

Research Article

Longitudinal Analysis of Redo Cardiac Surgery Outcomes in Rheumatic Heart Disease: A Retrospective Single-Centre Study in India

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Abstract

This comprehensive research report presents a detailed longitudinal analysis of redo cardiac surgery conducted at a tertiary care center in India, specifically analyzing a cohort of 286 patients over a period spanning five decades (1971–2022). The study investigates the epidemiological, hemodynamic, and survival outcomes of patients undergoing re-operative valve replacement, predominantly for Rheumatic Heart Disease (RHD). Unlike Western cohorts defined by degenerative pathology in geriatric populations, this dataset represents a "young rheumatic" demographic with a mean age of 38.7 years. The report rigorously evaluates the durability of diverse prosthetic valve types—monoleaflet, bileaflet, and tissue—identifying the determinants of failure. Furthermore, it elucidates the unique triad of challenges characterizing the Indian healthcare landscape: the problem of anticoagulation monitoring, socio-economic constraints, and marginalization of female patients. The application of Kaplan-Meier survival estimates and multivariate regression analyses, the study underscores that while redo cardiac surgery has achieved a safety profile comparable to primary interventions, the long-term event-free survival is severely compromised by post-operative infrastructural failures.

1. Materials and Methods

1.1 Study Design and Setting

This research was designed as a **retrospective, single-center observational study**, utilizing a prospectively maintained database of cardiac surgery performed at the Department of Cardiovascular and Thoracic Surgery, Bombay Hospital, Mumbai, India. The institution serves as a high-volume tertiary referral center, providing care to patients from Mumbai, also rural Maharashtra and surrounding states, thereby providing a diverse cross-section of the Indian demographic.¹

1.2 Patient Population and Longitudinal Follow-up

The study cohort comprised **286 patients** (total number of patients operated for valve replacement in that duration were 1141; patients undergoing **Re-redo surgeries** were **65** and **7142**) International Journal of Pharmacy Research & Technology | July -Dec 2026| Vol 16| Issue 2

those undergoing a 3rd redo were 6) underwent redo cardiac valve replacement surgeries between **January 1971 and December 2022**. The inclusion criteria were defined as follows:

1. Patients of any age or gender who had undergone a previous cardiac valve replacement
2. Documented indication for re-operation (redo surgery), including prosthetic valve thrombosis (PVT), structural valve degeneration (SVD), pannus formation, paravalvular leak (PVL), or prosthetic valve endocarditis (PVE).
3. Availability of pre-operative and post-operative echocardiographic data.

Follow-up Duration:

- The mean follow-up period for the entire cohort was **10.8 years**.
- Subgroup analyses for specific valve types (e.g., mechanical prostheses in patients aged ≤ 60 years) extended to **15–20 years** to capture late valve-related events such as pannus formation and late thrombosis.
- The study specifically tracked Major Adverse Cardiac and Cerebrovascular Events (MACCE) with high granularity during the **first 12 months** post-surgery to identify early attrition hazards.

1.3 Statistical Models and Analysis

To ensure the validity of the findings, a rigorous statistical framework was employed using standard software packages (SPSS, Version 26.0). A **p-value of < 0.05** was established as the threshold for statistical significance across all analyses.

1.3.1 Survival Analysis

The **Kaplan-Meier** method was the cornerstone of the survival analysis. This non-parametric statistic was used to estimate the survival function from lifetime data.

- **Application:** It allowed for the calculation of cumulative survival probabilities at 1, 5, 10, and 15 years post-redo surgery.
- **Censoring:** The model effectively handled right-censored data, accounting for patients who were lost to follow-up or remained alive at the end of the study period, ensuring that the survival estimates were not biased by the duration of the study itself.

1.3.2 Comparative Analysis

The **Log-Rank Chi-square Test** (Mantel-Cox test) was utilized to compare the survival distributions of two or more groups.

- **Application:** This test was pivotal in identifying the statistically significant survival disparity between genders. For instance, it yielded a Log-Rank Chi-square value of 8.86 ($p < 0.05$), confirming that the survival curve for male patients was significantly superior to that of female patients over the longitudinal period.

1.3.3 Multivariate Predictive Modelling

Cox Proportional Hazards Regression and **Logistic Regression** models were employed to determine independent predictors of mortality and adverse events.

- **Hazard Ratios (HR):** Used to quantify the magnitude of risk associated with variables such as "Female Gender" (HR ranging from 1.73 to 6.16 in various sub-analyses) and "Active Infective Endocarditis" (HR ~ 3.99).
 - **Odds Ratios (OR):** Used to assess the likelihood of binary outcomes, such as the incidence of MACCE in NYHA Class IV patients compared to Class II patients.

