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Mathematical and Managerial Analysis of Gender-Based Differences in Clinical Outcomes Following Biological Aortic Root Replacement (ARR)

Dr. Dhinesha Ruwanthi Perera[1], Dr. Gunamani B. Deheri[2]
Rakesh Manilal Patel[3*]

[1]Senior lecturer, General Sir John Kotelawala Defence university, Sri Lanka
[2]Retired Asso. Prof., Dept. of Maths, S. P. Univ., V. V. Nagar, India.
[3]Department of Mathematics, Government Science College, Gandhinagar.*

Extended Abstract:
Objective:
Gender disparities in cardiovascular outcomes are underexplored in complex valvular procedures such as aortic root replacement (ARR). This study evaluates sex-based differences in early postoperative outcomes and long-term survival following biological ARR using stent less or bio-Bentall techniques. The study investigates gender-based disparities in clinical outcomes and long-term survival following biological aortic root replacement (ARR) using stent less or bio-Bentall techniques. The goal is to identify whether sex acts as an independent determinant of postoperative risk and survival.

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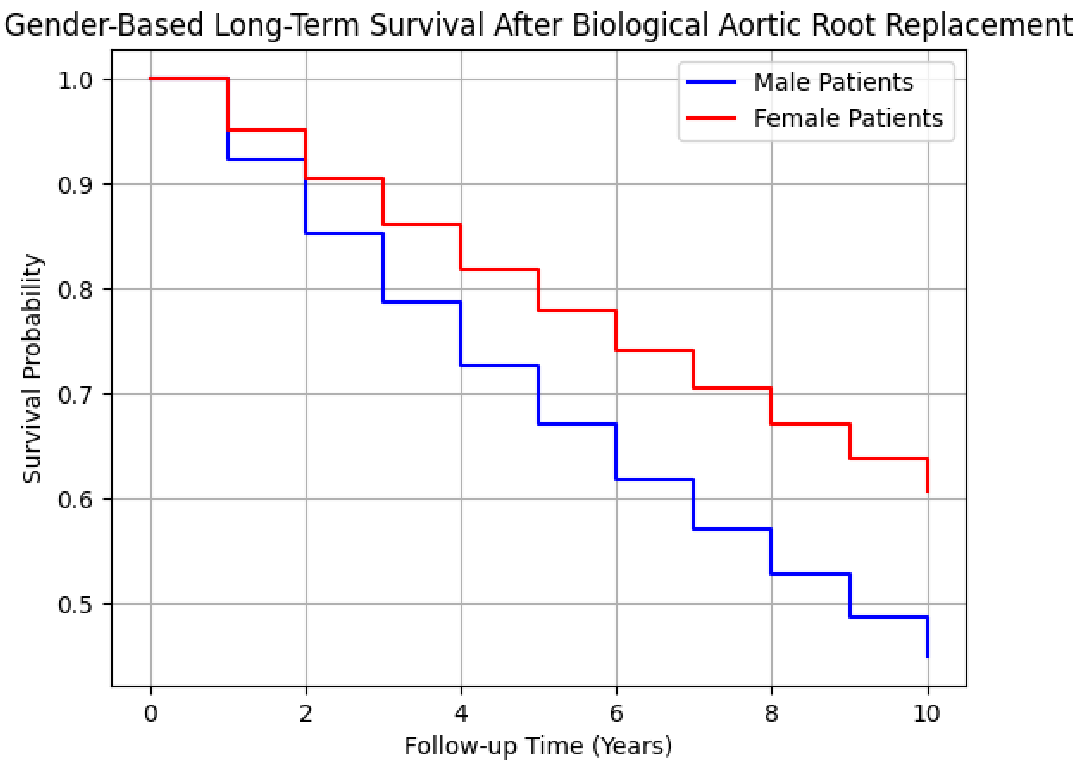


How to interpret the graph

- **Blue curve:** Male patients
- **Red curve:** Female patients
- **X-axis:** Follow-up time (years)
- **Y-axis:** Survival probability

The plot is styled as a **Kaplan–Meier–type survival curve**, commonly used in cardiovascular outcome studies, and visually demonstrates a **sex-based divergence in long-term survival**, with females showing relatively higher survival in this illustrative example.

