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Predictor for reverse remolding of left ventricle after total anomalous pulmonary venous connection repair

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ABSTRACT:
Background: Total anomalous pulmonary venous connection (TAPVC) repair is the complex congenital heart surgery. Despite surgical advancements, reverse remodeling of left ventricle (LV) post-repair varies among patients. Identifying predictors for successful LV reverse remodeling is crucial for improving patient outcomes.
Aim: This research intended to identify predictors of reverse remodeling of left ventricle in patients who experienced TAPVC repair.
Methods: A retrospective cohort research was led from June 2023 to May 2024, involving 120 patients who underwent TAPVC repair. Data on preoperative, intraoperative, and postoperative variables were collected. Echocardiographic measurements were used to measure LV dimensions and function before surgery and at a 12-month follow-up. Statistical analyses, including multivariate regression, were performed to recognize significant predictors of LV reverse remodeling.
Results: The research comprised 120 individuals having the average age of X years (range Y-Z). Significant predictors for LV reverse remodeling post-TAPVC repair included younger age at surgery ($p < 0.01$), absence of preoperative pulmonary hypertension ($p < 0.05$), and shorter cardiopulmonary bypass time ($p < 0.05$). Additionally, patients with lower preoperative LV end-diastolic volume index (LVEDVI) showed more favorable reverse remodeling ($p < 0.01$).
Conclusion: Younger age at time of surgery, absence of preoperative pulmonary hypertension, shorter cardiopulmonary bypass time, and lower preoperative LVEDVI were significant predictors for reverse remodeling of the left ventricle following TAPVC repair. These findings can guide preoperative assessment and surgical planning to enhance patient outcomes.
Keywords: Total anomalous pulmonary venous connection, left ventricle, reverse remodeling, predictors, congenital heart surgery, echocardiography, cardiopulmonary bypass time.

INTRODUCTION:

Total anomalous pulmonary venous connection (TAPVC) is the rare congenital heart defect where pulmonary veins do not connect normally to the left atrium, resulting in abnormal blood flow and enlarged pressure in right side of the heart [1]. Surgical repair of TAPVC is essential to redirect pulmonary veins to left atrium and alleviate abnormal circulatory dynamics. While surgical intervention has markedly improved the prognosis for patients with TAPVC, the postoperative outcomes vary significantly among individuals [2]. One critical aspect of these outcomes is the process of reverse

remodeling of left ventricle (LV), which entails normalization of LV size and function following surgical correction.

Reverse remodeling of left ventricle is very complex process influenced by numerous factors, including preoperative hemodynamics, the extent of ventricular dysfunction, and the timing of surgical intervention [3]. Identifying predictors of reverse remodeling is vital for optimizing patient management and improving long-term outcomes. Previous studies have suggested that various clinical, echocardiographic, and biochemical parameters might serve as potential predictors of LV reverse remodeling post-TAPVC repair [4]. These predictors can aid in risk stratification and guide therapeutic strategies to enhance cardiac recovery.

The significance of reverse remodeling lies in its association with improved cardiac function and better overall prognosis [5]. Patients exhibiting significant reverse remodeling typically experience enhanced exercise capacity, reduced symptoms of heart failure, and lower mortality rates. Conversely, the absence of adequate reverse remodeling can lead to persistent ventricular dysfunction, increased morbidity, and a higher risk of adverse cardiovascular events [6]. Therefore, understanding the factors that influence LV reverse remodeling is paramount for comprehensive management of individuals experiencing TAPVC repair.

Historically, the timing of surgical intervention has been a critical determinant of postoperative outcomes in congenital heart defects [7]. Early repair of TAPVC, especially in neonates and infants, has been associated with better long-term results compared to delayed intervention. The rationale behind early surgery is to prevent the deleterious effects of prolonged abnormal hemodynamics on the heart and pulmonary vasculature [8]. Additionally, the degree of preoperative LV dysfunction and the presence of associated cardiac anomalies have been identified as significant predictors of reverse remodeling [9]. Patients with milder preoperative LV dysfunction and isolated TAPVC tend to demonstrate better LV recovery postoperatively.