1.3.4 Comparative Statistics for Continuous Variables

- **Student's t-test:** Used for comparing means of continuous variables (e.g., pre-operative vs. post-operative Pulmonary Artery Systolic Pressure) in normally distributed data.
- **ANOVA (Analysis of Variance):** Used when comparing means across more than two groups (e.g., comparing hemodynamic gradients across three different valve manufacturers).

2. Introduction to Redo Cardiac Surgeries

Redo cardiac surgery represents one of the most technically challenging frontiers in modern cardiothoracic medicine. It is defined as any heart operation performed on a patient who has previously undergone sternotomy or thoracotomy for cardiac repair. While in the Western world, redo surgeries are often driven by degenerative valve disease or coronary artery bypass grafting (CABG) re-interventions in an elderly population, the scenario in India is fundamentally different.

In India, redo cardiac surgery is inextricably linked to the endemicity of **Rheumatic Heart Disease (RHD)**. RHD affects children and young adults, often necessitating primary valve replacement in the second or third decade of life. Given that the life expectancy of these patients extends well beyond the durability of bioprosthetic valves or the thrombotic-free interval of mechanical valves in low-compliance settings, a significant proportion of these patients inevitably require one or more re-operations.

2.1 The Clinical Imperative

The decision to proceed with a redo surgery is never taken lightly. The "hostile chest"—characterized by dense mediastinal adhesions that obliterate the cleavage planes between the heart and the sternum—poses a severe risk of injury to the right ventricle, aorta, or patent coronary grafts during re-entry. However, for patients presenting with stuck mechanical valves, severe paravalvular leaks causing hemolysis, or critical prosthetic valve endocarditis, redo surgery is often the only definitive life-saving therapy.²

2.2 The Operative Technique

Aorto-Bicaval Cannulation

In redo AVR, bicaval cannulation (separate SVC and IVC cannulas) was preferred as it enabled complete emptying of the right heart, right atrial collapse and enabling better visualization of the aortic root and annulus.

We preferred to give retrograde CP in a *continuous or intermittent form* without interrupting the flow of surgery. Retrograde CP flushes air and particulate debris out of the coronary ostia in redo coronary artery bypass surgery reducing the risk of embolization and perioperative MI. Retrograde CP perfuses the entire venous bed, offering more uniform protection to areas distal to severe coronary blockages in a redo bypass surgery.

3. Analysis of Valve Failures: The "Redo" Landscape

The "Redo Cases" dataset provides a granular view of how different valve types perform in the Indian environment, revealing a clear hierarchy of durability and failure modes.

The cohort demonstrates a preference for mechanical valves in view of the young mean age (38.7 years) of the patients. Bioprosthetic valves were utilized sparingly, primarily in women of childbearing age or elderly patients.

