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Postoperative Cardiac Arrest in Cardiac Surgery—How to Improve the Outcome?

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ABSTRACT

Background: In the early postoperative period after cardiac surgery the heart may be temporarily dysfunctional and prone to arrhythmias due to the phenomenon of myocardial stunning, vasoplegic syndrome, systemic inflammatory response syndrome (SIRS), electrolyte disturbances, operative trauma and myocardial edema. Most cases of cardiac arrest after cardiac surgery are reversible. **Objective:** To analyse the factors that may influence the outcome of cardiac arrest after adult and pediatric cardiac surgery. **Methods:** Retrospective analysis that included cardiac surgical procedures (886 adult and 749 pediatric patients) performed during the 18 month period of this study at Queen Alia Heart Institute/ Amman, Jordan. All cardiac arrest events were recorded and analysed. Data was collected on Utstein style templates designed for the purpose of this study. The outcome of cardiac arrest is examined as an early outcome (ROSC or lethal outcome) and late outcome (full recovery, recovery with complications, or in-hospital mortality). Factors that may influence the outcome of cardiac arrest were recorded and statistically analysed. Ethical committee approval obtained. **Results:** The overall mortality rate was 3.3%. Cardiac arrest occurred in 114 patients (6.97%). The age of patients ranged from 5 days to 82 years and constituted 66 pediatric and 48 adult patients. Most pediatric cardiac arrests manifested as non-shockable rhythms (77%). Most in-hospital cardiac arrests occurred in the intensive care unit (86.5%). The majority of patients were mechanically ventilated at the time of occurrence of arrest (62.5% and 54.5% in adult and pediatric patients, respectively). Average time of cardiopulmonary resuscitation was 32.24 minutes. Overall, CA survival was 20% higher in the paediatric sub-group (full recovery rate of 51.5%). Neurological injury was slightly lower in pediatric than adult cardiac arrest survivals. (2% vs. 3%). **Conclusion:** Shockable rhythms are more common in adult cardiac arrest, while non-shockable rhythms are more frequent in the pediatric sub-population. Hemodynamic monitoring, witnessed-type of cardiac arrest, non-interrupted cardiac massage, and early recognition of cardiac tamponade are the factors associated with higher rates of survival.

Keywords: Cardiac Arrest, Resuscitation, Rhythm, Cardiac surgery, Survival, Paediatric.

1. BACKGROUND

Cardiac arrest (CA) is a grave complication after cardiac operations, with a reported incidence of 0.7% to 5.2% and a case fatality rate of 30% to 80% (1, 2). In contrast to traditional in-hospital arrests, survival rates are significantly higher following cardiac surgery (3). This informs the reasoning why management of CA following cardiac surgery is different from conventional resuscitation; the key difference being in performing re-sternotomy within 5-10 minutes of CA, especially when there is evidence of cardiac tamponade due to mediastinal bleeding (4). Also, the re-sternotomy allows the administration of internal cardiac massage (ICM), which has been found by multiple human and animal studies superior to external cardiac massage (ECM) (5). However; benefits of emergency re-sternotomy must be balanced with the danger once adhesions have started to form after the tenth postoperative day, with risks of damage to increasingly adherent mediastinal structures (6).

Common causes for the deterioration of the postoperative cardiac surgical patient are: bleeding, tamponade, low cardiac output state, ventricular edema, graft and valve failure, severe left ventricular dysfunction, arrhythmias, aortic tears or dissection and acute pulmonary embolism (6).

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The in-hospital Utstein style data collection recommendations were first published in 1997 and revised in 2004 and 2015 (7). These recommendations defined a set of data elements that are essential for documenting IHCA and suggested guidelines for reviewing and reporting IHCA, to facilitate and structure resuscitation research and publication on the topic (8).

2. OBJECTIVE

The aim of the study was to analyse the factors that may influence the outcome of cardiac arrest after adult and pediatric cardiac surgery.

3. METHODS

This observational study took place at Queen Alia Heart Institute in Amman, Jordan in the period between July 2018 and December 2019.

The study looked into details surrounding CA victims after cardiac surgery including the type of the surgery, age, gender, heart rhythm at arrest, duration of arrest, patient's location in hospital at the time of CA, level of patient monitoring at the time of arrest, precipitating factor of the arrest, early and late outcome. Utstein style template (audit form) was designed to collect data for this study. Inclusion and exclusion criteria were implemented. Exclusion criteria: Pre-operative IHCA, OHCA (out of hospital cardiac arrest), IHCA of non-cardiac surgical patients, IHCA occurring at a different hospital admission of the cardiac surgical procedure, and terminally ill patient with DNR (do not resuscitate) direction.