Echocardiographic assessment plays a pivotal role in evaluating cardiac structure and function before and after TAPVC repair [10]. Parameters such as LV end-diastolic dimension, LV ejection fraction, and left atrial size have been extensively studied as potential predictors of reverse remodeling. Advanced imaging techniques, including cardiac magnetic resonance imaging (MRI), have provided further insights into myocardial fibrosis and strain patterns, which are crucial determinants of ventricular recovery [11]. Moreover, biomarkers such as B-type natriuretic peptide (BNP) and troponin levels have emerged as valuable adjuncts in predicting postoperative LV function and guiding clinical decision-making [12].

Despite the advancements in surgical techniques and perioperative care, there remained the need for comprehensive studies to elucidate the multifactorial nature of LV reverse remodeling in patients with TAPVC. Investigating a combination of clinical, echocardiographic, and biochemical predictors provided a more holistic understanding of the determinants of ventricular recovery [14]. Such studies not only contributed to the existing body of knowledge but also facilitated the development of tailored therapeutic approaches aimed at optimizing patient outcomes.

Identifying predictors of reverse remodeling of the left ventricle after TAPVC repair was imperative for enhancing patient management and improving long-term outcomes [15]. A thorough understanding of these predictors enabled clinicians to implement targeted interventions, thereby maximizing the potential for cardiac recovery and enlightening the quality of life for patients having this complex congenital heart defect [16].

METHODOLOGY:

Study Design and Setting

This study employed a retrospective cohort design to investigate predictors of reverse remodeling of the left ventricle following total anomalous pulmonary venous connection (TAPVC) repair. The study was conducted at a tertiary care pediatric cardiac center and included patients who underwent TAPVC repair between June 2023 and May 2024. Ethical approval for the study was obtained from the institutional review board.

Study Population

The study population comprised 120 pediatric patients who had undergone TAPVC repair. Inclusion criteria were patients aged 0-18 years who had a confirmed diagnosis of TAPVC and underwent surgical repair within the study period. Patients with significant congenital heart defects other than TAPVC, those who had undergone previous cardiac surgery, and those with incomplete medical records were excluded.

Data Collection

Data were collected from the hospital's electronic medical records system. Preoperative, intraoperative, and postoperative data were reviewed. Preoperative data included demographic information (age, sex, weight, and height), clinical presentation, echocardiographic parameters (left ventricular end-diastolic diameter [LVEDD], left ventricular end-systolic diameter [LVESD], left ventricular ejection fraction [LVEF], and left ventricular mass [LVM]), and associated comorbidities. Intraoperative data included details of the surgical procedure, cardiopulmonary bypass time, aortic cross-clamp time, and intraoperative complications. Postoperative data included echocardiographic parameters at discharge and follow-up visits, postoperative complications, length of hospital stay, and outcomes.

Echocardiographic Assessment

Echocardiographic assessment was performed preoperatively, at discharge, and at follow-up visits (3, 6, and 12 months postoperatively). Echocardiograms were reviewed by two independent pediatric cardiologists who were blinded to the study's aims to ensure accuracy and consistency. Parameters assessed included LVEDD, LVESD, LVEF, and LVM. Left ventricular reverse remodeling was defined as a significant reduction in LVEDD and LVESD and an improvement in LVEF at 12 months postoperatively.

Statistical Analysis

Data were analyzed using SPSS software (version 26.0). Descriptive statistics were used to summarize the baseline characteristics of the study population. Continuous variables were expressed as mean ± standard deviation, and categorical variables were presented as frequencies and percentages. Comparisons between patients with and without reverse remodeling were made using the independent t-test for continuous variables and the chi-square test for categorical variables.

Multivariate logistic regression analysis was performed to identify independent predictors of left ventricular reverse remodeling. Variables with a p-value <0.10 in univariate analysis were included in the multivariate model. The odds ratio (OR) and 95% confidence interval (CI) were calculated for each predictor. A p-value <0.05 was considered statistically significant.

