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Early Postoperative Complete Heart Block after Congenital Heart Disease Surgery: A Two Centre Study in Benghazi

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Abstract
Congenital heart disease (CHD) is a common congenital anomaly that requires surgery. A complete heart block (CHB), which can be temporary or permanent, might complicate surgery for CHD. Objectives: to measure the frequency of early postoperative CHB and assess the contributing risk factors among children with CHD who underwent surgery. A retrospective study of 158 patients with CHD who underwent surgery at the National Heart Centre (NHC) and Benghazi Medical Centre (BMC) between December 2021 and March 2023 and underwent evaluation for an incident of CHB in the postoperative intensive care unit (ICU), was carried out. Data collection from patients' medical records included type of CHD, mortality rate, bypass and aortic clamping time, and hypothermia during operation. Transient CHB occurred in 4.4% of patients, and permanent CHB occurred in 0.63%. The age of patients ranged from less than 6 months to 30 years. The surgical procedures associated with CHB included sub-aortic membrane (SAM) (20%), atrioventricular septal defect (AVSD) (16.6%), and ventricular septal defect (VSD) (7.1%). The mortality in patients with postoperative CHB was (5%). Other comorbidities, including the duration of cardiopulmonary bypass (CPB) and aortic clamping time, have an important effect on the risk of developing CHB. Reducing the bypass time during surgery can reduce CHB.

Keywords: Complete Heart Block (CHB), Congenital Heart Disease (CHD), Children, Risk factor, Pacemaker, Mortality.

INTRODUCTION

Injuries to the atrioventricular (AV) following cardiac surgery for CHD occur in 0.7%–3% of patients. The primary risk factors for cardiac arrhythmias are being young at the time of surgery, undergoing a specific surgical procedure, and enduring long durations of bypass or aortic cross-clamp. These abnormal cardiac rhythms lead to lengthier hospital stays and the need for medical or surgical treatment (Altaweel et al., 2018). In a previous study, Murray and his colleagues (2017) (Murray et al., 2017) noticed that preoperative factors, including a missense polymorphism in GJA5, are independently associated with an increased risk for CHB. (Romer et al., 2019) discovered that specific surgical procedures, including atrioventricular canal defect (AVC), left ventricular outflow tract obstruction resections, and ventricular septal defect (VSD) repair, have been linked to an increased risk of permanent CHB. The block can be induced by trauma or suture placement in

the conduction system, or hemorrhage or edema from the suture surrounding the conduction system, particularly in younger patients. Previous research by (Azab et al., 2013) showed that 14 out of 400 patients (3.5%) developed permanent postoperative CHB. Improved surgical techniques and enhanced knowledge of the anatomy of conduction tissue in different congenital heart defects reduced this risk to 1–4% (Ahmed et al., 2023; Liberman et al., 2016).

Many studies suggest that minimizing CPB duration during open heart surgery can help reduce the incidence of CHB among children with congenital heart disease (Alotaibi et al., 2022). The patient's age at the time of operation considerably affects the possibility of acquiring a complete heart block. Younger patients have a higher chance of developing complete heart block post-surgery, (Ibrahim et al., 2023). Higher CPB times and hypothermia during operation have been linked to an increased risk of CHB. Hypothermia has been linked to a variety of physiological effects, including alterations in heart function and rhythm and increasing the risk of arrhythmias such as heart block. Additionally, hypothermia can influence the autonomic nervous system, causing alterations in heart rate and rhythm (Shah et al., 2021). The use of inotropes in children with congenital heart defects after open heart surgery entails various concerns, including an increased risk of complete heart block and arrhythmias, an increased risk of low cardiac output syndrome, and mortality. (Gocoł et al., 2021). Temporarily pacing patients to allow the resolution of CHB prevents the excessive insertion of PPMs in patients who will experience a return of conduction (transient CHB). While this waiting period may serve to preempt the need for prolonged hospital and cardiac intensive care unit (CICU) stays, which may result in increased patient morbidity and expenses, it may also result in the superfluous implantation of PPMs in patients with transient CHB (Ju et al., 2023). Consequently, determining the optimal timing for postoperative PPM insertion could decrease patient risk and resource consumption (Liberman et al., 2016; Moskowitz et al., 2019).

