

# Surgical care for rheumatic heart disease patients: insights from the Netherlands Heart Registration

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## Abstract

### Background and Aims

Although rheumatic heart disease (RHD) has declined in high-income countries, migration sustains its presence. Definite therapy for RHD is surgical mitral valve replacement (MVR), but data are lacking in the Netherlands. This study evaluated the overall surgical care for RHD patients with data from the Netherlands Heart Registration (NHR).

### Methods

This prospective cohort study included RHD MVR patients from all cardiothoracic centres ( $n = 16$ ) in the Netherlands. RHD MVR patients aged  $\leq 75$  years were identified in the NHR database between 2017 and 2023. Baseline, admission, procedural, and outcome data were analysed, with up to 5 years of follow-up. RHD patients were compared across centre volumes, divided into tertiles, and with non-RHD MVR patients in the NHR database.

### Results

Overall, 435 RHD patients were included with a mean (SD) age of 58 (12) years, and 73.3% ( $n = 319$ ) was female. Upon admission, 77.0% ( $n = 335$ ) of patients had a LVEF  $\geq 50.0\%$ , 40.2% ( $n = 175$ ) had atrial fibrillation, and 45.3% ( $n = 197$ ) were highly symptomatic (NYHA III–IV). Within a median (IQR) post-operative follow-up of 2.9 (1.1–4.6) years, total uncensored mortality was 12.2% ( $n = 53$ ). One-year mortality was similar among RHD MVR patients in high-volume ( $> 200$  MVRs) (6.9%) and low-volume ( $< 132$  MVRs) (7.6%) centres ( $P = .791$ ). One-year mortality did not differ between RHD (6.4%) and non-RHD (13.8%) MVR patients (HR: 0.80; 95% CI 0.53–1.21;  $P = .288$ ).

### Conclusions

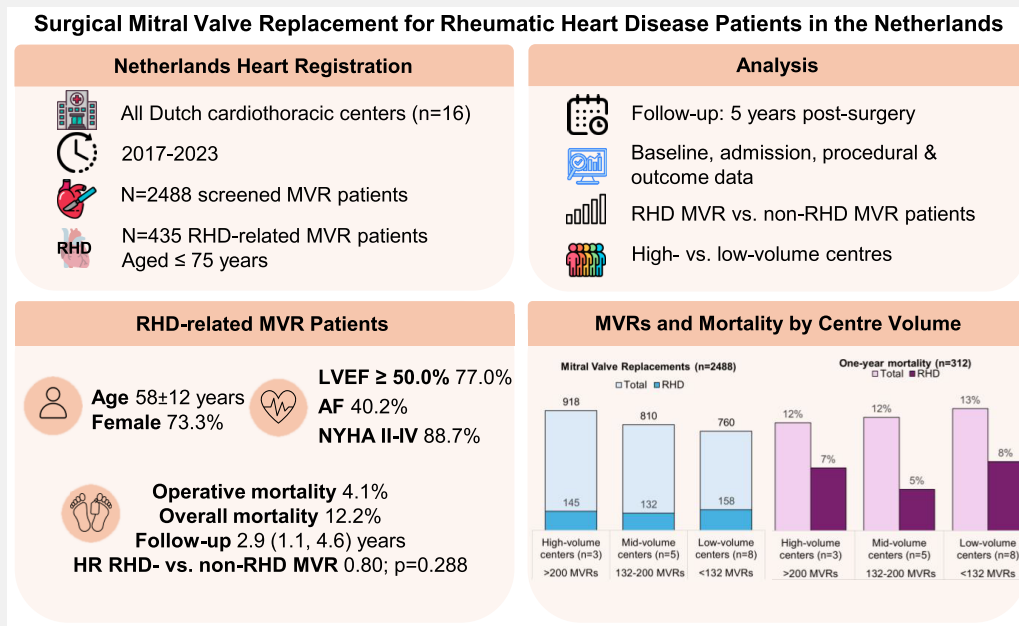
These data show effective surgical care for RHD MVR patients, with similar 1-year mortality rates across centre volumes and compared with non-RHD MVR patients, suggesting that RHD MVR patients can be managed similarly as non-RHD MVR patients.

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# Graphical abstract



## Keywords

Rheumatic heart disease • Mitral valve replacement

## Introduction

Rheumatic heart disease (RHD) is an important cause of mortality and morbidity, and continues to be the most prevalent form of heart valve disease.<sup>1</sup> With its main prevalence in low- and middle-income countries (LMIC), it affects 40 million people worldwide and yearly claims more than 300 000 lives.<sup>2,3</sup> RHD typically has its onset at an early age, following childhood rheumatic fever,<sup>4</sup> and shows a female preponderance,<sup>5</sup> with increased risk during pregnancy.<sup>6</sup>

RHD is the result of one or more episodes of acute rheumatic fever (ARF), an untreated throat or skin infection caused by Group A Streptococcus (GAS) bacterium.<sup>7,8</sup> GAS exposure can be heightened by poor socioeconomic conditions, such as household crowding, poor hygiene, inadequate education, and limited access to health care.<sup>8</sup> Recurrent episodes of ARF results in 60%–65% of patients in valvular heart disease due to an inappropriate autoimmune response,<sup>9</sup> mainly affecting the mitral valve.<sup>10</sup> As RHD progresses, combined involvement of the mitral- and aortic valve is seen in 20% of cases, additional involvement of the tricuspid valve is seen in 10% of cases.<sup>11</sup> Patients with advanced RHD present with complications such as heart failure, pulmonary hypertension, and atrial fibrillation.<sup>12</sup> Definite therapy for RHD is surgical mitral valve replacement.<sup>13</sup>

In recent years, RHD rates have decreased markedly in high-income countries (HIC), thanks to the use of antibiotics and improved socioeconomic conditions. Recently, this decrease is partly mitigated by migration.<sup>7</sup> Ojha et al. (2024) reported that the incidence of RHD in the Netherlands has increased over the past 30 years, reaching 2.34 and 2.87 per 100 000 for males and females, respectively, in 2019.<sup>14</sup> This indicates that former low-prevalence RHD regions are changing and highlighting the need to evaluate the surgical care for RHD patients in the Netherlands.

