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Original Article

Impact of International Fellowship Training Program on Pediatric & Congenital Cardiac Surgery Outcomes In A Low-Income Country

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ABSTRACT

Objective: To compare post procedural mortality and procedural diversity in pediatric and congenital cardiac surgery before and after implementation of an International Fellowship Training Program (IFTP) at a national referral center in a low-income country.

Study Design: Comparative cross sectional study design

Place and Duration of Study: Department of Pediatric and Congenital Cardiac Surgery, Armed Forces Institute of Cardiology/ National Institute of Health, Rawalpindi, Pakistan, from January 2014 to December 2023.

Methodology: All consecutive patients undergoing Congenital Cardiac surgery falling under Risk Adjustment for Congenital Heart Surgery (RACHS-1) categories II–IV from 2014–2023 were included using universal sampling. Outcomes and procedural distributions were compared between two time-defined cohorts: pre-fellowship training program (2014–2018) and post-fellowship training program (2019–2023). Mortality and procedural distribution were compared between eras.

Results: A total of 3388 patients were included. The proportion of high-complexity (RACHS III–IV) operations increased significantly post-fellowship (59.2% vs. 40.8%, $p < 0.001$). Overall mortality declined from 9.4% to 6.6% ($p = 0.004$). The biggest improvements occurred in BDG (12.6% to 5.3%, $p = 0.01$) and ASO (54% to 39%, $p < 0.05$), while lower-complexity repairs (VSD and TOF) showed smaller yet consistent gains.

Conclusion: lower mortality and higher procedural complexity rates were observed in the post-IFTP era compared to the pre-IFTP era at AFIC. Structured exposure to advanced training environments enhances surgical capacity and patient survival in LICs.

Keywords: Cardiac Surgical Procedures, Congenital, Fellowship, Heart Defects, Risk Adjustment, Treatment Outcome.

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INTRODUCTION

Congenital heart disease (CHD) is the most common congenital anomaly worldwide, affecting approximately 27.8 per 10,000 live births.[1] Almost 90% of impacted infants born in low- and middle-income countries (LMICs) face enduring shortages of diagnostic and surgical resources.[2] South Asian resources indicate an even greater burden; in Pakistan, it is estimated that 32.5 percent of the population is affected by CHD.[3]

World's high-income countries have surpassed the 90% survival rate beyond the first year of life, thanks to advancements in early detection, surgery, and perioperative care.[4] However, Low middle income countries (LMICs) continue to struggle with delays in presentation, inadequate pediatric intensive-care services, and an insufficient number of trained pediatric cardiac surgeons.[5,6] In Pakistan, cardiac surgery training is still largely adult-centered, since the College of Physicians and Surgeons Pakistan (CPSP) does not have a dedicated congenital cardiac surgery fellowship.[7] As a result, many complex lesions are either referred internationally or, unfortunately, managed locally, leading to significant morbidity and mortality.[8]

To address this deficiency, the Pakistan Army Medical Corp (AMC) established an International Fellowship Training Program (IFTP) with the Birmingham Children's Hospital (BCH), United Kingdom, providing two years of hands-on congenital cardiac training for Armed Forces Institute of Cardiology (AFIC) surgeons. [9] There is limited published evidence quantifying the effect of structured international fellowship training on both procedural diversity and short-term surgical outcomes within single-center programs in low-income countries. This study addresses that gap by comparing case-mix and 30-day mortality before and after an established IFTP, thereby providing empirical data on

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training-driven capacity building in a national referral center. This study aimed to evaluate the impact of the IFTP on mortality outcomes, with the hypothesis that surgical outcomes and procedural complexity differ between the pre- and post-IFTP periods.

METHODOLOGY

A retrospective comparative cross-sectional study was conducted to compare paediatric and congenital cardiac surgical outcomes across two time-defined cohorts at the Armed Forces Institute of Cardiology (AFIC), Rawalpindi, from January 2014 to December 2023. Ethical approval was obtained (IERB Letter No: 9/2/R&D/2024/308) on 28th March 2024.

