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Permanent Epicardial Pacemaker Therapy in Paediatrics' Population in a Single Centre in Pakistan

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ABSTRACT

Background: Permanent cardiac pacing is uncommon in children, and when performed, it is typically achieved through epicardial pacing. We analysed our clinical group's experience with epicardial pacemaker implantation.
Objective: To assess our experience with epicardial pacemakers and to identify potential factors that could predict early and late lead-related complications.
Materials and Methods: This study included 34 patients under the age of 12 who underwent implantation of an epicardial pacemaker between 2018 and 2020. A retrospective review of their medical records was conducted. The study was approved by the ethics committee of the institution. A thorough review of the cardiac surgical and pacemaker databases identified all the paediatric patients who underwent permanent epicardial pacemakers implantation at a tertiary care hospital of Peshawar. Adult patients with an age of were omitted to focus on paediatric cohort. Medical records were retrospectively studied.
Results: For each patient, the average age across all PPM implantations, including any repeat procedures, was 7.2 ± 2.6 years. The average weight at the time of lead implantation was 24.8±4.0kg. The majority of patients who underwent pacemaker implantation or lead replacement surgery were discharged from the hospital within a week of the procedure. Of all the patients, 36.8% required a pacemaker due to post-op atrioventricular block, 28% had sinus node dysfunction, 20% had congenital complete heart block, and approximately 15.2% of the patients required a pacemaker for other reasons, including bradycardia caused by antiarrhythmic medication.
Conclusion: The leads exhibited commendable longevity, enduring without significant variations based on their type. Lead and generator lifespan were unaffected by lead type, pacing mode, or patient age.
Keywords: Epicardial pacemaker, Generator longevity, Lead longevity, Paediatric epicardial pacing, Single ventricle pacing.

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INTRODUCTION

Congenital heart disease (CHD) requiring permanent pacing is a significant challenge in paediatric cardiology.[1] While advancements in pacemaker technology and implantation techniques have improved outcomes, specific data regarding paediatric epicardial pacing, particularly in resource-limited settings like Pakistan, remains scarce.[2-5]

While transvenous pacing is common in adults, epicardial pacing is often preferred in children due to anatomical considerations and long-term growth potential.[6] However, published data specifically focusing on the outcomes of epicardial pacing in paediatric populations, including lead and generator longevity, complications, and re-intervention rates, is limited, especially from developing countries.[1,7,8]

There is a significant dearth of published data on paediatric pacing from Pakistan.[10] This lack of local data makes it difficult to understand the specific challenges and outcomes related to this therapy within the Pakistani context. Factors such as patient demographics, access to care, socioeconomic status, and local practices may influence outcomes and require investigation.

Multi-centre studies often provide a broader perspective, but single-centre studies can offer valuable insights into the specific practices and outcomes within a particular institution. Understanding the experience of a single centre in Pakistan can inform local protocols and improve patient care.

Data on the long-term performance of epicardial pacing systems in children is essential, as these patients will require lifelong follow-up.[11-14] Studies with extended follow-up periods are needed to assess lead and generator longevity, the need for re-interventions, and the impact of growth on pacing system function.

The primary gap lies in the lack of comprehensive data on the outcomes of permanent epicardial pacemaker therapy in the paediatric population specifically within Pakistan. Existing literature primarily focuses on data from developed countries, which may not be directly applicable to the Pakistani context. Furthermore, there is a lack of published experience from single centres within Pakistan, which could provide valuable insights into local practices and challenges.

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A retrospective observational study examining permanent epicardial pacemaker therapy in the paediatric population at a single centre in Pakistan is scientifically justified for the following reasons:

This study will provide crucial data on the outcomes of epicardial pacing in Pakistani children, including demographics, indications for pacing, lead and generator longevity, complication rates, re-intervention rates, and short and mid-term follow-up data.

The findings will help inform clinical practice guidelines and protocols for paediatric pacing in Pakistan. This will contribute to improved patient selection, implantation techniques, and follow-up care.

The study can identify specific challenges related to paediatric pacing in Pakistan, such as access to care, cost constraints, and the need for specialized training. This will help guide future research and resource allocation.