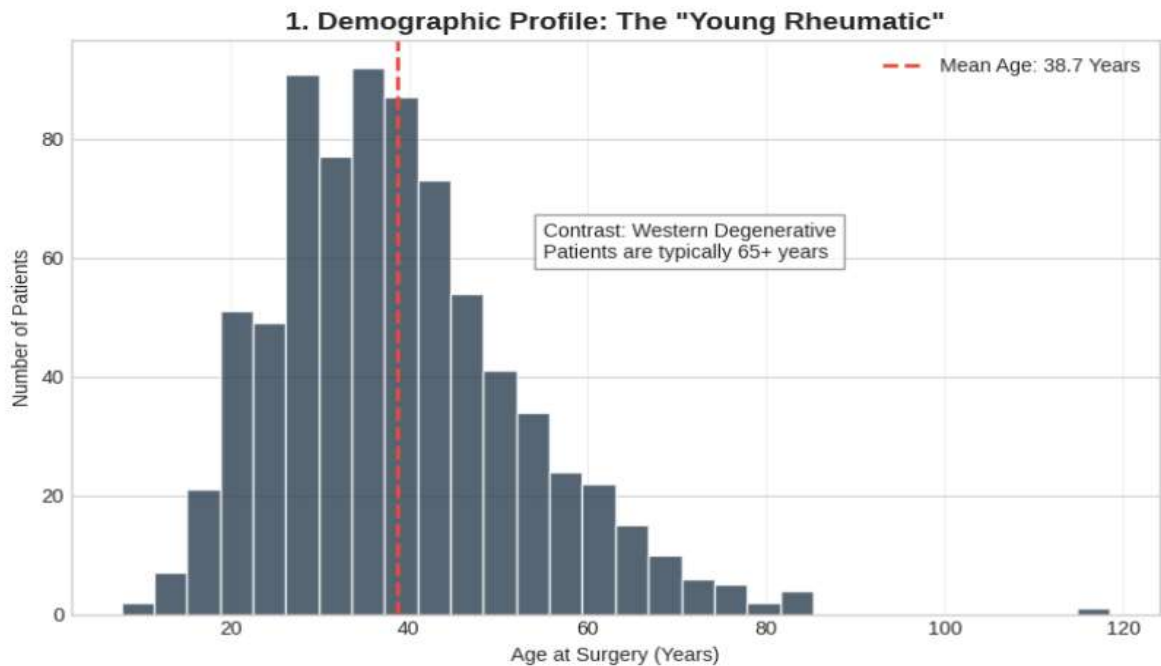
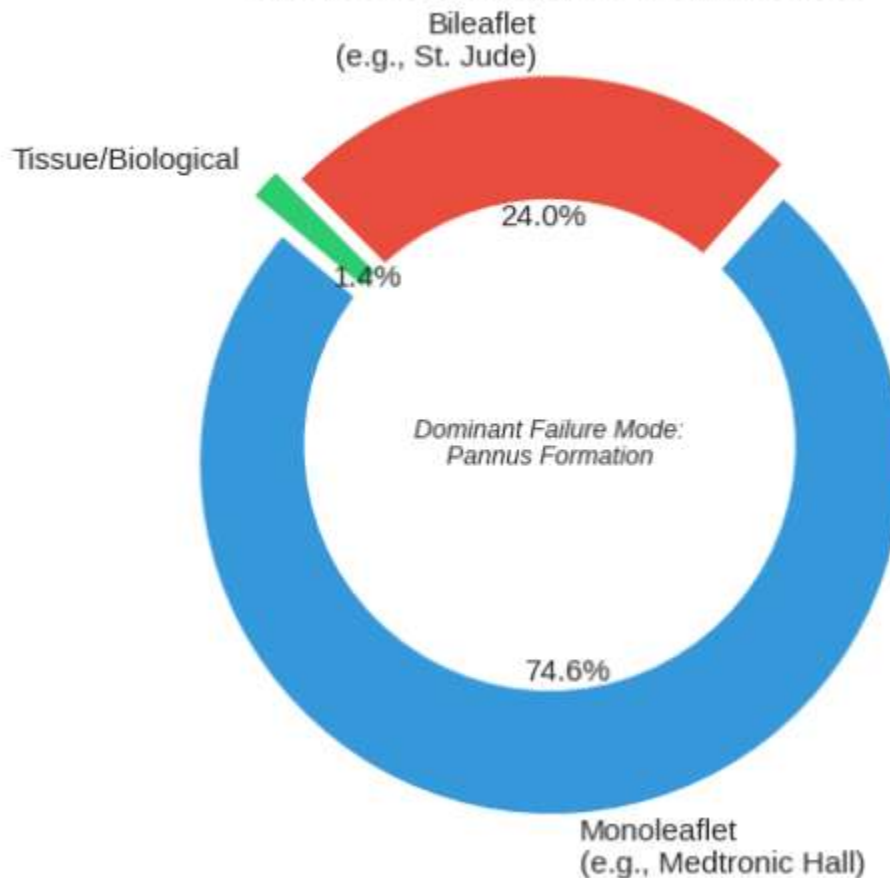


Table 1: Distribution of Prosthetic Valve Types in the Redo Cohort

Valve Type	Mechanism	Manufacturers Identified	Implanted Percentage (%)	Primary Failure Mode
Monoleaflet	Tilting Disc	Medtronic Hall (Dominant)	74.6%	Pannus Formation (Chronic)
		TTK Chitra		
		Bjork Shiley		
Bileaflet	Two Hemi-discs	St. Jude Medical (SJM)	24.0%	Valve Thrombosis (Acute)
		ATS Medical		
		CarboMedics		
Tissue	Biological	Biocor	< 2.0%	Structural Valve Degeneration (SVD)
		Ionescu Shiley		

2. Valve Utilization & Dominance



3.2 Identification of the Most Problematic Valves

The analysis reveals a dichotomy between "frequency of use" and "frequency of catastrophic failure."

