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Rapid response teams

This article reviews the RRT system concept and provides an update on the current state of such systems, their challenges, their performance, the evidence supporting their usefulness and their evolution.

is that they are intended to review patients at an earlier stage of clinical deterioration with the aim of preventing serious adverse events. The major function of RRTs is not to respond to cardiac arrests but rather to prevent cardiac arrests. Similarly, they function to prevent unexpected/preventable deaths and unplanned admissions to the intensive care unit. RRTs typically review, assess and treat patients with respiratory, neurological, and cardiac deterioration rather than patients who have already suffered a respiratory or cardiac arrest.

Multiple before-and-after studies in a few centres or in single centres (Chen et al. 2014; Bellomo et al. 2003; Jones et al. 2005; Sebat et al. 2007; Buist et al. 2007; Foraida et al. 2003; Sharek et al. 2007) have reported that the introduction of RRTs is associated with a significant reduction in cardiac arrests in ward patients. Such effectiveness appears greatest in hospitals where RRTs have operated for several years (so called mature systems) and deliver greater “RRT dose” (RRT assessments/1000 patients admissions) (Jones et al. 2009). Some meta-analyses have challenged the effectiveness of RRTs (Chan et al. 2010; McGaughey et al. 2007), but other more recent meta-analyses have reported that their implementation is associated with an overall reduction in mortality in both adult and paediatric studies ($P < 0.001$) as well as a significant reduction in cardiopulmonary arrests in adult and paediatric patients ($P < 0.001$) (Maharaj et al. 2015). Accordingly, there is continuing controversy regarding the overall effectiveness of RRTs. Importantly, RRTs do not appear to clearly lead to a decrease in hospital mortality. This is not surprising as most hospital deaths are neither preventable nor unexpected but represent the final event in a process called end-of-life care (EOLC).

Concept of failure to rescue

Patients in hospitals may develop a significant worsening of their condition and such change may herald the risk of a major adverse event. Despite such patients being in hospital, however, the doctors and nurses responsible for their care may fail to respond in a timely and/or appropriate manner. This failure to respond is termed “failure to rescue” (DeVita et al. 2006). Logical reasons for sudden critical illness and failure to rescue exist (Table 1), and explain why serious adverse events (SAEs) are surprisingly frequent even in major teaching hospitals.

Epidemiology of serious adverse events

Studies in the U.S. (Brennan et al. 1990; Thomas et al. 2000) and other countries (Wilson et al. 1995; Davis et al. 2002; McQuillan et al. 1998) demonstrate the following observations:

- Unexpected SAEs are relatively common; and many
- Are iatrogenic
- Contribute to disability and mortality; and
- Occur after failure to rescue (Wilson et al. 1999).

These studies also report that many serious adverse events are preceded by clinically detectable warning signs (Buist et al. 1999; Hodgetts et al. 2002; Bell et al. 2006). Many conditions have been reported to be associated with failure to rescue. These conditions include acute respiratory failure, acute changes in conscious state, hypotension, arrhythmias, pulmonary oedema and sepsis (Jones et al. 2006). The most commonly measured serious adverse events of such deteriorations include cardiac arrest, unexpected death, and unplanned/emergency ICU admission (Hillman et al. 2005).

Rapid Response Teams (RRTs) are the key components of Rapid Response Systems. RRT-based rescue systems were developed in response to evidence that many deteriorating hospital patients experienced “failure to rescue” and went on to develop serious adverse events (SAEs), including death, cardiac arrest and unplanned ICU admission (DeVita et al. 2006). The RRT approach is based on several key concepts:

- Identification of patients at risk
- Early notification of responders (RRT)
- Rapid intervention by the RRT, and
- Audit of the system’s performance (DeVita et al. 2006).

RRT-based systems have now been implemented in the whole of Australia, and in many, if not most hospitals, in New Zealand, Denmark, The Netherlands, Sweden, the United Kingdom, Canada and the USA (Steel and Reynolds 2008; Winers et al. 2006). RRTs have been reported to operate in some hospitals in Brazil, Italy, Portugal, Germany, Iran, Finland, Saudi Arabia and Japan.

