Rapid Response Team Activations in an Israeli Tertiary Care Pediatric Hospital: Analysis of 614 Events

Lisa D. Amir MD MPH

Department of Emergency Medicine, Schneider Children's Medical Center, Petah Tikva, affiliated with Sackler Faculty of Medicine, Tel Aviv University, Tel Aviv, Israel

ABSTRACT **Background:** Rapid response teams (RRT) reduce in-hospital mortality and cardiac arrests. There are only a few articles describing RRT activations outside of North America and Australia.

Objectives: To describe demographic and clinical variables of RRT activations using 13 years of data.

Methods: Schneider Children's Medical Center of Israel is the largest tertiary care pediatric hospital in Israel. We analyzed demographic and clinical data of RRT activation from 1 January 2008 to 31 December 2018.

Results: During the study period there were 614 RRT activations with an average of 55.8 activations per year (range 43–76). RRT activations occurred most commonly for children aged 0–12 months (43%) as compared to children 1–5 years of age (25%), 6–10 years of age (12%), 11–18 years of age (18%), and adults (2%). The most common reason for activation was respiratory deterioration (45.8%) followed by neurologic alteration (21%), and cardiac arrest (18%). Following resuscitation, 47% of the patients were admitted to the pediatric intensive care unit and 12% were pronounced dead. Intubation was performed in 48.9% of activations, chest compressions in 20.5%, intraosseous line insertion in 9.4%, and defibrillation in 3.4%. Procedures were more commonly performed in the emergency department (ED).

Conclusions: We describe RRT including RRT activations in the ED. The high frequency of interventions should be utilized to direct staff training for the RRT and the ED. The lack of standardization of reporting data for RRT activations makes comparisons among hospitals difficult.

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KEY WORDS: cardiac arrest, medical response team, pediatric, rapid response team (RRT), resuscitation

Rapid response teams (RRTs) were implemented to optimize treatment of the acutely deteriorating child and have been shown to reduce in-hospital mortality [1] and cardiac arrests [2-6], although this reduction has recently been called into question [7]. Teams are usually based in the pediatric intensive care unit (PICU) and activation may be based on preset physiologic criteria determined by medical staff [1,3-6,8-13], a Pediatric Early Warning Score (PEWS) [8,14], or staff or parental opinion that a child's condition has deteriorated [3,4,8,9,11-13,15]. Most reports describe the process and results of implementation in North American tertiary care pediatric hospitals [1,3-5,8,14-17]; however, there are only a few articles describing other geographic areas [6,9-11].

Schneider Children's Medical Center of Israel is an academic, freestanding, tertiary care pediatric hospital in central Israel with over 50,000 inpatient hospitalization days. It has the busiest pediatric emergency department (ED) in the country with over 55,000 visits per year. The RRT, which also serves as the cardiac arrest team, has been operational since the hospital opened in 1992.

The Israeli Ministry of Health mandated RRT since 2006 [18]. The medical center resuscitation committee, consisting of two attending physicians and one nurse, reviews all RRT activations to provide quality assurance and to identify situations and systems processes that could be improved.

The purpose of this study was to analyze 13 years of RRT activations. We describe demographic and clinical variables, including location, reason for activation, patient characteristics, outcome, and interventions.

PATIENTS AND METHODS

RAPID RESPONSE TEAM

The RRT consists of a PICU physician (attending/fellow from the hours 08:00 until 16:00 and third or fourth year on-call resident or fellow from the hours 16:00–08:00), anesthesiologist, PICU nurse, and charge nurse. The RRT does not include respiratory therapists. A PICU attending physician was consulted after every RRT activation and made all the final decisions regarding PICU admission. Response times were under 5 minutes. The RRT may be activated by any member of the medical staff but not by parents or family members. PEWS or other formal activation criteria do not exist in our medical center. The pediatric trauma bay is located in the adjacent adult hospital and has its own trauma team.

DATA COLLECTION AND ANALYSIS

Responsibility for quality assurance and data collection was transferred from the PICU to the hospital resuscitation committee in June 2007. The charge nurse at the time of RRT activation

is responsible for recording interventions performed, medications administered, and demographic and background information. A member of the hospital resuscitation committee reviews all data for completeness and accuracy within 48 hours. Activations from 1 January 2008 to 31 December 2018 were included in the analysis. Multiple activations for the same patient were analyzed as independent events.