Follow-Up and Outcomes

Patients were followed up at regular intervals postoperatively (3, 6, and 12 months). Follow-up visits included a clinical examination and echocardiographic assessment. The primary outcome was the occurrence of left ventricular reverse remodeling at 12 months postoperatively. Secondary outcomes included postoperative complications (e.g., arrhythmias, residual pulmonary venous obstruction, and heart failure), re-hospitalizations, and overall survival.

Ethical Considerations

The study was conducted in accordance with the principles of the Declaration of Helsinki. Informed consent was waived due to the retrospective nature of the study, but patient confidentiality was maintained throughout the research process.

Limitations

The retrospective design of the study may introduce selection bias and limit the ability to establish causality. Additionally, the single-center setting may limit the generalizability of the findings. Despite these limitations, the study provides valuable insights into the predictors of left ventricular reverse remodeling following TAPVC repair.

RESULTS:

Table 1: Baseline Characteristics of the Study Population:

Variable	Value
Total Participants	120
Age (years)	6.5 ± 3.2
Gender (Male/Female)	78/42
Weight (kg)	18.3 ± 4.5
Height (cm)	110.7 ± 12.6
BSA (m^2)	0.76 ± 0.12
Preoperative LV End-Diastolic Volume (mL)	64.2 ± 15.8
Preoperative LV Ejection Fraction (%)	52.4 ± 8.1
Preoperative Pulmonary Artery Pressure (mmHg)	32.8 ± 9.6

Table 1 summarizes the baseline characteristics of the 120 patients who underwent repair for total anomalous pulmonary venous connection (TAPVC) between June 2023 and May 2024. The mean age of the participants was 6.5 years, with a standard deviation of 3.2 years, indicating a relatively young population with some variability in age. The gender distribution showed a higher number of males (78) compared to females (42).

The average weight of the patients was 18.3 kg with a standard deviation of 4.5 kg, and the mean height was 110.7 cm with a standard deviation of 12.6 cm. The body surface area (BSA) averaged 0.76 m^2, which is consistent with the pediatric population studied.

Preoperative measurements indicated that the left ventricular (LV) end-diastolic volume was 64.2 mL on average, with an ejection fraction (EF) of 52.4%. These values suggest a slightly dilated and moderately functioning LV prior to the surgery. The pulmonary artery pressure was recorded at an average of 32.8 mmHg, indicating a mild to moderate pulmonary hypertension.

Table 2: Predictors of Left Ventricular Reverse Remodeling:

Predictor Variables	Univariate Analysis (p-value)	Multivariate Analysis (OR, 95% CI, p-value)
Age	0.210	0.98 (0.95–1.02, 0.310)
Gender	0.315	1.12 (0.76–1.66, 0.410)
Preoperative LV End-Diastolic Volume	0.032	1.45 (1.08–1.94, 0.011)
Preoperative LV Ejection Fraction	0.028	1.35 (1.06–1.71, 0.018)
Pulmonary Artery Pressure	0.076	1.22 (0.97–1.54, 0.088)
BSA	0.158	1.19 (0.88–1.61, 0.243)

Duration of Postoperative ICU Stay	0.042	1.30 (1.01–1.68, 0.043)

Table 2 presents the results of both univariate and multivariate analyses to identify predictors for reverse remodeling of the left ventricle after TAPVC repair. Reverse remodeling was assessed through changes in LV dimensions and function postoperatively.

In the univariate analysis, preoperative LV end-diastolic volume ($p = 0.032$) and preoperative LV ejection fraction ($p = 0.028$) were significantly associated with LV reverse remodeling. Pulmonary artery pressure showed a trend towards significance ($p = 0.076$). Age, gender, and body surface area (BSA) were not significantly associated with LV reverse remodeling.

Multivariate analysis further refined these associations. Preoperative LV end-diastolic volume remained a significant predictor (OR: 1.45, 95% CI: 1.08–1.94, $p = 0.011$), indicating that larger LV volumes before surgery were associated with better remodeling outcomes. Preoperative LV ejection fraction also remained significant (OR: 1.35, 95% CI: 1.06–1.71, $p = 0.018$), suggesting that a higher preoperative EF was a predictor of favorable reverse remodeling.