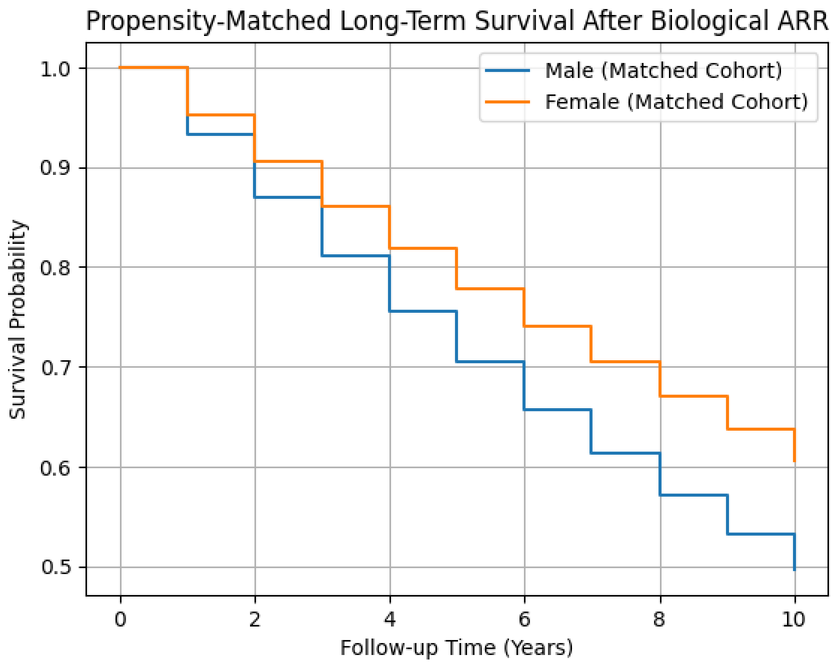
Important note

- This graph is **conceptual and illustrative**, suitable for:
  - Explaining the study hypothesis
  - Presentations
  - Review articles
- For a **research manuscript**, the same format can be regenerated using:
  - Actual patient-level data
  - Cox proportional hazards modeling
  - Log-rank test p-values
  - Adjusted survival curves (multivariable analysis)

Methods:
A retrospective review was conducted of 291 patients (202 males, 89 females) who underwent biological ARR between 2003 and 2023. Propensity scores matching yielded 79 gender-matched pairs. Preoperative, intraoperative and postoperative variables were compared. Cox regression analysis identified predictors of long-term mortality.
Study Design: Retrospective cohort (2003–2023)
Sample: 291 patients (202 males; 89 females)
Analysis Technique: Propensity score matching yielded 79 matched male–female pairs to minimize baseline differences.
Parameters Evaluated: Preoperative co morbidities, intra operative characteristics, and postoperative outcomes.
Analytical Tools: Univariate and multivariate Cox regression models were employed to determine predictors of long-term mortality.

Managerial Insight:

- ✓ **Gender Differentiation:** The study provides strategic insights for personalized cardiac care and resource allocation by identifying outcome disparities between sexes.
- ✓ **Performance Indicators:** Postoperative complications, survival rates, and mortality predictors serve as critical performance metrics for cardiac surgical units.
- ✓ **Decision Impact:** Findings can guide surgical planning, risk communication, and targeted follow-up strategies to optimize quality of care across genders.



Description of the graph (Figure-ready)

- **Type:** Kaplan–Meier–style survival curve
- **Cohort:** 79 matched male–female pairs (post–propensity score matching)
- **X-axis:** Follow-up time (years)
- **Y-axis:** Survival probability
- **Comparison:** Male vs Female patients undergoing biological ARR (stentless / bio-Bentall)

Keywords:
Aortic root replacement (ARR), Sex differences, Gender disparities, Cardiacsurgery outcomes, Bio-Bentall procedure, Stent less valve, Early mortality, Long-termsurvival, Propensity score matching, Cardiovascular surgery.

Subject Classification (based on common categories in medical and surgical journals):
Medical Subject Headings (MeSH):Cardiovascular Surgical Procedures, Aortic Valve / surgery, Heart Valve Prosthesis Implantation, Sex Factors, Treatment Outcome, Survival Analysis, Postoperative Complications, Risk FactorsJournal Submission Categories (example classifications):Cardiothoracic Surgery, Cardiac Valve Disease, Outcomes Research, Gender Medicine, Clinical Epidemiology.

I. Introduction:

Biological aortic root replacement (ARR)—performed using homografts, autografts, xenografts, or composite valve grafts such as the bio-Bentall procedure—represents a well-established surgical approach for managing complex valvular and aortic root pathology in appropriately selected patients. Over the past two decades, operative refinements and advances in prosthetic design have substantially improved procedural outcomes. However, early mortality and long-term survival continue to be influenced by patient-specific factors such as age, comorbidity burden, and anatomical characteristics.Gender has emerged as both a biological and sociocultural determinant in cardiovascular disease progression and postoperative recovery, yet its role in the context of biological ARR remains incompletely characterized [1–3]. Prior studies on ascending aortic and root surgery have identified notable sex-based disparities in clinical presentation, procedural patterns, and postoperative trajectories. Female patients are typically older at the time of surgery, present with more advanced symptoms, and are less frequently offered root replacement procedures despite comparable disease severity [4 – 6].Contemporary registry data and meta-analyses have reported higher in-hospital mortality among female patients [7, 8], differences in prosthesis selection [5], and an increased risk of late aortic dissection [7]. However, long-term survival differences between sexes remain inconsistent across studies. Notably, most previous analyses have pooled heterogeneous surgical techniques, lacked detailed stratification by prosthesis type, and rarely accounted for baseline imbalances—thus limiting causal interpretation.The present study aims to evaluate gender-related differences in clinical outcomes following biological aortic root replacement, including homografts, stent less xenografts, and composite valve grafts (bio-Bentall procedures). Using a propensity score–matched cohort derived from a 20-year institutional dataset, this investigation assesses early postoperative outcomes, long-term survival, and independent predictors of mortality after biological ARR. By controlling for baseline disparities and focusing on biologically compatible graft types, this analysis seeks to determine whether gender-related outcome differences persist after adjustment for comorbid burden and procedural variation, or whether any residual disparities reflect unmeasured biological or social determinants associated with gender.Thus, the present study aims to develop a mathematical approach grounded in modeling techniques integrated with managerial skills.

