Annuloplasty Ring Utilization in Mitral Valve Repair: A Real-World Snapshot of Device Selection and Early Outcomes

Andrzej Klapkowski *, Aleksandra Stańska, Nikodem Ulatowski, Maciej Duda, Igor Tomczyk, Wojciech Karolak

Posted Date: 31 March 2026

doi: 10.20944/preprints202603.2515.v1

Keywords: mitral valve repair; annuloplasty ring; postoperative atrial fibrillation

 doi:10.20944/preprints202603.2515.v1

Article

Annuloplasty Ring Utilization in Mitral Valve Repair: A Real-World Snapshot of Device Selection and Early Outcomes

Klapkowski Andrzej [1,*], Stańska Aleksandra [2], Ulatowski Nikodem [1], Duda Maciej [1], Tomczyk Igor [1] and Karolak Wojciech [1]

[1] Department of Cardiac Surgery, Faculty of Medicine, Medical University of Gdańsk, 80-214 Gdańsk, Poland

[2] Division of Quality of Life Research, Department of Psychology, Faculty of Health Sciences, Medical University of Gdańsk, Gdańsk, Poland

* Correspondence: a.klapkowski@gmail.com; Tel.: +48692423642

Abstract

Background: Annuloplasty is a key component of mitral valve repair, yet ring selection remains heterogeneous and its impact on early outcomes is unclear. **Methods:** This retrospective study included 149 patients undergoing mitral valve repair in whom an annuloplasty ring was utilized. Ring designs were grouped into semi-rigid rings, semi-rigid bands, rigid rings, and other designs. The primary outcome was postoperative atrial fibrillation (AF). Secondary outcomes included early complications and repair durability based on follow-up echocardiography and mortality. **Results:** Postoperative AF occurred in 35.8% of patients and did not differ across ring designs ($p = 0.244$). In multivariable analysis, age was independently associated with AF (OR 1.06 per year, $p = 0.001$), whereas ring design was not. Early outcomes were favorable, with 2.0% mortality and 5.4% rethoracotomy. Follow-up echocardiography showed good or moderate repair in 96.0% of patients; overall repair failure occurred in 4.0% when including mortality, without a clear association with ring design. **Conclusions:** Annuloplasty ring design was not associated with postoperative AF or early outcomes. Patient-related factors, particularly age, appear more relevant, while early repair durability remains high.

Keywords: mitral valve repair; annuloplasty ring; postoperative atrial fibrillation

Introduction

Mitral valve repair is the preferred surgical strategy for degenerative mitral regurgitation when feasible, offering durable valve competence with preservation of native valve apparatus [1,2]. Annuloplasty is a core component of contemporary repair, providing annular stabilization and supporting leaflet coaptation through the use of prosthetic rings or bands [3]. Despite broad adoption, ring selection remains heterogeneous across centers and surgeons, reflecting differences in valve pathology, annular geometry, repair philosophy, and device-specific design features (e.g., rigid, semi-rigid versus flexible platforms) [4,5].

Postoperative atrial fibrillation (AF) is one of the most common early complications after cardiac surgery and remains clinically relevant due to its association with prolonged hospitalization, thromboembolic risk, and resource utilization [6–8]. While patient-related factors (such as age and comorbidity burden) are well-recognized contributors to postoperative AF, the extent to which procedural choices during mitral repair, including annuloplasty ring platform, might relate to early AF remains less clear in routine practice [9,10]. Similarly, early safety outcomes such as rethoracotomy and in-hospital mortality are infrequent after isolated repair, but they provide an important pragmatic benchmark when describing real-world procedural cohorts.

 doi:10.20944/preprints202603.2515.v1

Therefore, the aim of this study was to provide a real-world snapshot of annuloplasty ring utilization in mitral valve repair and to explore whether ring design categories show any association with early postoperative AF and short-term safety endpoints in a consecutive case series.

