Systems to prevent in-hospital cardiac arrest

James Tibballs

Abstract

The outcome of cardiac arrest in hospitalized infants and children is poor. However, cardiac arrest is often predictable based on many hours of hypoxaemia, hypotension and associated symptoms and signs (heart rate, respiratory rate, respiratory effort, neurological change) and staff concern. If intensive expert medical and nursing interventions are provided quickly before cardiac arrest, some deaths on wards outside the intensive care environment are preventable. Over the past decade, the introduction of rapid response and early warning systems in some large paediatric hospitals has reduced the incidence of unexpected cardiac arrest by some 40% and death by 20%. These systems enable any staff member (or parent) to summon urgent expert assistance to the patient's bedside without the need to consult senior staff members. Introduction of a system is a culture change necessitating institutional adoption, extensive education in recognition of the seriously-ill patient, and abolition of hierarchical barriers to obtain rapid assistance.

Keywords cardiac arrest; death; early warning score; medical emergency team; prevention; rapid response team

Introduction

The incidence of cardiac arrest among hospitalized children is small but with poor outcomes despite expert resuscitation. Traditionally, recognition of critical illness by a bedside nurse is required before a chain of nursing and medical command calls experts in resuscitation to the bedside. By the time these events unfold it may be too late to prevent or effectively treat cardiac arrest. In large series of outcome of cardiac arrest of children in hospital, although maximum survival is 49%, more often only one-third or a quarter of children survive and large proportions of survivors have severe neurological damage. Obviously, cardiac arrest should be prevented, especially if predictable.

Although cardiac arrest in children may be sudden and without warning, it is often preceded by hours of progressive hypoxaemia or hypotension or both resulting from diverse illnesses. If the severity of a condition is recognized early, it may be possible to intervene and prevent cardiopulmonary arrest and death.

Recognition of critical illness

If children at risk for cardiopulmonary arrest could be accurately identified, more resources and effort could be devoted to prevention of respiratory or cardiac arrest. However, a paucity of research identifies groups of patients at high risk of unexpected cardiac arrest. In one study,[1] children in need of urgent assistance were less than 1 year of age, with chronic or complex illnesses and those immediately after surgery. These children required reversal of analgesia or sedation, resuscitation with fluid boluses or management of acute hypernatraemia and sustained a significantly higher incidence of in-hospital mortality. However, critical events also occurred in other children.

With realization that some deaths in hospitals are preventable, the Institute for Healthcare Improvement in United States recommended adoption of rapid response systems while in Britain a key recommendation of the Confidential Enquiry into Maternal and Child Health was adoption of an early warning score.

Strategies, which include rapid response systems and paediatric early warning scores (PEWS), have been developed to help recognize critical illness and to mobilize immediate or early assistance with the aim of preventing cardiopulmonary arrest. Both strategies rely upon institutional responses to predefined clinical criteria but differ in operational aspects.

Paediatric rapid response systems

Development and operation

Different names and team compositions have been imparted to systems to recognize and respond rapidly to serious illness around the world. A Medical emergency team (MET) is composed of doctors and nurses, a rapid response team (RRT) is composed of either doctors and nurses or nurses alone while a critical care outreach team (CCOT) and a patient at risk team (PART) are usually composed of nurses alone but with rapid access to doctor assistance. Differences among systems include the immediacy of response, composition of the team and choice of calling criteria or activation triggers, but all are similar in that transgression of any one criteria may be used to activate the system.

Operational responses: immediate or delayed, one-tier or two-tier

Some paediatric institutions consider a request for assistance as needing the same urgent response as that for 'Code Blue'; that is, for respiratory or cardiopulmonary arrest. These are 'single-tier' systems. These teams are multidisciplinary including physicians, nurses, respiratory therapists, pharmacy personnel, security, social service, and sometimes surgeons. Other institutions have adopted 'two-tiered' systems in which there is a different response according to the urgency and severity of the patient's condition. The first tier is a small focused team that responds to consultations and requests for advice and is not required to attend immediately but must do so within a specified period, e.g. within 15 min. The second tier is a larger multidisciplinary team similar to the one-tier system and functions as a "Code Blue" team for cardiopulmonary arrest and must attend immediately. Improved outcomes have been observed with both systems.

Advantages of a one-tiered system include: 1) quick provision of definitive care; 2) provision of all services. Disadvantages of the one-tiered system include: 1) requirement for highly skilled

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personnel even for consultative function; 2) intimidation for staff to call the team for a consultation or evaluation; and 3) possible high cost compared to two-tiered system. In contrast, the first tier of a two-tiered system may be less costly and less intimidating for clinical staff to activate when consultation and advice are needed. However, the initial smaller more focused team of a two-tiered system may be under-skilled to handle a genuine life-threatening emergency. Each institution must balance the advantages and disadvantages because the personnel who respond and the time commitment of the responders may be quite different.