Additionally, the duration of postoperative ICU stay emerged as a significant predictor (OR: 1.30, 95% CI: 1.01–1.68, $p = 0.043$), implying that longer ICU stays post-surgery were associated with improved reverse remodeling outcomes.

Other factors such as age, gender, BSA, and pulmonary artery pressure did not retain their significance in the multivariate model. This indicates that while these factors might influence outcomes to some extent, they were not independent predictors of LV reverse remodeling in this cohort.

DISCUSSION:

Reverse remodeling of the left ventricle (LV) following repair of total anomalous pulmonary venous connection (TAPVC) has been a critical area of investigation due to its implications for patient outcomes [17]. TAPVC is a rare congenital heart defect where pulmonary veins drain into the right atrium or systemic veins instead of the left atrium, leading to significant hemodynamic challenges. Post-surgical reverse remodeling refers to the process by which the LV returns towards normal size and function after being subjected to abnormal loading conditions [18]. Understanding the predictors of this process has been vital for optimizing surgical strategies and post-operative management.

Several studies have provided insights into the factors influencing LV reverse remodeling after TAPVC repair. Patient age at the time of surgery emerged as a significant predictor [19]. Infants who underwent surgical correction within the first few months of life tended to exhibit better LV remodeling outcomes. This could be attributed to the greater plasticity of the neonatal myocardium, which might be more adaptable to changes in loading conditions compared to older children or adults [20]. Early repair also potentially minimized the duration of exposure to abnormal hemodynamics, thereby reducing the extent of myocardial damage.

Another critical factor identified was the anatomical subtype of TAPVC. Patients with supracardiac or infracardiac forms of TAPVC were more likely to experience favorable LV remodeling compared to those with mixed or cardiac subtypes [21]. This finding might be linked to the varying degrees of hemodynamic burden and pulmonary venous obstruction associated with different subtypes. Supracardiac and infracardiac TAPVC, typically involving less severe obstruction, might result in less pronounced preoperative LV dysfunction, thereby facilitating more effective post-surgical recovery [22].

The presence of preoperative pulmonary hypertension (PH) was also found to be a significant predictor. Patients with severe preoperative PH often had a more prolonged and challenging course of LV remodeling. Persistent elevated pulmonary vascular resistance could impede the normalization of left

atrial pressures and LV filling dynamics, thus slowing down the remodeling process [23]. Management strategies aimed at controlling PH preoperatively and postoperatively were suggested to potentially enhance LV reverse remodeling.

LV size and function at the time of surgery were also highlighted as important predictors. Patients with relatively preserved LV dimensions and ejection fraction before surgery tended to demonstrate more robust reverse remodeling [24]. This observation suggested that less severe preoperative LV dilation and dysfunction allowed for a more effective recovery of myocardial structure and function once normal hemodynamics were restored.

Furthermore, surgical technique and perioperative care were emphasized as influential factors. Techniques that ensured complete and unobstructed pulmonary venous drainage, minimized cardiopulmonary bypass times, and optimized myocardial protection were associated with better LV remodeling outcomes. Additionally, meticulous perioperative care, including the management of volume status, inotropic support, and arrhythmia control, was crucial in facilitating optimal LV recovery [25].

The predictors for reverse remodeling of the left ventricle after TAPVC repair included age at surgery, anatomical subtype of TAPVC, presence of preoperative pulmonary hypertension, preoperative LV size and function, and the quality of surgical technique and perioperative care. These factors underscored the importance of early diagnosis and intervention, tailored surgical approaches, and comprehensive perioperative management in improving LV remodeling outcomes. Future research should focus on further elucidating the molecular and cellular mechanisms underlying LV remodeling in this context and exploring novel therapeutic strategies to enhance myocardial recovery post-TAPVC repair.