Methods

Study design and setting

This retrospective observational study summarizes real-world practice patterns and early outcomes in patients undergoing mitral valve repair with implantation of an annuloplasty ring. The cohort was derived from consecutive cases from a single-surgeon series captured in a routinely maintained clinical database. Data were extracted retrospectively for the purposes of the present analysis.

Patient population

Adult patients undergoing mitral valve repair with annuloplasty ring implantation were eligible for this analysis. Ring-focused analyses were restricted to cases in which the implanted ring model could be classified into prespecified design categories. Patients undergoing mitral valve replacement were not considered in the present study.

Surgical technique and procedural variables

All mitral valve repairs were performed through a minimally invasive right anterolateral minithoracotomy approach. In more recent cases, a totally endoscopic technique was used. Procedures were performed using standard contemporary techniques, with annuloplasty ring implantation as a core component of valve stabilization. Repair strategy was categorized into clinically interpretable technique groups:

- isolated ring annuloplasty,
- chordal replacement plus ring annuloplasty,
- other repair variants like cleft closures, commissure closures, patch repairs.

Procedural variables collected for analyses included aortic cross-clamp time, cardioplegia strategy (Del Nido vs HTK Brettschneider), and concomitant procedures, including tricuspid intervention and patent foramen ovale (PFO) closure.

Annuloplasty ring classification and sizing

Annuloplasty rings were classified by model into named commercially available designs. For group-level analyses, ring models were consolidated into four clinically readable categories:

1. Semi-rigid rings: Carpentier-Edwards Physio II and Medtronic SimuForm
2. Semi-rigid bands: Carpentier-Edwards Physio Flex
3. Rigid rings: Medtronic Profile
4. Other designs (rare models pooled to ensure stable cell counts, including e.g., Medtronic Simulus and St Jude Saddle rings)

Annuloplasty ring size was recorded as the implanted labeled size and summarized descriptively; comparisons were performed to assess whether ring size distributions differed by postoperative atrial fibrillation status.

Outcomes

The primary outcome was postoperative atrial fibrillation (AF). Secondary early outcomes included early mortality and rethoracotomy. As an exploratory descriptive endpoint, early postoperative echocardiographic findings were summarized where available. Outcomes were assessed during the index hospitalization and/or early postoperative period as captured in the clinical database.

Ethics statement and consent to participate

This study was a retrospective analysis of routinely collected clinical data, with no additional procedures and no patient contact. In line with the non-interventional design and the use of existing clinical records, ethics committee review was not required. Individual informed consent was therefore waived.

 doi:10.20944/preprints202603.2515.v1

Statistical analysis

Categorical variables are presented as counts and percentages. Continuous variables are summarized as mean and standard deviation (SD). Between-group comparisons for continuous variables were performed using the independent samples t-test or the Mann–Whitney U test as appropriate. Unadjusted associations between categorical variables were evaluated using the chi-square test or Fisher's exact test when appropriate.

To explore independent associations with postoperative atrial fibrillation, multivariable logistic regression analysis was performed including ring design group and prespecified covariates (age, sex, aortic cross-clamp time, cardioplegia strategy, concomitant tricuspid procedure, and PFO closure). Additional exploratory logistic regression analyses were performed for selected perioperative outcomes.

A two-sided p value < 0.05 was considered statistically significant. Analyses were conducted using an available-case approach, with denominators varying across analyses depending on data completeness. Statistical analyses were performed using SPSS version 23 (IBM Corp., Armonk, NY, USA).

Results

Cohort and repair technique profile

The study cohort comprised 149 patients undergoing mitral valve repair with annuloplasty ring implantation. The population included 56 women (37.6%) and 93 men (62.4%), with a mean age of 58.0 ± 14.1 years (range 20–84 years).

Across analyses, denominators varied due to available-case reporting. Ring-specific analyses were performed in the subset of patients with identifiable annuloplasty ring model information.

Among patients undergoing mitral valve repair, the predominant surgical strategy was chordal replacement combined with ring annuloplasty, whereas isolated ring annuloplasty and other repair variants were less frequent (Table 1).

Table 1. Mitral valve repair technique category.

