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Widespread Deviations from PALS Guidelines in the Hospital Management of Pediatric OHCA: A Regional Cohort Study

Fiona McAllister[1]*, Megan Stewart[1]

[1]*Department of Nursing Care, School of Health, University of Glasgow, Glasgow, UK.*

Abstract

Pediatric out-of-hospital cardiac arrest (POHCA) is uncommon and carries substantial risks of death and long-term neurological impairment. Following Pediatric Advanced Life Support recommendations helps unify in-hospital management and may enhance survival. We proposed that in-hospital treatment of POHCA varied and that departures from guideline-based practice were linked to increased mortality. Children experiencing POHCA in the London-Middlesex area from January 2012 to June 2020 were analyzed. Care during active resuscitation (intra-arrest) and outcomes after resuscitation were assessed using the Children's Hospital, London Health Sciences Centre (LHSC) database and the Adverse Event Management System. A total of 50 POHCA cases reached hospital care; 15 (30%) were admitted, and 2 (4.0%) were discharged alive, both exhibiting severe neurological deficits without improvement at 90 days. Deviations were noted in every case, with most intra-arrest departures involving drug administration and defibrillation (98%). Post-arrest issues occurred primarily with temperature surveillance (60%). Missing data accounted for 15.9% of intra-arrest variables and 1.7% of post-arrest elements. Guideline deviations were frequent in both active resuscitation and subsequent care. The sample was insufficient to determine links between deviations and clinical outcomes. Future efforts should target the improvement of specific intra-arrest and post-arrest practices in POHCA and enhance digital documentation processes.

Keywords: Pediatrics, Cardiac arrest, Pediatric Advanced Life Support, CPR, Guidelines, Deviations

Introduction / Background

POHCA is an infrequent but critical condition, with survival to discharge reported at 2–24% [1–5]. Among survivors, substantial neurological injury is common [3,6]. An epidemiological report by Fink *et al.* indicated stable incidence and survival trends for POHCA in North America, emphasizing the need for ongoing research [5].

Adhering to Pediatric Advanced Life Support (PALS) guidance—which outlines optimal resuscitative and post-resuscitative strategies—may help streamline the management of POHCA and improve clinical outcomes [7,8]. Early actions recommended for these patients include effective CPR, securing the airway, prompt administration of epinephrine, and timely defibrillation when indicated [7,9–13]. Post-cardiac arrest care (PCAC) further stresses targeted temperature control, regulated O_2 and CO_2 levels, close hemodynamic assessment, and appropriate prognostication [8]. Despite this, in-hospital management during active arrest in POHCA has not been carefully studied.

Because POHCA events are rare and complex, deviations (DEVs) from PALS recommendations may arise. Wolfe *et al.* reviewed deviations from the American Heart Association guidance for in-hospital cardiac arrest and noted that lapses in compressions, shocks, medications, or vascular access reduced the likelihood of achieving return of spontaneous circulation (ROSC) [14].

Corresponding author: Fiona McAllister
Address: Department of Nursing Care, School of Health, University of Glasgow, Glasgow, UK
E-mail: ✉ f.mcallister.study@outlook.com
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McKenzie *et al.* identified frequent DEVs in pre-hospital POHCA care in Ontario's Middlesex-London region, though the sample size limited outcome associations [15]. Pitetti *et al.* demonstrated higher survival when ROSC occurred before arrival in the emergency department [16]. In the Middlesex-London POHCA cohort, paramedics achieved ROSC before ED arrival in 35.3% of cases, yet survival remained low (5.8%), and all survivors had neurological deficits [15].

The present study examined in-hospital management for POHCA within the Middlesex-London region from 2012 to 2020. We anticipated that intra-arrest and post-arrest interventions at Children's Hospital – London Health Sciences Centre (CH-LHSC) would show considerable variability and that deviations from guideline-based care would correlate with poorer outcomes.