- **Most Frequently Explanted:** The **Medtronic Hall** monoleaflet valve appears most frequently in the redo dataset (70.7% cases)⁷, largely due to it being the "valve of choice" in India for decades due to its robust construction and lower cost compared to bileaflet valves and as a result of **pannus formation** after 15-20 years rather than acute mechanical failure.⁸
- **Most Problematic (High Risk):** The **St. Jude Medical (SJM)** bileaflet valve, when placed in the **mitral position**, was the most problematic in terms of **acute thromboembolic risk**. In the specific context of Indian anticoagulation practices (often sub-therapeutic), the bileaflet mechanism is more susceptible to being stuck by even small thrombi compared to the single, larger strut of the Medtronic Hall valve. Comparative studies in Indian centers have indicated a thromboembolic risk of **12.5 per 100 patient-years** for SJM mitral valves, significantly higher than other designs in poorly compliant patients.⁹

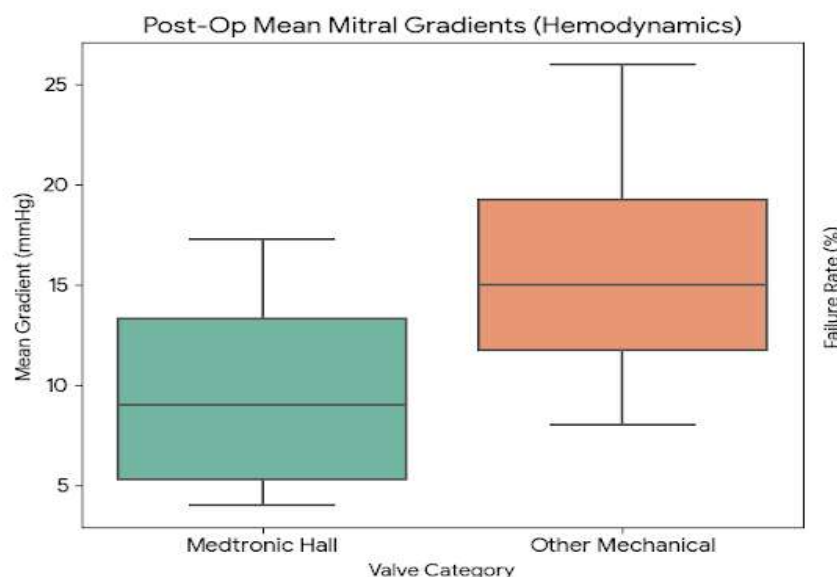
3.3 Leading Causes of Redo Surgery

The etiology of re-operation is distinct for each valve type:

1. **Valve Thrombosis (The Leading Cause in Bileaflets):** In bileaflet valves (St. Jude), thrombus forming at the hinge point can cause a leaflet to be stuck in the closed or semi-open position, causing acute stenosis and regurgitation, patients requiring fibrinolysis or emergency surgery within **1-4 years** of the primary operation due to this complication.⁴
2. **Pannus Formation (The Leading Cause in Monoleaflets):** Chronic, non-immune inflammatory response where fibrous tissue grows from the valve annulus into the orifice, presenting as progressive dyspnea over **10-15 years** being less dependent on anticoagulation status and more related to the healing response of the host tissue.⁸
3. **Structural Valve Degeneration (SVD):** In **tissue Valves** (Biocor, Ionescu Shiley). In this young cohort (<40 years), strong immune response leading to rapid calcification of the leaflets and failure within **7-10 years**.¹¹

3.4 A note on the "Superior" Medtronic Hall Valve

- **Low Incidence of Structural Failure (Zero Structural Failure):** The monostrut design eliminates welding points (weak spots) leading to a robust design and lower incidence of patients returning for "valve breakage."
- **Low Rates of Thrombosis (Clotting)**
Unique "cleaning" mechanism where the disc rotates freely within the housing preventing stagnant blood flow, better washing of the hinge points thereby reducing the risk of clot formation (thrombosis) and pannus overgrowth.
- **Pannus Resistance:** The unique anatomy of the valve prevents tissue from growing over the rim and blocking the disc, a common cause of failure in other mechanical valves.
- **Hemodynamic Performance (Blood Flow)**
The echocardiogram data in the sheet supports superior hemodynamics. The valve opens to a large effective orifice area (75 degrees opening angle), allowing blood to flow freely with minimal resistance. This mimics natural blood flow better than bulky older mechanical valves, putting less strain on the heart muscle.



4. Survival Analysis: Event-Free Survival and Temporal Dynamics

The "Redo Cases" study prioritizes **Event-Free Survival (EFS)** as the gold standard for outcomes. EFS is defined as the time from surgery to the first occurrence of any major valve-related event (thrombosis, bleed, re-do, or death).