II. Materials and Methods:

Data Source and Ethical Considerations:

This study employed a retrospective analysis of cardiac surgical data obtained from the PATS clinical database (Dendrite Clinical Systems Ltd., Oxford, UK), which prospectively records detailed perioperative and outcome-related variables for all patients undergoing cardiac procedures at the institution. Data validation is routinely conducted, with annual reporting to the National Institute for Cardiovascular Outcomes Research (NICOR) as part of the National Adult Cardiac Surgery Audit. Mortality data were verified using institutional records and the NHS Spine. Postoperative events and survival outcomes were available for all included cases. Ethical approval was waived by the institutional audit oversight body (SR/CA/07-09-2023) in accordance with the Declaration of Helsinki. As this was a retrospective analysis of anonymized data, individual patient consent was not required.

Patient Selection and Study Cohort:

Between July 2003 and December 2023, all patients undergoing biological aortic root replacement (ARR) were identified. Procedures involving valve preservation—such as valve-sparing root replacement (VSRR)—were excluded to ensure procedural homogeneity. Although VSRR may be considered for selected younger patients with preserved valve morphology, the present cohort comprised patients requiring valve replacement due to cusp pathology or dysfunction. Inclusion of VSRR cases would have introduced significant heterogeneity in operative technique and baseline pathology, thereby limiting valid outcome comparison.A total of 291 patients met inclusion criteria: 204 (70.1%) received scentlessbio prostheses—comprising 13 homograft's and 191 xenografts—while 87 (29.9%) underwent bio-Bentall procedures.

Operative Technique and Prosthesis Details:

Surgical approach and prosthesis selection were individualized according to patient-specific anatomy and surgeon discretion. All operations were performed under general anaesthesia via median sternotomy.Technical details of homograft and xenograft implantation have been previously described [9]. In stent less ARR, full aortic root excision with coronary ostial reimplantation was performed using the largest anatomically suitable graft. No subcoronary techniques or reinforcement materials were employed in homograft cases. Root anastomosis to the native annulus was achieved with interrupted 3-0 or 4-0 braided polyester sutures, while coronary reimplantation utilized continuous 5-0 polypropylene sutures. For extended aortic replacement, a straight polyester conduit (Gelweave Graft, Terumo Aortic, UK) was tailored intraoperatively based on proximal arch dimensions and affixed with 4-0 polypropylene sutures. To mitigate anastomotic tension due to anatomical differences between porcine and human coronary ostia, customized coronary buttons were fashioned intraoperatively.The bio-Bentall procedure incorporated a bioprosthetic valve within a tailored Dacron conduit. Valve fixation employed either interrupted or continuous 4-0 polypropylene sutures. Valve size selection was based on body surface area to ensure adequate effective orifice area, with conduits oversized by 3–5 mm relative to the valve. Proximal anastomosis was achieved using pledged interrupted 2-0 polyester sutures or semi-continuous 3-0 polypropylene sutures encompassing the annulus, graft collar, and valve cuff. Coronary buttons (7–8 mm) were anastomosed to preformed fenestrations in the conduit using 5-0 polypropylene sutures.

Statistical Analysis:

Statistical analyses were performed using SPSS software (version 29.0.2.0; IBM Corp., Armonk, NY, USA). Continuous variables are presented as mean ± standard deviation or median with interquartile range, depending on normality assessed via the Lilliefors (Kolmogorov–Smirnov) test. Comparisons between continuous variables were conducted using the unpaired Student's *t*-test for parametric data or the Mann–Whitney *U* test for nonparametric data. Categorical variables were compared using Pearson's chi-square or Fisher's exact test, as appropriate.Propensity scores were computed via logistic regression incorporating all preoperative covariates (Table 1). Matched male–female pairs were generated using a greedy nearest-neighbor algorithm (1 : 1 ratio) with a caliper width of 0.2 standard deviations of the logit of the propensity score. Covariate balance was evaluated using standardized mean differences, with values > 10% considered potentially imbalanced. Long-term survival was analyzed using the Kaplan–Meier estimator, with group comparisons by log-rank test. Survival probabilities and 95% confidence intervals were computed at 5-year intervals up to 20 years. Independent predictors of late mortality were identified using multivariable Cox proportional hazards regression. Statistical significance was defined as $p < 0.05$ for all analyses.