Methods

This investigation used a retrospective cohort design and examined POHCA events in the Middlesex–London area from January 1, 2012 to June 30, 2020. Eligible cases were located through the Canadian Resuscitation Outcomes Consortium (CanROC), a national registry containing de-identified OHCA data. Information regarding pre-hospital care and transport was extracted from paramedic call reports. Details about in-hospital treatment and patient outcomes were obtained from the Children's Hospital, London Health Sciences Centre (CH-LHSC) Electronic Medical Records (EMR). Equipment issues, including failures or lack of availability, were identified through the Adverse Event Management System (AEMS). Ethics approval was granted by the Western University Health Science Research Ethics Board (ID: 119460).

Patient population

Children aged from one day to under 18 years living in the Middlesex–London region were included if they experienced an OHCA within the study timeframe and were transported by ambulance to CH-LHSC. Patients were excluded if the arrest was traumatic or if outcome information could not be retrieved. Medical histories were grouped into cardiac (e.g., congenital heart problems, cardiomyopathy), respiratory (e.g., asthma, recurrent pneumonia, congenital lung disease), neurological (e.g., cerebral palsy, seizure disorders, hydrocephalus, tumors), or other diagnoses (e.g., mental health conditions, developmental issues, non-cardiac and non-neurological disorders). Pre-arrest ability to carry out age-appropriate daily activities was also noted. Neurological function was assessed using the Pediatric Overall Performance Category (POPC) at discharge and again at 90 days. The main endpoint was survival to discharge, and secondary endpoints included admission survival, 90-day survival, and neurological status at discharge and at 90 days.

Process of care deviation definitions

A deviation (DEV) was defined as any action that did not align with current PALS/AHA or Heart and Stroke Foundation Canada recommendations for resuscitation or post-resuscitation care [7,8]. Patients treated between January 1, 2012 and November 3, 2015 were assessed according to the 2010 guidelines, while those managed between November 4, 2015 and June 30, 2020 were evaluated using the 2015 version, released on November 4, 2015. Categories from McKenzie *et al.* were adapted for this study [15]. Eleven types of DEVs were outlined: (1) airway, (2) vascular access, (3) CPR/compressions, (4) defibrillation, (5) drug administration, (6) leadership/team function, (7) equipment reliability, (8) temperature control, (9) hemodynamic assessment, (10) prognostication, and (11) general monitoring. Altogether, 32 possible deviations were reviewed—24 related to intra-arrest care and 8 to post-arrest care. Each deviation was counted per patient and evaluated both individually and by category. Hyperkalemia was defined as >5.5 mmol/L. A definitive airway included endotracheal intubation, supraglottic insertion, or a surgical airway. A delay of ≥2 minutes from ED arrival to first epinephrine administration during persistent arrest was considered a deviation.

Intra-Arrest and Post-Arrest care group definitions

To clarify how POHCA patients were managed after arriving at the hospital, treatment was separated into intra-arrest (active resuscitation) and post-arrest (post–ROSC management). Patient assignment depended on their clinical status in the emergency department. The two groups were overlapping, not mutually exclusive. The intra-arrest group included all patients requiring resuscitation in the ED, including those who initially had ROSC but re-arrested. Only ED resuscitative actions provided by pediatric emergency staff were recorded for this group. The post-arrest group consisted of patients who survived long enough to receive an admission order and who subsequently underwent PCAC in the ED and/or the Pediatric Critical Care Unit (PCCU). Only PCAC measures were captured. The primary outcome for the intra-arrest group was survival to hospital admission, whereas the primary outcome for the post-arrest group was survival to discharge.

Data analysis

Descriptive analyses summarized management variables, deviations, and outcomes for each care group. Continuous data were represented as medians with interquartile ranges (IQR), while categorical information was reported as percentages and counts. Each deviation and deviation category was evaluated using logistic regression for binary outcomes and Pearson correlation for continuous outcomes. Missing data were examined via Pearson correlation for continuous variables and chi-square testing for categorical variables. Missingness was assessed for relevance (e.g., epinephrine dosing information was not applicable if epinephrine had not been administered). Missing items were not coded as deviations. Statistical analyses were conducted using SPSS version 29 (IBM Corporation, Armonk, NY, USA), and significance was defined as $p < 0.05$.

