Rapid response systems: recognition and rescue of the deteriorating hospital patient

The last 25 years have witnessed significant change in the approach to the deteriorating patient. This article reviews and discusses the merits and drawbacks of the various systems used across the world.

The year 2015 marked a number of key anniversaries in the recognition and management of the deteriorating patient: 25 years since the antecedent physiological abnormalities which commonly precede in-hospital cardiac arrests were highlighted (Schein et al, 1990), 20 years since a model of care designed to identify and rescue deteriorating patients – the medical emergency team – was described (Lee et al, 1995), and 10 years since the most ambitious randomized trial to examine response to the deteriorating patient (Hillman et al, 2005) (*Table 1*).

In the intervening quarter century, recognition and rescue of the deteriorating patient has become a key principle in most advanced health services. For the hospital-based professional, involvement in these so-called rapid response systems has become integral to their role. This article reflects upon various approaches used to recognize and rescue deteriorating patients, and considers evidence relating to their effectiveness.

Appreciation of the scope and magnitude of the problem of deteriorating patients began with studies examining antecedents to serious adverse events. Patients were often found to demonstrate signs of deterioration in the hours preceding cardiac arrest (Schein et al, 1990) or unplanned admission to intensive care (McQuillan et al, 1998). Many of these signs are routinely recorded physiological markers, such as blood pressure and respiratory rate. Intuitively, early recognition of deterioration, and prompt response by professionals with appropriate experience, skills and resources, is likely to improve outcomes. The fundamental principles of all rapid response system are therefore early recognition and prompt, appropriate intervention.

Rapid response systems consist of four 'limbs'. The afferent limb refers to measures implemented to identify the deteriorating patient, the efferent limb describes the subsequent intervention. Long-term efficacy of the systems requires the support of administrative and governance limbs.

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Table 1. An evolution of understanding of the deteriorating patient: three key papers

Authors	Type of study	Main findings
Schein et al (1990)	Prospective study of 64 patients	Arrest is frequently preceded by a clinical deterioration involving either respiratory or mental function. Early detection of these derangements may prove beneficial to patient outcome
Lee et al (1995)	Prospective study of 522 medical emergency team calls	Decreased level of consciousness and abnormal blood pressure were the most commonly reported reasons for calls Discharge following a cardiac arrest was 29%, higher than other reported studies
Hillman et al (2005)	Cluster randomized trial of 23 hospitals (MERIT trial)	In intervention hospitals: ■ Only 30% of eligible cases had medical emergency team activation ■ Higher rate of false-positive calls ■ Only 19% of applicable patients had complete observations recorded Incidence of cardiac arrest and unexpected deaths fell in both intervention and control hospitals The following limitations were identified in the study: ■ Inadequate statistical power ■ Control group contamination

> The current lack of a perfect afferent limb is reflected by the number of different approaches used. In 2010, eleven different track and trigger systems were in use in London hospitals alone.

Afferent limb

The afferent limb 'tracks' patient physiology for evidence of deterioration and 'triggers' a response. It is therefore commonly referred to as a 'track and trigger system'. Track and trigger systems are based upon deviation of commonly recorded observations from a predetermined 'normal' range (*Figure 1*). The efficacy of the afferent limb is judged by sensitivity and specificity. Ideally, the limb would be sensitive enough to detect all deteriorating patients at a point amenable to treatment, while being sufficiently specific to disregard aberrant observations which represent normality for that patient, thereby reducing false-positive activation.

The current lack of a perfect afferent limb is reflected by the number of different approaches used. In 2010, eleven different track and trigger systems were in use in London hospitals alone (Patterson et al, 2011). The Royal College of Physicians responded by recommending that a nationally standard track and trigger system be implemented (Royal College of Physicians, 2012).

Among the available systems, the most simplistic approach is the single parameter track and trigger system in which one severely aberrant observation activates the system. The single parameter track and trigger system is popular in Australasia, although there is little consensus, and significant variation, between hospitals regarding appropriate thresholds (Jones et al, 2012). Mathematical evaluation of 33 single parameter track and trigger systems suggests low sensitivity (7–53%) but reasonable specificity (69–98%) in identifying those patients who will die in the current admission (Smith et al, 2008). Despite the apparent low sensitivity of the single parameter track and trigger system, systems using this afferent limb appear in before and after studies to be effective in reducing the incidence of cardiac arrest (Bellomo et al, 2004; Winters et al, 2013).