At present, it is not known how many RHD patients undergo mitral valve surgery and how they are divided over the Netherlands, including

insight into low- vs high-volume centres. Here, the aim was to evaluate the overall surgical care for RHD patients, including baseline characteristics, admission data, procedural details, and outcome data. Additionally, comparing RHD patients with non-RHD mitral valve replacement patients provides a broader clinical context for interpreting the results.

## Methods

### Study population

This study included data from the national database of the Netherlands Heart Registration (Nederlandse Hart Registratie, NHR). In the Netherlands, all cardiothoracic centres (n = 16) share their data about cardiothoracic interventions with the NHR, thereby creating a prospective database and enabling anonymized long-term follow-up.<sup>15,16</sup> Demographic characteristics, type of intervention, and outcome variables are included in this database. The NHR has an advanced, certified data quality control system in place to ensure completeness and quality of data.<sup>17</sup> For this study, a new variable was added to the NHR database for patients who have undergone mitral valve replacement (MVR) due to a rheumatically affected valve. Medical records from all patients who underwent MVR in one of the cardiothoracic centres between 2017 and 2023 (n = 2488) were screened for RHD. Letters, clinical notes, surgical reports, pathology reports, and medical images were reviewed to confirm RHD diagnosis.

### Design

This study was a prospective multicentre cohort study with data from all cardiothoracic centres (n = 16) in the Netherlands. Data were collected for RHD patients undergoing MVR between 2017 and 2023. Patients aged ≤75 years old were included, and patients with endocarditis were excluded. This excluded the large amount of mitral valve replacements due to aging and endocarditis. The study was approved by the institutional review board MEC-U (W19.270) and conducted in agreement with the principles

of the Declaration of Helsinki. A waiver for informed consent for analysis with the data of the NHR data registry was obtained.

## Outcomes

The NHR database was searched for baseline characteristics, admission data, procedural details, and outcome data.

Outcome data were reported according to the Mitral Valve Academic Research Consortium (MVARC) endpoint definitions for mitral interventions,<sup>18</sup> whenever these data were available in the NHR database. Follow-up data were available up to 5 years after surgery. The primary endpoint of this study was survival, assessed as in-hospital, 30-day, 1-year, and overall uncensored mortality.

## High- vs low-volume centres

The 16 cardiothoracic centres were divided into tertiles, aiming to create an even distribution of the total number of MVRs performed between 2017 and 2023. This distribution created high-volume centres ( $n=3$ ) with >200 MVRs, middle-volume centres ( $n=5$ ) with 132–200 MVRs, and low-volume centres ( $n=8$ ) with <132 MVRs between 2017 and 2023. One-year mortality was used to compare the surgical care within the centres.

## Rheumatic heart disease vs non-rheumatic heart disease mitral valve replacement

From the NHR database, non-RHD MVR patients were included to compare RHD MVR patients with non-RHD MVR patients. The same inclusion and exclusion criteria were applied. Consequently, the non-RHD MVR group consisted of the remaining MVR patients after RHD MVR patients were identified from all cardiothoracic centres between 2017 and 2023. An adjusted hazard ratio, corrected for all clinically relevant and EuroSCORE II variables, was used to compare 1-year mortality between these groups.

## Missing values

The NHR database has a high data completeness for the required variables in this study. Descriptive analyses were based on available data in the database. Missing values were not imputed and were excluded from the respective analyses, applying a complete case approach. For the Cox regression analysis, missing values were imputed, using mean/median imputation for continuous parameters and the most prevalent (mode) category within the variable was imputed for categorical parameters.

## Statistical analysis

Continuous variables are presented as mean  $\pm$  SD, in case of non-normality as median with interquartile range (IQR). Categorical variables are presented as counts with percentages. Continuous variables were analysed using *t*-test, and Mann–Whitney *U* test was used for parameters with non-normal distribution. Categorical variables were analysed using the  $\chi^2$  test. A Cox regression analysis was performed to identify variables associated with mortality. All individual EuroSCORE II variables and other clinically relevant variables were considered. Variables with a *P*-value < .1 in the univariable analysis or deemed clinically relevant were included in the multivariate model. Hazard ratios (HR) with corresponding 95% confidence intervals (CI) were reported. All reported *P*-values were two-sided and were considered statistically significant if *P* < .05. Statistical analyses and graphics were performed using SPSS software (V28, IBM, Armonk, NY, USA) and R statistics (R Foundation, Vienna, Austria).

## Results

### Baseline and admission characteristics

In total, 435 RHD patients underwent MVR surgery between 2017 and 2023 in one of the 16 cardiothoracic centres in the Netherlands. Baseline characteristics are depicted in Table 1. The mean (SD) age was 58.0 (12.0) years, and the majority was female (73.3%, 319/435).