Results

Between January 1, 2012 and June 30, 2020, 51 non-traumatic POHCA cases were transported to CH-LHSC. One case lacked hospital documentation and was removed, leaving 50 patients for analysis. **Table 1** presents demographic features, and **Table 2** outlines event-level characteristics. Pre-hospital ROSC occurred in 6 (12%) patients, although **5** of these lost circulation again in the ED. ROSC achieved in-hospital was documented in 9 (18%) patients. A total of 49 (98%) were classified into the intra-arrest cohort, while 15 (30%) were managed in the post-arrest cohort **(Figure 1)**. Two (4%) children survived to discharge, both exhibiting new neurological impairments with POPC scores of 4 and no improvement by 90 days.

Table 1. Patient Characteristics

Patient characteristic	Total (n = 50)
Age, years – median (IQR)	2 (0–14)
Age category	
Infant (1 day–12 months)	20 (40.0%)
Child (1–11 years)	13 (26.0%)
Adolescent (12–<18 years)	17 (34.0%)
Male gender	26 (52.0%)
Body weight, kg – median (IQR)	14 (6.55–43.75)
Pre-existing medical conditions	
Congenital or acquired cardiac disease	7 (14.0%)
Neurological disorder	6 (12.0%)
Chronic respiratory condition	10 (20.0%)
Other comorbidities	14 (28.0%)
No known comorbidity	23 (46.0%)
Baseline Pediatric Overall Performance Category (POPC)	
1 (Good overall performance)	40 (80.0%)
2 (Mild overall disability)	≤5
3 (Moderate overall disability)	≤5
4 (Severe overall disability)	7 (14.0%)
5 (Coma or vegetative state)	≤5
Unknown	≤5
Age-appropriate independent function before the arrest	41 (83.7%)

Summary of demographic and clinical variables with corresponding proportions.

Table 2. Event Specific Characteristics

Characteristic	Total (n = 50)
Period of event	
2012–2014	18 (36.0%)
2015–2017	12 (24.0%)
2018–2020	20 (40.0%)
Time of emergency department arrival	
00:01–06:00	9 (18.0%)
06:01–12:00	11 (22.0%)
12:01–18:00	16 (32.0%)
18:01–24:00	14 (28.0%)
Return of spontaneous circulation (ROSC) on ED arrival	6 (12.0%)
ROSC course during hospital stay	
ROSC on arrival, sustained to discharge	1 (2.0%)
ROSC on arrival, subsequently lost, not regained	5 (10.0%)
Ongoing CPR on arrival, ROSC achieved and sustained to discharge	1 (2.0%)
Ongoing CPR on arrival, ROSC achieved but later lost	8 (16.0%)

Ongoing CPR on arrival, no ROSC ever achieved	35 (70.0%)
First recorded rhythm in the ED	
Ventricular fibrillation	1 (2.0%)
Pulseless electrical activity	8 (16.0%)
Asystole	30 (60.0%)
Sinus rhythm	2 (4.0%)
Not documented	9 (18.0%)
Pupillary light reflex on ED arrival	
Fixed/non-reactive	43 (86.0%)
Sluggish	1 (2.0%)
Brisk/reactive	1 (2.0%)
Not recorded	5 (10.0%)
Systolic blood pressure on ED arrival	
Normotensive	5 (10.0%)
Hypotensive	12 (24.0%)
Hypertensive	5 (10.0%)
Not recorded	22 (44.0%)
Temperature on ED arrival	
Normothermia	5 (10.0%)
Hypothermic	31 (62.0%)
Hyperthermic	1 (2.0%)
Not recorded	13 (26.0%)
Heart rate on ED arrival	
Normal	6 (12.0%)
Bradycardic	2 (4.0%)
Tachycardic	7 (14.0%)
Not recorded	35 (70.0%)
Definitive airway secured pre-hospital	18 (36.0%)
Pre-hospital airway type (not mutually exclusive)	
Oropharyngeal airway	17 (35.0%)
Endotracheal intubation	21 (42.0%)
Surgical airway	3 (6.0%)
Definitive airway established in hospital	26 (52.0%)
Endotracheal intubation in hospital	26 (52.0%)
Intravenous access obtained by EMS	8 (16.0%)
Intraosseous access obtained by EMS	32 (64.0%)
Intravenous access established in hospital	28 (56.0%)
Intraosseous access established in hospital	19 (38.0%)
Defibrillation performed in ED	4 (8.0%)
Medications administered in ED	
Epinephrine	45 (90.0%)
Amiodarone	1 (2.0%)
Lidocaine	0 (0.0%)
Dopamine	2 (4.0%)
Fluid bolus	39 (78.0%)
Reversible causes identified in ED	
Hypovolemia	37 (74.0%)
Acidosis	29 (58.0%)
Hypoglycemia	2 (4.0%)
Hyperkalemia	17 (34.0%)
Hypokalemia	2 (4.0%)
Toxins/overdose	1 (2.0%)
Survival to hospital admission	15 (30.0%)
Survival to hospital discharge	2 (4.0%)
Mode of death (n = 48)	
Termination of resuscitation in ED	35 (70.0%)
Withdrawal of life-sustaining therapy	12 (24.0%)
Physiological death despite full support	1 (2.0%)
Alive at 90 days post-discharge	2 (4.0%)