RRTs are not the same as cardiac arrest teams, and in many hospitals they exist in parallel with cardiac arrest teams. However, members of the RRT can also respond to cardiac arrests and act both as cardiac arrest team and RRT depending on the circumstances. A measure of success of the RRT system is that cardiac arrests decrease to the point of becoming rare events. The key distinguishing feature between RRTs and cardiac arrest teams

Warning signs

Abnormal vital signs are typically present for more than one hour and often more than one day in most patients who experience deterioration in the ward and go on to develop SAEs (Buist et al. 1999; Franklin and Mathew 1994). Logically, therefore, vital signs can be used to identify deteriorating patients from minutes to hours before a cardiac arrest or death or emergency ICU referral occurs. Thus, in most cases, there is a significant time-window to deliver intervention. Frequent and accurate measurement and reporting of vital signs is the key step in this process (DeVita 2005). Similarly, abnormalities in common laboratory tests can help identify patients at risk (Loekito et al. 2013).

Although the measurement of vital signs is risk-free and identifies most deteriorating patients, it does not occur predictably, accurately or completely (Leuvan and Mitchell 2008; Cretikos et al. 2008). Respiratory rate monitoring is particularly striking and the strongest predictor of a major clinical complication occurring within 24 hours (Cretikos et al. 2007). However, it is not optimally measured (Cretikos et al. 2008), contributing to the risk of “failure to rescue”. Because of such limitations, there has been a growing call for hospital patients to have continuous or semi-continuous vital sign monitoring. As easily wearable noninvasive technology develops to at least measure respiratory rate, heart rate, oxygen saturation and becomes more widely and less expensively available, it is likely that a transition to such technology will start taking place in hospitals in developed countries (Bellomo et al. 2012; Subbe et al. 2017).

Responding to abnormal vital signs

When patients develop abnormal vital signs or abnormal laboratory tests, the traditional model of hospital response may be of limited quality and reliability. There may be triage errors (Chen and Hillman 2014), delayed doctor notification, failure by doctor to attend (Wilson et al. 1999), inadequate clinical assessment (Maharaj et al. 2015; McQuillan et al. 1998; Wilson et al. 1999; Hodgetts et al. 2002), suboptimal response to the urgency of the symptoms (Wilson et al. 1999), and failure to seek help or advice (Wilson et al.

1999). Having objective criteria, which clarify staff expectations, is thus seen as important in triggering a rapid response. In addition, rapid referral to personnel with appropriate expertise and equipment is likely beneficial. Deficiencies in identifying and responding to deteriorating patients provide an additional rationale for RRTs.

Key principles

An important principle underlying RRTs (and all critical illness) is that early intervention can improve patient outcome. In this regard, multiple studies reporting on delayed RRT activation have found that such delays lead to increased risk of serious adverse events (Chen et al. 2015). A key principle is the ICU without walls principle that delivers critical care expertise to the patient before (not after!) the development of adverse clinical outcomes.

Continuing controversy regarding the overall effectiveness of RRTs

Rapid response team-based system

The RRT is part of a system without which the team cannot deliver improved care. The system has an *afferent arm* whose task is to identify deteriorating patients and trigger a response. This arm includes having RRT calling criteria, their measurement and a mechanism of RRT activation. Its *efferent arm* is the RRT. A third arm is the *performance review arm*, which collects and analyses data from events and continuously seeks to improve prevention and response. Finally, there is the *administrative arm* (DeVita et al. 2006), which coordinates resources and implements policy changes.

The key characteristic of the response teams is that they are activated when a patient fulfils pre-defined criteria. Many organisations print mnemonic cards or posters to promote use. RRT activation is rapid and usually bypasses traditional unit-based approaches to care. The team responds rapidly (within minutes) to the call and delivers critical care equipment and expertise to the patient’s bedside (DeVita et al. 2006).