Data analyzed included patient demographic information (age, background illness), location, time of day, reason for activation, procedures performed, medications administered, and disposition after resuscitation. Shifts were defined according to nursing shifts (morning hours 07:00–15:00, evening hours 15:00–23:00, and night hours 23:00–07:00). Israel has a subtropical climate with essentially only two seasons per year: winter and summer. Winter months were designated as December to March based on the number of reported cases of influenza-like illness that exceeded epidemic threshold [19]. Oncology inpatient and outpatient services were combined under one heading due to shared staff and resources. The three inpatient units were combined for analysis since patients are admitted to one of the three wards on a rotating basis and there was no difference in the number of activations (50, 50, and 49). Other locations in the hospital included outpatient clinics (excluding oncology), PICU, neonatal intensive care unit (NICU), and public spaces including the grounds surrounding the hospital.

Statistical analysis was primarily descriptive. Data was entered on a spreadsheet and analyzed using a commercially available statistical program (https://www.medcalc.org). The hospital ethics committee approved this study (RMC 19-0303).

RESULTS

During the study period there were 614 RRT activations with an average of 55.8 activations per year (range 43–76). For inpatient units, the average number of activations was 0.40/1000 patient care days (range 0.32–0.63) and for the emergency department, the average number of activations was 0.48/1000 patient visits (range 0.34–0.79). There was an overall average of 15.25 calls per month in the winter as compared to 10.3 calls per month in the summer. For inpatient units, the average number of activations was 0.48/1000 hospitalization days in the winter as compared to 0.36 in the summer (risk ratio [RR] 1.33, 95% confidence interval [95%CI], 0.85–2.11). For the ED, the average number of activations was 0.29/1000 patient visits in the winter as compared to 0.14/1000 patient visits in the summer (RR 2.07, 95%CI 1.06–4.24).

Compared to other age groups, RRT activations occurred most commonly for children aged 0–12 months (43%) compared to children 1–5 years of age (25%), 6–10 years of age (12%), and 11–18 years of age (18%). There was a statistically significant higher rate of activations for children aged 0–12 months in the inpatient wards (reference group 6–10 years, RR 2.13, 95%CI 1.88–2.41) and in the ED (RR 3.23, 95%CI 2.94–3.75). Notably, there were 11 (2%) activations for adult visitors or staff.

Figure 1. Rapid response team activation by hospital location
ED = emergency department, NICU = neonatal intensive care unit, PICU = pediatric intensive care unit

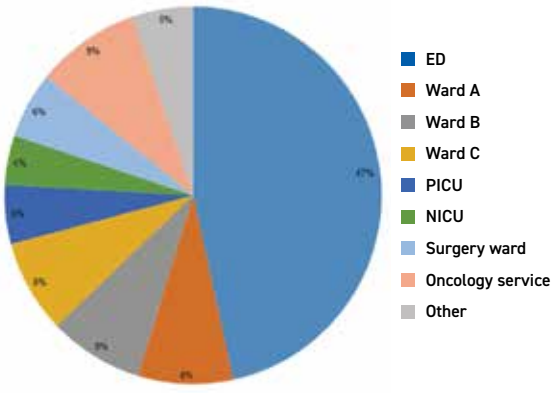
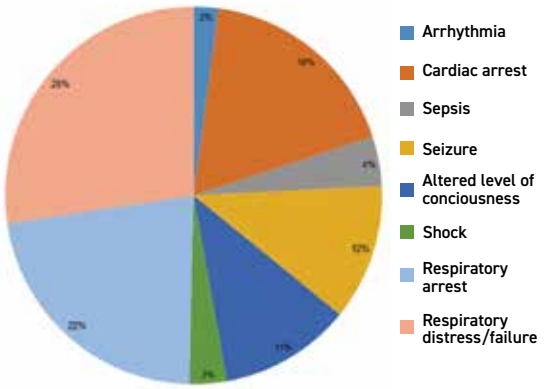