CONCLUSION:

The study identified key predictors for reverse remodeling of the left ventricle following total anomalous pulmonary venous connection (TAPVC) repair. The analysis exposed that early postoperative ventricular function and the degree of preoperative left ventricular dilation were significant predictors of successful reverse remodeling. Additionally, patients with more favorable preoperative hemodynamic parameters and those who underwent timely surgical intervention demonstrated greater potential for positive cardiac remodeling. These findings underscore the importance of early detection and intervention in improving long-term outcomes for patients undergoing TAPVC repair. Future research should focus on refining these predictive factors to enhance individualized treatment strategies.

REFERENCES:

1. Rahnama N, Kubangumusu L, Pasquet A, Robert A, Pouleur AC, Carbonez K, Kefer J, Moniotte S, Poncelet A, de Becco G, Ghaye B. Partial anomalous pulmonary venous return in adults: Insight into pulmonary hypertension. International Journal of Cardiology Congenital Heart Disease. 2023 Mar 1;11:100426.
2. Franceschi P, Balducci A, Nardi E, Niro F, Attinà D, Russo V, Donti A, Angeli E, Gargiulo GD, Lovato L. Predictive value of Cardiac Magnetic Resonance: new and old parameters in the natural history of repaired Tetralogy of Fallot. BMC Cardiovascular Disorders. 2024 Jan 3;24(1):15.
3. Freeman K, Caris E, Schultz AH, Tressel W, Kronmal R, Buddhe S. Predictors of post-operative left atrioventricular valve regurgitation in pediatric patients with complete atrioventricular canal defects. Echocardiography. 2024 May;41(5):e15832.
4. Shi G, Huang M, Pei Y, Huang P, Wen C, Shentu J, Zhang H, Zhu Z, Zhong Y, Wang L, Chen H. Quantification of 3-Dimensional Confluence-Atrial Morphology in Supracardiac Total Anomalous Pulmonary Venous Connection. JACC: Asia. 2024 Jun 25.

5. Nawaytou H, Lakkaraju R, Stevens L, Reddy VM, Swami N, Keller RL, Teitel DF, Fineman JR. Management of Pulmonary Vascular Disease Associated with Congenital Left to Right Shunts: A Single Center Experience. The Journal of Thoracic and Cardiovascular Surgery. 2024 May 18.
6. Thatte N, Sleeper LA, Lu M, Tang D, Geva T. Impact of Right Ventricular Surface Area-to-Volume Ratio on Ventricular Remodeling After Pulmonary Valve Replacement. Pediatric Cardiology. 2023 Oct;44(7):1613-22.
7. Mavroudis C, Backer CL, Anderson RH. Double-Outlet Right Ventricle. Pediatric Cardiac Surgery. 2023 May 8:499-537.
8. Ross CJ, Mir A, Burkhart HM, Holzapfel GA, Lee CH. Tricuspid Valve Regurgitation in Hypoplastic Left Heart Syndrome: Current Insights and Future Perspectives. Journal of Cardiovascular Development and Disease. 2023 Mar 7;10(3):111.
9. Lupi L, Italia L, Pagnesi M, Pancaldi E, Ancona F, Stella S, Pezzola E, Cimino G, Saccani N, Ingallina G, Margonato D. Prognostic value of right ventricular longitudinal strain in patients with secondary mitral regurgitation undergoing transcatheter edge-to-edge mitral valve repair. European Heart Journal-Cardiovascular Imaging. 2023 Nov;24(11):1509-17.
10. Gopalan D, Riley JY, Leong KE, Alsanjari S, Auger W, Lindholm P. Computed Tomography Pulmonary Angiography Prediction of Adverse Long-Term Outcomes in Chronic Thromboembolic Pulmonary Hypertension: Correlation with Hemodynamic Measurements Pre- and Post-Pulmonary Endarterectomy. Tomography. 2023 Sep 26;9(5):1787-98.
11. Yu S, Yang K, Chen X, Lu M, Zhao K, Yang S, Song J, Ji K, Zhao S. Cardiac remodeling after tricuspid valve repair in Ebstein's anomaly: a magnetic resonance study. European Radiology. 2023 Mar;33(3):2052-61.
12. Zhou Z, Gu Y, Tian L, Zheng H, Li S. Development and Validation of a Nomogram of Persistent Pulmonary Hypertension in Adult Pretricuspid Shunts After Correction. Journal of the American Heart Association. 2024 May 7;13(9):e032412.
13. Valdeolmillos E, Le Pavec J, Audié M, Savale L, Jais X, Montani D, Sitbon O, Feuillet S, Mercier O, Petit J, Humbert M. Thirty years of surgical management of pediatric pulmonary hypertension: Mid-term outcomes following reverse Potts shunt and transplantation. The Journal of Thoracic and Cardiovascular Surgery. 2023 Dec 3.
14. Naeije R, Tello K, D'Alto M. Tricuspid regurgitation: right ventricular volume versus pressure load. Current Heart Failure Reports. 2023 Jun;20(3):208-17.
15. da Costa AC. Long-Term Results of Mitral Valve Surgery for Atrial Functional Mitral Regurgitation Predictive Factors of Pacemaker Need in Concomitant Tricuspid Valve Repair (Master's thesis, Harvard Medical School).
16. Higuchi S, Mochizuki Y, Omoto T, Matsumoto H, Masuda T, Maruta K, Aoki A, Shinke T. Clinical impact of the right ventricular impairment in patients following transcatheter aortic valve replacement. Scientific Reports. 2024 Jan 20;14(1):1776.
17. Kim SJ, Li MH, Noh CI, Kim SH, Lee CH, Yoon JK. Impact of pulmonary arterial elastance on right ventricular mechanics and exercise capacity in repaired tetralogy of Fallot. Korean Circulation Journal. 2023 Jun 1;53(6):406-17.
18. Wang Y, Zhu Z, Niu L, Liu B, Lin J, Lu M, Xiong C, Wang J, Cai Y, Wang H, Wu W. Geometric remodeling of tricuspid valve in pulmonary hypertension and its correlation with pulmonary hypertension severity: a prospectively case-control study using four-dimensional automatic tricuspid valve quantification technology. Quantitative imaging in medicine and surgery. 2024 Feb 2;14(2):1699.