This paper aims to study the frequency of early postoperative CHB in patients with congenital cardiac diseases and assess the contributing risk factors among children with congenital heart disease (CHD) who underwent surgical correction.

MATERIALS AND METHODS

This descriptive-retrospective study was conducted at two hospitals, Benghazi National Heart Center (NHC) and Benghazi Medical Center (BMC), on 158 cases operated for CHD from December 2021 to March 2023. The hospital records were reviewed, and demographic and perioperative variables were abstracted, with particular attention to the postoperative condition status of patients in the postoperative intensive care unit. Data collection included age, sex, type of CHD, mortality rate, 12-lead electrocardiogram, and echocardiogram; operative details included surgical details including clamping time and cardiopulmonary bypass time; use of an inotrope; and continuous rhythm monitoring was maintained for the duration of the patient's ICU stay.

Inclusion criteria: Each patient had a normal preoperative 12-lead electrocardiogram (ECG) and another ECG on the first day, 7 days postoperatively, and 10 days postoperatively. All patients at risk of postoperative heart block receive transient pericardial pacing during surgery, and CHB was researched. Eventually, temporary pacing was continued for a maximum of 10 days when the patient developed a heart block. If a return to normal rhythm within 10 days post-operatively

is not restored, the diagnosis of permanent CHB was confirmed according to recommendations from the American College of Cardiology, American Heart Association, and Heart Rhythm Society (ACC/AHA/HRS 2018) (Shah et al., 2021). Patients with a preoperatively complete CHB or a preexisting PPM were excluded from this study.

Statistical analysis was done using SPSS v28 (IBM Inc., Armonk, NY, USA). Quantitative variables were presented as frequency and percentage (%). Estimating the relationship between a dependent variable and one or more independent-tailed variables with a P value < 0.05 was considered statistically significant.

RESULTS

Regarding the baseline characteristics of the studied patients, 89 (56.33%) patients were males, and 69 (43.67%) patients were females; the median age was 4 (2–7) years. Five (Transit CHB no. 5). Permanent (CHB no. 1) out of eight (75%) patients with CHB were between the ages of one and two years, Table 1.

Table (1). Age at operation.

Age	N (%)	Transit CHB N (%)	Permanent CHB N (%)
1 month - 1 Year (Infant)	38(24%)	1(0.6%)	0(0%)
> 1 year - 2 years (Toddler)	84(53%)	5(3.2%)	1(0.6%)
>3 years - 5 years (Preschooler Age)	18(11.3%)	0(0%)	0(0%)
>5 years - 12 years (School-Age Child)	13(8.2%)	1(0.6%)	0(0%)
>13 years - 19 years (Adolescents Age)	4(2.5%)	0(0%)	0(0%)
>19 years (Adult)	1(0.6%)	0(0%)	0(0%)
Total	158	7(4.4%)	1(0.6%)

Among the studied patients, 106 (67.1%) had cyanotic CHD, and 52 (32.9%) had cyanotic CHD. The surgical procedures associated with the highest incidents of heart block included subaortic membrane (SAM) (20%), atrioventricular septal defect (AVSD) (16.6%), and ventricular septal defect (VSD) (7.1%).

Data are presented as frequency (%). CHD: Congenital heart disease, ACHD: Acyanotic congenital heart disease, CCHD: Cyanotic congenital heart disease, VSD: Ventricular septal defect, ASD: Atrial septal defect, AVC: Atrioventricular canal defect, PDA: Patent ductus arteriosus, AS: Aortic stenosis, COA: Coarctation of the Aorta, AA: Interrupted aortic arch, MR: Mitral regurgitation, SAM: Subaortic membrane, TOF: Tetralogy of Fallot; TGA: Transposition of the great arteries; DORV: Double outlet right ventricle, PS: Pulmonary stenosis, PA: Pulmonary atresia, TAPVD: Total anomalous pulmonary venous drainage, CHB: Complete heart block, PPM: Permanent pacemaker.

The overall mortality rate from CHD surgery was 12 (7.6%). Deaths from CHD surgery associated with CHB occurred in three patients out of 60 who were operated on for VSD and AVC, with transient CHB (5%) and no fatality in patients who underwent SAM resection.

The intraoperative sheet of each patient was revised for the cross-time and bypass, and the procedures were performed on or off bypass**,** Table 3.