**Table 1** Baseline and admission characteristics for RHD MVR and non-RHD MVR patients

| Characteristics                    | RHD<br><i>n</i> = 435 <sup>a</sup> | Non-RHD<br><i>n</i> = 2 053 <sup>a</sup> |
|------------------------------------|------------------------------------|------------------------------------------|
| Sex, females                       | 319 (73.3%)                        | 890 (43.4%)                              |
| Age                                | 60 (50, 69)                        | 67 (59,71)                               |
| BMI (kg/m <sup>2</sup> )           | 26.6 (22.9, 30.1)                  | 26.0 (23.3, 29.4)                        |
| Diabetes                           | 67 (15.4%)                         | 311 (15.1%)                              |
| Serum creatinine (μmol/L)          | 80 (65, 96)                        | 88 (73, 108)                             |
| eGFR (ml/min/1.73 m <sup>2</sup> ) | 72.8 (25.3)                        | 67.5 (22.7)                              |
| Kidney insufficiency               |                                    |                                          |
| eGFR $\geq$ 60                     | 298 (68.7%)                        | 1304 (63.5%)                             |
| eGFR 30–59                         | 123 (28.3%)                        | 619 (30.2%)                              |
| eGFR 15–29                         | 10 (2.3%)                          | 76 (3.7%)                                |
| eGFR <15                           | 2 (.5%)                            | 12 (.6%)                                 |
| Dialysis                           | 1 (.2%)                            | 38 (1.9%)                                |
| Pre-operative Hb (g/dL)            | 8.0 (1.1)                          | 8.1 (1.2)                                |
| sPAP                               |                                    |                                          |
| $\leq$ 30 mmHg                     | 221 (50.8%)                        | 1275 (62.1%)                             |
| 31–49 mmHg                         | 132 (30.3%)                        | 464 (22.6%)                              |
| 50–59 mmHg                         | 24 (5.5%)                          | 91 (4.4%)                                |
| $\geq$ 60 mmHg                     | 58 (13.3%)                         | 221 (10.8%)                              |
| Previous cardiac surgery           | 56 (12.9%)                         | 549 (26.7%)                              |
| Valve surgery                      | 50 (11.5%)                         | 466 (22.7%)                              |
| Aortic valve                       | 10 (2.3%)                          | 135 (6.6%)                               |
| Mitral valve                       | 32 (7.4%)                          | 323 (15.7%)                              |
| Pulmonary valve                    | 1 (.2%)                            | 0                                        |
| Tricuspid valve                    | 4 (.9%)                            | 29 (1.4%)                                |
| Recent MI                          | 9 (2.1%)                           | 227 (11.1%)                              |
| LVEF                               |                                    |                                          |
| $\leq$ 40%                         | 82 (18.9%)                         | 577 (28.1%)                              |
| 41%–49%                            | 16 (3.7%)                          | 115 (5.6%)                               |
| $\geq$ 50%                         | 335 (77.0%)                        | 1351 (65.8%)                             |
| Atrial fibrillation                | 175 (40.2%)                        | 533 (26.0%)                              |
| Paroxysmal                         | 50 (11.5%)                         | 225 (11.0%)                              |
| Non-paroxysmal                     | 90 (20.7%)                         | 203 (9.9%)                               |
| NYHA-class                         |                                    |                                          |
| I                                  | 34 (7.8%)                          | 231 (11.3%)                              |
| II                                 | 189 (43.4%)                        | 730 (35.6%)                              |
| III                                | 176 (40.5%)                        | 686 (33.4%)                              |
| IV                                 | 21 (4.8%)                          | 280 (13.6%)                              |
| Urgency                            |                                    |                                          |
| Elective                           | 363 (83.4%)                        | 1453 (70.8%)                             |
| Urgent                             | 69 (15.9%)                         | 423 (20.6%)                              |

Continued

**Table 1 Continued**

| Characteristics | RHD<br><i>n</i> = 435 <sup>a</sup> | Non-RHD<br><i>n</i> = 2 053 <sup>a</sup> |
|-----------------|------------------------------------|------------------------------------------|
| Emergency       | 2 (.5%)                            | 126 (6.1%)                               |
| Salvage         | 1 (.2%)                            | 48 (2.3%)                                |
| EuroSCORE II    | 2.4 (1.5, 4.4)                     | 3.4 (1.9, 7.0)                           |

BMI, body mass index; eGFR, estimated glomerular filtration rate; MVR, mitral valve replacement; pre-operative Hb, pre-operative haemoglobin level; RHD, rheumatic heart disease; sPAP, systolic pulmonary arterial pressure; Recent MI, recent myocardial infarct; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association

<sup>a</sup>Mean (SD); *n* (%); Median (Q1, Q3)

Upon admission, 12.9% (56/435) of patients underwent previous cardiac surgery, and 40.2% (175/435) had atrial fibrillation. RHD patients had a median (IQR) EuroSCORE II of 2.4 (1.5–4.4).

## Procedural details

Half of patients (51.5%, 224/435) underwent isolated MVR surgery, 21.6% (94/435) of patients underwent mitral and tricuspid valve surgery, 20.0% (87/435) of patients underwent mitral and aortic valve surgery, and 6.9% (30/435) of patients underwent mitral, tricuspid and aortic valve surgery (Supplementary Table S1). The median (IQR) length of hospital stay for patients who underwent isolated MVR was 7 (5–10) days, which was significantly shorter than the 9 (6–14) days observed for patients who underwent multiple valve surgery ( $P < .001$ ). Patients who underwent multiple valve surgery had significantly higher re-operation rate due to complications within 30 days compared to those with isolated MVR (21.3% (45/211) vs 8.9% (20/224),  $P = .003$ ). Similarly, 30-day mortality was significantly higher in the multiple valve surgery group (6.6%, 14/211) than in the isolated MVR group (1.8%, 4/224) ( $P = .010$ ).