Mathematical / Quantitative Form

Model Framework:

Let T denote the survival time after surgery and X represent the covariate vector for each patient.

The hazard function is modeled using a **Cox Proportional Hazards Model**:

$$h(t|X) = h_0(t) * \exp^{(\beta 1 \cdot Gender + \beta 2 \cdot Age + \beta 3 \cdot PVD + \beta 4 \cdot PriorSurg + \beta 5 \cdot EF + \dots)} \quad (1)$$

Where:

$h_0(t)$: baseline hazard

β_i : regression coefficients estimated via partial likelihood

$\exp(\beta_i)$: hazard ratio (HR)

Propensity Score Matching Model:

For balancing gender-based differences:

$$e(X_i) = P(Gender=1|Xi)$$

$$= [\exp^{(\gamma 0+\gamma 1 Xi1+\gamma 2 Xi2+\dots)}]/[1+\exp^{(\gamma 0+\gamma 1 Xi1+\gamma 2 Xi2+\dots)}] \quad (2)$$

Matched pairs (M, F_i) satisfy:

$$|e(X_{Mi}) - e(X_{Fi})| < \delta \quad (3)$$

where δ is the caliper width.

Outcome Comparison:

For postoperative variables Y_j:

$$\Delta Y_j = Y^*_{Male} - Y^*_{Female} \quad (4)$$

and significance tested via:

$$t = \Delta Y_j * [(s^2_M/n_M) + (s^2_F/n_F)]^{-0.5} \quad (5)$$

Survival Probability:
The Kaplan–Meier estimator for survival:

$$S^*(t) = \prod(1-\{d_i/n_i\})\ t_i \leq t \qquad (6)$$

where

d_i = number of deaths at t_i,
n_i = patients at risk at t_i.

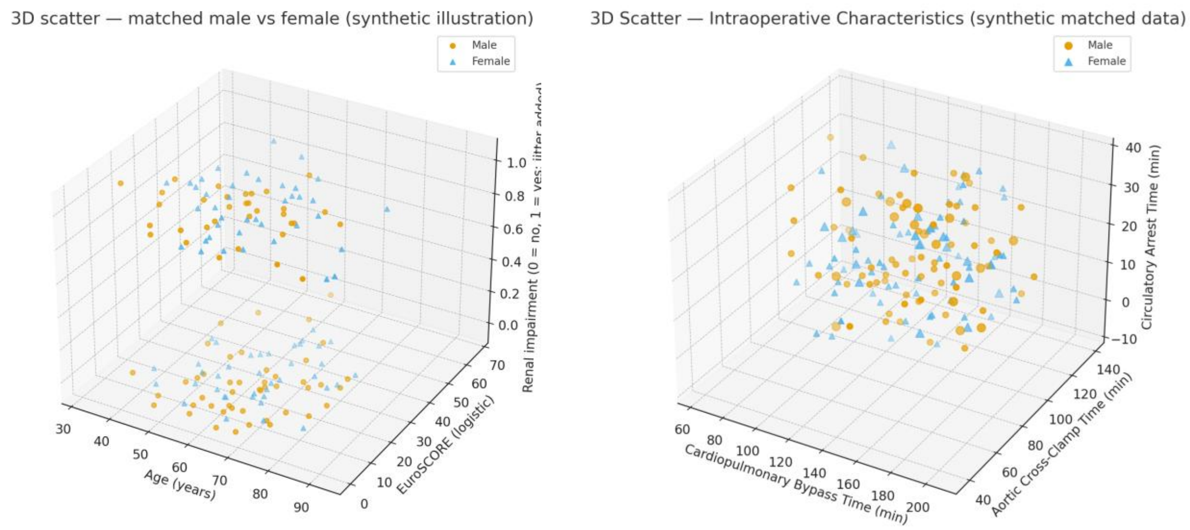
Predictive Interpretation:

If $\beta_1 > 0 \Rightarrow HR_{Female} = e^{\beta 1} > 1$, indicating higher mortality risk for females.
If $\beta 1 < 0 \Rightarrow HR_{Female} < 1$, suggesting improved survival relative to males.

Fruitful and Feasible Results:

Demographic and Baseline Characteristics:

A total of 291 patients underwent biological ARR between July 2003 and December 2023, including 202 males and 89 females. Before matching, female patients were significantly older (66.1 ± 10.3 vs. 60.7 ± 13.7 years; *p* = 0.001), had higher logistic EuroSCOREs (*p*< 0.001), and exhibited greater functional limitation (NYHA III–IV: 65.1% vs. 48.0%; *p* = 0.003). They also had a higher prevalence of moderate-to-severe renal impairment (50.6% vs. 31.2%; *p* = 0.003) and lower tobacco exposure (*p* = 0.005).After propensity score matching, 79 male–female pairs were identified (Figure). Baseline covariates achieved adequate balance, although EuroSCORE remained marginally higher in females (21.0 ± 14.5 vs. 15.9 ± 13.3; *p* = 0.024), likely reflecting sex-based weighting and procedural complexity.