Table 1. Possible reasons for failure to rescue

- Lack of continuous or near continuous or even frequent vital signs monitoring in the general ward
- Lack of automated alarm or alert systems in association with vital signs which are independent of human factors
- Incomplete measurement of vital signs (esp. of respiratory rate)
- Lack of explicit criteria or policies for activating higher level interventions
- Infrequent physical presence and visual review by a ward nurse
- Infrequent assessment and attendance by a ward doctor
- In surgical wards, lack of presence by doctors because of their need to be in an operating room
- Judgment by variable members of staff regarding whether escalation is necessary
- Judgment by staff members varies according to training, experience, professional attitude, working environment and position
- Slow response to a crisis or deterioration because of a multi-step response chain (bedside nurse to charge nurse to junior doctor to registrar/fellow to consultant/attending)
- Increasing patient complexity in modern hospital wards with more frequent episodes of deterioration

Triggering criteria

The efferent arm is triggered in response to so-called “calling criteria” based on derangements in vital signs. However, many hospitals include “I am worried” type criteria to allow staff to escalate treatment if they perceive there is a serious problem even in the absence of such criteria. In some hospitals family members can also activate the RRT if they are worried about the condition of their hospitalised family member. Criteria can be used to trigger intervention in at least two major different ways. One uses them to calculate an Early

Warning Score (McGauhey et al. 2007; Gao et al. 2007), where components are summed to obtain a score, and if the score achieves a certain value a response is triggered. In other centres, the presence of any one abnormality is sufficient for activation of the RRT. No studies have compared RRT performance under such different triggering systems.

RRT composition

Typically, in larger hospitals, at least one RRT member is a dedicated critical care fellow or trainee (so called Medical Emergency Team or MET), who is accompanied by a nurse with a dedicated set of drugs and equipment (England and Bion 2008). In some hospitals, however, the team may simply be based on an ICU nurse or respiratory therapist or both, who are “first responders” and then themselves decide whether to activate the full response involving ICU doctors. In Australia (Bellomo et al. 2003), New Zealand and Scandinavia, the typical model is the MET. Most studies demonstrating improved patient outcomes have involved a MET (Jones et al. 2009). The RRT must bring with it the necessary medications and tools to deliver the ICU without walls to the patient’s bedside (**Figure 1**).

Interventions and outcomes

Some interventions performed by the response team are simple (oxygen, intravenous fluid, diuretics, bronchodilators and diagnostic blood or radiology tests). However, a significant proportion of patients require critical care level interventions (Bellomo et al. 2003). Evidence from several studies indicates that the system can also help address end-of-life care planning (Hillman et al. 2005).

The only cluster-randomised multicentre controlled trial of RRTs was termed MERIT (Medical Emergency Response and Intervention Trial) (Hillman et al. 2005). On primary analysis, MERIT failed to show an outcome benefit, although both trial arms showed an outcome benefit compared to baseline. However, more detailed analysis of the results found evidence of benefit. For example, a post hoc analysis of the MERIT study showed a significant outcome improvement (death, cardiac arrest) when the data was analysed in an *as treated* rather than an *intention to treat* (as assigned) model. In this analysis, there



Figure 1. Typical rapid response system cart containing the necessary tools and medications to create an intensive care unit like system at the patient’s bedside

was a significant and linear decrease in poor outcome as RRT responses increased (Chen et al. 2009). Other studies have revealed a significant reduction in all-cause hospital mortality, particularly in surgical patients (Bellomo et al. 2003; Jones et al. 2007).

Several single-centre before-and-after trials supported the contention that RRTs improve outcome (Bellomo et al. 2003; Jones et al. 2003; Sebat et al. 2007; Buist et al. 2007; Foraida et al. 2003; Sharek et al. 2007), and recent meta-analysis strongly supported such an effect (Maharaj et al. 2015). The limited evidence available for such RRT-based systems is in great part due to the fact that individual randomisation trials or blinding of

the intervention are simply not possible. The highest-level approach to obtain randomised controlled evidence would require cluster randomisation trials and such trials would require up to 200 clusters (hospitals) to have sufficient statistical power to detect a realistic effect on SAEs. Moreover, as these systems require time to “mature” (to make staff change behaviour from the traditional model to the new model), simply randomising to a RRT intervention or no-RRT is not representative of the true effect of the team once the new model has been accepted. Another way to assess such RRT systems is to study the impact of national programmes. The introduction of RRTs in The Netherlands offered such an

opportunity and demonstrated a clear effect on cardiac arrests (Ludikhuijze et al. 2015).

In another before-and-after study, the reduction in cardiac arrests was estimated to save approximately 2,000 post-cardiac arrest bed days annually (Bellomo et al. 2003). The RRT can also deliver education of nursing and medical staff (Buist and Bellomo 2004), and teach them how to better manage acutely ill patients (Jones et al. 2006). Finally, as RRT systems mature and encounter more and more out of ICU critical illness, they begin to significantly contribute to end-of-life care decisions and management (Chen et al. 2008; Brown et al. 2017; Tan and Delaney 2014).