The integration of multiple variables may increase the sensitivity of physiological observations in the prediction of adverse events (Kenward et al, 2004; Bleyer et al, 2011). Multiple parameter track and trigger systems use lower thresholds of abnormality for each variable, but require more than one abnormality to activate. For example, one multiple parameter track and trigger system – the Patient at Risk Team score – denotes a respiratory rate of <10 or >25 breaths per minute and a heart rate of <55 or >110 beats per minute as abnormal; a typical single parameter track and trigger system by comparison uses a rate of <5 or >36 breaths and <40 or >140 beats per minute as the trigger. This reduction in threshold for abnormality should increase sensitivity; the requirement for multiple derangements maintaining specificity. This is not borne out in practice, however; the Patient at Risk Team score having been demonstrated to be a poor early identifier of those deteriorating to the point of intensive care unit admission (Goldhill et al, 1999).

A further modification of the multiple parameter track and trigger system is the aggregate weighted track and trigger system in which the degree of physiological derangement is weighted and reflected in the score. For example, in the Modified Early Warning Score (MEWS), a heart rate between 40 and 49 beats per minute is recognized as mildly abnormal and awarded one point; a heart rate less than 29 beats per minute is considered severely abnormal and awarded three points. Aggregate systems are popular in the UK and allow graded response based upon the total score produced by all variables. Another aggregate weighted track and trigger system, the National Early Warning Score (NEWS), has been shown to be a good predictor of deterioration leading to unexpected intensive care unit admission and death (Smith et al, 2013).

Aside from objective, physiological criteria, many track and trigger systems include the facility for activating on a subjective basis when staff, family or even the patient are 'worried'. Clinical intuition is recognized as an important contributor to patient assessment (Psirides et al, 2013). Analysis of subjective system activations suggests that most 'worried' calls concerned respiratory observations where deterioration was too subtle to trigger on a physiological basis (Santiano et al, 2009).

Efferent limb

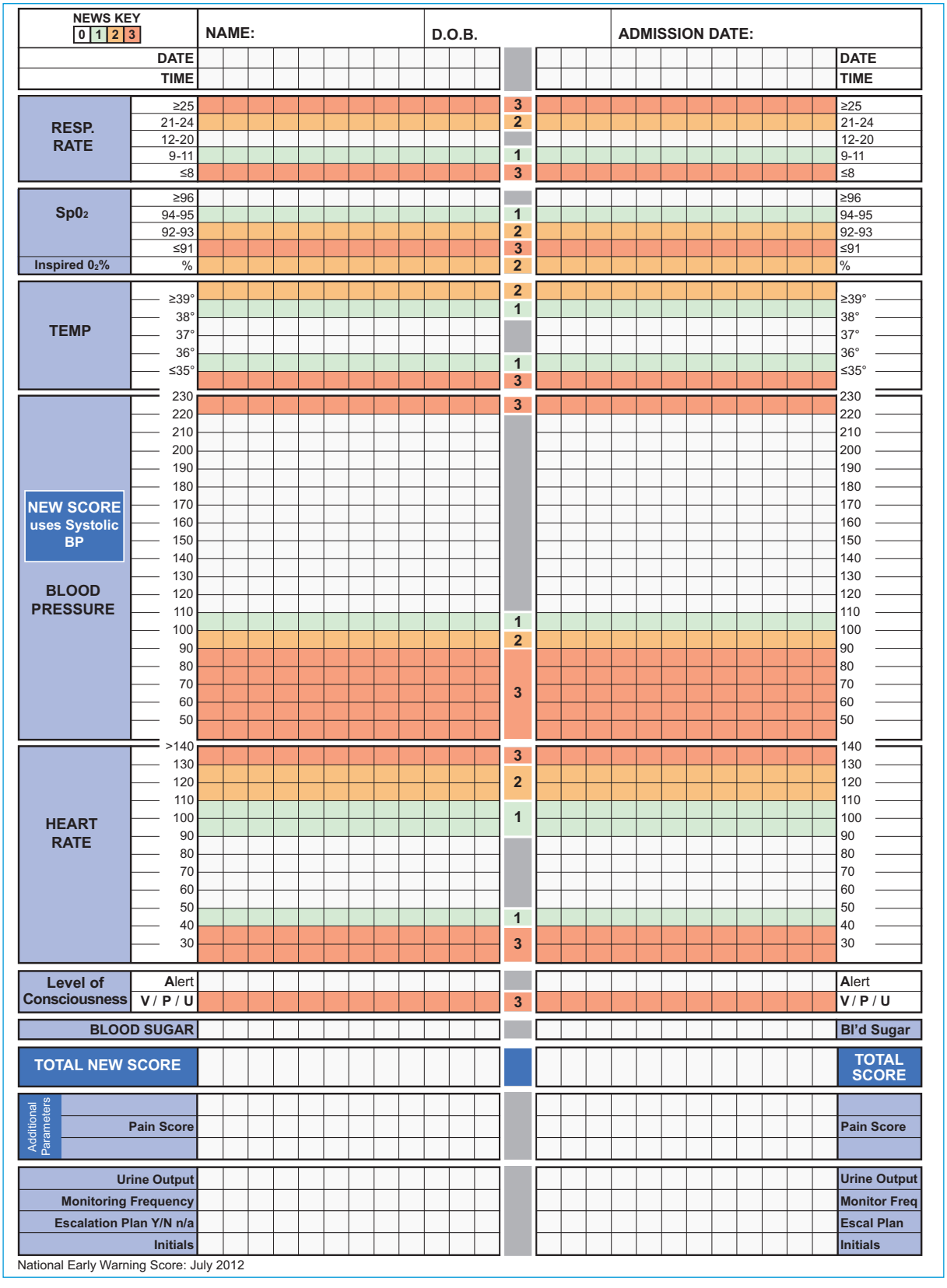
Like the afferent limb, approach to the efferent limb varies considerably. Efferent limbs can be broadly divided into 'ramp-up' and 'ramp-down' systems.

