CPR before admission to intensive care but no effect on unit mortality.

A systematic review by Esmonde et al. [22] and a subsequent Cochrane review [23] on the impact of outreach services highlighted similar issues of poor quality research and lack of evidence to support the outreach concept. Based on the fact that there are only two good quality RCTs available with conflicting outcomes, no strong recommendations can be made based on the available evidence. However, with the introduction of similar services in Sweden, Netherlands, Italy, Portugal, and the USA, further data regarding the impact of outreach services will become available for consideration. A broad range of process and outcome measures is recommended to evaluate the impact of outreach [7].

Educational Tools

There is some evidence that simple educational training tools imparted to a large number of front line staff empowers action [24]. The recognition of the fact that averting patient deterioration to cardiac arrest is as important as treating the cardiac arrest, has led to advances in resuscitation training which emphasize both recognition of impending cardiac arrest and its treatment. The Immediate Life Support (ILS) course [25] and the Acute Life-threatening Events-Recognition and Treatment (ALERT™) course [26] provide a wide range of healthcare professionals with the competence to recognize acutely ill patients before cardiac arrest, as well as the core resuscitation skills.

A six-year prospective audit [24] of 3,126 in-hospital emergency calls within a multi-site 1,200 bed London teaching hospital following the organization-wide adoption of the ILS course was conducted. The observation showed a reduction in the proportion of emergency calls for cardiac arrest ($p < 0.0001$; from 85 % in 2002 to 45 % in 2007) a corresponding increase in the proportion of 'pre-arrest' calls ($p < 0.0001$; from 15 % in 2002 to 55 % in 2007), a reduction in deaths at cardiac

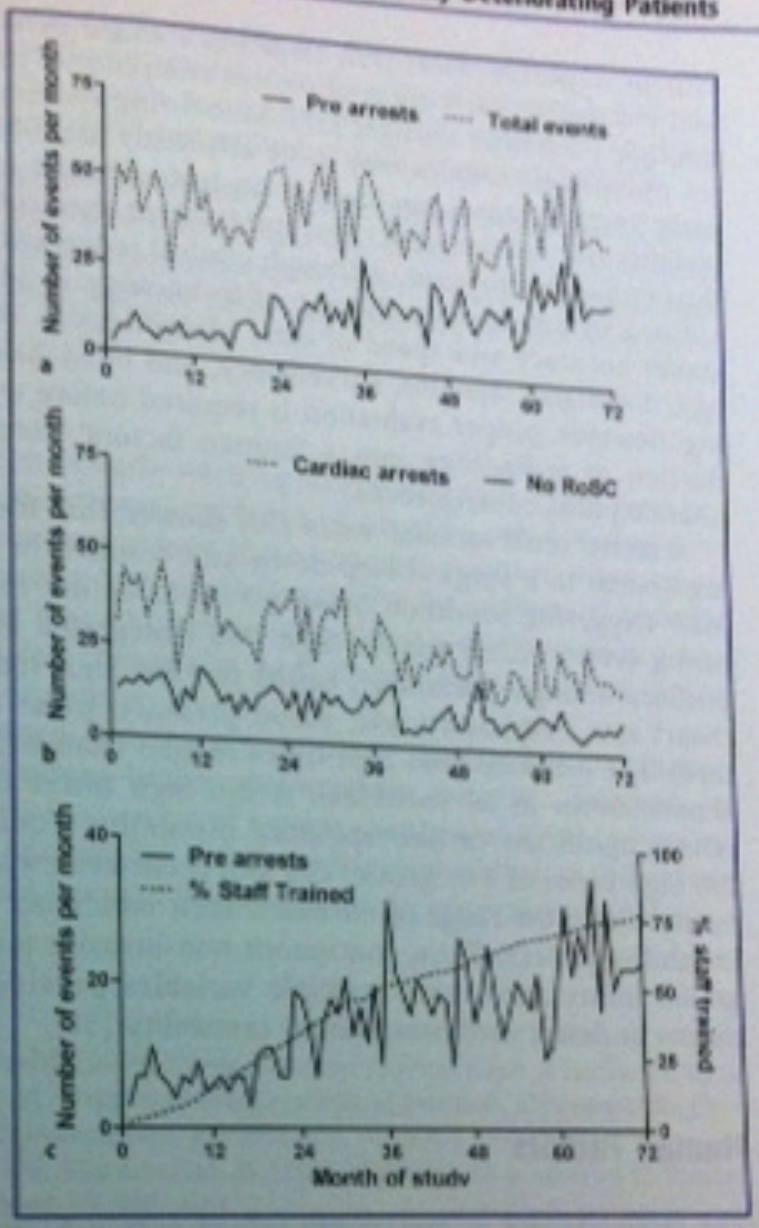

Fig. 1. Results from a six-year (January 2002 to December 2007) prospective audit of 3,126 in-hospital emergency calls in a London teaching hospital following the organization-wide adoption of the Immediate Life Support (ILS) course [24]. a) Monthly numbers of all in-patient emergency alert calls (dashed line) and pre-arrest calls (solid); b) Monthly numbers of in-patient cardiac arrests (dashed line, this includes events which were full cardiac arrests from the start and pre-arrest calls which proceeded to full cardiac arrests), and events during which a resuscitation attempt took place but without achieving return of spontaneous circulation (RoSC, solid); c) Monthly numbers of pre-arrest calls (solid line, left hand y-axis) plotted with the percentage of workforce who were ILS trained (dashed line, right hand y-axis). Modified from [24]

arrest ($p = 0.0002$), and an increased survival to hospital discharge from an emergency call from 28 % in 2004 to 39 % in 2007 (Fig. 1).