Overall, the aortic valve was predominantly replaced (99.1%, 116/117) and the tricuspid valve was predominantly repaired (99.2%, 123/124). Of the 435 MVRs, 287 (66.0%) mitral valves were replaced with a mechanical valve and 144 (33.1%) with a bioprosthetic valve; type of valve implant was missing for four cases. The mean (SD) age of patients with a mechanical implant was 54 (11.0) years, and of patients with a bioprosthetic implant was 66 (12) years. An adjusted hazard ratio for age shows no significant difference in survival among valve implants (adjusted HR: 1.28; 95% CI .68–2.41,  $P = .448$ ). In total, 552 valves were replaced of which 65.4% (361/552), of valves were replaced by a mechanical valve and 33.5% (185/552) of valves by a bioprosthetic valve; type of valve implant was missing for 6 (1.1%) cases.

## Outcomes

The median (IQR) length of hospital stay was 8 (6–12) days; missing data for 1.6% of patients (Table 2). Reoperations due to complications within 30 days from the initial surgery were required for 14.9% of patients (65/435), of whom six patients (1.4%, 6/435) required reoperation during hospitalization due to new cardiac complications; the types of cardiac complications were not specified, and data about reoperations were missing for 19 (4.4%) cases. The main reason for reoperation was bleeding/tamponade (90.8%, 59/65). The operative mortality, in-hospital and 30-day, was 4.1% (18/435), of which 83.3% (15/18) died in the ICU. Within a median (IQR) follow-up time of 2.9 (1.1–4.6) years, the total uncensored mortality was 12.2% (53/435) (missing data for one patient (.2%)).

**Table 2 In-hospital and post-hospitalization outcomes for RHD and non-RHD patients**

| Outcomes                       | RHD<br><i>n</i> = 435 <sup>a</sup> | Non-RHD<br><i>n</i> = 2 053 <sup>a</sup> | <i>P</i> -value |
|--------------------------------|------------------------------------|------------------------------------------|-----------------|
| <i>In-hospital</i>             |                                    |                                          |                 |
| Hospital stay, days            | 8 (6, 12)                          | 8 (6, 14)                                | .005            |
| Stroke                         | 8 (1.8%)                           | 67 (3.3%)                                | .115            |
| Vascular complications         | 2 (.5%)                            | 25 (1.2%)                                | .166            |
| Kidney failure                 | 21 (4.8%)                          | 167 (8.1%)                               | .020            |
| Arrhythmias                    | 104 (23.9%)                        | 600 (29.2%)                              | .025            |
| Re-operations                  | 6 (1.4%)                           | 38 (1.9%)                                | .502            |
| <i>Post-hospitalization</i>    |                                    |                                          |                 |
| Re-intervention within 30 days |                                    |                                          | .403            |
| Bleeding/tamponade             | 59 (13.6%)                         | 262 (12.8%)                              |                 |
| Cardiac problems               | 4 (.9%)                            | 37 (1.8%)                                |                 |
| Other                          | 2 (.5%)                            | 20 (.9%)                                 |                 |
| <i>Mortality</i>               |                                    |                                          |                 |
| In-hospital                    | 18 (4.1%)                          | 178 (8.7%)                               | .001            |
| 30-day                         | 18 (4.1%)                          | 172 (8.4%)                               | .003            |
| One-year                       | 28 (6.4%)                          | 284 (13.8%)                              | <.001           |
| Overall, uncensored            | 53 (12.2%)                         | 415 (20.2%)                              | <.001           |
| Survival, days                 | 1065 (406; 1675)                   | 1040 (365; 1616)                         | .234            |

RHD, rheumatic heart disease

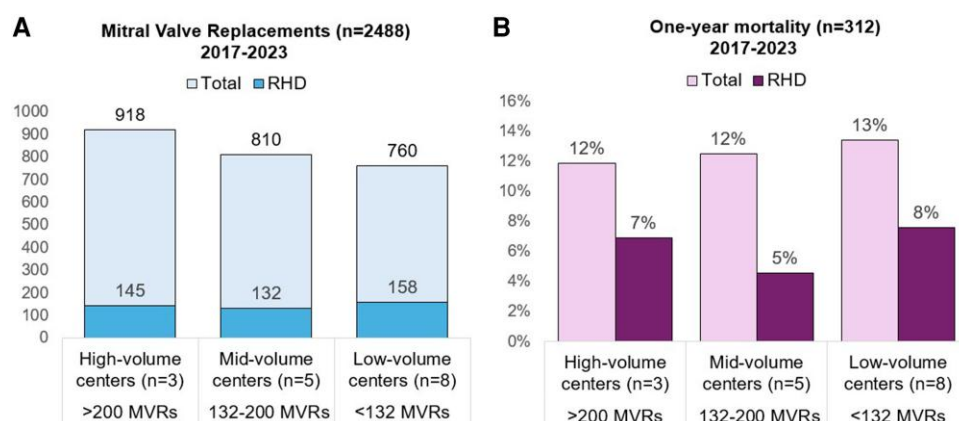
<sup>a</sup>Mean (SD); *n* (%); median (Q1, Q3)

## High- and low-volume centres

There were 145 (33.3%) RHD MVRs in high-volume centres (>200 MVRs,  $n = 3$ ), 132 (30.3%) RHD MVRs in mid-volume centres (132–200 MVRs,  $n = 5$ ), and 158 (36.3%) RHD MVRs in low-volume centres (<132 MVRs,  $n = 8$ ) (Figure 1A). In total, 10 (6.8%, 10/145) RHD MVR patients died in high-volume centres, six (4.5%, 6/132) in mid-volume centres, and 12 (7.6%, 12/158) in low-volume centres (Figure 1B). There was no significant difference in 1-year mortality between RHD patients treated in a high- or a low-volume centre ( $P = .791$ ).