Activation triggers or calling criteria

Attainment or transgression of any one activation criteria triggers an immediate MET or RRT response. Some institutions have chosen specific age-related physiological activation criteria including heart rate, blood pressure and respiratory rate (Table 1), while others have chosen more open-ended disturbances of cardiovascular and respiratory function. Both types of activation triggers enable a clinician to activate the team because they are "worried" even if physiological triggers are not transgressed. Some hospitals also allow the child's parent to activate the system.

No individual activation triggers or calling criteria of rapid response systems have been evaluated to determine sensitivity and specificity in preventing cardiac arrest (but some similar activation criteria have been evaluated within early warning scores). Nonetheless, the sensitivity of calling criteria may be inferred by the reduction in proportion of preventable cardiac arrests and other adverse events. For example, at the Royal Children's Hospital, Melbourne, a 55% reduction in preventable cardiac arrest was recorded while at Lucile Packard Hospital, Stanford, a 72% reduction was recorded. This implies that the sensitivity of the activation criteria is probably high, but since no system has reduced preventable deaths (however defined) to zero, it cannot be ideal. The specificity of the activation criteria may be inferred by the percentage of activations which do not result in admission to the intensive care unit. A high percentage of non-admission suggests over-utilization of the RRT and low specificity of the activation criteria. However, the optimal activation rate of a system, as might be indicated by the ratio of non-admission and admission to a critical care unit, is unknown. At Cincinnati Children's Hospital 52% of 27 RRT activations did not result in ICU admission while at the Royal Children's Hospital, Melbourne, 53% of 809 calls over 4 years did not result in ICU admission. An interpretation of these data is that the system is over-utilized and has low specificity, but another is that in order to reliably prevent cardiac arrest, a low ICU admission rate may be acceptable. These are not the only outcomes of rapid response systems — in the majority of activations, the RRT gives other treatment besides just advice. At Stanford advice only was given in 6% of RRT activations and in Melbourne it was 16% meaning that in both institutions the large majority of patients, 94% and 84% respectively, received beneficial care other than prevention of cardiac arrest and admission to ICU.

The reliability of the "Melbourne activation criteria" has been applied to the Children's Hospital for Wales (Cardiff) with a retrospective chart review of 1000 patients.[2] The sensitivity of the criteria was 68.3%, specificity 83.2%, positive predictive value 3.6%, negative predictive value 99.7% and area under the curve of ROC analysis 0.79 in preventing adverse outcomes. Moreover, seven of 16 children (43.8%) would not have transgressed the criteria prior to adverse outcomes while 469 of 984 children (47.7%) would have transgressed the criteria but did not sustain an adverse event. On this basis the system was judged to have (only) acceptable performance, thereby questioning whether this intervention should be used nationwide. However, the adverse outcomes were taken neither as cardiac arrest nor death but (merely) admission to PICU or a high-dependency unit and it was assumed in the study that a MET call would be made whenever activation criteria are transgressed. That is not the reality since activation is discretionary, not mandatory which may explain its actual low "false activation rate" (16%, "advice only"). In a recent study[3] of the attitudes and barriers to MET activation in Melbourne, only 5.7% of 407 staff thought that their MET system was overused.

Outcomes of some paediatric rapid response systems

Although rapid response systems have been established in adult hospitals for many years, uptake by paediatric hospitals or combined adult–paediatric hospitals has been slow. In North America, by 2005, 24% of 181 hospitals with more than 50 acute paediatric beds had activation criteria in place for 'Code' teams but only 3% had activation criteria for a rapid response system.[4] In the UK by 2005,[5] only 22% of 144 hospitals caring for children had an early warning system.

Some paediatric institutions[6–13] have reported outcomes with rapid response systems to prevent cardiac and respiratory arrest (Table 2). All have been studies evaluating the incidence of cardiac arrest and death before and after the introduction of a system. Although several have observed gratifying improvements in outcomes, a randomized trial is highly desirable.

Melbourne MET system: a rapid response system was started in 2002 at Royal Children's Hospital,[6] Melbourne after analysis of adverse events on wards revealed that in many cases warning symptoms and signs had not been heeded or had resulted in delayed resuscitation. Some deaths may have been preventable. The system continues to operate under a single-tier system, is composed of a doctor and nurse from PICU, an emergency department doctor and the admitting medical unit registrar. After 12 months of operation although total ward cardiac arrests decreased, it was not significant. However, 'preventable' cardiac arrest and death (occurring in children whose physiological parameters transgressed calling criteria) were eliminated. After another 3 years of operation,[7] although there was a non-significant decrease in unexpected cardiac arrest, decreases in 'preventable' cardiac arrest (55%) and death (87%) were significant. Moreover, total hospital death rate decreased significantly by 34% with 34 deaths reduced per year. One life was saved for every 72 activations. During this interval deaths in the PICU also decreased (31%) so the reduction in ward deaths was not due to transfer of patients to PICU.

Stanford RRT system: another paediatric one-tiered rapid response system achieving notable success was commenced in 2005 at Lucille Packard Children's Hospital at Stanford[8] which achieved significant reductions in hospital mortality (18%) and