Description of Fellowship Training Program: During the study period, two AFIC congenital cardiac surgeons completed a structured two-year international fellowship at Birmingham Children's Hospital (BCH), UK. The fellowship included complete integration into patient care, hands-on surgical training, multidisciplinary exposure (ICU, anesthesia, perfusion), participation in audits, journal clubs, Morbidity and Mortality meetings, Multidisciplinary Team conferences, workshops, and standardized Birmingham Children's Hospital in the United Kingdom training modules.

Upon return, fellows implemented BCH surgical protocols, perioperative pathways, neonatal and complex CHD strategies, and introduced procedures previously not performed at AFIC (including Ross, Rastelli, and expanded neonatal ASO work). Dissemination pathways included team lectures, structured training of anesthetists, perfusionists, and ICU teams, reinforcement of the WHO Surgical Safety Checklist, and regular morbidity and mortality review cycles.

The sample size was calculated using the WHO sample size calculator. The proportion of RACHS-1 category 2 procedures was taken as 58%, based on the study by Furnaz *et al.*, 2023.[10] Using a 95% confidence level and a 5% margin of error, the minimum sample size calculated were 374 participants.

Inclusion Criteria: All patients who underwent one of eight congenital cardiac operations within Risk Adjusted Congenital Heart Surgery (RACHS-1) categories II–IV were included:RACHS-II: VSD repair, TOF repair, RACHS-III: Bidirectional Glenn (BDG), Supracardiac TAPVR repair, RACHS-IV: Fontan, ASO (± VSD), Ross, and Rastelli.

The study used the AFIC operative and ICU records from 2014–2023 to compare 30-day mortality between two time-defined cohorts on procedural capability and short-term outcomes.

Exclusion Criteria: All other congenital or acquired operations and redo procedures.

They study had two time periods, era A (2014–2018): Pre-international fellowship training program (IFTP) and era B (2019–2023): Post-international fellowship training program (IFTP).

The study used retrospective extraction of consecutive patients from operative and ICU records without randomization or alteration in clinical assignment. Variables collected included patient identifier (de-identified for analysis), procedure type, RACHS-1 category, date of surgery (used to assign era A vs B), and 30-day mortality outcome. Two eras were defined a priori: Era A (2014–2018) and Era B (2019–2023). Source documents were the departmental operative logbooks and ICU outcome registers.

Analyses were performed using SPSS (Statistical Package for Social Sciences) version 23.0. Descriptive statistics included frequency and proportions for procedures and mortality by era. Inferential analysis used the Chi-square test to compare proportions (procedure frequency and mortality) between eras. A two-sided p-value ≤ 0.05 was considered statistically significant.

RESULTS

Over ten years, 3388 operations were performed, 3182 traditional (RACHS II–III) and 206 novel procedures (RACHS IV). Result of traditional procedures showed that while the total number of cases decreased slightly from 1,735 in Period A to 1,447 in Period B, there was a significant improvement in patient outcomes. There remained a high volume of most common procedures, VSD and TOF repairs, but they represented a smaller portion of the total caseload due to a shift in more complex procedures. Mortality for VSD decreased significantly (p=0.047); and for BDG it improved markedly (p=0.010). Mortality reductions for TOF and TAPVR procedures were noted, but were not statistically significant. Overall, across all traditional procedures, there was a decline in 30-day mortality (p=0.004), as shown in Table I.

There was a Significant change towards more complicated procedural cases after 2019 (p<0.001). Table II highlights the proportion of RACHS III–IV procedures. As for the analysis of new procedures,

there is a noticeable increase in the number of procedures in the post-IFTP period. Adding to the institution's ability to perform the more complex surgeries, the total count of new procedures increased from 84 cases (40.8%) in Period A (2014–2018, pre-fellowship) to 122 cases (59.2%) in Period B (2019–2023, post-fellowship). ASO/ASO + VSD procedures increased, and mortality decreased from 54.3% to 39%; this decrease was not statistically significant (p=0.219). Similarly, there was a noted increase in the number of Rastelli procedures, and although there was a noted decrease in mortality, it also was not significant (p=0.490). There was an increase in Ross procedures from 5 to 14 and Fontan procedures decreased slightly in number but mortality decreased from 17.9% to 11.5% (p=0.728). Overall, post-fellowship there was a decline in 30-day mortality (p=0.21) for all the new procedures.