Figure 2. Reason for rapid response team activation

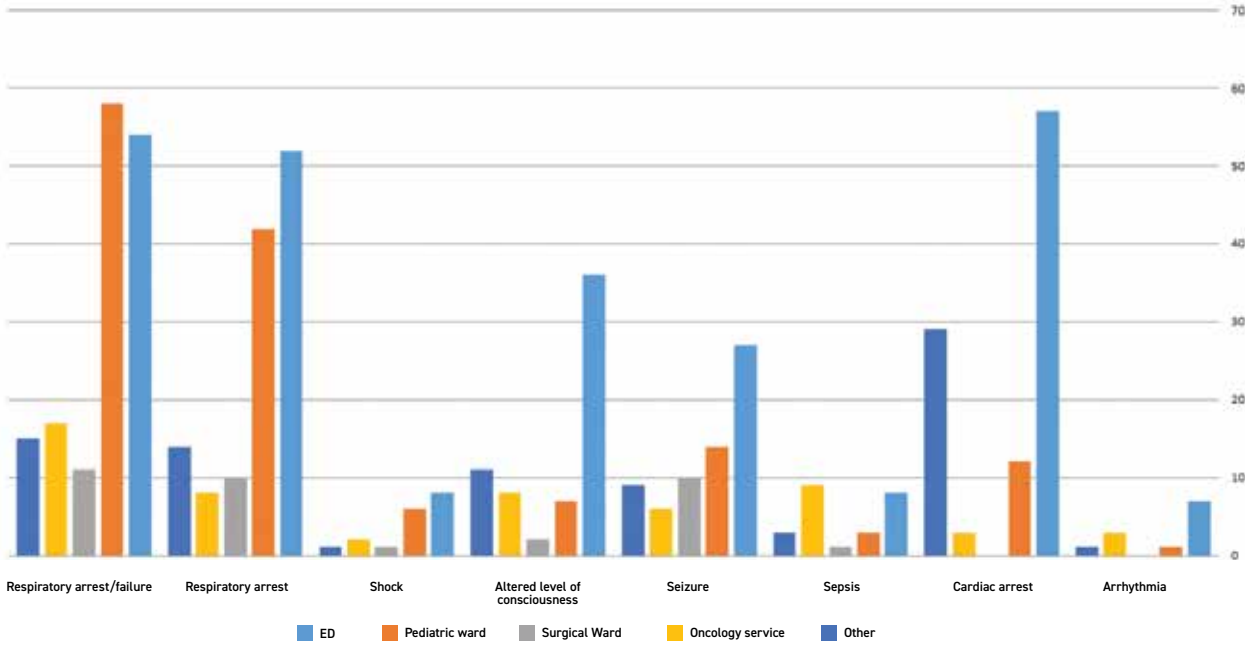


The location of activation is shown in Figure 1. The majority of activations occurred during the evening shift (43%), followed by the morning shift (34%) and night shift (23%). When analyzed by location, this proportion was preserved with the exception of the oncology service, which had morning shift preponderance, reflecting the day clinic when the majority of oncology patients are examined.

Overall, 45.8% of activations were for respiratory deterioration [Figure 2] and cardiac arrest was the cause in 18%. When analyzed by department [Figure 3], respiratory deterioration remained the most common cause. Cardiac arrests were most common in the ED and other locations, which included the PICU and NICU.

Resuscitations were generally of short duration with 71% of resuscitations lasting less than 30 minutes and only 7% exceeded 1 hour. Resuscitation in the ED was more likely to last over 1 hour (10%) as compared to the general pediatric wards, surgical wards, or oncology service (4%, 0%, and 4% respectively).

Figure 3. Reason for rapid response teams activation by location
ED = emergency department



No background illness was recorded at the time of the RRT call in 32% of children; 41% had one background illness and 27% had two or more. Children treated by the RRT in the ED were less likely to be chronically ill as compared to the inpatient or surgical wards (51% vs. 11% and 26%, respectively). Figure **4** describes the type of chronic illness by department. Analysis of the incidence of children with chronic illness reveals that there was no trend for increasing percentage of children to have a chronic illness over the 13 years in which data were collected in the ED, inpatient ward, or surgery department. Using mortality or PICU admission as a proxy measure of severity of illness did not demonstrate an increasing percentage of deaths or PICU admissions over time.

