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Research Article

Safety and Early Outcomes of Off-Pump Bidirectional Glenn Procedure in Pediatric Patients with Single-Ventricle Physiology: A Five-Year Single-Center Experience

Zara Shirazi[1]*, Ammad Hussain[1], Javeria Khalid Khan[1], Kajal Khatri[1], Mahak Iqbal[1], Sohail Khan Bangash[3]

[1]National Institute of Cardiovascular Diseases (NICVD), Karachi, Pakistan.

***Corresponding Author:** Dr. Zara Shirazi, MBBS, FCPS (Cardiac Surgery) Clinical Fellow – Congenital Cardiac Surgery, National University Heart Centre Singapore and Former Fellow – Adult & Congenital Cardiac Surgery National Institute of Cardiovascular Diseases (NICVD), Karachi, Pakistan.

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Abstract

Background: The bidirectional Glenn (BDG) procedure is a key step in staged palliation for single-ventricle physiology and is traditionally performed using cardiopulmonary bypass (CPB). Avoidance of CPB may reduce perioperative morbidity, particularly in resource-limited settings.

Methods: We performed a retrospective observational analysis of pediatric patients undergoing off-pump bidirectional Glenn procedures at a single tertiary cardiac center between January 2020 and January 2025. Demographic characteristics, operative details, and early postoperative outcomes were evaluated. Due to the retrospective nature of the study, analysis was limited to variables available from institutional records.

Results: Off-pump BDG was successfully completed in all selected patients without routine use of CPB (n = 96). The mean intensive care unit (ICU) stay was 3.1 days. Early postoperative complications occurred in 11.0% of patients, most commonly re-exploration for bleeding (four cases). No early mortality was observed

Conclusion: In carefully selected pediatric patients, the off-pump bidirectional Glenn procedure is a feasible and safe surgical strategy, associated with acceptable early outcomes and efficient resource utilization.

Keywords: *Single-ventricle physiology; Congenital heart surgery; Pediatric cardiac surgery; Cardiopulmonary bypass avoidance; Resource-limited settings; Congenital heart disease; Early postoperative outcomes.*

Introduction

The bidirectional Glenn (BDG) procedure represents an important stage in the surgical palliation pathway for children with single-ventricle physiology. By establishing a cavopulmonary connection, BDG reduces the volume load on the single ventricle and serves as a bridge toward definitive Fontan circulation in appropriately selected patients.

Traditionally, BDG has been performed using cardiopulmonary bypass (CPB), which provides optimal surgical exposure and hemodynamic stability during the procedure. Although conventional on-pump BDG has demonstrated excellent outcomes, CPB exposure may be associated with systemic inflammatory response, coagulation abnormalities, increased blood product requirements, and postoperative morbidity [2,3].

In recent years, off-pump BDG has gained increasing interest as an alternative surgical strategy aimed at reducing CPB-related effects while achieving comparable early outcomes. However, concerns regarding technical complexity, temporary superior vena cava occlusion, and maintenance of hemodynamic stability have limited its widespread adoption. Careful patient selection and coordinated surgical and anesthetic management remain essential for successful implementation [2,3].

This study presents our five-year single-center experience with off-pump BDG in pediatric patients with single-ventricle physiology, evaluating its feasibility, safety, and early postoperative outcomes in a resource-limited healthcare setting.

Methods

This retrospective observational study was conducted at the National Institute of Cardiovascular Diseases (NICVD), Karachi. Pediatric patients undergoing off-pump bidirectional Glenn procedures between January 2020 and January 2025 were included. Patient selection was based on favorable anatomy, acceptable pulmonary artery pressures, and stable perioperative physiology.

The procedure was performed without CPB using meticulous dissection, temporary superior vena cava occlusion, and close communication between the surgical and anesthesia teams to maintain hemodynamic stability. Postoperative outcomes included ICU stay, early complications, and in-hospital mortality.

Results

A total of 96 pediatric patients underwent off-pump bidirectional Glenn (BDG) procedures during the study period. The procedure was successfully performed in all selected patients without the routine use of cardiopulmonary bypass.

The mean intensive care unit (ICU) stay was 3.1 days, with the majority of patients requiring only a short postoperative ICU course and being discharged within 2–4 days (Figure 1).

Early postoperative complications occurred in 11.0% of patients. Re-exploration for postoperative bleeding was required in four cases, while pleural effusion was the most commonly observed non-surgical complication (Figure 2). No early mortality was recorded during the study period.