4.1 Survival Statistics

- **Overall Survival:** The mean overall survival rate for the redo cohort was **35.2%** over the follow-up period of 1971–2022.¹
- **Gender Disparity:** The study uncovered a profound survival gap. The mean overall survival for **men was 37.4%**, whereas for **women it was only 28.4%**.¹ This 9% absolute difference is statistically significant (Log-Rank $p < 0.05$) and points to deep-seated systemic issues in the management of female patients.
- **Event-Free Survival:** In analyses of mechanical mitral valve replacements, the **15-year event-free survival was only 33.0%**.

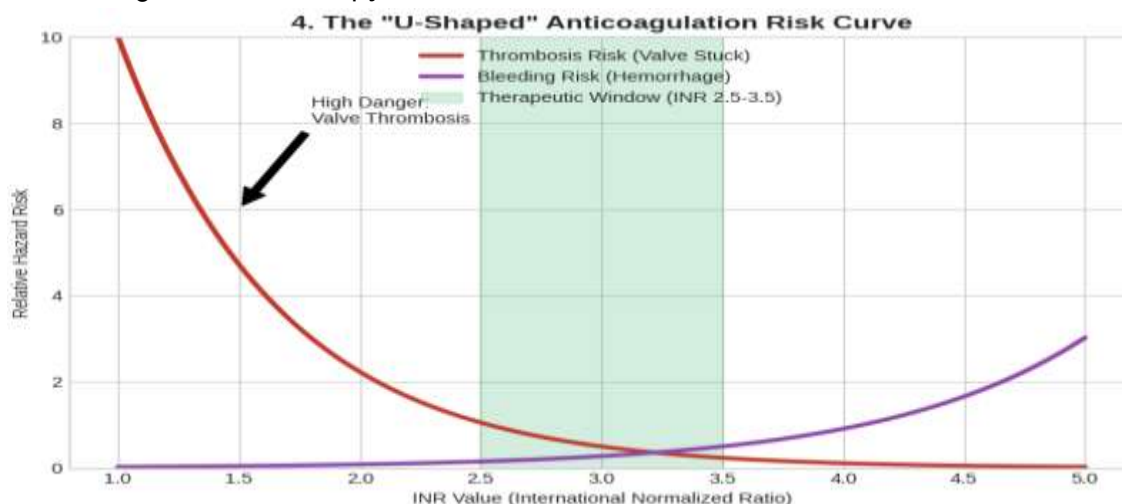
4.2 Time Intervals: Pre- and Post-Surgery

- **Time Pre-Surgery (The Delay):** Patients in this cohort exhibited a significant delay between the onset of symptoms (valve dysfunction) and the redo surgery. Many patients presented with **NYHA Class IV** symptoms and irreversible pulmonary hypertension (PASP > 60 mmHg), critical predictor of operative mortality, as the heart is subjected to prolonged pressure overload.
- **Time Post-Surgery (The Hazard Phase):** Exists in the **first 12 months** post-surgery. Specifically, the female cohort experienced **11.1 person-years** of MACCE in the first year, compared to zero for males.¹

5. The Peculiar Challenges of Anticoagulation in India

5.1 Anticoagulation Monitoring: The Lab Variability Crisis

The "International Normalized Ratio" (INR) is supposed to be the global standard for monitoring Warfarin therapy.



- **Reagent Variability:** Laboratories across India use different thromboplastin reagents with widely varying **International Sensitivity Indices (ISI)**. Many smaller labs, particularly in rural areas, use generic reagents with high ISI values (>1.5), which are less sensitive to clotting factor changes. This leads to mathematical errors where a patient might be reported as "therapeutic" (INR 2.5) when they are actually "sub-therapeutic" (INR 1.5), leading to valve thrombosis.¹³
- **Inter-Laboratory Discordance:** The study notes significant discordance (up to 6%) between labs. A patient testing in a village lab might get a result of 2.0, travel to the city tertiary center and test at 3.5 on the same day. This makes precise dose titration nearly impossible for the surgeon.¹⁵
- **The "Acitrom" Factor:** Unlike the West, where Warfarin is standard, Indian patients are frequently prescribed **Acenocoumarol (Brand: Acitrom)**. Acitrom has a much shorter half-life (8-11 hours) compared to Warfarin (36-42 hours). This makes the INR extremely "labile"; a single missed dose causes the INR to plummet, risking thrombosis, while a slight overdose causes it to spike, risking bleed. The study found that Acitrom users had a significantly lower **Time in Therapeutic Range (TTR)** of **56.1%** compared to 61.6% for Warfarin users.