Distribution of POHCA incident features in Middlesex–London, including Termination of Resuscitation (TOR) and Withdrawal of Life-Sustaining Therapy (WLST). Physiologic death refers to death without withdrawal of supportive care.

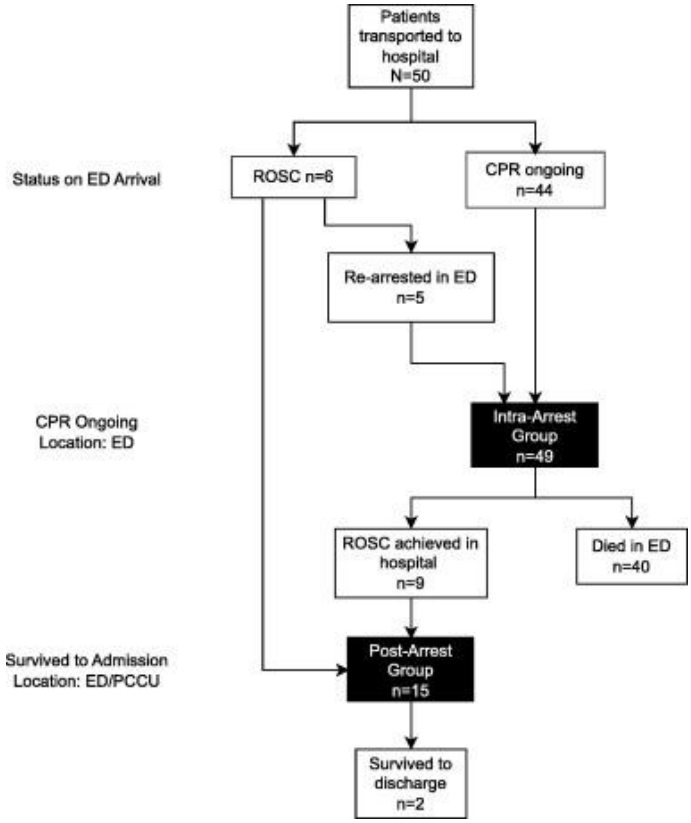

Figure 1. Overview of grouping based on ROSC status

Intra-Arrest group deviations

Every patient in the intra-arrest cohort (n = 49) exhibited at least one deviation, with a median (IQR) of 6 (5.0–9.0) per event. The maximum number observed in a single case was 13. Medication-related and defibrillation-related deviations were the most common, detected in 48/49 (98%) patients, with medians of 3 (2–4) and 1 (1–2) deviations per patient, respectively. Deviations related to airway management occurred in 61%, and chest-compression-related deviations in 53%. Problems with vascular access were documented in 39%. No issues were noted in the equipment-function category, and leadership-related information could not be assessed. The most frequent individual deviations were irregular rhythm-check intervals (65%), improper fluid bolus dosing (61%), absence of $ETCO_2$ monitoring during airway placement (53%), and improper epinephrine dosing intervals (51%). Neither total deviations nor categorical deviation counts showed an association with survival to admission or secondary outcomes ($p > 0.05$).