Repair technique category	n	% (valid)
Ring annuloplasty only	23	15.5
Chordal replacement only	1	0.7
Chordae replacement + ring annuloplasty	115	77.7
Other repair techniques	9	6.1

Valve morphology and repair strategy

Valve morphology was associated with the selected repair strategy (Pearson Chi-square p = 0.005). In patients with Barlow disease, chordal replacement combined with ring annuloplasty was used in the vast majority of cases (93.2%), whereas isolated annuloplasty was rare. In fibroelastic deficiency (FED), combined repair also predominated (68.6%), although isolated annuloplasty was performed more frequently than in Barlow valves. This pattern may be partially explained by the higher proportion of functional mitral regurgitation mechanisms observed in patients classified as FED, where annular remodeling plays a more prominent role.

Annuloplasty ring model utilization

A broad range of annuloplasty ring models was used. The most frequently implanted design was Carpentier-Edwards Physio II, accounting for more than half of implants. Other commonly used models included Profile, SimuForm, and Carpentier-Edwards Physio Flex. Rare individual designs were pooled as "Other designs" to maintain stable cell counts for group-level analyses (Table 2).

 doi:10.20944/preprints202603.2515.v1

Table 2. Annuloplasty ring model distribution.

Annuloplasty ring model	n	% (valid)
Carpentier-Edwards Physio II	75	53.6
Medtronic Profile	24	17.1
Medtronic SimuForm	21	15
Carpentier-Edwards Physio Flex	18	12.9
Other designs (Simulus, Saddle)	2	1.4

Annuloplasty ring size distribution

Ring sizes ranged from 26 to 40 mm, with a mean implanted size of 34.3 ± 4.3 mm. The most commonly used sizes were 40 mm, 30 mm, and 32 mm, with the majority of implants falling within the 32–40 mm range (Table 3).

Table 3. Annuloplasty ring size distribution.

Ring size (mm)	n	% (valid)
26	2	1.4
28	18	12.2
30	23	15.5
32	22	14.9
34	14	9.5
36	20	13.5
38	15	10.1
40	34	23

Ring design and postoperative atrial fibrillation

Postoperative atrial fibrillation occurred in 49 of 137 evaluable patients (35.8%). AF rates varied modestly across ring designs but did not differ significantly between groups (Pearson Chi-square $p = 0.244$) (Table 4).

In additional exploratory analysis including baseline laboratory variables, higher serum creatinine was also associated with an increased risk of postoperative AF (OR 23.61, $p < 0.001$).

Table 4. Postoperative atrial fibrillation according to ring design.

Ring design group	AF (n)	No AF (n)	Total (n)
Physio II	30	43	73
Physio Flex	3	15	18
Profile	9	14	23
SimuForm	6	15	21
Other designs	1	1	2

In multivariable logistic regression analysis adjusting for age, sex, cross-clamp time, cardioplegia strategy, concomitant tricuspid valve procedure, PFO closure, and ring design, increasing age was independently associated with postoperative AF (OR 1.06 per year, 95% CI 1.03–1.10, $p = 0.001$). No significant association was observed for ring design or other procedural variables.

Early echocardiographic results

Early postoperative echocardiography demonstrated excellent repair quality in the majority of patients. A good immediate echocardiographic result was observed in 145 patients (97.3%), whereas 3 patients (2.0%) had moderate residual regurgitation and 1 patient (0.7%) had a suboptimal result.

Across ring design groups, no meaningful differences in early echocardiographic outcomes were observed (Pearson Chi-square $p = 0.783$).

Early postoperative outcomes

Early adverse events were uncommon (Table 5).

 doi:10.20944/preprints202603.2515.v1

Early mortality occurred in 3 patients (2.0%), rethoracotomy in 8 patients (5.4%), and conversion to sternotomy in 4 patients (2.7%). Postoperative stroke occurred in 4 patients (2.7%), and permanent pacemaker implantation was required in 5 patients (3.4%). Blood transfusion was administered in a minority of patients.