Drugs used during CPR are as per ACLS latest guidelines and include the following: Adenosine for supraventricular tachycardia given as a first dose: 6 mg IV push and a second dose: 12 mg IV. Amiodarone for pulseless ventricular tachycardia or Ventricular fibrillation given as a first dose: 300 mg bolus and a second dose: 150 mg with a maximum of 2.2 grams/day. Atropine for symptomatic bradycardia given as 0.5 mg IV every 3-5 min up to a maximum dose of 3 mg. Dopamine for symptomatic bradycardia (if atropine fails) and as a vasopressor and inotrope for shock/hypotension at a dose of 2 to 20 mcg/kg IV per min titrated to blood pressure response. Epinephrine for cardiac arrest at a dose of 1 mg (1:10000) IV OR 2-2.5 mg (1:1000) ETT every 3 to 5 min followed by an infusion after ROSC (if needed) at 0.1-0.5 mcg/kg/min titrated to blood pressure response. Epinephrine used for symptomatic bradycardia (if atropine fails) at a dose of 2-10 mcg/min. Lidocaine for cardiac arrest due to ventricular fibrillation or ventricular tachycardia (not associated with acute myocardial infarction) at a dose of 1-1.5 mg IV up to maximal dose of 3 mg per kg, an infusion of 1-4 mg/min for recurrent ventricular fibrillation or tachycardia. Magnesium Sulfate used for pulseless torsades de pointes at a dose of 1-2 gram IV bolus and for torsades de pointes with a pulse at dose of 1-2 gram over 5 to 60 minutes.

Post resuscitation care included a multidisciplinary team work that focuses on stabilization of cardiopulmonary status, determining the aetiology of the CA, neuroprotection and preventing the recurrence of CA. Initial

neurological assessment after ROSC is clinical and was repeated frequently taking considerations of presence of sedative medications and hypothermia. The initial neurological examination included: GCS score (modified GCS for intubated patients), pupillary response to light, corneal reflex and presence of seizures. Patients who did not achieve an initial neurological full recovery were managed with therapeutic hypothermia (TH). Neuroprognostication (for comatose patients) using cerebral performance category (CPC) score was done after 72 hours post ROSC and repeated daily. Other tests for neurological assessment performed on basis of specific patient's condition included: neurophysiological studies (such as somatosensory evoked potentials (SSEPs) and electroencephalography (EEG)), biochemical markers (neuron-specific enolase (NSE)), and imaging studies – brain CT and/or magnetic resonance imaging (MRI).

4. RESULTS

Duration of CPR averaged 32.24 min (ranged from 1 to 90 min). The time of CA concerning the surgical procedure ranged from day 0 to 43 (median value (central tendency) is at day 5)).

The adult sub-population (48 patients) had an average age of 59 years (ranging from 20 to 82 years, (SD \pm 9.89 years)). Most adult CA victims were between 60 and 70 years of age (modal value 64 years). Male: Female ratio was 1.7: 1. The leading rhythm of CA in adults was shockable (53%). VF was encountered in 37% and pulseless VT in 16% (Figure 1). Adult CA victims had ROSC of 41.7% and hospital discharge rate of 31.25%. Post CA neurological injury was higher in adults (3%) (Table 1).

Re-opening of sternum, internal cardiac massage and internal defibrillation was carried out in 54.2% of adult CA victims (26 patients), with the establishment of ROSC in 34.6% of cases (9 patients).

IABP was used in 14.6% of adult CA with ROSC of 57.1%. Unfortunately, two patients of this group (28.6%) had later neurological complications and one patient developed lower limb ischemia. ECMO was not used for resuscitation after CPR in this cohort.

The paediatric sub-population (66 patients) age ranged between of 5 days and 12 years. Majority of paediatric patients were infants (below one year of age). Male to Female ratio was 0.8:1. The pediatric CA presented more commonly with non-shockable rhythm (77%); distributed between asystole (65%) and PEA (11%) (Figure 2). Pediatric victims of CA had a greater incidence of ROSC (60.6%) and higher rates of full recovery (51.5%) compared to the adult-subpopulation (Table 2). Post CA neurological injury occurred in 2% of paediatric CA survivors (Table 3).

Re-opening of sternum, internal cardiac massage and internal defibrillation was carried out in 4.5% of the pediatric CA victims (3 patients).

5. DISCUSSION

This study inspects the multitude of factors that may influence the outcome of IHCA after cardiac surgery. The outcome is examined as an initial outcome (ROSC

or lethal outcome) and late outcome (full recovery, recovery with complications, or in-hospital mortality).