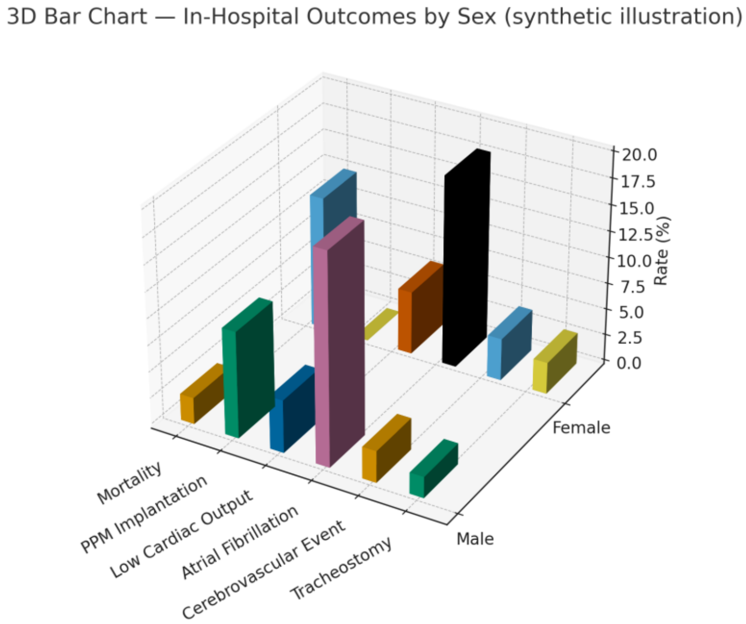
3D scatter (Age × EuroSCORE × Renal impairment)

Intraoperative Characteristics:

Procedural distribution differed significantly by sex before matching, with bio-Bentall procedures performed more frequently in males (34.2% vs. 20.2%; *p* = 0.017). This difference was not significant after matching (20.3% vs. 22.8%; *p* = 0.699). The use of homografts and xenografts did not differ by sex. Operative parameters—including cardiopulmonary bypass time, aortic cross-clamp duration, and circulatory arrest time—were similar between groups.

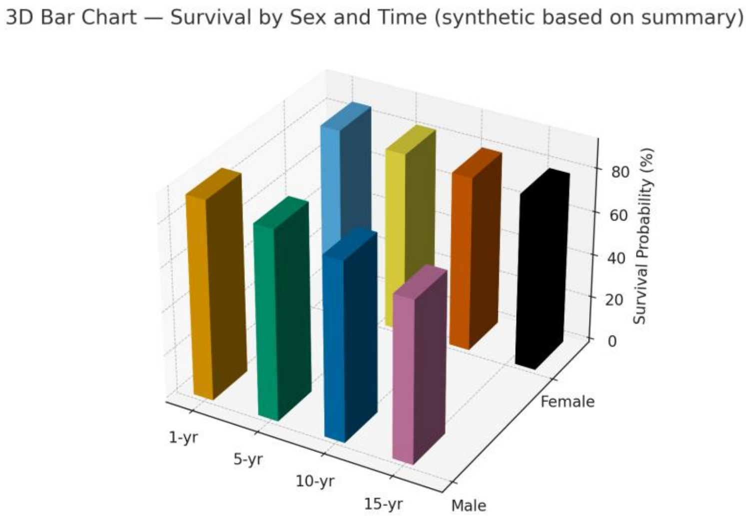
In-Hospital Outcomes:

Female patients exhibited higher in-hospital mortality (12.7% vs. 2.5%; *p* = 0.016), whereas permanent pacemaker (PPM) implantation occurred exclusively among males in the matched cohort (10.1% vs. 0%; *p* = 0.004). Rates of low cardiac output syndrome, atrial fibrillation, cerebrovascular events, and tracheostomy did not differ significantly between sexes.



Survival Analysis:

In the unmatched cohort, males demonstrated numerically higher early survival (1-year: 91.5% vs. 86.1%; 5-year: 87.2% vs. 83.2%), though long-term outcomes converged (10-year: 82.2% vs. 80.6%; log-rank $p = 0.384$; Table 4, Figure 1).Within the matched cohort, Kaplan–Meier analysis showed no significant difference in survival by sex (Table 5). Ten-year survival was 79.2% in females versus 74.3% in males (log-rank $p = 0.792$), with sustained survival observed in females at 15 years.