The PICU was the most frequent destination after resuscitation with 47% of patients admitted after interventions by the RRT. Of these patients 71% were from the oncology ward, 58% from inpatient wards, 50% from the ED, and 29% from the surgical ward. Analysis of unscheduled PICU admissions resulting from activations of the RRT showed that 50% were admitted from the ED, 30% from inpatient wards, 14% from the oncology service, and 3% from surgery wards and 3% from other wards. Overall 12% of the patients were pronounced dead at the end of the RRT activation. Of these 14% in the ED, 8% from the inpatient wards, 5% from oncology, and none from surgery. No adult died. Among children who had no reported background illness 11.2% died and all but two of those died in the ED. Among children with one background illness, 9.6% died and among children with two or more illnesses, 16.0% died.

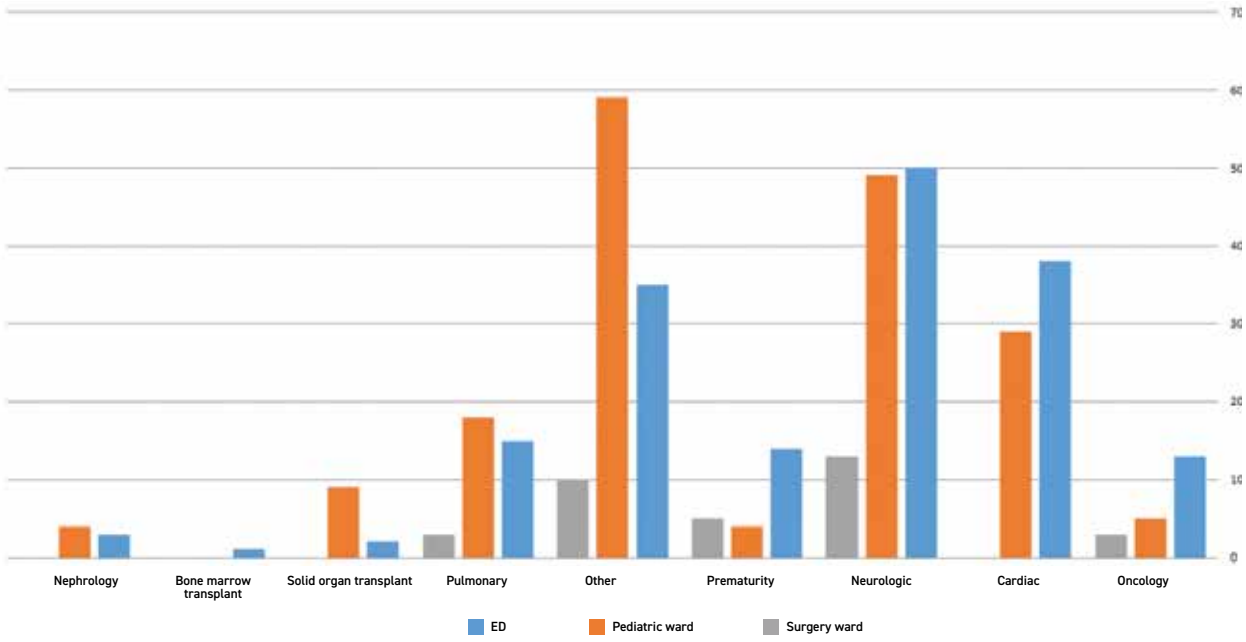
Intubation was performed in 48.9% of RRT activations. Chest compressions were performed in 20.5%, intraosseous line insertion (IO) insertion in 9.4%, and defibrillation in only 3.4% of activations. Of note, all procedures were performed more frequently in the ED compared to other locations. At least one dose of adrenaline was administered in 30.6% of all activations, but was rarely administered in the surgical ward (5.7%). Multiple doses of adrenaline were administered in the ED four times more often than in the inpatient wards and 14.4 times more than in the oncology service.

