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Neuropsychologic outcomes from paediatric cardiac arrest: an important step forward

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Although outcomes from paediatric cardiac arrest are improving, outcomes are still relatively poor. Current estimates of survival for out-of-hospital cardiac arrest (OOHCA) are 4.4–7.6 % whilst those for in-hospital cardiac arrest (IHCA) are 35–40 % [1–3]. The major determinants of favourable outcomes: survival and survival with favourable neurological outcomes are related to minimizing the time of inadequate myocardial and cerebral blood flow [3, 4]. For example, after OOHCA, bystander CPR, time to defibrillation (for a shockable rhythm), time to ROSC, first documented arrest rhythm and good quality CPR each influence survival and neurological outcome [3, 4]. Although currently only a third to half of children in CA receive bystander CPR, well-publicised campaigns are in progress to increase bystander CPR, and in many countries CPR is taught in schools as part of the school curriculum for children [3, 4].

Most outcome studies show that whilst the prognosis for survival after paediatric CA is poor, the prognosis for neurological functioning in survivors is relatively good. This is particularly true for patients after IHCA compared to OOHCA [2, 4–7]. The differences in outcome are presumably because of briefer periods of untreated CA with no cerebral blood flow and superior quality of CPR by in-hospital professionals, compared with bystanders, resulting in superior myocardial and cerebral blood flow. The majority of studies assessing neurological outcome use the PCPC and POPC scores [8]. Scores of 1 and 2 are considered as favourable outcomes but these are broad stroke groupings and each PCPC grouping may encompass a fairly wide range of clinically significant neurological and functional differences [9]. There are fewer studies reporting cognitive outcomes post CA despite the significant influence these may have on schooling, subsequent employment, society and individual esteem.

In a recent article in *Intensive Care Medicine*, van Zelle et al. describe the neuropsychological outcome of 43 children who were long-term survivors of paediatric CA [10]. They evaluated 43 children out of a possible 132 survivors (25 were lost to follow-up, four were too severely mentally retarded to evaluate, 60 chose not to participate) from a total of 401 children who had suffered CA over a 10-year period in the Netherlands. The authors studied IQ, language, attention, memory, visuospatial processes and executive functioning using a number of validated neuropsychological assessment tools at a median time of 5.6 years after the arrest (2–11 years after discharge from ICU). Of the children studied, 55 % had suffered an IHCA, 45 % OHCA and 86 % had presented with a non-shockable rhythm (PEA/asystole). Not surprisingly, they found deficits in IQ with a mean score of 87.3 (the bottom 20 % of population). The authors then performed a number of neuropsychological tests adjusting for low IQ score. The main deficits found were for visual processing and memory

Table 1 Neuropsychological outcomes among cardiac arrest survivors

References	Patient population	Type of CA	Age ^a	Main outcomes
vanZeltem et al. [10]	43 children	IHCA 55 % OOHCA 45 %	Median 0.4 years old (range 0–16 years old)	Mean IQ 87.3 Visuospatial deficits Visual memory deficits
Moler et al. [14]	55 % pre-existing conditions 87 children	VF/VT 14 % OOHCA	47 pts: ≤5 years 9 months	48 % good neuro at 1-year follow-up
Suominen et al. [11]	50 % pre-existing conditions 21 children (over 22-year period)	VF/VT 8 % OOHCA	40 pts: ≥6 years old Median 2.4 years old (IQR 1.8–5.5 years old)	31 % profound disabilities 40 % IQ < 80 (20–78)
Morris et al. [12]	25 children 20/25: congenital heart disease	All drowning IHCA 100 %	Median 55 months (IQR 21–179 months)	80 % cognitive or neuro deficits 66 % <1SD below mean for IQ
Maryniak et al. [13]	10 children	OOHCA 100 % VF/VT 100 %	11–19 years old	40 % no neurocognitive deficits 20 % total dependence on caregivers

IHCA in-hospital cardiac arrest, *OOHCA* out-of-hospital cardiac arrest, *VT* ventricular tachycardia, *VF* ventricular fibrillation, *pts* patients, *IQR* interquartile range, *SD* standard deviation

^a Age at time of cardiac arrest

whilst verbal processing and memory were largely intact. Parents were asked to fill in questionnaires about their child's functioning and scored them higher than actually achieved by the children on testing or when scored by their teachers. The authors postulated that this might be because of the largely verbal instructions given by parents, whilst school learning requires visuospatial processing and hypothesised that school work reinforced by verbal instructions may aid the children's progress. Interestingly they documented attention and behavioural problems in only a few children and these were children with pre-existing conditions. The authors concluded that although the children had significant weaknesses, they had relatively intact functioning. There was greater representation of children from higher socio-economic groups that took part in the study which may have skewed the results and this highlights the difficulties with follow-up studies, where factors such as the costs of travel may impact participation. The study was unable to link deficits found to time to ROSC, illness severity, PCPC at hospital discharge or other acute parameters.

Table 1 provides an overview of several studies that reported neuropsychological outcomes after CA in children [10–14]. The paucity of reported post-CA neuropsychological data is remarkable despite thousands of paediatric CA survivors each year. Nevertheless, the observations about the few children in these studies reinforce the findings by van Zelle and colleagues: (1) neuropsychological testing reveals many more abnormalities than the PCPC categorizations; (2) all of these studies lacked information on the quality of CPR provided, which is a major contributor to cerebral blood flow during CPR and presumably neurocognitive outcomes; and (3) this is a ripe area for further investigation.

Moler and colleagues recently published the largest cohort of paediatric post-CA neurodevelopmental outcomes to date, including 87 children with 1-year follow-up

evaluations [14]. Importantly, patients with a Glasgow Coma Scale motor score of 5 or 6 prior to enrolment were excluded. The study was designed to focus on patients predicted to have poor neurological outcomes because the authors were evaluating a potential neuroprotective strategy, induced hypothermia. Only 96/287 patients enrolled were alive 1 year later, and only 42/85 (49 %) with 1-year neurodevelopmental testing had “good neurologic functioning,” defined as at least 70 on the Vineland Adaptive Behavioral Scale-II (VABS-II) of these 1-year survivors. 27/85 (33 %) had profound disabilities, whereas 38/87 (44 %) had a less than 15-point difference in VABS-II score from baseline. These precious data are certainly useful for clinicians and families. Further studies that include all children surviving an OOHCA could provide additional information about the neuropsychological outcomes of children with less severe injuries (initial Glasgow Coma Scale motor scores of 5 and 6).

Cardiac arrest is a severe global hypoxic-ischaemic (H-I) insult. The burden of poor cognitive functioning and neuropsychiatric deficits may be an increasing problem for society and the individual. It therefore seems prudent to investigate more carefully the difficulties these children may have. Better data can inform new approaches for prevention and treatment in the ICU and in rehabilitation programs to help these individuals of all socioeconomic status to reach their potential. Better data can also inform future research by providing adequate information for investigators to develop thorough approaches to analyse neuropsychological outcomes of paediatric CA patients (e.g., standardized protocols that adequately address the important issues). The study by van Zelle et al. is a small but important step on this pathway.

Compliance with ethical standards

Conflicts of interest The authors have no conflicts of interest to disclose.

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