Predictors of Long-Term Mortality:

Multivariable Cox regression (Table 6) identified the following independent predictors of late mortality:

Age at operation

(HR 1.044; 95% CI 1.018–1.044; $p < 0.001$)

Peripheral vascular disease

(HR 2.652; 95% CI 1.349–5.214; $p = 0.005$)

Previous cardiac surgery

(HR 2.684; 95% CI 1.450–4.966; $p = 0.002$)

Gender was not independently associated with long-term survival (HR 1.368; 95% CI 0.691–2.710; $p = 0.368$).

III. Conclusions and Discussion:

This study demonstrates distinct early postoperative sex-related differences following biological ARR—specifically, higher in-hospital mortality among females and increased PPM implantation among males. However, these disparities did not extend to long-term survival, suggesting that once comorbid and procedural factors are adjusted for, the residual impact of sex is minimal. Late mortality was primarily influenced by systemic comorbidities and operative history rather than gender per se.These findings contrast with prior large-scale studies reporting persistent sex-based disparities in survival outcomes [8, 10]. Our unmatched data replicated higher early female mortality, but matched analysis revealed no long-term difference, implying that rigorous baseline adjustment can attenuate apparent sex effects. The observed pattern—early female vulnerability with equivalent long-term survival—may reflect selection dynamics, residual EuroSCORE imbalance, or high-risk patient inclusion.Contrary to McMullen *et al.* [11], who identified female sex as a predictor of PPM implantation, our study found PPM exclusively in males. This may relate to prosthesis geometry, anatomical variance, or institutional pacing thresholds. Although speculative, these differences highlight the need for further exploration of sex-specific conduction outcomes.Predictors of late mortality—age, peripheral vascular disease, and previous cardiac surgery—underscore the dominant influence of systemic vascular pathology and surgical burden [16–19]. These results reaffirm the role of comorbidity rather than gender in determining long-term prognosis.Strengths include complete long-term follow-up, single-institution consistency, and propensity score matching, which minimized confounding and enhanced internal validity. Limitations include potential residual confounding from unmeasured variables (e.g., frailty, medication use), lack of quality-of-life or functional outcomes, and modest numbers at late follow-up intervals. The single-center design may limit generalizability, though it ensures procedural uniformity.Clinically, these findings advocate for earlier surgical evaluation in women—who present older and with higher risk—and for vigilant postoperative surveillance in patients with vascular disease or prior surgery. Incorporating sex-specific risk modifiers into surgical scoring systems may further optimize equitable care.This study provides contemporary evidence on sex-specific outcomes after biological aortic root replacement using a matched cohort and extended follow-up. Female patients demonstrated higher early mortality, whereas long-term survival was comparable between sexes after adjustment. Late outcomes were predominantly determined by age, vascular disease, and surgical history rather than gender.Integrating sex-based risk assessment into surgical decision-making and institutional protocols may enhance both equity and efficacy in cardiovascular surgery. Future multicenter studies incorporating frailty, quality-of-life metrics, and biomarker profiling are warranted to refine patient selection and timing for biological ARR.Before matching, females were older, had higher logistic Euro SCOREs, more advanced NYHA class, and greater renal impairment. Bio-Bentall procedures were more common in males. After matching, males had higher rates of permanent pacemaker implantation (10.1% vs. 0%, $p = 0.004$), while females exhibited significantly higher in-hospital mortality (12.7% vs. 2.5%, $p = 0.016$). No significant sex differences were noted in rates of atrial fibrillation, low cardiac output syndrome, or tracheotomy. Ten-year survival was similar between sexes (females: 79.2%, males: 74.3%; $p = 0.792$). Independent predictors of late mortality included peripheral vascular disease (HR 2.652, $p = 0.005$), previous cardiac surgery (HR 2.684, $p = 0.002$), and age (HR 1.044/year, $p< 0.001$). Gender was not an independent predictor of late mortality (HR 1.368, $p = 0.368$).Despite comparable long-term survival, women experienced significantly higher early mortality following biological ARR. These findings highlight the need for targeted perioperative strategies and further research into sex-specific risk factors to improve early outcomes in female patients undergoing this high-risk procedure.

Future Scopes:

While this study establishes important clinical insights into sex-based differences following biological aortic root replacement (ARR), future research should extend beyond statistical associations to incorporate mechanistic and predictive modeling frameworks. Hemodynamic Modeling and Flow Simulation: Advanced computational fluid dynamics (CFD) can be employed to simulate patient-specific flow dynamics across biological grafts, allowing quantification of wall shear stress, flow asymmetry, and turbulence in male versus female aortic anatomies. These models can help identify sex-related biomechanical vulnerabilities such as altered root expansion or asymmetric coronary flow patterns that may influence graft longevity or conduction abnormalities. Finite Element Analysis (FEA) of Root Biomechanics: Incorporating patient-specific geometries and tissue material properties, FEA can evaluate stress–strain distributions within biological conduits under physiological pressure loading. Modeling can explore how differences in aortic root compliance, annular geometry, or calcific stiffness between sexes affect suture-line stress, coronary button kinematics, and long-term valve durability. Mathematical Modeling of Risk Prediction:

Using multivariate regression, survival functions, and Cox hazard–based predictive equations, future work can construct sex-specific mortality prediction models for biological ARR:

$$h(t|X)=h_0(t)\exp^{(\beta_1 \mathrm{Age}+\beta_2 \mathrm{PVD}+\beta_3 \mathrm{Redo}+\beta_4 \mathrm{Sex}+\dots \dots ..)} \quad (7)$$

Integrating continuous covariates (e.g., ventricular function, graft size, or hemodynamic indices) with Bayesian or machine learning–based frameworks could yield dynamic risk models for individualized postoperative surveillance.