Post-Arrest group deviations

Within the post-arrest group, 12 (80%) patients had one or more deviations, with a median (IQR) of 2 (1–2.5) per case and a maximum of 3. Temperature-related deviations were most frequent, seen in 9/15 (60%) cases. Deviations involving airway management and general monitoring occurred in 40% each, while hemodynamic-monitoring and prognostication deviations occurred in 20% and 13%, respectively. No medication-delivery deviations were identified. The most common individual deviations were: interruptions of continuous temperature monitoring (60%), lack of echocardiography (40%), and failure to maintain O_2 saturation targets of 94–99% (or baseline for the child) (40%). Neither total deviations nor category totals were associated with survival to discharge or other outcomes ($p > 0.05$). There were no reports of equipment malfunction, absence, or misuse.

Intra-Arrest group missingness

All intra-arrest cases had missing information, averaging 15.9% (±6.2%) missing per patient. Completely absent for every patient were: CPR rate, compression fraction, compressor-switch frequency, and reassessment after fluid bolus administration. Other highly missing data included ventilation rate (n = 30, 97%), clarity of team-role assignment (n = 38, 78%), and $ETCO_2$ monitoring during airway placement (n = 19, 61%). Missingness—overall or by category—did not correlate with outcomes ($p > 0.05$).

Post-arrest group missingness

In the post-arrest cohort, missing data averaged 1.7% (±1.7%) per patient. No entries were available on interruptions during continuous EEG (cEEG). The next most commonly missing items were records of TTM use (n = 4, 27%) and cEEG use (n = 1, 11%). Total missingness did not relate to outcomes ($p > 0.05$).

Discussion

This investigation examined the management of POHCA cases within hospitals in the Middlesex–London area. The principal observations were: 1) deviations (DEVs) from established resuscitation and/or PCAC recommendations occurred frequently, and 2) substantial gaps in documentation were especially evident in the ED. Several targets for improvement were identified, along with potential strategies that could be adapted by other institutions.

The proportion of our cohort surviving to discharge (4%) was lower than figures reported elsewhere in the literature [1–5]. Paramedics attained ROSC rates prior to ED presentation that exceeded typical findings—35.3% versus 16.2% in a large North American multicenter POHCA investigation [5, 15]. ROSC upon ED arrival (14%) aligned closely with that same report (16.7%) [5]. Challenges in sustaining ROSC before hospital arrival may be linked to DEVs in PCAC, warranting additional research.

Intra-arrest group deviations

Every patient in the intra-arrest category exhibited at least three DEVs, with a median (IQR) of six (5.0–9.0) per event. The high prevalence of DEVs may reflect the infrequency of POHCA at CH-LHSC, which saw an average of 5.5 incidents yearly across the study timeframe. Providers seldom encounter POHCA, and PALS certification is not universally required. Although multidisciplinary simulations occur regularly, POHCA represents only one of many emergency scenarios covered.

In-hospital intra-arrest DEVs were considerably more common than pre-hospital DEVs, which had a median (IQR) of three (2–5) in the same cohort [15]. While PALS is not mandatory for Middlesex-London paramedics, they participate in annual arrest simulations. Their teams manage more than 500 adult cardiac arrests per year, with individual paramedics attending 2–50 events annually. This frequent exposure, paired with yearly training, may support strong pre-hospital performance with relatively few deviations. Emulating these conditions within hospitals—particularly pediatric centers integrated with adult hospitals—could be beneficial.

Almost all intra-arrest patients experienced medication-related DEVs (98.0%) and defibrillation-related DEVs (83.7%), followed by airway management (61.2%). A comparable pediatric IHCA analysis by Wolfe *et al.* noted airway issues as the most frequent categorical deviation (38.8%) [14]. Our rates for the top three categories considerably exceeded those in similar IHCA studies [14, 17], potentially reflecting distinctions between OHCA and IHCA response teams, despite similar arrest management principles. Thus, interpretation must consider local operational practices and the scarcity of regional POHCA cases.