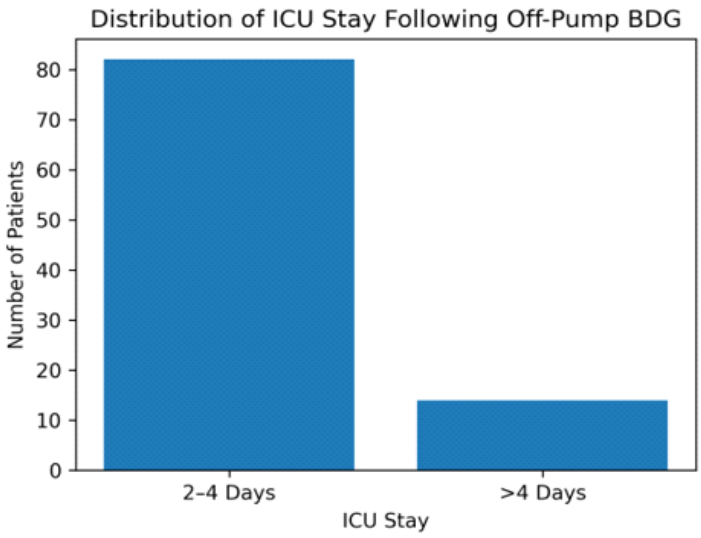

Figure 1. Distribution of ICU stay (days) following off-pump bidirectional Glenn procedure.

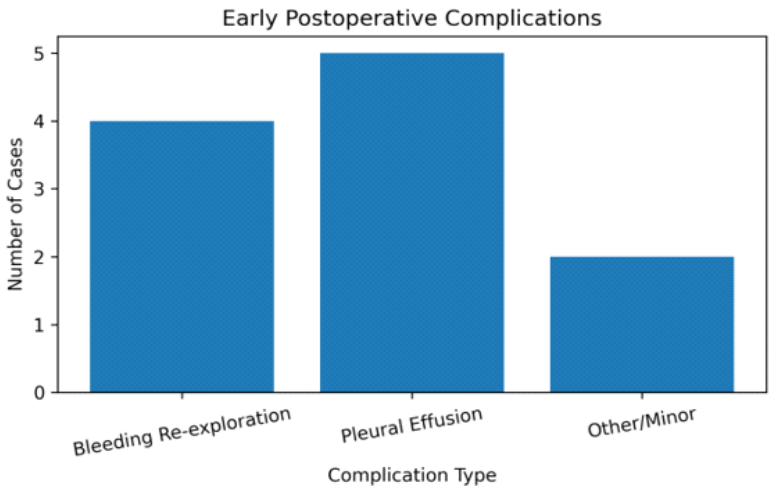

Figure 2. Frequency of early postoperative complications.

Discussion

The present study describes our five-year single-center experience with the off-pump bidirectional Glenn (BDG) procedure in pediatric patients with single-ventricle physiology. In this cohort of 96 patients, off-pump BDG was successfully performed with acceptable early postoperative outcomes, a mean intensive care unit (ICU) stay of 3.1 days, and no early mortality. These findings support the feasibility and safety of this approach when applied to appropriately selected patients with careful perioperative management.

Traditionally, the BDG procedure has been performed using cardiopulmonary bypass (CPB), which provides a controlled operative field but may be associated with systemic inflammatory responses, coagulation disturbances, and increased postoperative morbidity. Avoidance of CPB through an off-pump approach may help reduce these adverse effects while maintaining satisfactory surgical outcomes [2,3]. Previous studies have demonstrated that off-pump BDG can be performed safely in selected patients, and our findings are consistent with reported experiences following cavopulmonary palliation [2,4,5].

In our series, early postoperative complications occurred in 11.0% of patients. Re-exploration for bleeding and pleural effusion were the most notable complications; however, all were successfully managed without early mortality. These complications are well-recognized following Glenn circulation and were not increased compared with previously published outcomes [4,5]. The absence of early mortality in our cohort further supports the role of careful patient selection, meticulous surgical technique, and close collaboration between surgical and anesthesia teams.

The potential advantages of an off-pump strategy are particularly relevant in resource-limited healthcare settings, where minimizing CPB exposure, blood product utilization, and intensive care requirements may improve overall resource efficiency. However, successful implementation requires appropriate anatomical selection, stable perioperative physiology, and experienced surgical management [2].

The limitations of this study include its retrospective single-center design, absence of a contemporaneous on-pump comparison group, and lack of long-term follow-up data. Additionally, selection bias cannot be excluded because only patients considered suitable for an off-pump approach underwent this technique. Nevertheless, the relatively large cohort and consistent early outcomes provide valuable insight into the feasibility and safety of off-pump BDG in selected pediatric patients.

Conclusion

The off-pump bidirectional Glenn procedure is a safe, reproducible, and cost-effective alternative to the conventional on-pump approach in selected pediatric patients. Broader adoption of this technique may contribute to improved efficiency and outcomes in congenital cardiac surgery.

Ethical Approval

This retrospective observational study was approved by the Institutional Review Board of the National Institute of Cardiovascular Diseases (NICVD), Karachi. The requirement for individual informed consent was waived due to the retrospective nature of the study and use of anonymized patient data.

Conflict of Interest

The authors declare no conflict of interest.

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