The above study [24] is an example of how a simple and widespread educational program, which is easy to implement, and is inexpensive with high uptake amongst healthcare professionals can influence behavior within the institution and reduce the number of in-hospital cardiac arrests and of unsuccessful CPR attempts. Although a positive study, identifying the critical nature of a patient's condition just proximal to a cardiac arrest still seems rather late and presents a clear opportunity for improvement; the key message seems to be around balancing complexity of concept with simplicity of introduction and retention. Perhaps for some things, broad but relatively shallow coverage is better than deep coverage which can be delivered to only a few.

Use of Technology as a Tool to 'Track and Trigger'

Continuous monitoring of cardiorespiratory variables by nursing staff at a central station or periodic bedside direct inspection potentially reflects an inefficient use of

human resources. Moreover, targeting a single variable anomaly may be inefficient and insensitive; early signs of patient compromise might be identified by combining multiple parameter changes [27]. Monitoring systems that integrate data from multiple physiologic sources may more efficiently identify patients at risk [28]. Although early warning scores can identify unstable patients earlier [29], such non-automated systems still require direct and intermittent data collection and calculation and are thus vulnerable to error. Although clinical judgment and experience cannot be substituted by automation, the use of technology in identifying 'at-risk' patients may confer accuracy and speed of early identification. With the advent of new technology, 'intelligent' systems, surveillance, and hand-held electronic devices are emerging; however, proper evaluation is required before widespread deployment as introduction of technology into a 'human factors' dominated environment may have unanticipated consequences.

A recent observational study [30] showed that the use of an automated monitoring system in a surgical step-down unit resulted in the mean time of identifying a MET triggering condition being 6.3 hours earlier than previously. A patient monitoring system called the Bio Sign IMS (Integrated Monitoring System) was used to produce a single parameter, called the Bio Sign Index, from five input vital signs (heart rate, respiratory rate, blood pressure, pulse oximetry [SpO_2] and temperature). The generated Bio Sign Index ranged from 0 (no abnormalities) to 10 (severe abnormalities in all variables). A Bio Sign Index of 3 or greater was deemed to reflect significant cardiorespiratory instability requiring medical attention [30]. A Bio Sign Index of 3 or greater can still occur even when no single vital sign parameter is outside the range of normal if their combined patterns are consistent with an instability pattern. Thus, continuous non-invasive monitoring augmented with integrated information from multiple variables provides a more sensitive and faster means to detect cardiorespiratory instability [31].

Human Factors

The establishment of apparently robust outreach and emergency response systems can have unanticipated consequences, usually related to human factors. One of the authors (SB) was an external expert at a review of some adverse episodes that occurred at a large well-organized teaching hospital, enquiring into some unanticipated deaths. In spite of apparently robust systems, a number of important contributory factors were identified:

1. The availability of outreach services encouraged over reliance on these systems and allowed poorly motivated on-call medical staff to duck their responsibility.
2. Outreach services do not have embedded diagnostic capacity, yet were relied on to respond and generate a management plan, a task for which they were ill equipped.
3. Out of hours there was a lack of clarity over who was responsible for the care of deteriorating patients when identified; this confusion leading to lack of 'ownership' of such patients.
4. The European Working Time Directive has mandated on-call systems associated with multiple shift handovers; these handovers, unless supervised by very senior staff, were an opportunity for information to be lost, and for a lack of continuity of plan and responsibility to creep in.

5. Research staff who had been recruited primarily for their research capacity via a casual mechanism and were poorly integrated into the clinical life of the hospital, had on-call responsibilities. They had a poor understanding of how to generate the rapid action often needed to avert impending critical illness or disaster.

The lesson here is that the introduction of outreach or emergency response systems is the equivalent of starting a complex intervention and one needs to be open-minded about the possibility of unanticipated consequences, and ensure that a thorough watch is kept for this. Senior night nursing staff are often good sources of information.

Conclusion

It seems odd that the introduction of early warning scores, outreach, rapid response teams, etc., has not produced unequivocal evidence of benefit – why? Perhaps the answers lie in a better understanding of how these concepts function when translated from paper to the clinical arena, and are challenged by the addition of humans, both patients and staff. It may be that ambitious plans do not work because of a tendency for diminishing returns for complexity and unanticipated negative consequences; both concepts hard to quantify.

Taken overall we would contend that there is evidence that system and human behavior can be changed to produce better outcomes for patients. However, we would further conclude that the introduction of system change and novel technological propositions are evaluated thoroughly before widespread adoption and investment, much the same as we would expect for new drugs or surgical procedures.

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