The data generated can serve as a baseline for future studies and allow for comparisons with data from other centres and countries. This will facilitate quality improvement efforts and promote best practices in paediatric pacing.

Ultimately, this study will contribute to improved care and outcomes for children in Pakistan requiring permanent epicardial pacing. By understanding the local experience and challenges, healthcare providers can better address the needs of this vulnerable population.

MATERIALS AND METHODS

This was a retrospective, observational study. The study was approved by the ethics committee of the institution via letter no 29/DMR/PIMC, dated 20/06/2018. The study was conducted in a tertiary care hospital in Peshawar-KP Pakistan. The sample size was 34. Children in the 20-48 kg weight range and who received epicardial pacemakers from 2018 to 2020 were included in the study.

Operational Definition

Epicardial Pacemaker Implantation: Epicardial pacemaker implantation was defined as the surgical placement of a permanent pacemaker system with the lead(s) directly attached to the epicardium. This was confirmed by intraoperative surgical visualization and fluoroscopy.

Age at Implantation: Age at implantation was calculated as the difference between the patient's date of birth and the date of pacemaker implantation, expressed in years.

Pacemaker Type: Pacemaker type was classified as either single-chamber (atrial or ventricular) or dual-chamber (atrial and ventricular) based on the number and location of the leads implanted. This information was obtained from the operative report.

Lead Type: The specific type of lead used for epicardial pacing.

Data source: A retrospective review of the medical records of the patients was conducted. A thorough review of the cardiac surgical and pacemaker databases identified all the paediatric patients who underwent permanent epicardial pacemaker implantation. Patients having a weight more than 48 were omitted to focus on paediatric cohort. Medical records were retrospectively studied. Data collected from these records included cardiac malformation, age, sex, congenital heart disease status, surgical procedures, approach, pacing indication, mode, steroid lead properties, chamber placement, lead fixation, complications, and follow-up information.

A vertical incision, a side incision or an incision below the breastbone was made in the chest to implant the epicardial leads. The choice of surgical approach depended on the patient's heart anatomy, the heart's location, previous surgical history, and any other procedures being done simultaneously. The ventricular lead was typically attached to the inferior wall of the left ventricle. The atrial lead was placed in either the *right atrium* or the *left atrium*, depending on intraoperative assessment of optimal pacing and sensing thresholds. The excess lead was accommodated by forming loops of the electrode inside the pacemaker pocket and the pericardium. The leads were carefully tunneled subcutaneously, avoiding the intended abdominal generator implant site and the costal margins (rib edges), to minimize the risk of lead damage or displacement.

The pacing system analyser was used to obtain implant measurements. Lead impedance was measured at a pulse width of 0.5 milliseconds and a voltage of 5 volts to assess electrical resistance. The minimum stimulation threshold was determined at a typical pulse width of 0.4 milliseconds to identify the lowest amplitude required for effective pacing. Sensing measurements were conducted at the native rhythm to detect intrinsic cardiac signals, specifically P-waves and R-waves, ensuring appropriate device response. Additionally, the electrical current necessary for consistent capture under defined conditions was evaluated to optimize pacemaker performance.

Acute pacing characteristics included energy threshold (ET), impedance, and sensing at implantation. The patient's infirmary records were analysed for time spent in hospital, adverse events, antibiotic use, and pacing parameters upon discharge. All systems were checked for pacing and sensing thresholds 48 hours before the patient was discharged from the hospital.

Capture threshold and sensing amplitude checked at one, three, and every six months thereafter. Outpatient check-ups involved real-time monitoring of battery and lead data. The threshold was established by progressively reducing the pulse width until the device failed to detect or record the signal. The lowest pulse width setting that consistently triggered a response was identified as the threshold.

The pacing and sensing thresholds were assessed at the initial implantation, upon hospital discharge, and at 1-, 6-, 12-, and 24-months follow-up. Lead failure was considered to have occurred when the lead needed to be replaced or abandoned because of physical damage, difficulty in pacing or sensing, or stimulation of nearby muscles. Infections were categorized as either superficial infections with or without positive blood cultures or deep infections that required removal of the generator. Lead data were excluded if the lead was replaced for elective reasons, if the patient died, or if they received a heart transplant.