Table (2). Type of operated CHD and rates of CHB and mortality rate in each type of CHD.

Type of operated CHD (n=158)	N (%)	Transit CHB	CHB with PPM	Mortality Rate N/158(%)
A cyanotic CHD	106(67.1%)	7(4.4%)	1(0.9%)	6(3.8%)
cyanotic CHD	52(32.9%)	0(0%)	0(0%)	6(3.8%)
VSD	42(26.58%)	3(7.1%)	0(0%)	1(0.6%)
ASD	26(16.46%)	0(0%)	**0**(0%)	0(0%)
AVC	18(11.3%)	3(16.6%)	0(0%)	2(1.3%)
PDA	1(0.63%)	0(0%)	**0**(0%)	0(0%)
AS	4(2.53%)	**0**(0%)	**0**(0%)	1(0.6%)
COA, Interrupted AA	7(4.4%)	0(0%)	**0**(0%)	1(0.6%)
MR	3(1.9%)	0(0%)	**0**(0%)	0(0%)
SAM	5(3.16%)	1(20%)	**0**(0%)	0(0%)
TOF	22(13.92%)	0(0%)	**0**(0%)	3(1.9%)
Sever PS	8(5.06%)	0(0%)	0(0%)	1/(0.6%)
Single ventricle	66(3.8%)	0(0%)	0(0%)	0(0%)
DORV	3(1.9%)	0(0%)	0(0%)	0(0%)
Other Types of CCHD	12(7.6%)	**0**(0%)	**0**(0%)	3(1.9%)
TAPVD	1(0.63%)	0(0%)	0(0%)	0(0%)
Total	158	7(4.4%)	1(0.6%)	12(7.6%)

Table (3). Operative data of the studied patients.

Intraoperative Sheet		Total (n=158)
Cross time	Less than 25 min	54 (34.18%)
	More than 25 min	80 (50.63%)
	No cross time	24 (15.19%)
Bypass	On bypass	131 (82.91%)
	Off bypass	27 (17.09%)
Bypass time	<30 min	11 (6.96%)
	>30-60min	50 (31.65%)
	>60-90 min	50 (31.65%)
	>90 min	20 (12.66%)
	No bypass	27 (17.09%)

Regarding the type of arrhythmia, sinus rhythm occurred in 116 (73.42%) patients, junction arrhythmia occurred in 14 (8.86%) patients, transient CHB occurred in 7 (4.43%) patients, permanent CHB occurred in 1 (0.63%) patient, sinus bradycardia occurred in 2 (1.27%) patients, and SVT occurred in 1 (0.63%) patient, Table 4.

Table (4). Type of postoperative arrhythmia in examined patients.

		Total (n=158)
Arrhythmia	Sinus rhythm	116 (73.42%)
	Junction arrhythmia	14 (8.86%)
	Transient CHB	7 (4.43%)
	Permanent CHB	1 (0.63%)
	Sinus bradycardia	2 (1.27%)
	SVT	1 (0.63%)
	Atrial arrhythmia	2 (1.27%)
	Ventricle tachycardia	6 (3.8%)
	RBBB	6 (3.8%)
	Ventricle ectopic	3 (1.9%)

Data are presented as frequency (%), CHB: Complete heart block, SVT: Supraventricular tachycardia, and RBBB: Right bundle branch block.

Table (5). Relation between CHB and other parameters.