DISCUSSION

The literature describing pediatric RRTs is largely from North America [1,3,5,8,14-17] and Australia [6,9,10]. Other than one article from Pakistan [11], we were unable to locate any other English language articles describing activations in Europe, South America, Asia, or Africa. It is likely that other countries have developed RRTs but may have a composition or mandate different from North America or Australia. Our descriptive data and analysis provide a perspective on the result of RRT activations in a different medical culture.

RRT activation to the ED has not been previously described. The need to care for a critically ill child in the ED frequently results in RRT activation to provide additional manpower. The PICU and NICU accounted for 5% and 4%, respectively, of activations, demonstrating the need for additional medical staff during critical deterioration of a patient even in these departments.

Figure 4. Type of background illness
ED = emergency department



The reported frequency of activation ranges from 11–664/year [8,12,15] with Sen et al. [8] reporting a median frequency of 130/year in 2011 in a survey of tertiary care pediatric hospitals. Our number of activations is substantially lower, but when standardized by inpatient care days, our rate of 0.40/1000 inpatient days was similar to other studies [3, 13]. Our rate of 50% PICU admissions is within the range of 17–80% reported in the literature [1,3,6,8,10-12,16]. The number of advanced life support interventions performed was substantially higher than reported in the literature: 48.9% intubation vs. 0–8% [3,6,16], 20.5% chest compressions vs. 0–2% [3,6,16], 9.4% IO insertion vs. 0.3–1.0% [6,16], and defibrillation 3.4% vs. 0–0.5% [3,6]. All of these procedures were performed more frequently in the ED, suggesting a sicker patient population; however, we did not collect data on elapsed time between ED admission and RRT activation, and as such it is unknown whether the patient arrived in the ED in critical condition or the condition deteriorated after admission. The high percentage of intubations may reflect a more aggressive policy of invasive rather than non-invasive airway management in our hospital or the need to intubate patients prior to PICU admission due to delays in obtaining a PICU bed. Our mortality rate of 12% at the end of activation is higher than the 0.14–10% reported in the literature [9,15,16]. We are not mandated to perform a follow-up examination on patients admitted to the PICU; therefore, the final mortality rate after RRT activation is unknown. Our higher mortality and intervention rate suggest that despite guidelines promoting early RRT activation when a patient deteriorates, RRT activation was late. PEWS is not in use in our hospital but is slated for implementation in 2020 and a decrease in interventions and PICU admissions would support this hypothesis.

Respiratory deterioration was the most frequent reason for activation, ranging from 46–90% in the literature [1,3,9,10,16] followed by neurologic alteration [3,8,16]. Only one study [1] found cardiac as the second most common reason. Cardiac arrest was our third most common reason and the second most common reason in the ED. Our results clearly showed a higher incidence of RRT activations among children less than one year of age in both inpatient wards and the ED when standardized by the number of patient days or visits, consistent with most studies [6,10,15] but less than the 7 years of age reported by others [3,13]. Activations for respiratory decompensation were much more common in this age group.

Most articles suggested a daytime prevalence of activations [1,6,8,9,11,12,15]. We found a significantly higher incidence of calls in evening hours, particularly with the surgical service. There was no statistically significant difference in the proportion of children mortality by shift, suggesting that the absence of an attending physician in the RRT during evenings and nights did not influence outcome, similar to results reported for adult RRT activations [20].

Our results suggest that there was a lower threshold for RRT activation for patients in the surgical ward. Compared to the general pediatric ward, the surgical ward had a substantially lower rate of intubation (6% vs. 36%), adrenaline adminis-

tration (6% vs. 19%), PICU admission (29% vs. 58%), and no deaths, although rates of chest compression and IO insertion were similar. Similar to the general pediatric wards, the most common reason for activation was respiratory decompensation but seizure was the reason in 28% of cases as compared to 10% in the pediatric ward. More staff training in basic pediatric emergencies may decrease the activations for seizures and increase medical staff confidence with treatment of clinical deterioration, as suggested by Acker and colleagues [21]. However, given the much lower frequency of interventions and PICU transfers as compared to general pediatric wards, the surgical ward may actually serve as a model for earlier identification of the deteriorating child.