Bias

Selection Bias: Referral patterns and inclusion/ exclusion criteria at the single centre can introduce selection bias, making the study population not fully representative.

Information Bias (Data Retrieval Bias): The quality and completeness of medical records can vary, leading to missing data or inaccuracies. This is a major potential limitation.

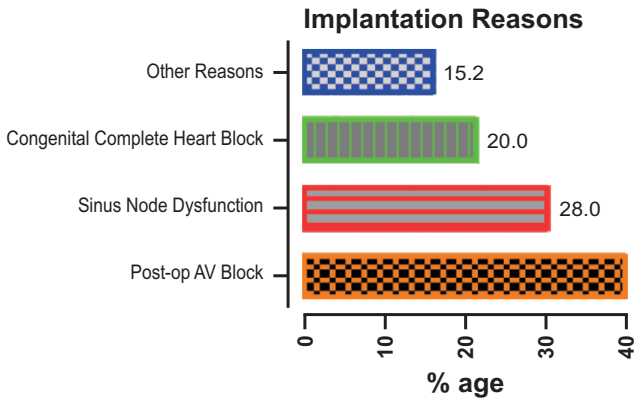
Confounding: It can be difficult to control for all potential confounding factors in a retrospective study, as all relevant data may not have been collected.

Statistical Methods: Data was analysed using statistical programme SPSS version 24. Proportions and their standard deviations were used to describe categorical variables. Normally distributed continuous variables were described using means and standard deviations, while skewed variables were summarized with medians and ranges. The χ^2 test was used to evaluate the strength of the relationship between categorical variables. The Wilcoxon rank sum test was employed to assess the significance of differences between continuous variables that were not normally distributed.

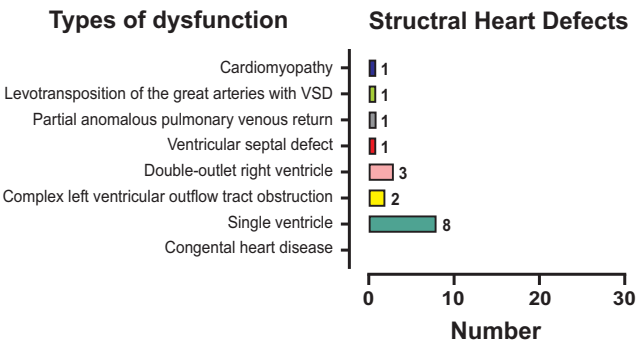
RESULTS

Thirty-four paediatric patients under the age of 12 were part of this research, having undergone the surgical placement of an epicardial pacemaker. Considering all PPM implantations for each patient, including repeat procedures, the average age was 7.2 ±2.6 years. The average weight at the time of lead implantation was 24.8±4.0kg. The majority of patients who underwent pacemaker implantation or lead replacement surgery were discharged from the hospital within a week of the procedure. Due to progressively worsening capture thresholds (requiring increasingly higher stimulation voltages), epicardial leads were explanted and replaced with transvenous leads in two patients. After surgery, two patients experienced complications such as hematoma in the generator pocket, phrenic nerve palsy, wound complications or abdominal discomfort and sudden ventricular dysfunction. Due to these complications, two readmissions were necessary for procedures like pacemaker generator resetting, debridement and irrigation, generator pocket reformation, and addressing hematoma and abdominal irritation.

Of the patients, 36.8% required a pacemaker due to post-op atrioventricular block, 28% had sinus node dysfunction, 20% had congenital complete heart block, and approximately 15.2% of the patients required a pacemaker for other reasons, including bradycardia caused by antiarrhythmic medication. The results are displayed in figure 01.



A significant portion (73.52%) of the study population (n=25) exhibited structural heart defects that required intricate surgical interventions to rectify complex cardiac malformations. Of the 25 patients born with heart problems, 32% (8 individuals) had a single heart chamber. The remaining 68% (n=17) exhibited a variety of cardiac defects including complex left ventricular outflow tract obstruction, double-outlet right ventricle, ventricular septal defect, partial anomalous pulmonary venous return, reversed position of the aorta and pulmonary artery with a ventricular septal defect and cardiomyopathy etc. the results are displayed in figure 02.