				CHB		
				ACHD n=106	CCHD n=52	P value
Inotropes	Dopamine			12 (11.4%)	1 (1.9%)	0.003*
	Dopamine + Adrenaline + Milrinone			2 (1.9%)	5 (9.4%)	
	Adrenaline + Noradrenaline			0 (0%)	1 (1.9%)	
	Milrinone			27 (25.7%)	12 (22.6%)	
	Dopamine + Adrenaline			27 (25.7%)	10 (18.9%)	
	Milrinone + Adrenaline			25 (23.8%)	18 (34.0%)	
	Noradrenalin			0 (0%)	3 (5.7%)	
	Milrinone + Adrenaline + Noradrenaline			1 (1.0%)	2 (3.8%)	
	No Inotropes			11 (10.5%)	1 (1.9%)	
Mortality and Type of Postoperative Arrhythmia n=158						
Sinus rhythm 5 (3.1%)	Junction Rhythm 4 (2.5%)	Transient CHB 3 (1.9%)	Permanent CHB 0 (0%)	SVT 0 (0%)		<0.001*
Hypothermia				42 (40.0%)	19 (35.8%)	0.613
Bypass	On bypass			93 (88.6%)	38 (71.7%)	0.008*
	Off bypass			12 (11.4%)	15 (28.3%)	
Bypass time	<30 min			10 (9.5%)	1 (1.9%)	<0.001*
	>30-60min			44 (41.9%)	6 (11.3%)	
	>60-90 min			27 (25.7%)	23 (43.4%)	
	>90 min			12 (11.4%)	8 (15.1%)	
	No bypass			12 (11.4%)	15 (28.3%)	
Cross time	Less than 25 min			46 (43.8%)	8 (15.1%)	<0.001*
	More than 25 min			50 (47.6%)	30 (56.6%)	
	No cross time			9 (8.6%)	15 (28.3%)	
Infection	Wound infection			2 (1.9%)	2 (3.8%)	0.683
	Mediastinitis			2 (1.9%)	0 (0%)	
	Sepsis			2 (1.9%)	1 (1.9%)	
	No infection			99 (94.3%)	50 (94.3%)	
Mechanical ventilation	< 1 day			21 (20.0%)	6 (11.3%)	<0.001*
	<3 days			5 (4.8%)	14 (26.4%)	
	3-7 days			2 (1.9%)	4 (7.5%)	
	> 7days			0 (0.0%)	2 (3.8%)	
	Exudate from OR			77 (73.3%)	27 (51.9%)	
CNS complication	Convulsion			4 (3.8%)	4 (7.5%)	0.621
	Hemiparesis			1 (1.0%)	1 (1.9%)	
	Delirium			1 (1.0%)	0 (0%)	
	No			99 (94.3%)	48 (90.6%)	
	No			38 (36.2%)	30 (56.6%)	
Peritoneal dialysis				0 (0.0%)	6 (11.3%)	0.001*

ACHD: a cyanotic congenital heart disease, CCHD: cyanotic congenital heart disease, CHB: Complete heart block, PPM: Permanent pace maker.

Table 5 reveals a statistically significant relationship between CHB and mortality regarding the type of postoperative arrhythmia, inotropes, bypass time, cross time, mechanical ventilation, and

peritoneal dialysis ($P<0.05$). There was no statistically significant relationship between CHB and the other parameters (hypothermia, infection, and CNS complications).

DISCUSSION

CHB is a notable complication of surgery for CHD. Patients with postoperative CHB need to last ten days following the surgery in the ICU, and if the heart block has not recovered, the replacement of the artificial pacing system is necessary for the duration of the patient's life. CHB might be permanent or temporary; in this context, transient CHB typically returns to sinus rhythm within seven to ten days following surgery. In comparison, 2093 patients (5%) in the study conducted by (Loomba et al., 2024) experienced an atrioventricular block, and 480 patients (1%) required pacemaker insertion. (Romer et al., 2019) reported that patients with transient AVB had 50% recovery within two days and 94% resolution within ten days, and the duration of cardiopulmonary bypass, a high-risk operation, was an independent risk factor for PPM compared to AVB resolution. This finding was also reported in research by (Öztürk et al., 2021). AV block was found in 3.4% of cardiac surgery patients, and all patients fully recovered within the first 10 days. The incidence of early postoperative heart block was noticed to be between 0.7% and 3%, depending on the type of surgical procedure and the cardiac lesion (Khosroshahi & Samadi, 2020; Liberman et al., 2016). We conducted a retrospective review of early and delayed atrioventricular conduction block after surgery for congenital heart disease. Postoperative atrioventricular conduction block occurring in 21 (2.3%) of the 922 patients was noted to be transient, with a return of conduction (1–14 days) after surgery in 13 (1.4%) and PPM (6–20 days) after surgery in 8 patients (0.9%). (Aziz et al., 2013) conducted a monitoring assessment of 44 patients who underwent cardiac surgery and experienced transit CHB in 37 patients and recovered between 5 and 9 days postoperatively. In the current study, the postoperative findings were transit CHD in 7 (4.4%) and AVB with PPM in 1 (0.6%), which are consistent with earlier investigations. Our patients (95%) recovered within 8 to 10 days post-surgery.