## Rheumatic heart disease vs non-rheumatic heart disease mitral valve replacement

In total, 2488 MVRs were performed between 2017 and 2023. Besides the RHD MVRs, 2053 non-RHD MVR patients were identified. Non-RHD MVR patients had a median (IQR) age of 67 (59–71) years, and 56.6% (1163/2053) were male (Table 1). There were 26.7% (549/2053) of non-RHD MVR patients who underwent previous cardiac surgery, 26.0% (533/2053) had atrial fibrillation, and the median (IQR) EuroSCORE II was 3.4 (1.9–7.0). All were significantly different compared to RHD MVR patients. RHD MVR patients had significantly more multiple valve surgeries compared to non-RHD MVR patients, 48.5% vs 33.9%, respectively. Non-RHD MVR patients had a total uncensored mortality of 20% (415/2053); missing data of one patient (Table 2). An adjusted hazard ratio showed no significant difference for 1-year mortality between RHD (6.4%) and non-RHD (13.8%)



**Figure 1** Mitral valve replacements and 1-year mortality by centre volume (2017–2023). Mitral valve replacements ( $n = 2488$ ) and 1-year mortality ( $n = 312$ ), stratified by centre volume according to the total number of mitral valve replacements between 2017 and 2023. A. Mitral valve replacements in high-volume centres ( $n = 3$ ; >200 mitral valve replacements), mid-volume centres ( $n = 5$ ; 132–300 mitral valve replacements), and low-volume centres ( $n = 8$ ; <132 mitral valve replacements). B. One-year mortality for mitral valve replacement patients. There is no significant difference in rheumatic heart disease-related mitral valve replacement mortality between high and mid-volume centres ( $P = .402$ ), mid and low-volume centres ( $P = .272$ ), and high- and low-volume centres ( $P = .791$ )

MVR patients (adjusted HR: .80; 95% CI .53–1.21;  $P = .288$ ) (Supplementary Table S2). After excluding patients with previous cardiac surgery ( $n = 605$ ) to allow comparison of primary surgeries only, the adjusted hazard ratio between RHD and non-RHD MVR patients remained non-significant (adjusted HR: 1.21; 95% CI .78–1.89;  $P = .391$ ).

## Discussion

This nationwide cohort study evaluated the overall surgical care for RHD patients undergoing MVR in the Netherlands. This study included 435 RHD MVR patients with a mean age of 58 years, of whom 73.3% were female. Median follow-up time was 2.9 years, with an overall mortality rate of 12.2%. Between 2017 and 2023, 17.5% of all MVRs involved patients with RHD, underscoring the need to evaluate surgical care for RHD patients in the Netherlands.

In this study, RHD patients undergoing MVR had a mean age of 58 years, which is younger than that of non-RHD MVR patients but older than the mean age of RHD patients reported in the literature. Zühlke *et al.*<sup>6</sup> studied 3343 children and adults with RHD and reported a median age of 28 years (18, 40). This finding aligns with the fact that the initial episode of ARF typically occurs in childhood, followed by progressive valvular damage leading to the highest prevalence of RHD between the ages of 25 and 45.<sup>19</sup> This shift in age in our cohort is confirmed by Watkins *et al.*<sup>20</sup> noting that the disappearance of RHD and ARF in HICs has resulted in an older clinical caseload of RHD. Additionally, this older age may reflect the availability of bridging therapies in HICs, such as percutaneous balloon mitral valvuloplasty,<sup>21</sup> although the use of such therapies in this study cohort is unknown. The female predominance of 73.3% in this cohort might be attributed to greater autoimmune susceptibility,<sup>22</sup> greater exposure to GAS infections, and reduced access to primary and secondary ARF prophylaxis compared to males.<sup>23</sup>

Half of the surgeries were isolated mitral valve procedures (51%), suggesting that the disease had not yet progressed to involve other valves. While RHD is considered a left-sided valve disease, the involvement of the tricuspid valve is overlooked.<sup>24</sup> In this population, 28.5% of patients underwent tricuspid valve repair, a notably higher rate than the 10%

reported in the literature, but consistent with the fact that it always occurs in combination with the mitral or aortic valve surgery, likely as a consequence of left-sided heart valve disease.<sup>11</sup> These results underscore the need for right-sided screening when echocardiography is performed for diagnosis. Notably, the pulmonary valve was never surgically treated in this cohort, which reflects its minimal involvement in RHD pathology.

Even though the pre-operative parameters were similar for isolated- and multiple-valve surgery patients, the EuroSCORE II and 30-day mortality were significantly higher for patients with multiple-valve surgery. These findings could be explained by the fact that the complexity of the surgery is an individual predictor of the EuroSCORE II,<sup>25</sup> which implies that patients with two major procedures will have a higher EuroSCORE II. Among all MVR surgeries, most patients received a mechanical mitral valve implant. This cohort had a relatively young mean age, suggesting adherence to European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS) guidelines, which recommend mechanical mitral valve implants for patients under 65 years.<sup>26</sup> Although data on the indications for valve choice are lacking, leaving the large standard deviation unexplained, the mean ages in our cohort align well with the current guidelines.