In our analysis of 34 patients who received a total of 67 pacing leads and 48 pacemaker generators, we found that dual-chamber pacing was the most frequently used generator mode.

Using a pacemaker to regulate heart rhythm in patients with a single ventricle

In the single ventricle cohort (n=8), six patients presented with heterotaxy syndrome: two with left atrial isomerism and one with right atrial isomerism. The primary indications for pacing were sinus node dysfunction, with or without concurrent atrial fibrillation, and post-operative complete atrioventricular (AV) block. The pacing modes used were DDD, DDR, VVI and VVIR respectively. On average, the pacemaker generators in these patients lasted 3.0 years, with a variability of 1.8 years. This longevity was comparable to that observed in patients with different heart pathologies.

Generator Longevity

The average lifespan of the pacemaker generators was 5.0 years, with a variation of 0.2 years (ranging from 7.2 to 9.4 years). Younger patients tended to require readjustment sooner, but there was no statistically significant correlation between age and generator longevity (p = 0.050). Neither the type of lead nor the pacing mode used with the generator had a statistically significant impact on its longevity.

Lead Longevity

The leads lasted an average of 10.0 years with a variability of 0.6 years, outlasting the generators. The probability of avoiding reoperation for lead revision was 90.0% at 1 year, 86.4% at 2 years, and 78.8% at 5 years. Lead failures were primarily attributed to problems with rhythm control or monitoring resulting due to a higher electrical stimulation requirement within the lead.

Table 01. The measured pacemaker telemetry data

Lead Location	Lead Impedance (Ω)			Energy Threshold (μJ)		
	Steroid	Non-Steroid	P-value	Steroid	Non-Steroid	P-value
Acute						
Atrial	288±22	256±12	NS	0.48±0.20	2.02±1.80	0.414
ventricular	304±30	314±42	NS	1.40±1.28	6.10±6.64	0.246
After a Year						
Atrial	306±20.0	278±18.6	NS	0.58±0.10	1.34±1.24	NS
Ventricular	412±30.8	318±32.8	NS	1.68±1.32	5.80±4.42	≤0.02
After 05 Years						
Atrial	324±20.4	270±12.2	NS	0.58±0.24	1.36±1.12	NS
Ventricular	344±32.4	348±22.6	NS	1.12±1.10	3.04±4.66	≤0.01

DISCUSSION

Typically, epicardial pacemakers do not last as long as endocardial pacemakers.[7,8] Because of the challenges of accessing the heart through tiny vessels or dealing with intricate heart anatomy in patients with congenital heart defects or paediatric patients, epicardial pacemakers are often the most practical choice.[4] Lead problems can also arise due to mismatched lead lengths caused by growth or challenges in removing leads in growing children. Due to high stimulation outputs, higher pacing rates, and recurring lead malfunction caused by rapid growth, paediatric patients frequently need pacemaker generator or lead changes.

Non-steroid-eluting leads were the predominant choice in our patients compared to steroid-eluting leads. We started with non-steroid-eluting leads, and a significant number of patients in the study continue to use these leads without requiring any lead changes. Although we observed a lower minimum energy threshold for steroid-releasing leads in the heart's lower chamber and previous studies suggested that these leads have a lower threshold, we did not find a significant difference in lead lifespan between steroid-releasing and non-steroid-releasing leads in our research.[11,12] Our results align with those of a Japanese study[13], and we think these factors were connected to positive patient results.

In patients with a history of several previous heart surgeries, the epicardium was often severely scarred and adhered to the pericardium or nearby structures. The scarring caused higher electrical stimulation requirements for the epicardial leads in the study population. Merely implanting a steroid-eluting lead might not resolve this problem. We believe our successful follow-up outcomes can be attributed to our efforts to identify an optimal site for lead placement, which included greater surgical manipulation of the tissue surrounding the heart's outer layer or alternative incisions like a lateral thoracotomy to approach areas not accessed in previous surgeries. Furthermore, regular monitoring of pacing instrumentation and parameters during follow-up visits in our working facility helped maintain optimal pacing.