Table-I: Frequency and 30-day Mortality of Traditional Procedures by Time Period (2014–2018) (n=3182)

Procedure	Time Period (2014–2018)	Total (n=3182)	Mortality (n=258)	*p*-value
		[Frequency (%)]		
VSD	Period A	780(54.3%)	49(66.2 %)	0.047
	Period B	656(45.7%)	25(33.8%)	
	Total	1436(100%)	74(5.2%)	
TOF	Period A	682(57.1%)	73(59.8%)	0.587
	Period B	512(42.9%)	49(40.1%)	
	Total	1194(100%)	122(10.2%)	
BDG	Period A	230(50.3%)	29(70.7%)	0.010
	Period B	227(49.7%)	12(29.3%)	
	Total	457(100%)	41(9.0%)	
TAPVR	Period A	43(45.3%)	12(57.1%)	0.322
	Period B	52(54.7%)	9(42.9%)	
	Total	95(100%)	21(22.1%)	
Overall Total	Period A	1735(54.5%)	163(63.2%)	0.004
	Period B	1447(45.5%)	95(36.8%)	
	Total	3182(100%)	258(8.1%)	

Period A: (2014–2018); Period B: (2019–2023); VSD: Ventricular Septal Defect; TOF: Tetralogy of Fallot; BDG: Bidirectional Glenn; TAPVR: Total Anomalous Pulmonary Venous Return

These findings suggest that the fellowship not only enhanced the institution's ability to perform complex novel procedures but also led to significant improvements in outcomes for routine congenital surgeries, reflecting overall institutional capacity building and improved surgical care.

DISCUSSION

This retrospective comparative cross-sectional study evaluated differences in procedural complexity and 30-day outcomes in pediatric and congenital cardiac surgery at a national referral center in a low-income country. Surgical cases were compared between two time-defined cohorts: pre-IFTP (Era A, 2014–2018) and post-IFTP (Era B, 2019–2023). Observed differences in surgical complexity and outcomes are reported without implying causality, acknowledging that temporal trends and concurrent institutional changes may have influenced the findings.

Table-II: Frequency and 30-day Mortality of Novel Procedures by Time Period (2019-2023) (n=206)

Procedure	Time Period (2019–2023)	Total (n=206)	Mortality (n=60)	*p*-value
		[Frequency (%)]		
ASO / ASO+VSD	Period A	35(37.2%)	19(45.2%)	0.219
	Period B	59(62.8%)	23(54.7%)	
	Total	94(100%)	42(44.7%)	
Ross	Period A	5(26.3%)	0(0.0%)	1.00
	Period B	14(73.7%)	1(100%)	
	Total	19(100%)	1(5.3%)	
Rastelli	Period A	5(17.9%)	1(14.3%)	1.00
	Period B	23(82.1%)	6(85.7%)	
	Total	28(100%)	7(28.0%)	
Fontan	Period A	39(60.0%)	7(70%)	0.726
	Period B	26(40.0%)	3(30%)	
	Total	65(100%)	10(15.4%)	
Overall Total	Period A	84(40.8%)	27(45%)	0.421
	Period B	122(59.2%)	33(55%)	
	Total	206(100%)	60(29.6%)	

ASO: Arterial Switch Operation; VSD: Ventricular Septal Defect; ASO+VSD: Arterial Switch Operation with VSD repair; ROSS: Ross procedure (pulmonary autograft for aortic valve replacement); RASTELLI: Rastelli procedure (repair for transposition of great arteries with VSD and pulmonary stenosis)

Over the decade the AFIC is noted to have statistically significant increase in case complexity and concomitant improvement in 30-day mortality post the BCH, IFTP. The data indicates an absolute increase in advanced RACHS IV operations and a concurrent decrease in overall early mortality, demonstrating improvement in institutional capability. Pakistan is critically understaffed in the area of pediatric cardiac surgery, with a dismally lowest workforce density of 0.08 pediatric cardiac surgeons per million population worldwide.[11] This scarcity, compounded by the absence of a dedicated pediatric cardiac surgery training pathway under the CPSP, severely limits access to timely and definitive treatment for children with CHD.