In this cohort, the operative mortality was 4.1%, and the overall uncensored mortality was 12.2%. Contextualizing this mortality rate is challenging due to the limited availability of data on RHD in HICs. A brief review of the literature reveals considerable global variation in post-MVR mortality rates among patients with RHD (Table 3). Our Dutch study cohort had an acceptable mortality rate compared to those of other countries. A recent article analysed the baseline characteristics and outcomes of rheumatic mitral valve disease across 222 centres in 28 European countries.<sup>32</sup> This prospective study included patients with severe native valvular heart disease ( $n = 470$ ) and those with previous surgical or transcatheter valve intervention ( $n = 332$ ), including one patient from the Netherlands. Mechanical valve replacement was the most common intervention. Hospital mortality was 1.5%, 6-month mortality was 3.2%, which is slightly lower than the overall valvular heart disease mortality of 3.5%. These results align with our findings, where RHD MVR patients have a lower mortality rate compared to non-RHD MVR patients (12% vs 20%). The lower mortality rate observed in the Abdelhamid *et al.*<sup>32</sup> study might be explained by

**Table 3 Mortality rate post-MVR in RHD patients**

| Author and year                       | Country                     | Follow-up | n      | Mortality (%) |
|---------------------------------------|-----------------------------|-----------|--------|---------------|
| Karthikeyan et al. 2024 <sup>27</sup> | Multiple RHD-endemic LMICs  | 30 days   | 13 696 | 10            |
|                                       |                             | 3 years   |        | 15            |
| Soesanto et al. 2024 <sup>28</sup>    | Indonesia                   | 30 days   | 1382   | 8.7           |
|                                       |                             | 2.8 years |        | 16.7          |
| Russel et al. 2017 <sup>29</sup>      | Australia                   | 30 days   | 1078   | 3.8           |
|                                       |                             | 5 years   |        | 15.8          |
| Pillai et al. 2020 <sup>30</sup>      | India                       | 30 days   | 277    | 2.5           |
|                                       |                             | 5 years   |        | 6.8           |
| Chen et al. 2022 <sup>31</sup>        | Taiwan                      | 6 years   | 5086   | 32.5          |
| Abdelhamid et al. 2025 <sup>32</sup>  | Multiple European Countries | Hospital  | 802    | 1.5           |
|                                       |                             | 6-month   |        | 3.2           |

LMICs, low- and middle-income countries; MVR, mitral valve replacement; RHD, rheumatic heart disease

the shorter follow-up time and the inclusion of a broader range of intervention types within the EURObservational study.

Comparison between high-volume ( $n = 3$ ; >200 MVRs) and low-volume centres ( $n = 8$ ; <132 MVRs) revealed no significant difference in RHD-related MVR 1-year mortality. This uniformity suggests that surgical care for RHD patients is comparable across all cardiothoracic centres ( $n = 16$ ) in the Netherlands. The differences in the number of RHD MVRs performed across the centres may partly reflect variations in the registration of RHD diagnosis in medical records. Although the medical records may be suggestive of RHD, a definitive diagnosis of RHD is sometimes missing in medical letters, clinical notes, surgical reports, pathology reports, and medical images, potentially leading to a slight under registration of RHD cases.

RHD MVR patients were on average younger than non-RHD MVR patients. This difference may partly be explained by valvular degeneration in the non-RHD MVR patient group combined with the earlier onset of valvular disease typically seen in RHD MVR patients.<sup>19</sup> Although RHD MVR patients underwent more multiple valve surgeries, their EuroSCORE II was lower than that of non-RHD MVR patients. This outcome may be due to several characteristics of non-RHD patients: they are older, have undergone more cardiac surgeries, have worse critical pre-operative conditions and recent myocardial infarctions, and require more urgent, emergent, and life-saving procedures. Despite significant differences in baseline characteristics between RHD and non-RHD MVR patients, there was no significant difference in mortality, suggesting that RHD MVR patients can be managed similarly to non-RHD MVR patients.

## Limitations and future research

The 435 patients identified for this study might be an underestimation of the RHD MVR prevalence in the Netherlands. During screening of all 2488 medical records of MVR patients in the Netherlands between 2017 and 2023, it was noted that while some records were suggestive of RHD, a definitive diagnosis of RHD was at times missing in medical letters, clinical notes, surgical reports, pathology reports, and medical images. Medical records may overlook RHD diagnosis as a consequence of underreporting valve fibrosis or calcification related to ARF. Furthermore, during pathological examination, it can be challenging to determine whether a calcified valve has a rheumatic origin, especially when the history of ARF is not known.

For future research within HICs, it will be of interest to identify the bridging therapies that RHD patients undergo before MVR. To go

beyond HICs, future research on RHD should focus on endemic areas, where the highest prevalence of RHD is found. For example, there is only one cardiothoracic centre per 38 million inhabitants in Sub-Saharan Africa.<sup>33</sup> This situation underscores the urgent need to bridge the healthcare inequalities between HICs and LMICs.