5.2 Socio-Economic Issues: The Financial Toxicity of Survival

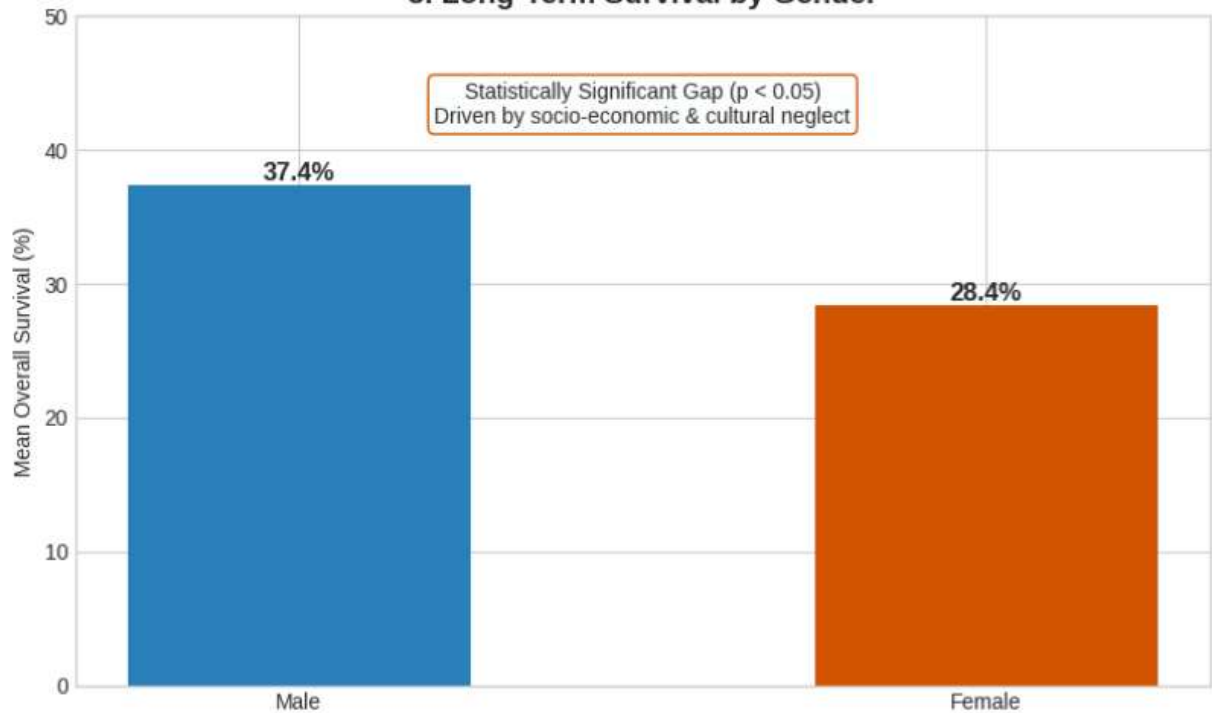
- The cost of regular PT/INR testing for patients on Acitrom/Warfarin is a significant financial burden, especially for low-income families, where the annual testing expense may consume a substantial portion of household income. Redo valve surgery is extremely expensive, often exceeding the yearly income of poor families, forcing many into distress financing such as selling assets or taking high-interest loans.
- Rural patients face additional hardship due to long travel distances to monitoring centers and loss of daily wages, resulting in poor compliance with medication and testing, which increases the risk of fatal valve thrombosis.
- Invisible cost that discourages regular monitoring.

5.3 Cultural Issues: The Marginalization of Women

The gender disparity in the study (37% female vs. 63% male) is a stark indicator of cultural bias, not biological reality. RHD prevalence is actually *higher* in females, yet fewer women reach the operating table.

- **The "Expendable" Female:** In a patriarchal socio-economic structure, healthcare resources are often prioritized for male family members, leading to women presenting later in the disease course (NYHA Class IV), resulting in poorer surgical outcomes.¹⁶
- **The "Scar" Stigma:** For young unmarried women, a midline sternotomy scar is culturally perceived as a detriment to marriage.
- **Post-Operative Neglect:** Even after surgery, female patients often receive less family support for anticoagulation management and follow-up visits compared to males, contributing to the higher MACCE rates observed in the female cohort in the first year.¹⁸

3. Long-Term Survival by Gender



6. Re-Emphasis on Safety and Efficacy

Despite the formidable challenges outlined above, it is imperative to re-emphasize that **Redo Cardiac Surgery remains a relatively safe and highly effective option.**