Incorrect timing of epinephrine administration was the most common specific medication-related DEV, occurring in 25 (51.0%) patients, with most (65.0%) spaced more than five minutes apart. Emerging literature suggests that shorter dosing intervals may improve outcomes [18–22]. Furthermore, 23 (46.9%) patients experienced delays in initial epinephrine (beyond two minutes from arrival/arrest onset). Such delays have been linked to reduced ROSC, lower discharge survival, and poorer neurological recovery [11, 23–25]. These two deviations may have contributed to the low survival percentage, although our study lacked power to confirm this association. They represent priority areas for future training and quality-improvement efforts.

Post-arrest group deviations

A majority of post-arrest patients (80%) had at least one DEV, with the most prevalent relating to lapses in continuous temperature surveillance (60%). Continuous monitoring facilitates the timely initiation of TTM and prompt reaction to temperature elevations, including fever, which correlates with worse neurological outcomes [26]. The post-arrest group showed fewer DEVs overall compared to the intra-arrest group. This reduction may reflect the relative stability of the post-arrest phase, characterized by fewer staff members, less pressure, and more controlled workflow. One strategy to limit PCAC-related DEVs is formally entering PCAC orders in the patient's medical chart. Causes of guideline non-adherence are multifaceted—ranging from limited guideline familiarity and communication challenges to workload and adaptation to updates—and occur at both individual and system levels [27–29]. Localized assessments of contributors to guideline deviations can support targeted, sustainable improvements in acute and inpatient care processes.

Documentation & missing data

The intra-arrest cohort showed a substantially larger proportion of missing key information than the post-arrest cohort (15.9% vs 1.7%). All ED charting was completed manually, increasing the chance of incomplete or inaccurate entries, particularly for time- or dose-related details. Transitioning to EMRs could mitigate the inherent limitations of handwritten notes. Regional paramedic crews benefit from dedicated documentation time and use a

unified EMR system. Moreover, Root *et al.* reported improved adherence to guidelines and more consistent charting after introducing weekly audits incorporating visual and physiologic indicators of NICU resuscitation events [30].

CPR quality indicators—including compression fraction, compression rate, and provider rotation—were unavailable for this analysis. High-quality CPR correlates strongly with survival and relies on rapid onset, limited interruptions, and effective compressions, among other elements [31–44]. Without such metrics, CPR quality cannot be assumed, as previous studies show frequent deviations from recommended practice [45–49]. Enhanced data capture for POHCA CPR metrics has been achieved elsewhere through defibrillator pads capable of monitoring and automatically logging relevant CPR data, a practice supported by PALS guidance [46]. In the Middlesex-London Paramedic Services, these recordings are reviewed, and teams receive targeted feedback to reinforce adherence to protocols.

Systematic recording of resuscitation variables can also strengthen documentation accuracy and consistency [47–49]. Jiang *et al.* demonstrated that audio-visual CPR recordings, reviewed during structured post-event feedback sessions, can reveal DEVs in real time and lead to improvements in CPR delivery [50]. Debriefing sessions play an important role in enhancing team performance. Hunt *et al.* showed that creating a resuscitation quality bundle informed by weekly IHCA debriefs improved compliance with AHA CPR guidelines by identifying strengths, obstacles, and opportunities for quality enhancement [51]. In our centre's ED, debriefs are not routinely performed after cardiac arrests, in contrast to the region's paramedic services, where they are mandatory.

This study carries several limitations. Local procedures and the characteristics of the community may reduce the generalizability of the results. Nonetheless, the study environment resembles many institutions where structured quality-improvement efforts for cardiac arrest and post-arrest management have not yet been implemented. Significant gaps in documentation were present in patient files; to address this, missing information was never interpreted as evidence of specific actions or lack thereof.

Conclusion

Guideline DEVs occurred during both arrest and post-arrest phases for every POHCA case treated in-hospital. The most common deviations involved medication administration and lapses in continuous temperature monitoring. Our study lacked sufficient sample size to evaluate relationships between DEVs and key outcomes. Missing data were frequent; we propose that uniform electronic charting, improved acquisition of CPR quality metrics, documentation audits, and structured CPR-focused feedback could strengthen performance and potentially enhance survival outcomes.

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