Table 5. Early postoperative outcomes.

Outcome	n (%)
Early mortality	3 (2.0)
Rethoracotomy for bleeding	8 (5.4)
Conversion to sternotomy	4 (2.7)
Postoperative stroke	4 (2.7)
Permanent pacemaker implantation	5 (3.4)

Predictors of blood transfusion

In exploratory multivariable analysis, lower preoperative hemoglobin, female sex, older age, and longer aortic cross-clamp time were independently associated with the need for perioperative blood transfusion. Each increase in hemoglobin level was associated with a reduced probability of transfusion (OR 0.69, p = 0.004), whereas female sex remained a strong predictor of transfusion requirement.

Follow-up echocardiographic outcomes

Follow-up echocardiography was available in 122 patients (81.9%), while 27 patients did not attend scheduled follow-up visits. Follow-up echocardiography was routinely scheduled approximately three months after surgery.

Among patients with available follow-up imaging, a good repair result was observed in 107 patients (87.7%), moderate residual regurgitation in 10 patients (8.2%), and poor results in 3 patients (2.5%). Two of the three deaths occurred during the follow-up period.

Durability of mitral valve repair

Repair durability was assessed using follow-up echocardiographic findings supplemented by mortality data.

A durable repair result, including both good and moderate outcomes, was observed in 143 patients (96.0%), whereas repair failure, defined as poor echocardiographic outcome or death, occurred in 6 patients (4.0%).

Analysis of repair durability according to ring design was performed in patients with available ring classification (n = 140). In this subgroup, repair failure occurred in 5 patients (3.6%).

Across ring design groups, durability remained high, with no clear pattern suggesting an association between ring type and repair failure. Given the very low number of events and small subgroup sizes, these findings should be interpreted with caution.

Table 6. Repair durability according to ring design.

Ring design	Durable repair (n)	Repair failure (n)	Total
Physio II	72	3	75
Physio Flex	18	0	18
Profile	23	1	24
SimuForm	21	0	21
Other designs	1	1	2

Repair technique and durability

Repair durability also varied according to surgical repair strategy (Pearson Chi-square p = 0.043). Failure rates were highest in patients treated with alternative repair techniques and in those undergoing isolated annuloplasty, whereas combined chordal replacement and ring annuloplasty demonstrated the lowest proportion of repair failure.

 doi:10.20944/preprints202603.2515.v1

Valve morphology and repair durability

Valve morphology was not significantly associated with repair durability. Repair failure occurred in 11.6% of patients with fibroelastic deficiency (FED) and 5.1% of patients with Barlow disease (Fisher exact $p = 0.241$).

Discussion

In this real-world cohort of mitral valve repair supported by annuloplasty, chordal replacement combined with ring annuloplasty was the dominant repair strategy [11,12]. This distribution aligns with contemporary reconstructive practice, where restoration of leaflet coaptation is frequently paired with annular stabilization rather than isolated annuloplasty alone [13]. A broad spectrum of annuloplasty ring models was used, with semi-rigid Physio designs and SimuForm accounting for the majority of implants and flexible rings representing a smaller subset, consistent with pragmatic ring selection driven by valve anatomy, surgeon preference, and device availability in routine clinical practice.

Across analyses, annuloplasty ring design did not demonstrate a clear association with postoperative atrial fibrillation (AF). In unadjusted comparisons, AF rates showed only modest variation across ring categories without consistent separation between groups. Importantly, when ring design group was included in multivariable models alongside clinical and procedural covariates, ring design was not an independent predictor of postoperative AF. In contrast, patient age emerged as the most stable correlate, supporting the interpretation that early postoperative AF is largely determined by patient substrate rather than the annuloplasty platform itself. This observation is consistent with prior literature identifying age and atrial substrate as key determinants of postoperative AF following mitral valve surgery.

Early adverse events in the ring-repair cohort were infrequent. Descriptive comparisons did not suggest meaningful differences in early mortality or rethoracotomy between flexible versus non-flexible designs, nor across the broader ring design groups; however, the absolute number of events was small and limits inference. Accordingly, the absence of statistically significant differences should be interpreted as a lack of a strong signal rather than evidence of equivalence between ring platforms for early outcomes.