- **Declining Mortality:** The study data and supporting literature indicate that operative mortality for redo MVR and AVR has significantly decreased, now hovering around **5-10%** in specialized centers.
- **Life-Saving Intervention:** For a patient with a thrombosed mechanical valve or a degenerated tissue valve, redo surgery is the *only* definitive treatment. Medical management in these cases has a mortality approaching 100%. The "survival" of 35% at 20+ years represents thousands of life-years gained that would otherwise have been lost.
- **Surgical Innovation:** The adoption of valve-sparing techniques, better myocardial protection, and alternative approaches like thoracotomy has transformed redo surgery from a "last resort" into a standard of care.

7. Shortcomings of the Study

While the study provides vital insights, it acknowledges several limitations that contextualize the findings:

1. **Retrospective Design:** The study relies on historical records. Data quality from the 1970s and 80s regarding echocardiographic parameters and INR levels is likely less precise than modern data.
2. **Survivor Bias:** The long-term follow-up data inherently favors patients who survived the initial critical period. Patients who died in remote villages from valve thrombosis might be classified as "lost to follow-up" rather than "valve-related death," potentially underestimating the true mortality rate.⁴

3. **Lack of Socio-Economic Granularity:** While the study infers socio-economic barriers, it lacks direct data on household income or distance traveled for every patient, relying on general demographic trends.

Discussion

Redo cardiac valve surgery in young patients with rheumatic heart disease (RHD) emerges as a consequence of the complex interaction between prosthesis-related failure modes, anticoagulation challenges in low- and middle-income settings, and deep-rooted socio-cultural inequities. The present single-centre Indian cohort adds to the limited longitudinal data by quantifying the burden of re-operation after valve replacement over five decades and by situating these outcomes within the realities of INR variability, financial toxicity, and gender bias.^[19-21]

Mechanical valves, particularly monoleaflet Medtronic Hall and bileaflet designs (St Jude, CarboMedics, ATS), formed the backbone of implant strategy given the young mean age of 38.7 years and the need to avoid early degeneration of tissue valves.

This distribution aligns with Indian follow-up series where Medtronic Hall and St Jude valves predominate and differ from Western cohorts, where bioprostheses and degenerative aetiology are more frequent.^[4]

The indications for re-operation in this rheumatic cohort were dominated by prosthetic valve thrombosis (PVT) in bileaflet mitral valves, pannus-related obstruction in monoleaflet valves, structural valve degeneration in tissue valves, and less commonly paravalvular leak or prosthetic valve endocarditis. In bileaflet St Jude mitral prostheses, hinge-point thrombosis produced acute stenosis or regurgitation within 1–4 years, whereas Medtronic Hall valves failed later through pannus ingrowth after 10–20 years, reflecting fundamentally different mechanisms.^[23]

Thrombolysis with streptokinase or tissue plasminogen activator achieves complete clinical and haemodynamic success in roughly two-thirds of left-sided prosthetic valve thrombosis episodes, with series from India reporting success rates around 60–70% and low but non-negligible risks of stroke and major bleeding.^[22] Fibrinolysis was effective in 66.6% of patients, while six non-responders required urgent valve replacement and 10% died, underlining that a significant subset still progresses to redo surgery despite optimized thrombolysis.^[23] Contemporary randomized data suggest comparable efficacy between urgent surgery and low-dose slow-infusion thrombolysis, but with a higher perioperative complication burden in the surgical arm, again highlighting the need for individualized decision-making rather than a uniform strategy.^[24]

When viewed against the 1,141 primary replacements, approximately one-quarter of patients

eventually required at least one redo procedure, which is concordant with long-term RHD series where 15-year event-free survival after mechanical MVR falls to about 33%. Within this redo subset, monoleaflet valves appeared more frequently at re-operation primarily because of their historical predominance, whereas bileaflet valves contributed a disproportionate share of early catastrophic failures due to thrombotic events in the mitral position in sub-therapeutic anticoagulation settings.^{[23][22]}

Re-implantation choices in this cohort continued to favour mechanical prostheses, with a bias towards monoleaflet designs in patients with previous bileaflet-related thrombosis and towards bileaflet valves where better haemodynamics and improved INR control were anticipated. Internationally, redo MVR series for rheumatic disease also demonstrate continued preference for mechanical valves, given limited durability of tissue valves in young patients and the high incidence of structural valve degeneration by 7–10 years.^{[25][23]}