## Conclusions

In the Netherlands, surgical outcomes for patients with RHD undergoing MVR are favourable, reflecting effective surgical care for this patient group. Of all MVRs performed between 2017 and 2023, 17.5% involved RHD patients aged 18–75 years. Data from the NHR show an acceptable mortality rate (30 days 4.1%, overall 12.2%), at the lower bounds of international reported data, with no difference between high- and low-volume centres. There is no difference in 1-year mortality between RHD and non-RHD MVR patients, suggesting that RHD MVR patients can be managed similarly to non-RHD MVR patients.

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## Supplementary data

Supplementary data are available at *European Heart Journal – Valvular and Structural Heart Disease* online.

## Declarations

## Data availability

The data underlying this article were provided by the Netherlands Heart Registration by permission. Data will be shared on request to the corresponding author with permission of the Netherlands Heart Registration.

## Disclosure of Interest

Nothing to disclose.

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None supplied.

## References

- Carapetis JR. Rheumatic heart disease in developing countries. *N Engl J Med* 2007;**357**: 439–41. <https://doi.org/10.1056/NEJMp078039>
- Roth GA, Mensah GA, Johnson CO, Addolorato G, Ammirati E, Baddour LM, et al. Global burden of cardiovascular diseases and risk factors, 1990–2019: update from the GBD 2019 study. *J Am Coll Cardiol* 2020;**76**:2982–3021. <https://doi.org/10.1016/j.jacc.2020.11.010>
- Beaton A, Carapetis J, Okello E. A hunter who hesitates to strike may just get the tail. *Circulation* 2024;**149**:277–8. <https://doi.org/10.1161/CIRCULATIONAHA.123.065487>
- Shrestha NR, Karki P, Mahto R, Gurung K, Pandey N, Agrawal K, et al. Prevalence of subclinical rheumatic heart disease in Eastern Nepal: a school-based cross-sectional study. *JAMA Cardiol* 2016;**1**:89–96. <https://doi.org/10.1001/jamacardio.2015.0292>
- Okello E, Longenecker CT, Beaton A, Kamya MR, Lwabi P. Rheumatic heart disease in Uganda: predictors of morbidity and mortality one year after presentation. *BMC Cardiovasc Disord* 2017;**17**:20. <https://doi.org/10.1186/s12872-016-0451-8>
- Zühlke L, Karthikeyan G, Engel ME, Rangarajan S, Mackie P, Cupido-Katya Mauff B, et al. Clinical outcomes in 3343 children and adults with rheumatic heart disease from 14 low- and middle-income countries: two-year follow-up of the Global Rheumatic Heart Disease Registry (the REMEDY study). *Circulation* 2016;**134**:1456–66. <https://doi.org/10.1161/CIRCULATIONAHA.116.024769>
- Watkins DA, Hasan B, Mayosi B, Bukhman G, Marin-Neto JA, Rassi A Jr, et al. Structural heart diseases. In: Prabhakaran D, Anand S, Gaziano TA, Mbanya JC, Wu Y, Nugent R (eds.), *Cardiovascular, Respiratory, and Related Disorders*. 3rd ed. Washington (DC): The International Bank for Reconstruction and Development / The World Bank, 2017, 191–208.
- Carapetis JR, Beaton A, Cunningham MW, Guilherme L, Karthikeyan G, Mayosi BM, et al. Acute rheumatic fever and rheumatic heart disease. *Nat Rev Dis Primers* 2016;**2**: 15084. <https://doi.org/10.1038/nrdp.2015.84>
- Marijon E, Mirabel M, Celermajer DS, Jouven X. Rheumatic heart disease. *Lancet* 2012; **379**:953–64. [https://doi.org/10.1016/S0140-6736\(11\)61171-9](https://doi.org/10.1016/S0140-6736(11)61171-9)
- Simpson MT, Kachel M, Neely RC, Erwin WC, Yasin A, Patel A, et al. Rheumatic heart disease in the developing world. *Struct Heart* 2023;**7**:100219. <https://doi.org/10.1016/j.shj.2023.100219>
- Dass C, Kanmanthareddy A. *Rheumatic Heart Disease*. Treasure Island (FL): StatPearls, 2025.
- Zühlke L, Engel ME, Karthikeyan G, Rangarajan S, Mackie P, Cupido B, et al. Characteristics, complications, and gaps in evidence-based interventions in rheumatic heart disease: the Global Rheumatic Heart Disease Registry (the REMEDY study). *Eur Heart J* 2015;**36**:1115–22a. <https://doi.org/10.1093/eurheartj/ehu449>
- Vahanian A, Beyersdorf F, Praz F, Milojevic M, Baldus S, Bauersachs J, et al. 2021 ESC/EACTS guidelines for the management of valvular heart disease. *Eur Heart J* 2022;**43**: 561–632. <https://doi.org/10.1093/eurheartj/ehab395>
- Ojha U, Marshall DC, Saliccioli JD, Al-Khayatt BM, Hammond-Haley M, Goodall R, et al. Temporal trend analysis of rheumatic heart disease burden in high-income countries between 1990 and 2019. *Eur Heart J Qual Care Clin Outcomes* 2024;**10**:108–20. <https://doi.org/10.1093/ehjqcco/qcac083>