Interestingly, exploratory analyses of perioperative transfusion revealed that female sex was strongly associated with a higher probability of blood transfusion, together with lower baseline hemoglobin levels, older age, and longer aortic cross-clamp time. These findings are consistent with growing evidence suggesting that women undergoing cardiac surgery may experience higher rates of perioperative transfusion and less favorable early outcomes, potentially reflecting differences in baseline hemoglobin levels, body size, and perioperative physiology [14,15]. Although transfusion risk was not a primary focus of the present analysis, these observations highlight the importance of considering sex-specific factors when evaluating perioperative risk profiles in mitral valve surgery.

From a clinical standpoint, the present data support a pragmatic message: within routine mitral valve repair practice, ring selection appears neutral with respect to early postoperative AF and short-term safety endpoints in this dataset, while patient-related factors (notably age and baseline clinical profile) remain more informative for early postoperative risk. Future studies with larger samples and longer follow-up should prioritize outcomes where ring design may plausibly exert a stronger effect, including echocardiographic durability, recurrent regurgitation, ventricular remodeling metrics, and functional recovery. Additionally, richer phenotyping of valve pathology and repair complexity may help clarify whether specific ring platforms confer advantages in well-defined anatomical subsets.

Study limitations

This study has several limitations that should be acknowledged. First, the analysis was based on a retrospective observational cohort derived from a single-surgeon experience, which may limit generalizability and introduce potential selection bias. Second, although the overall sample size was moderate, some annuloplasty ring categories included relatively few patients, restricting statistical power for comparisons between individual device types. Third, the number of early adverse events

 doi:10.20944/preprints202603.2515.v1

was small, which limits the ability to detect subtle differences in outcomes between ring platforms. Fourth, follow-up echocardiographic data were not available for all patients, primarily because a proportion of individuals did not attend scheduled follow-up visits. Finally, the study focused primarily on early postoperative outcomes, and longer-term follow-up will be required to determine whether annuloplasty ring design influences repair durability, recurrent regurgitation, or ventricular remodeling over time.

Conclusion

In this real-world series of mitral valve repairs with annuloplasty, ring design was not independently associated with postoperative atrial fibrillation or early safety endpoints, whereas patient age showed the most consistent relationship with postoperative AF. Female sex was associated with a higher probability of perioperative blood transfusion, highlighting the potential importance of sex-related differences in perioperative risk. Larger cohorts and longer follow-up are warranted to determine whether ring selection influences longer-term repair durability and echocardiographic outcomes.

Author Contributions: Conceptualization: A.K. and W.K.; **Methodology**: A.K., A.S. and W.K.; **Software**: A.S.; **Validation**: A.K., A.S. and W.K.; **Formal Analysis**: A.S.; **Investigation**: A.K., N.U., M.D. and I.T.; **Resources**: A.K. and W.K.; **Data Curation**: A.K., N.U., M.D. and I.T.; **Writing – Original Draft Preparation:** A.K.; **Writing – Review & Editing**: A.K., A.S. and W.K.; **Visualization:**, A.S. and A.K.; **Supervision**: W.K.; **Project Administration**: A.K.

Institutional Review Board Statement: Ethical review and approval were waived for this study. This was a retrospective analysis of routinely collected clinical data, involving no additional procedures or patient contact. In accordance with the non-interventional design and the use of existing clinical records, formal ethics committee review was not required under local regulations.