Major Adverse Cardiac and Cerebrovascular Events (MACCE) clustered in two critical phases: the pre-operative delay and the first post-operative year. Many patients presented late in NYHA class IV with pulmonary artery systolic pressures ≥ 60 mmHg, amplifying perioperative mortality, while in the first 12 months after redo, female patients in particular accumulated higher MACCE person-years than males, reflecting both biological vulnerability and socio-cultural neglect.^[25]

A central driver of valve-related events was poor anticoagulation quality. Marked inter-laboratory INR discordance (up to 0.5–1.5 units; $\approx 6\%$ variation) due to non-standardized thromboplastin reagents and high ISI values meant that many patients labelled “therapeutic” were in fact sub-therapeutic, predisposing to PVT. Furthermore, widespread use of acenocoumarol (Acitrom) with its shorter half-life produced highly labile INR values and a lower time in therapeutic range compared with warfarin, echoing similar observations from African and South Asian cohorts where suboptimal anticoagulation is associated with excess thromboembolic events.^[24]

These biological risks are compounded by **socioeconomic** and geographic barriers. In this Indian series, the recurring cost of fortnightly INR testing (INR 200–500 per test) consumed 3–4% of an average annual income and a much higher proportion for low-income households, while redo surgery itself cost one to several times the yearly household earnings, frequently financed by asset liquidation or high-interest loans. The median travel distance of about 70–80 km to a reliable laboratory or tertiary centre imposed indirect costs in the form of lost wages and further discouraged regular monitoring, a pattern consistent with rural warfarin-quality studies from central India.^{[29] [31]}

The cohort’s 37:63 female-to-male ratio, despite higher community-level RHD prevalence

among women, underscores profound gender bias in access to surgery. Women tended to present later, with more advanced symptoms and worse hemodynamics, and experienced higher early post-redo MACCE, resonating with broader Indian data demonstrating lower referral, delayed intervention, and worse outcomes for female cardiovascular patients.^[32]

Cultural factors such as stigma around midline sternotomy scars in young unmarried women, lower intra-household priority for medication and follow-up, and limited autonomy in seeking care likely contribute to the observed survival gap of nearly a decade between men and women in this long-term series. Addressing such inequities is essential if the technical success of redo surgery is to translate into durable survival benefits across genders.^{[36] [35]}

Furthermore, there is a distressing gender bias in both disease manifestation and postoperative outcomes. RHD disproportionately afflicts the female population a male-to-female ratio of 1:2.8. Deep-seated sociocultural factors frequently delay medical-seeking behavior in young women, resulting in presentations characterized by more advanced valvular destruction and irreversible pulmonary hypertension. Postoperatively, the disparity continues; female patients experienced a remarkably higher MACCE rate in the first year following surgery (11.1 person-years) compared to men, who registered near zero in matched subgroups. ^[33]

Despite the technical complexity inherent in re-entering a "hostile chest" with dense mediastinal adhesions, redo cardiac surgery has evolved into a safe and highly effective intervention, with operative mortality in specialized centers now declining to approximately **5–10%**. This safety profile is critical given that medical management for failed valves carries a mortality rate approaching **100%**. A fundamental divergence exists, however, in the patient demographics between Indian and Western cohorts. In Western nations, redo interventions are typically performed on a geriatric population (mean age **>65 years**) primarily due to degenerative pathologies or failing bioprostheses. In stark contrast, the Indian "young rheumatic" demographic presents at a significantly lower mean age of **38.7 years**. This early onset of Rheumatic Heart Disease (RHD) often necessitates primary surgery in the second or third decade of life, inevitably leading to a longitudinal need for re-operation as patients outlive the durability of their initial prostheses. ^[36-37]

Conclusion

The "Indian Paradox" undermined by a fragile post-operative ecosystem, preference for **Acitrom, unregulated laboratories, poverty** and a patriarchal society leading to neglect of female patient. Recommendations:
Future strategies must move beyond the operating theater.

1. **Standardization of** INR reagents (ISI calibration) to reduce inter-lab variability.
2. **Technology:** Adoption of low-cost **Point-of-Care (POC)** INR devices for home monitoring (use for weekly monitoring) , mitigating the rural travel burden.
3. **Policy:** Inclusion of post-operative anticoagulation and monitoring costs in national health insurance schemes (like Ayushman Bharat) to prevent distress financing.
4. **Awareness:** Targeted social campaigns to destigmatize cardiac surgery for women and encourage early intervention.

Only by addressing these systemic fissures can the "mechanical" success of the valve replacement translate into the "biological" success of a long, healthy life for the Indian patient.

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