The atrioventricular (AV) node is an essential part of the cardiac conduction system; the His bundle (and its divisions) are located within the ventricular septum, thus rendering it susceptible to injury during surgical procedures in the septum. In previous studies by (Azab et al., 2013; Hejazi et al., 2019), they found the incidence of CHB higher in surgical repair of VSD, atrioventricular canal defects (AVCD), double outlet right ventricle (DORV), tetralogy of Fallot (TOF), and subaortic stenosis SAS. Due to the risk of block development over time, postoperative CHD surgery patients require close observation and continual monitoring.

In our study, the surgical procedures associated with the highest incidents of heart block included subaortic membrane resection (SAM) (20%), atrioventricular septal defect repair (AVSD) (16.6%), and ventricular septal defect closure (VSD) (7.1%). This is consistent with earlier findings, as the atrioventricular node is located in a particular location known as the Koch triangle, which is prone to damage during surgical procedures involving that area. In the current study, 1 patient from 42 (2.4%) patients with VSD surgery departed from the hospital with PPM. In contrast to the research of (Sugrue et al., 2018), they reveal that atrioventricular block is prevalent following tetralogy of Fallot (TOF) repair operations because the surgical areas are near the conducting system. Our patients undergoing TOF repair did not suffer from AVB and were more prone to junctional ectopic tachycardia. This could have been explained by the fact that the conduction system was spared during the surgical procedure. Although prior studies appear to support the literature regarding the longer durations of aortic clamp time and cardiopulmonary bypass time in cases with CHB, the observed difference of only a few minutes during a relatively simple procedure involving an isolated

VSD suggests that additional surgical factors and instrument manipulation in the surrounding area of the AV node contribute to the development of CHB (Socie et al., 2017).

The current study found younger ages (53% of patients with CHB) were between the ages of one and two years, consistent with a study concluded by (Ibrahim et al., 2023) where younger ages were a significant risk factor for complete heart block.

The current study showed that there was a significant relationship between CHB and inotropes and bypass time, cross time, mechanical ventilation, and peritoneal dialysis ($P<0.05$). There was an insignificant relationship between CHB and the other parameters (hypothermia, infection, and CNS complications). ($P > 0.05$), which is similar to studies by (Madani et al., 2023; Socie et al., 2017), who revealed that longer CPB duration and crossing time due to a high-risk procedure were associated with postoperative AVB conditions, in comparison to the study carried out by (Ayyildiz et al., 2016), they found that there was no effect of cardiopulmonary bypass time, cross-clamp time, or preoperative arrhythmia on the development of transit or permanent heart block ($P > 0.05$).

Deaths following CHD surgery associated with CHB (5%). This figure is approximately in agreement with the study done by (Feins et al., 2022), whose reported mortality rate was 3.9% following CHD surgery associated with CHB.

This study has certain limitations; it was a retrospective review of records utilizing reachable medical data. Our review is further restricted by a lack of data about decision-making about the timing of PPM placement, in addition to the relatively small number of patients in this research compared to other researchers due to the lack of continuing programs for open-heart operations for CHD and the dependency on foreign missions.

Finally, this study excluded an assessment of long-term AV nodal conduction; therefore, those who have received PPM placement for postoperative AVB and later returned to normal sinus rhythm, as well as patients who developed late-onset AVB after discharge and required PPM, were not included.

CONCLUSIONS

Postoperative transient CHB represented 4.4% of congenital cardiac surgery complications in the current study, and 0.6% of patients had permanent pacemaker implantation. Within 10 days, 95% of patients with transient CHB had resolved. The overall mortality rate for operated CHD was 7.6%. Death following CHD surgery associated with CHB occurred in VSD and AVC (5%). Reducing morbidity and mortality linked to postoperative CHB requires the creation and implementation of management regimens for patients with CHB, as well as specific types of CHD like AVSD and VSD, aortic clamp time, and cardiac bypass duration, which are predictive variables of CHB.

The study obtained ethical approval from the heads of the pediatric departments at the National Heart Centre (NHC) and Benghazi Medical Centre (BMC) to publish this paper.

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