How to make a RRT work

The introduction of a RRT is sociologically complex because it subverts a traditional model of care. Thus, a coordinated strategy is needed to prevent poor implementation (DeVita and Hillman 2006), and support from hospital medical, nursing and administrative leaders is needed to achieve success. Time, patience, education and collegially constructive interactions are also needed (Bellomo et al. 2003). It should be made clear that the role of the RRT is to provide a safety net rather than taking over patient care. The team should be adequately resourced to enable appropriate management of any critical care event.

The afferent arm requires sustained education of nursing and medical ward staff. Without this effort the RRT system will underperform. Accordingly, repeated education of all existing and new hospital ward staff is crucial. Inclusion of a physician team leader is key because it can expedite transfer to the ICU, and/or facilitate end-of-life care when needed (Jones et al. 2009).

Successful RRTs in teaching hospitals deliver a “dose” of least 40 triggers/1000 patient admissions (Jones et al. 2009). Increasing response “dose” is key to reducing cardiac arrests (Jones et al. 2005; Buist et al. 2007; Foraida et al. 2003).

Simulation training improves team performance and allows a structured approach to managing the deteriorating patient. Regular audits are needed to assess performance (DeVita et al. 2006).

Controversies

The preponderance of evidence supporting RRT-based systems comes from short-term before-and-after studies. Meta-analyses of studies assessing such systems have reported inconsistent findings. However, it is extremely unlikely that a “definitive” trial will ever be conducted. Thus, the decision to introduce RRT-based systems or not in healthcare jurisdictions and/or a single institution is based on judgement and considerations of risks, costs and likely benefits. As stated at the outset, several healthcare systems (USA, UK, Australia, New Zealand, The Netherlands, Denmark, Canada, Sweden) have taken the view that RRT-based system should be a standard of care.

Implementation of a RRS may theoretically de-skill ward staff. However, surveyed nurses in both Canada and Australia disagree (Bagshaw et al. 2010). Inappropriate patient management or conflict with the primary team is a concern but, in fact, uncommon. The optimal team composition remains unknown, but a medical team leader seems desirable (Jones et al. 2009).

Implementation of a RRT-based system may divert resources away from ICU patients (Winters et al. 2006). No evidence of this, however, exists. RRT systems may divert the focus away from other effective patient safety initiatives (Winters et al. 2006) (e.g. hospitalists, nurse practitioners, or increased number of ICU beds). However, the opposite may be true. Implementation of a RRT-system is potentially expensive. However, no cost analyses have been undertaken to assess its monetary value.

Finally, an unexpected problem has recently been noted in very mature systems that have

operated for >20 years, as is the case in several Australian centres: “RRT addiction”. In such hospitals the number of RRT activations has reached the several thousand calls/year value with a dose of >100 calls/1000 admissions and wards have become dependent on the RRT for all kinds of “episodes” with the threshold for activating the team becoming lower and lower. In this setting, concerns have developed that ward staff deskilling and disengagement may be a serious problem. However, such hospitals also report persistent major reductions in cardiac arrest rates, making it uncertain whether such high rates of RRT activation are desirable or undesirable.

Conclusions

RRT-based systems are now an established part of medical and nursing practice in many hospitals and countries. Their goal is to make hospitals safer and to prevent cardiac arrests, emergency late ICU admission and unexpected death. Even though conclusive evidence is not available (as is the case for ICUs or cardiac arrest teams or coronary care units), the logic behind their development is compelling. Hospitals or healthcare jurisdictions that adopt such RRT systems typically never look back and ask themselves why they had not implemented such a system earlier. In some ways, even though the evidence of benefit is not conclusive, RRTs represent a key component of an overall shift in culture and thinking toward greater and more predictable safety and quality in acute healthcare. In this regard, it is surprising that the adoption of RRTs has not spread more widely beyond English-speaking and Nordic/Scandinavian healthcare systems. Accordingly, it is likely that the future will see the slow but steady spread of such systems or similar systems to other developed countries. ■

Conflict of interest

Rinaldo Bellomo declares that he has no conflict of interest.

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