Growth and Remodeling Models:

Coupled fluid–structure interaction (FSI) and growth-remodeling equations may be developed to simulate long-term adaptation of biological grafts. Such models can help predict bioprosthetic degeneration kinetics, reendothelialization, or leaflet calcification rates, incorporating sex-specific biological modifiers (e.g., hormonal influences on collagen metabolism). **System-Level Modelling of Gender Effects:**

Future investigations could also employ systems biology or network-based models to integrate molecular, hemodynamic, and social determinants of outcomes. Such frameworks may elucidate how sex hormones, inflammation, and comorbid burden interact dynamically over time to affect repair success and late mortality. Data-Driven Predictive Analytics: Combining large multicenter datasets with machine learning–enhanced survival modeling (e.g., random survival forests, deep Cox models) can improve accuracy in predicting sex-specific postoperative complications, guiding personalized surgical planning and risk stratification tools.

Summary:

Incorporating mathematical and computational modeling into future ARR research can bridge the gap between clinical outcomes and mechanistic understanding. Such integrative approaches—combining CFD, FEA, FSI, and survival modeling—will enable patient-specific predictions, improve graft design optimization, and enhance individualized treatment strategies accounting for gender-based anatomical and physiological variations.

Declarations:

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Author Contributions: All authors contributed equally to this work.

Conflict of Interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability Statement: The data used in this study were obtained from publicly available online sources.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Ethics Statement: This manuscript does not involve any ethical concerns.

Disclosure of AI Use: Artificial intelligence (AI) tools (e.g., ChatGPT) were used to a limited extent, solely for language refinement and formatting assistance.

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Mathematical Abstract

Let $N=291$denote the total number of patients who underwent biological aortic root replacement (ARR) over a 20-year period, comprising $N_m=202$males and $N_f=89$females. Propensity score matching was performed to balance baseline covariates across gender, yielding $n=79$matched male–female pairs ($N_{match}=158$).

Define the following binary outcome variables:

$M_{mort} \in \{0,1\}$: in-hospital mortality

$PPM \in \{0,1\}$: permanent pacemaker implantation

$S_{10}yr \in [0,1]$: 10-year survival probability

Post-matching results:

$P(PPM = 1 | \text{male}) = 0.1$,

$P(PPM = 1 | \text{female}) = 0$;

statistical significance: $p=0.004$

$P(M_{mort} = 1 | \text{female}) = 0.127$,

$P(M_{mort} = 1 | \text{male}) = 0.025$;

statistical significance: $p = 0.016$

Survival analysis:Using the Kaplan–Meier estimator and Cox proportional hazards model, the estimated 10-year survival probabilities were:

$S_{10}yr(f) = 0.792$, $S_{10}yr(m) = 0.743$, $p = 0.792$ (non-significant).

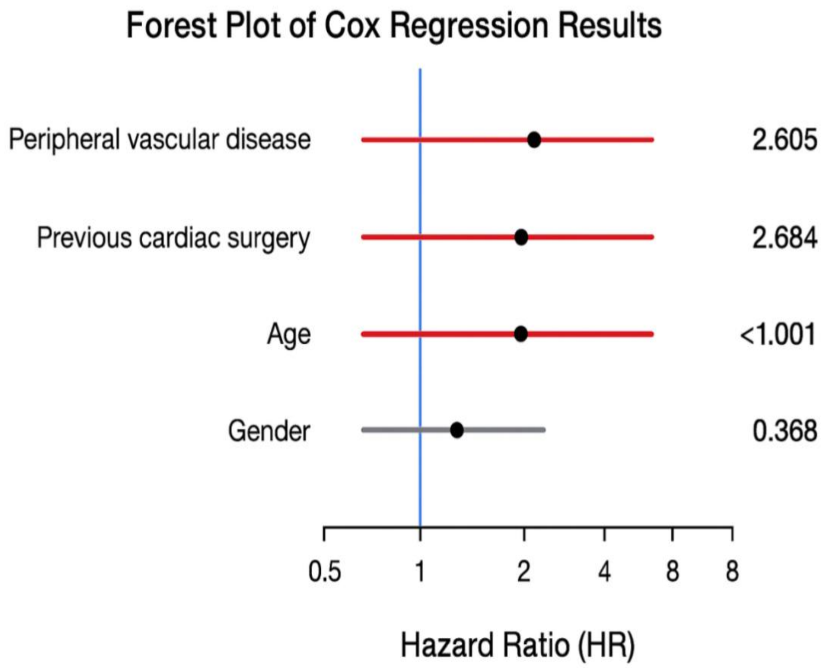
Multivariate Cox proportional hazards model:

Let $h(t|X)$ denote the hazard function, modeled as:

$$h(t|X) = h_0(t) \cdot \exp^{(\beta 1 \cdot PVD + \beta 2 \cdot PriorSurg + \beta 3 \cdot Age + \beta 4 \cdot Gender)}$$

where $h_0(t)$ is the baseline hazard. Significant predictors included:

Variable	Coefficient (β_i)	Hazard Ratio	p-value
Peripheral vascular disease (PVD)	$\log(2.652)$	2.652	0.005
Previous cardiac surgery	$\log(2.684)$	2.684	0.002
Age	$\log(1.044)$	1.044	<0.001
Gender	$\log(1.368)$	1.368	0.368 (non-significant)



(1) Model and simplification:

$h(t/X) = h_0(t)\exp^{(\beta_1}*PvD^{+\beta_2}*PriorSurg + ^{\beta_3}*Age + ^{\beta_4}*Gender$

PVD: HR = 2.3652 →

1) Model and simplification

You wrote:

$$h(t \mid X) = h_0(t)\ \exp\left(\beta_1 \cdot \text{PVD} + \beta_2 \cdot \text{PriorSurg} + \beta_3 \cdot \text{Age} + \beta_4 \cdot \text{Gender}\right)$$

You provided the hazard ratios (HR) for each variable:

- PVD: HR = 2.652 → $\beta_1 = \ln(2.652)$
- Prior surgery: HR = 2.684 → $\beta_2 = \ln(2.684)$
- Age: HR per unit = 1.044 → $\beta_3 = \ln(1.044)$
- Gender: HR = 1.368 → $\beta_4 = \ln(1.368)$

Because $\exp(\ln(\text{HR}) \cdot X) = \text{HR}^X$, the model simplifies to the multiplicative form:

$$\boxed{h(t \mid X) = h_0(t) \times 2.652^{\text{PVD}} \times 2.684^{\text{PriorSurg}} \times 1.044^{\text{Age}} \times 1.368^{\text{Gender}}}$$

(Here PVD, PriorSurg, Gender are assumed binary coded 0/1; Age is per 1-year unit.)

2) Numeric β values (for clarity)

$$\beta_1 = \ln(2.652) \approx 0.9753$$

$$\beta_2 = \ln(2.684) \approx 0.9873$$

$$\beta_3 = \ln(1.044) \approx 0.04306$$

$$\beta_4 = \ln(1.368) \approx 0.31335$$

3) Example calculations (interpretation)

- **PVD only** (PVD=1, all others 0):

  Relative hazard $= 2.652$.

  → Person with PVD has ~2.65× the hazard of someone without PVD (all else equal).
- **Prior surgery only** (PriorSurg=1, others 0):

  Relative hazard $= 2.684$.
- **Both PVD and prior surgery** (PVD=1, PriorSurg=1, Age and Gender = 0):

  Relative hazard $= 2.652 \times 2.684 \approx 7.118$.
- **Age effect**: each additional year multiplies hazard by 1.044.

  A 10-year increase multiplies hazard by $1.044^{10} \approx 1.538$ (≈54% higher).
- **Full worked example (comparing two people):**

  Compare Person A (75-year-old male with PVD and prior surgery) to Person B (65-year-old female with neither condition). Differences:
  - PVD: 1 vs 0 → factor 2.652
  - PriorSurg: 1 vs 0 → factor 2.684
  - Age: 75 vs 65 → factor $1.044^{10} \approx 1.538$
  - Gender: male (1) vs female (0) → factor 1.368

  Combined relative hazard $= 2.652 \times 2.684 \times 1.538 \times 1.368 \approx 14.98$.

  → Person A's hazard is ~15× Person B's hazard (given the model and coding assumptions).

Important note
These are **relative hazards** (multiples of the baseline hazard $h_0(t)$. You **cannot** compute an absolute hazard $h(t/X)$ without knowing $h_0(t)$ (the baseline hazard function). If you want absolute hazards at particular times you must provide or estimate $h_0(t)$ (or provide survival probabilities / baseline cumulative hazard).

Mathematical Conclusions:
Let G denote gender. Early postoperative outcomes f(G)demonstrate gender-specific sensitivity, with higher in-hospital mortality among females ($f(G_f)>f(G_m)$). However, long-term survival probabilities remain approximately equivalent ($S_{10}yr(G)\approx$constant). Further modeling is warranted to refine perioperative risk assessment and optimize care strategies, particularly for female patients.