In a ramp-up system, the initial response is variable. It may range from a sole junior nurse or doctor with limited critical care knowledge and skill through to an advanced resuscitation team. The magnitude of the initial response is determined by the severity of the patient's physiological derangement. Following initial assessment, if the situation exceeds the capability of the initial responders, there is provision within the system to escalate to a larger, better resourced team, typically with critical care capability. The ramp-up response lends itself to an aggregate weighted track and trigger system – which quantifies severity of illness – and is popular in the UK.

In contrast, Australasian and American rapid response system typically use a ramp-down system: maximal resources are gathered initially and dissipated once situational needs are assessed and patient triage has occurred. While there is no high-quality evidence directly comparing the efficacy of different systems, advantages and disadvantages of both have been suggested (DeVita et al, 2006; *Table 2*).

Guidance regarding minimum acceptable standards of personnel and skills has been produced for both ramp-up (Scottish Intercollegiate Guideline Network, 2014) and ramp-down (New South Wales Government, 2013)

Figure 1. National Early Warning Score (NEWS) observation chart. From Royal College of Physicians (2012).



systems. Yet an Australian survey of rapid response systems reported significant variation in the response (Jones et al, 2012). Of note, 17.9% of hospitals within the survey had no provision of advanced airway skills despite advanced resuscitation skills being a recommended standard (New South Wales Government, 2013).

Table 2. Advantages and disadvantages of ramp-up and ramp-down efferent limb systems

	Ramp-down system	Ramp-up system
Advantages	Immediate provision of definitive care	Response can be tiered according to patient need
	All services provided	May be less expensive
	Permits triage of patients who require critical care	May up-skill junior medical staff
	Training can be concentrated on a limited number of hospital staff	May feel less intimidating to junior staff enabling prompt activation
Disadvantages	May feel intimidating resulting in delayed or failed activation	Historic evidence suggests that deteriorating patients are not reliably recognized and effectively managed
	Requires highly trained first responder team which may be costly to provide	
	Impacts on critical care resources	Lacks the potential advantages of obtaining an acute second opinion
	Intensive care unit patients may suffer harm in absence of critical care staff	Staff may not have necessary skills required in scenario
	Potentially deskills ward staff	Need to train all hospital staff in recognition and response
	Errors made because of unfamiliarity with patient	May cause delay in provision of care while awaiting initial response and further escalation
	Staff have no rapport with patient and family	

Current evidence

While the uptake of rapid response systems is widespread, evidence that implementation improves patient outcomes has not been forthcoming. Four meta-analyses (McGaughey et al, 2007; Chan et al, 2010; Winters et al, 2015; De Jong et al, 2016) reported reduction in cardiac arrest rates but not total hospital mortality. However, only one meta-analysis has shown a reduction in all-cause in-hospital mortality (Maharaj et al, 2015). Explanation for a lack of consistent reduction in mortality may lie within the largest trial of deteriorating patient systems to date: the Medical Early Response Intervention and Therapy (MERIT) study.