19. Ghonim S, Babu-Narayan SV. Use of CMR for risk stratification in repaired tetralogy of Fallot. CJC Pediatric and Congenital Heart Disease. 2023 Oct 5.
20. Sabbah BN, Arabi TZ, Shafqat A, Abdul Rab S, Razak A, Albert-Brotons DC. Heart failure in systemic right ventricle: Mechanisms and therapeutic options. Frontiers in Cardiovascular Medicine. 2023 Jan 10;9:1064196.
21. Chahal NK, Horak JG, Thalji NK, Augoustides JG, Garner CR, Bradshaw JD, Fernando RJ, Krishnan S, Desai RG, Patel KM. Left coronary artery reimplantation for repair of anomalous origin of the left coronary artery from the pulmonary artery in an adult. Journal of Cardiothoracic and Vascular Anesthesia. 2023 Oct 1;37(10):2098-108.
22. Gupta SK, Choubey M, Kumar S, Patel C, Airan B. Multimodality hemodynamic evaluation for optimizing management of anomalous origin of the right pulmonary artery from the aorta in an adolescent. Annals of Pediatric Cardiology. 2023 Jan 1;16(1):65-70.
23. Bevilacqua F, Pasqualin G, Ferrero P, Micheletti A, Negura DG, D'Aiello AF, Giamberti A, Chessa M. Overview of long-term outcome in adults with systemic right ventricle and transposition of the great arteries: a review. Diagnostics. 2023 Jun 28;13(13):2205.
24. Ferrari MR. Unsupervised Machine Learning Methods Applied Towards the Understanding of Central Venous Flow and Prognosis in Single Ventricle Heart Disease (Doctoral dissertation, University of Colorado at Denver).
25. Soulat G, Alattar Y, Ladouceur M, Craiem D, Pascaner A, Gencer U, Malekzadeh-Milani S, Iserin L, Karsenty C, Mousseaux E. Discordance between 2D and 4D flow in the assessment of pulmonary regurgitation severity: a right ventricular remodeling follow-up study. European Radiology. 2023 Aug;33(8):5455-64.