The frequency of procedures performed during RRT activation has been infrequently reported [3,16]. This knowledge would allow for appropriate direction of staff training. It is crucial that chest compressions and defibrillation be performed immediately, before arrival of the RRT. Analysis of the frequency of interventions such as IO insertion and chest compressions resulted in the implementation of a semi-annual course in these interventions with skills stations and mega-code simulations for all ED staff and hospital residents.

LIMITATIONS

Information on background illnesses, reason for activation, duration of resuscitation, and procedures performed by the medical team prior to arrival of the RRT was obtained by debriefing the medical staff who initially treated the patient and was not verified in the medical record. Moreover, ward level interventions as defined by Raymond, et al [16], such as intravenous (IV) insertion and IV fluid bolus, administration of oxygen, and suctioning, were not recorded. Follow-up data on outcomes after the resuscitation are not obtained. Thus, we have no follow-up data on mortality and neurologic morbidity after resuscitation. Electrocardiogram strips are not routinely collected so the actual arrhythmias witnessed during resuscitation cannot be verified. Furthermore, although many of the articles cited report the effects of implementation of RRTs, we compared them to our post-implementation results.

CONCLUSIONS

Standardized reporting for RRTs, similar to Utstein criteria, should be developed to allow comparisons between published data. This reporting should include patient care areas served, presence of separate cardiac arrest team, clearly stated and standardized activation criteria, and data presented with consistent denominators (i.e., per 1000 patient days, or per 1000 hospital admissions). The type and frequency of interventions should be recorded in order to direct staff training, both for the RRT and the departmental staff. Hospitals with resident-led RRTs should invest in intensive training of these residents in resuscitation interventions, teamwork skills, and leadership before they assume leadership of the RRT [22-24]. Finally, the need to care for adult visitors and staff in a pediatric hospital is a rare, but real possibility. The RRT should be familiar with common life threatening conditions in adults and have protocols in place for the transfer of adults to definitive care.

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Correspondence

Dr. L. Amir
Dept. of Emergency Medicine Schneider Children's Medical Center of Israel, Petah Tikva 49202, Israel
Phone: (972-3) 925-3777
Fax: (972-3) 922-3011
email: lamir@clalit.org.il

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Capsule

TopoBuilding precision vaccines

To induce strong and targeted neutralizing antibody (nAb) responses against vaccine targets, one strategy has been to use computationally designed immunogens. However, the structural complexity of many known neutralization epitopes has posed a major challenge for the design of accurate epitope mimetics. **Sesterhen** and colleagues created a protein design algorithm called TopoBuilder to design scaffolds for irregular and discontinuous neutralization epitopes. As a proof of principle, the authors generated epitope-focused immunogens based on the prefusion conformation of the respiratory syncytial virus (RSV) fusion protein. When these immunogens were used to vaccinate mice and nonhuman primates in RSV infection models, they generated targeted nAb responses to RSV and boosted site-specific nAb responses in heterologous prime-boost vaccination schemes.

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Eitan Israeli

Capsule

Predicting protection from malaria

A highly effective malaria vaccine would save many lives, but correlates of protection remain ill defined. **Moncunill** and co-authors studied peripheral blood cells isolated from individuals who had received sporozoites under chemoprophylaxis or the RTS,S vaccine. Transcriptomic analysis of gene expression after in vitro stimulation of cells revealed pre- and postimmunization signatures that were validated with separate cohorts. The preimmunization signatures hint at mechanisms of differential vaccine responses between individuals. Once validated in additional studies, the postimmunization signatures could be used as a surrogate for protection in clinical trials, possibly accelerating vaccine development.

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Eitan Israeli

Capsule

AMPing up killing by cytotoxic T cells

Cytotoxic T cells form immune synapses at the interface formed with their target cells and then reorient intracellular lytic granules toward the contact site to ensure efficient killing. **Zurli** et al. found that stimulation of the receptor CD2 on cytotoxic T cells by target B cells enhanced T cell receptor signaling during the formation of immune synapses. CD2 stimulation led to activation of the metabolism-regulating kinase adenosine monophosphate (AMP)-activated protein kinase on lysosomes, which promoted lytic granule translocation to the immune synapse. Boosting either of these factors may thus enhance cytotoxic T cell efficacy.

Sci Signal 2020; 12: eaaz1965
Eitan Israeli