MERIT (Hillman et al, 2005) was a cluster randomized controlled study consisting of 23 hospitals in Australia. It remains the only multicentre randomized assessment of deteriorating patient systems. Twelve 'intervention' hospitals implemented a medical emergency team; eleven control hospitals continued with the existing system. There was no significant difference in unplanned intensive care unit admission, cardiac arrest or mortality between the arms. Rather, a reduction in cardiac arrest and hospital mortality was noted in both arms. Indeed, a difference in outcome was encountered when an 'as-treated' (rather than 'intention-to-treat') analysis was conducted (Jones et al, 2011). Combined, these findings may represent contamination of the control arm: traditional cardiac arrest teams being activated as a surrogate medical emergency team for patients in control hospitals who were deteriorating but not yet at the point of cardiac arrest. This contamination – in combination with variable protocol compliance within the intervention arm, and a lower than expected incidence of the primary outcome of death – led MERIT to be underpowered. In addition, the run-in period for the MERIT study was relatively short, and the 'dose' of calls was relatively low in comparison to hospitals where the medical emergency team has been shown to be effective (Jones et al, 2009).

A post-hoc analysis of the MERIT data set (Chen et al, 2009) demonstrated that early activation of a deteriorating patient team (either a medical emergency team in the intervention arm, or a cardiac arrest team where reviews were non-cardiac arrests calls in the control arm) did reduce mortality: an analysis which, if included, may have altered the results of the systematic reviews (Hillman et al, 2010).

A second randomized study was conducted in a single centre in the UK; individual wards within one hospital were randomized to a deteriorating patient system or standard care (Priestley et al, 2004). Intervention led to a statistically significant reduction in hospital mortality but also an increased length of hospital stay.

The remaining studies have, in general, been single centre, before–after investigations and therefore prone to the weaknesses inherent in observational work. Inclusion of these studies into a systematic review (Winters et al, 2013) produces a statistical difference in hospital mortality.

Failure to rescue

Suboptimal and inconsistent performance of rapid response systems is frequently attributed to a failure of activation (Chrysochoou and Gunn, 2006), with activation rates of as low as 30% reported (Robb and Seddon, 2010). Indeed, even delayed activation – by as little as 30 minutes – has been associated with increased risk of patient death (Downey et al, 2008; Quach et al, 2008).

Factors potentially contributing to this activation failure include inadequate staff education (Kenward et al, 2004) and sociocultural barriers (Shearer et al, 2012). However, educational initiatives alone may have limited beneficial impact upon clinical performance (Ludikhuize et al, 2011).

Computerization of medical records offers potential opportunities for overcoming activation failures. The implementation of an electronic health record-triggered system in one centre was reported to lead to a reduction in intensive care unit admissions and, in the surgical population, a reduction in mortality (Huh et al, 2014). More recently, a group of English hospitals demonstrated a significant and sustained reduction in hospital-wide mortality following the introduction of an electronic system for the recording and display of physiological observations and aggregate weighted track and trigger system score (Schmidt et al, 2015). Almost a quarter of activations in the electronic arm related to abnormal laboratory findings, illustrating another potential benefit of computerisation (Huh et al, 2014).

The benefits of electronic activation must be offset against the detrimental effects of losing clinical acumen. Electronic systems frequently fail to disregard artefact or monitoring malfunction (such as displacement of the pulse oximetry probe). In addition, increased sensitivity is thus accompanied by reduced specificity with a resultant rise in the frequency of false alarms and the potential for alarm fatigue (Taenzer et al, 2010).

Failure to rescue may also result from inadequate performance from the responding clinicians. There is limited training available to prepare medical and nursing staff for operating in the novel and unique environment of the deteriorating patient system, particularly in relation to the non-technical skills required for effective performance in the time-pressured, high stakes setting of acute, life-threatening illness (Gillon et al, 2012).

Standardization of deteriorating patient systems across regions may impact upon system performance. Provisional results from a standardization of deteriorating patient systems in New South Wales suggest an improvement in outcomes (Hughes et al, 2014).

Conclusions

Rapid response systems represent a hospital-wide initiative to improve patient outcomes and, despite the lack of clear evidence of efficacy, enjoy widespread use in many forms. Current efforts are directed towards system standardization while research centres on integration of the initiative into computerized systems. Twenty years from inception, rapid response systems have become institutions within health care, and an inescapable, and central, aspect of the hospital professional's role. **BJHM**

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KEY POINTS

- It has long been recognized that adverse patient events, for example cardiac arrest and intensive care unit admission, may be preceded by abnormal vital signs.
- The last 25 years have seen the development of many different rapid response systems.
- The monitoring of physiological parameters enables clinicians to detect the early deterioration of a patient and different systems dictate the response activated.
- The translation into better patient outcomes is contentious with different systems claiming different strengths and weaknesses.

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