- Derks L, Medendorp NM, Houterman S, Umans V, Maessen JG, van Veghel D, et al. Building a patient-centred nationwide integrated cardiac care registry: intermediate results from the Netherlands. *Neth Heart J* 2024;**32**:228–37. <https://doi.org/10.1007/s12471-024-01877-5>
- Timmermans MJC, Houterman S, Daeter ED, Danse PW, Li WW, Lipsic E, et al. Using real-world data to monitor and improve quality of care in coronary artery disease: results from the Netherlands Heart Registration. *Neth Heart J* 2022;**30**:546–56. <https://doi.org/10.1007/s12471-022-01672-0>
- Houterman S, van Dullemen A, Versteegh M, Aengevaeren W, Danse P, Brinkman E, et al. Data quality and auditing within the Netherlands Heart Registration: using the PCI registry as an example. *Neth Heart J* 2023;**31**:334–9. <https://doi.org/10.1007/s12471-022-01752-1>
- Stone GW, Adams DH, Abraham WT, Kappetein AP, Genereux P, Vranckx P, et al. Clinical trial design principles and endpoint definitions for transcatheter mitral valve repair and replacement: part 2: endpoint definitions: a consensus document from the Mitral Valve Academic Research Consortium. *Eur Heart J* 2015;**36**:1878–91. <https://doi.org/10.1093/eurheartj/ehv333>
- Lawrence JG, Carapetis JR, Griffiths K, Edwards K, Condon JR. Acute rheumatic fever and rheumatic heart disease: incidence and progression in the Northern Territory of Australia, 1997 to 2010. *Circulation* 2013;**128**:492–501. <https://doi.org/10.1161/CIRCULATIONAHA.113.001477>
- Watkins DA, Beaton AZ, Carapetis JR, Karthikeyan G, Mayosi BM, Wyber R, et al. Rheumatic heart disease worldwide: JACC scientific expert panel. *J Am Coll Cardiol* 2018;**72**:1397–416. <https://doi.org/10.1016/j.jacc.2018.06.063>
- Wilkins GT, Weyman AE, Abascal VM, Block PC, Palacios IF. Percutaneous balloon dilatation of the mitral valve: an analysis of echocardiographic variables related to outcome and the mechanism of dilatation. *Br Heart J* 1988;**60**:299–308. <https://doi.org/10.1136/hrt.60.4.299>
- Fink AL, Klein SL. The evolution of greater humoral immunity in females than males: implications for vaccine efficacy. *Curr Opin Physiol* 2018;**6**:16–20. <https://doi.org/10.1016/j.cophys.2018.03.010>
- Diao M, Kane A, Ndiaye MB, Mbaye A, Bodian M, Dia MM, et al. Pregnancy in women with heart disease in sub-Saharan Africa. *Arch Cardiovasc Dis* 2011;**104**:370–4. <https://doi.org/10.1016/j.acvd.2011.04.001>
- Sultan FA, Moustafa SE, Tajik J, Warsame T, Emani U, Alharthi M, et al. Rheumatic tricuspid valve disease: an evidence-based systematic overview. *J Heart Valve Dis* 2010;**19**:374–82.
- Nashef SA, Roques F, Sharples LD, Nilsson J, Smith C, Goldstone AR, et al. EuroSCORE II. *Eur J Cardiothorac Surg* 2012;**41**:734–44; discussion 44–5. <https://doi.org/10.1093/ejcts/ezs043>
- Praz F, Borger MA, Lanz J, Marin-Cuartas M, Abreu A, Adamo M, et al. 2025 ESC/EACTS guidelines for the management of valvular heart disease. *Eur Heart J* 2025;**46**:4635–736. <https://doi.org/10.1093/eurheartj/ehaf194>
- Karthikeyan G, Ntsekhe M, Islam S, Rangarajan S, Avezum A, Benz A, et al. Mortality and morbidity in adults with rheumatic heart disease. *JAMA* 2024;**332**:133–40. <https://doi.org/10.1001/jama.2024.8258>
- Soesanto AM, Rudikto E, Tjubandi A, Ariani R, Azzahra FN, Adam MF, et al. Clinical outcome of rheumatic mitral valve repair and replacement surgery in Indonesia: a comparison with non-rheumatic aetiology. *Glob Heart* 2024;**19**:4. <https://doi.org/10.5334/gh.1285>
- Russell EA, Walsh WF, Reid CM, Tran L, Brown A, Bennetts JS, et al. Outcomes after mitral valve surgery for rheumatic heart disease. *Heart Asia* 2017;**9**:e010916. <https://doi.org/10.1136/heartasia-2017-010916>
- Pillai VV, Sreekantan R, Nemani N, Karunakaran J. Survival and long-term outcomes after concomitant mitral and aortic valve replacement in patients with rheumatic heart disease. *Indian J Thorac Cardiovasc Surg* 2021;**37**:5–15. <https://doi.org/10.1007/s12055-020-01017-9>
- Chen SW, Chen CY, Chien-Chia Wu V, Chou AH, Cheng YT, Chang SH, et al. Mitral valve repair versus replacement in patients with rheumatic heart disease. *J Thorac Cardiovasc Surg* 2022;**164**:57–67.e11. <https://doi.org/10.1016/j.jtcvs.2020.07.117>
- Abdelhamid M, Abdel Meged AM, Prendergast B, Calvo-Iglesias FE, Taha SM, Kazamel GA, et al. Baseline characteristics and outcomes of rheumatic mitral valve disease: the EURObservational Research Programme Valvular Heart Disease II Survey. *Eur Heart J* 2025;**46**:1431–42. <https://doi.org/10.1093/eurheartj/ehaf050>
- Yankah C, Fynn-Thompson F, Antunes M, Edwin F, Yuko-Jowi C, Mendis S, et al. Cardiac surgery capacity in sub-Saharan Africa: quo vadis? *Thorac Cardiovasc Surg* 2014;**62**: 393–401. <https://doi.org/10.1055/s-0034-1383723>