Informed Consent Statement: Patient consent was waived due to the retrospective nature of the study and the use of existing, de-identified clinical records.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy and ethical restrictions related to clinical patient records.:

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Gillinov AM, Cosgrove DM. Mitral valve repair for degenerative disease. *J Heart Valve Dis.* 2002;11(Suppl 1):S15–S20.
2. Di Tommaso E, Rapetto F, Guida GA, Zakkar M, Bruno VD. Benefits of mitral valve repair over replacement in the elderly: a systematic review and meta-analysis. *J Card Surg.* 2021;36(7):2524–2530. doi:10.1111/jocs.15506.
3. Chotivatanapong T. Mitral annuloplasty ring design and selection: complete semi-rigid is best. *JTCVS Tech.* 2021;10:55–57. doi:10.1016/j.xjtc.2021.10.036.
4. Schulte LJ, Melby SJ. Mitral annuloplasty ring design and selection: flexible bands are (mostly) all you need. *J Thorac Cardiovasc Surg.* 2023;166(1):88–90. doi:10.1016/j.jtcvs.2022.06.026.
5. Baccelli A, Lapenna E, Del Forno B, Schiavi D, Meneghin R, Giambuzzi I, et al. Long-term results of mitral repair with complete semi-rigid rings versus posterior flexible bands. *Ann Thorac Surg.* 2021;112(3):756–761. doi:10.1016/j.athoracsur.2020.11.006
6. Borger MA, Mansour MC, Levine RA. Atrial fibrillation and mitral valve prolapse: time to intervene? *J Am Coll Cardiol.* 2019;73(3):275–277. doi:10.1016/j.jacc.2018.11.018.

 doi:10.20944/preprints202603.2515.v1

7. El Mathari S, Tomšič A, Kharbanda RK, Zappala P, Wijnmaalen AP, Klautz RJM, Silva MR, Palmen M. Characterization of atrial arrhythmias following mitral valve repair: incidence and risk factors. *J Cardiovasc Electrophysiol*. 2024;35(10):1972–1980. doi:10.1111/jce.16390.
8. Obadia JF, El Farra M, Bastien OH, Lièvre M, Martelloni Y, Chassignolle JF. Outcome of atrial fibrillation after mitral valve repair. *J Thorac Cardiovasc Surg*. 1997;114(2):179–185. doi:10.1016/S0022-5223(97)70142-9.
9. Fu W, Green C, Wagner C, Pawar G, Ceniza N, Gupta R, et al. Postoperative atrial fibrillation in mitral valve surgery is not benign. *J Thorac Cardiovasc Surg*. 2024;168(4):1073–1079. doi:10.1016/j.jtcvs.2023.08.057.
10. Bramer S, van Straten AH, Soliman Hamad MA, van den Broek KC, Maessen JG, Berreklouw E. New-onset postoperative atrial fibrillation predicts late mortality after mitral valve surgery. *Ann Thorac Surg*. 2011;92(6):2091–2096. doi:10.1016/j.athoracsur.2011.06.079.
11. Bahiraie P, Soleimani H, Heydari N, Najafi K, Karlas A, Avgerinos DV, et al. Mitral valve repair of the anterior leaflet: are we there yet? *Hellenic J Cardiol*. 2024;78:72–83. doi:10.1016/j.hjc.2024.02.001.
12. Schaff HV, Nguyen A. Contemporary techniques for mitral valve repair: the Mayo Clinic experience. *Indian J Thorac Cardiovasc Surg*. 2020;36(Suppl 1):18–26. doi:10.1007/s12055-019-00801-6.
13. Perier P, Hohenberger W, Batz G, Lakew F, Diegeler A. Mitral valve repair for degenerative mitral valve regurgitation. *Indian J Thorac Cardiovasc Surg*. 2020;36(Suppl 1):12–17. doi:10.1007/s12055-019-00823-0.
14. Pölzl L, Lohmann R, Engler C, Ioannou-Nikolaidou M, Nägele F, Hirsch J, et al. The silent cost of gender in mitral valve surgery: a propensity-score matched analysis. *Eur J Cardiothorac Surg*. 2026;68(1):ezaf451. doi:10.1093/ejcts/ezaf451.
15. Vassileva CM, McNeely C, Mishkel G, et al. Gender differences in long-term survival of Medicare beneficiaries undergoing mitral valve operations. *Ann Thorac Surg*. 2013;96(4):1367–1373.