Higher mortality rates after combined and more complex cardiac surgeries can be attributed to the longer duration of aortic clamping and cardiopulmonary bypass (9).

The observation that long ICU stays and long-time of mechanical ventilation (MV) after cardiac operations is associated with higher mortality rates is reported by Hein who estimated that 36% of cardiac surgical patients needed long ICU stay and MV with a dramatic increase in mortality rate after 14 days due to non-cardiac organ failure (10). Zamora estimated long ICU stay and prolonged MV in 20% of patients with mortality mainly due to multi-organ failure and sepsis (11).

The role of hemodynamic monitoring and early recognition as a factor that is associated with higher survival rates and hospital discharge with favourable neurological outcome was concluded in research by Brady et al. in the Resuscitation Journal (12). The importance of hemodynamic monitoring as a crucial factor for the survival of CA

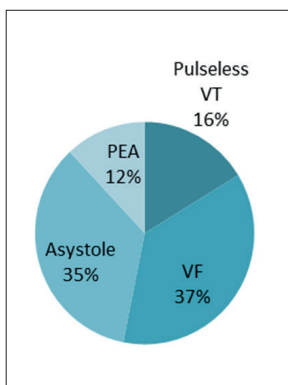


Figure 1. Adult Cardiac Arrest Rhythms. PEA: pulseless electrical activity; VT: ventricular tachycardia; VF: ventricular fibrillation

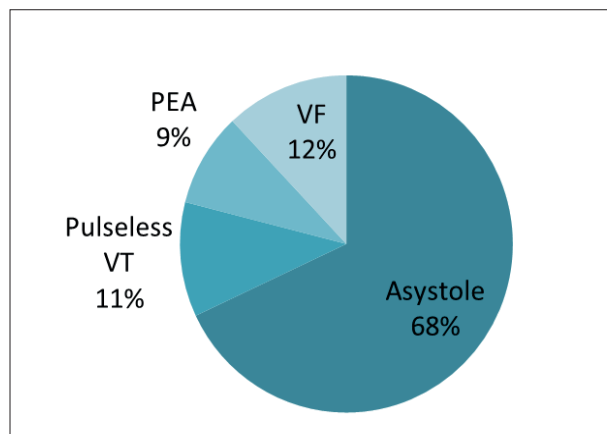


Figure 2. Paediatric Cardiac Arrest Rhythms. PEA: pulseless electrical activity; VT: ventricular tachycardia; VF: ventricular fibrillation

after cardiac surgery was also emphasized by Pothitakis (13).

The shorter the duration of resuscitation was, the higher the likelihood of a favourable outcome. Still, survival was achievable until 40 min in some cases, and the ideal duration of resuscitation should remain a bedside decision taking into consideration the whole clinical picture. The inverse relation between duration of CPR and one-month survival after IHCA was described by Rohlin (14).

Regarding oxygenation during CPR in adults, slightly less than half of patients were already intubated prior to occurrence of CA; ROSC was established in nearly half of them. The American Heart Association 2010 -and

Type of Surgery	Number of CA victims	Causes	Initial ROSC (%)	Number of CA patients discharged from hospital (%)
CABG	24	Graft occlusion (18) Right sided heart failure (2) Sepsis (1)	10 (41.7%)	6 (25%)
AVR	2	Bleeding (1) Ischemia (1)	1 (50%)	1 (50%)
AVR + CABG	5	Bleeding (1) Ischemia (2) Multi-organ failure (1) Unknown (1)	3 (60%)	2 (40%)
AVR + MVR+ CABG	2	Failing heart and Low cardiac output syndrome (2)	0	0
MVR	3	Recurrent arrhythmias (1) Failing heart (1) Sepsis and multi-organ failure (1)	2 (66.7%)	2 (66.7%)
MVR + CABG	5	Failing heart after long cross clamp time (1) Right sided heart failure (1) Bleeding (1) Sepsis and multi-organ failure (1) Unknown (1)	2 (40%)	1 (20%)
MVR + TV Repair	2	Recurrent arrhythmias (1) Respiratory failure (1)	1 (50%)	1 (50%)
MVR +TV Repair +CABG	2	Failing heart after long cross clamp time (1) Bleeding (1)	0	0
AVR + MVR + TV Repair	1	Sepsis (1)	0	0
Bentall procedure	2	Bleeding (2)	0	0

Table 1. Adult sub-population type of surgery. CA: cardiac arrest; ROSC: return of spontaneous circulation; CABG: Coronary arteries bypass grafting; AVR: aortic valve replacement; MVR: mitral valve replacement; TV Repair: tricuspid valve repair

thereafter- guidelines rearrangement of CPR steps from ABC (Airway, Breathing, and Circulation) to CAB emphasizes the priority of defibrillation and cardiac massage over airway management; to reduce the time of "no blood flow" during CA (15).