Our study explored the long-term performance of epicardial pacemakers in a paediatric population, yielding several key findings. While we observed a trend towards earlier generator replacement in younger patients, likely due to the higher pacing rates required in this age group as described in previous studies,[14-16] this difference did not reach statistical significance. This observation aligns with the understanding that younger patients often necessitate higher pacing rates, potentially contributing to accelerated battery depletion. Furthermore, although implanting pacemakers in neonates and very young infants presents unique challenges, including hemodynamic instability, higher pacing thresholds, and increased risk of lead-related complications such as fracture and sensing difficulties, our data demonstrated a low incidence of such issues, supporting the safety and efficacy of pacemaker therapy in this vulnerable population. This favorable outcome, despite the inherent complexities of infant pacing, underscores the advancements in pediatric pacing techniques.

In the subset of patients with epicardial leads implanted for over two years, we documented stable pacing thresholds and sensing amplitudes, coupled with a low rate of lead failure. This reinforces the long-term viability of epicardial pacing in children. The use of steroid-eluting leads, particularly for ventricular pacing, has been shown to reduce battery consumption and the need for re-interventions.[17] Given the lifelong dependence on pacing for many paediatric patients, prioritizing long-term lead performance is paramount. While transvenous endocardial leads are often feasible in children weighing approximately 15 kg or more, as noted by Konta et al,[18] our findings suggest that delaying epicardial lead implantation until later childhood, when the innominate/cephalic veins are more developed, may minimize the risk of long-term vascular and valvular complications. This strategic approach to timing could further optimize the long-term outcomes for these patients.

In a small group of epicardial leads implanted for over two years, the study found acceptable electrical stimulation and detection levels, along with a low rate of lead failure. Steroid leads, especially for ventricular pacing, have demonstrated significant reductions in battery drain and the potential for subsequent surgery. Considering that most children will need pacemakers for life, paediatric cardiologists should prioritize long-term pacing solutions. While endocardial leads are technically feasible in most children weighing around 15 kg, implanting epicardial leads when the child is older and the innominate/cephalic veins are more developed may be a wiser approach to minimize long-term vascular and/or valvular injury.

Limitations/Future Study Prospects

The inherent limitations of this retrospective studies, such as reliance on existing data, potential for missing data, and difficulty in controlling for confounders, apply here. Prospective studies with clearly defined protocols and standardized data collection would address many of the limitations of retrospective studies and provide more robust evidence. Future studies should incorporate validated quality of life instruments to assess the impact of pacemaker therapy on paediatric patients' well-being.

CONCLUSION

The leads exhibited commendable longevity, enduring without significant variations based on their type. Notably, the generators' lifespan remained unaffected by the specific lead employed, the pacing mode selected, or the patient's age at the time of pacemaker implantation. These findings underscore the durability and reliability of the pacing components utilized in the study, suggesting that patients can anticipate extended periods of effective pacing without the need for frequent replacements.

Ethical Consideration

This study was approved by Institutional Review Board of Pak International Medical College, Peshawar, Pakistan.

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Conflict of Interest

Authors declared no conflict of interest.

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DATA SHARING STATEMENT: The data that support the findings of this study are available on request from the corresponding author. The data is not publicly available due to privacy or ethical restrictions.

AUTHORS' CONTRIBUTION

The following authors fulfill authorship criteria as per ICMJE guidelines;

Qazi HK, Shais R: Substantial contribution to conception and design, drafting the manuscript, final approval, agreed to be accountable for all the work.

Gohar F, Zaman A: Substantial contribution to conception and design, data acquisition, drafting the manuscript, final approval, agreed to be accountable for all the work.

Saleem O, Zohra B: Analysis and interpretation of data, drafting the manuscript, final approval, agreed to be accountable for all the work.

Ahmad W: Analysis and interpretation of data, critical revision, final approval, agreed to be accountable for all the work.

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