The present study covers a decade of study demonstrates that the IFTP program was effective in enhancing surgical capacity at the AFIC. The program facilitated the acquisition of new advanced surgical skills and the mentoring of local trainees and a significant improvement in institutional capacity. In contrast to short-term, visiting team models, the fellowship model places local surgeons at high-

volume teaching hospitals for extended stints. This approach is designed for profound deep immersion in the clinical and surgical management of complex cases and perioperative care, as well as the management of multidisciplinary teams. Such immersion is intended to foster the graduate's ability to think independently and to identify and articulate problems, as well as to bolster leadership in resource-poor environments to establish programs for sustainable congenital cardiac care.[12]

The improvement in all- cause institutional mortality (from 9.4% to 6.6%) is similar to that reported by Novick *et al.*,[5] and the Children's HeartLink network.[13] Most improvements were in the mid to high- level complexity procedures- particularly ASO and BDG where the expertise peri-operatively and in the post-operative management is critical to survival. These enhancements indicate that the IFTP was not limited to the surgical component but also to the realms of perfusion, anesthesia, and the intensive care teams.[14]

More importantly, the IFTP also had a positive impact on the institutional systems of care. Post-operative management at AFIC is now more aligned with the BCH, IFTP, and includes goal-directed perfusion, early extubation, and neuroprotection, which likely facilitated the improved short-term outcomes.[15] Additionally, the returning fellows took on important responsibilities as local mentors, thus perpetuating a cycle of capacity building which is consistent with the World Health Organization Global Surgery 2030, which emphasizes the importance of training partnerships as a means of achieving sustainable surgical development.[16]

Similar patterns of improvement have been noted in other neighbouring LMICs. In India, which shares a similar healthcare structure to Pakistan, emphasis has been placed on the role of international fellowship training in creating a highly specialized tier of cardiac surgeons.[17,18] The 2022 Annual Report from Children's Heart Link detailed similar successes in Bangladesh, Brazil, India, Malaysia, and Vietnam, where post-fellowship programs were linked with heightened procedural complexity and substantial reductions in mortality.[13] Taken together, these regional experiences reinforce that internationally focused fellowships of a structured design are both economically and operationally viable in the long-term for the enhancement of pediatric cardiac surgical services in poor resource environments.

LIMITATIONS OF STUDY

In present study, lack of randomization, no concurrent control, and an inability to prove causality are a few limitations. There may be improvements based on concurrent enhancements that could influence the outcomes, and unmeasured confounders could lack improvements. There is a possibility that a retrospective bias could be introduced with a cover sheet, and a generalization will reflect that there are only two surgeons involved. The longitudinal control does show that there is substantial influence on the fellowship. More studies could be done in multi-centered and prospective settings.

CONCLUSION

In contrast to pre-IFTP conditions, the post-IFTP period at AFIC showed decreased early mortality, along with an increased rate of more complicated congenital cardiac surgeries. Post fellowship the unit consolidated the ability to perform advanced congenital operations independently and showed substantial improvements in early mortality and built an early structured system of continuous professional development. These results underline the impact of international fellowships on the development of specialized and sustainable pediatric cardiac surgical skills in resource-poor settings.

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Authors' Contribution

Following authors have made substantial contributions to the manuscript as under:

DKM & IUH: Data acquisition, data analysis, critical review, approval of the final version to be published.

MA & MAA: Study design, data interpretation, drafting the manuscript, critical review, approval of the final version to be published.

MM & AN: Conception, data acquisition, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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