CA is categorized by the initial cardiac rhythm. The category of tachyarrhythmias includes ventricular fibrillation (VF) and pulseless ventricular tachycardia (VT), while the non-tachyarrhythmia category includes pulseless electrical activity (PEA), ventricular asystole, and extreme bradycardia (16). Shockable rhythms are more common in adult victims of CA and that they have a better prognosis than non-shockable rhythm (17).

Resternotomy was carried out in 54.2% of the adult postcardiosurgical IHCA cases, with the establishment of ROSC in 34.6% of cases. This can be attributed to the fact that resternotomy is usually reserved for patients with protracted CPR and resistant to ECM and external defibrillation CA.

The use of IABP is commonplace in resuscitation after cardiac surgery and its first use dates back to 1967 (18). It assists the heart indirectly by decreasing the afterload and augments diastolic aortic pressure (19).

However, there has been controversy regarding its beneficial effects. The "SHOCK II" trial showed that the use of IABP did not significantly reduce 30-day mortality in patients with cardiogenic shock complicating acute myocardial infarction (20). Several recent studies have also shown that there is no long-term benefit of IABP in cardiogenic shock or CA (21).

IABP usage in a pediatric population was first described in 1989. However; despite the availability of pediatric size balloons, the usage of IABP for circulatory support in children has not been widespread (22).

Outcome	Adults (%)	Pediatrics (%)
ROSC	20/48 (41.7%)	40/66 (60.6%)
Full recovery	15/48 (31.25%)	34/66 (51.5%)
Neurological manifestation(e.g. brain hypoxia)	3/48 (6.25%)	2/66 (3%)

Table 3. Overall outcome of Cardiac Arrest Patients, ROSC: return of spontaneous circulation

Type of surgery	Number of patients	Causes* (n)	Number of CA survivors	Number of CA patients discharged from hospital
B.T. Shunt	12	Shunt occlusion (7) Respiratory failure (3) Sepsis (1) Renal failure (1)	6	6
TCPC	8	Right heart failure (3) Bleeding (2) Respiratory failure (2) Sepsis (1)	5	4
Glenn	3	Anastomosis occlusion (1) Multi-organ failure (1) Bleeding (1)	2	1
Arterial switch (TGV)	5	Myocardial ischemia (2) Bleeding (2) Low cardiac output due to long cross clamp time (1)	2	1
A.V.Canal defect	7	Recurrent arrhythmia (2) Sepsis (2) Renal failure (1) Unknown (2)	6	5
Coarctation of Aorta	8	Low cardiac output (2) Respiratory failure (2) Associated anomalies (2) Sepsis (1) Unknown (1)	6	6
Hypoplastic Aortic Arch	2	Bleeding (2)	1	1
P.A. Banding	5	Respiratory failure (2)	3	3
VSD closure	5	Right heart failure (2) Respiratory failure (1) Recurrent arrhythmia (1) Low cardiac output (1)	2	2
DORV repair	2	Bleeding (1) Sepsis (1)	2	1
TOF Repair	4	Respiratory failure (1) Renal failure (1) Low cardiac output (1) Sepsis 1	3	3
TAPVR	1	Respiratory failure (1)	0	0
RVOT obstruction	2	Right heart failure (1) Renal failure (1)	1	0
PDA ligation	2	Respiratory failure (1) Unknown (1)	1	1

Table 2. Pediatric sub-population type of surgery. CA: cardiac arrest; B.T. Shunt: Blalock-Taussig shunt; TCPC: total cavo-pulmonary connection; TGV: transposition of great vessels; A.V Canal defect: atrioventricular canal defect; P.A. Banding: pulmonary artery banding; VSD: ventricular septal defect; DORV: double outlet right ventricle; TOF: tetralogy of Fallot; TAPVR: Total anomalous pulmonary venous return; RVOT: right ventricular outflow tract; PDA: patent ductus arteriosus

6. CONCLUSION

Majority of cardiac arrests occurred in the ICU (86.5%). Shockable rhythms are more commonly encountered in adult CA (53%), while non-shockable rhythms are more frequently faced in the pediatric CA (77%). Most pediatric CA patients were infants. Open-sternum resuscitation with direct cardiac massage and internal defibrillation was more in use in the adult postoperative cardiac arrest patients (54.2%) in comparison with pediatric patients (4.5%). Survival after pediatric cardiac arrest was

higher and was associated with less neurological complications.

Limitations of the study

Our work was a single-centre retrospective study.

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- **Conflict of interest:** The authors declare that they have no conflict of interest.
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