Survival after surgical ablation for atrial fibrillation in mitral valve surgery: Analysis from the Polish National Registry of Cardiac Surgery Procedures (KROK)

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ABSTRACT

Objectives: Surgical ablation for atrial fibrillation (AF) performed at the time of other valvular- or nonvalvular cardiac procedure is a mainstay of therapy; yet the data regarding its influence on remote survival are sparse. We aimed to evaluate late survival in patients undergoing mitral valve (MV) surgery with concomitant surgical ablation for AF.

Methods: Procedure-related data from the Polish National Registry of Cardiac Surgery Procedures (Krajowy Rejestr Operacji Kardiologicznych) were retrospectively collected. A total of 11,381 patients with baseline AF (46.6% men; mean age 65.6 ± 9.0 years) undergoing MV surgery between 2006 and 2017 in 37 reference centers across Poland and included in the registry were analyzed. Median follow-up was 5 years (mean, 4.6 years; interquartile range, 1.9-7.9 years). Cox proportional hazards models were used for computations. Propensity score matching for the comparison of MV + ablation versus MV alone was performed.

Results: Of included patients, 2449 (21.5%) underwent surgical ablation for AF. Patients in this group were significantly younger (63.8 ± 8.7 years vs 66.1 ± 9.0 years; $P < .001$) and were at lower baseline surgical risk (EuroSCORE, 2.86 vs 3.69; $P < .001$). During the 12-year study period, there was a significant survival benefit (hazard ratio, 0.71; 95% confidence interval, 0.63-0.79; $P < .001$) for MV + ablation compared with MV alone. After rigorous propensity matching (logit model, 1784 pairs) surgical ablation was associated with nearly 20% improved survival (hazard ratio, 0.82; 95% confidence interval, 0.70-0.96; $P = .011$). Benefit of surgical ablation was maintained in subgroup analyses, yet most benefit was appraised in low-risk patients such as those with EuroSCORE of 2 to 5 or age < 50 years.

Survival analysis between mitral valve (MV) + concomitant surgical ablation versus MV surgery alone.

Central Message

In one of the largest European registries, we found that surgical ablation performed for atrial fibrillation during mitral valve surgery was associated with significantly improved long-term survival.

Perspective

Up to 40% of patients undergoing mitral valve surgery present with atrial fibrillation. Although Cox-maze III and Cox-maze IV procedures are safe and recommended in current guidelines, antiarrhythmic corrections are not always performed at index mitral valve surgery due to inconclusive data regarding long-term survival.

See Commentaries on pages 1019 and 1021.

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Abbreviations and Acronyms

AF	= atrial fibrillation
CAD	= coronary artery disease
EuroSCORE	= European system for cardiac operative risk evaluation
HLoS	= hospital length of stay
IABP	= intra-aortic balloon pump
ICU	= intensive care unit
KROK	= Krajowy Rejestr Operacji Kardiologicznych (Polish National Registry of Cardiac Surgery Procedures)
LVEF	= left ventricle ejection fraction
MI	= myocardial infarction
MV	= mitral valve
STS	= Society of Thoracic Surgeons

Scanning this QR code will take you to the article title page to access supplementary information.

Conclusions: Concomitant surgical ablation for AF in patients undergoing mitral valve procedures is safe, feasible, and significantly improves late survival. (*J Thorac Cardiovasc Surg* 2019;157:1007-18)

Advancements in understanding of the pathogenesis of atrial fibrillation (AF) and development of new technologies have resulted in numerous improvements in the surgical ablation of AF, particularly in patients with mitral valve (MV) disease. For patients with both MV dysfunction and AF, a variety of new approaches are available to enable a complete operation that includes both MV repair or replacement and ablation of AF, on many occasions all done in minimally invasive fashion.¹⁻⁴

Left untreated, AF increases mortality and morbidity in patients undergoing MV surgery.⁵⁻⁹ Although the maze procedure effectively eliminates AF in most of these patients, its complexity and increased operative time has precluded widespread application.¹⁰ New operations that use radiofrequency or cryoablation to create left atrial lesion, have been demonstrated to reduce long-term AF rates and to improve quality of life.¹¹⁻¹⁷ More recently, others described that surgical ablation in patients with multiple valve disease and AF may have been associated

with lower operative mortality.¹⁸ Implementation of surgical ablation is increasing,¹⁹ but up to 60% of patients have their AF left untreated.²⁰

Performance of surgical ablation at the time of mitral disease operations recently has attained a class IA recommendation in the Society of Thoracic Surgeons (STS)^{21,22} and class IIA in the European Society of Cardiology/European Society of Cardiothoracic Surgery guidelines.²³ Refinements in mapping and ablation technology are on the horizon, and these will facilitate more widespread application of minimally invasive approaches and further improve results^{24,25} that to date, partially due to paucity of data, are inconclusive regarding remote safety and efficacy of surgical ablation for AF in patients undergoing MV surgery.

In the current analysis, we report long-term survival results after concomitant surgical ablation for atrial fibrillation in patients undergoing MV procedures from the Polish National Registry of Cardiac Surgery Procedures (Krajowy Rejestr Operacji Kardiologicznych [KROK]).

METHODS**Registry Design**

All data were collective in a retrospective fashion from the KROK registry (www.krok.csioz.gov.pl). The registry is an ongoing, nationwide, multi-institutional registry of heart surgery procedures in Poland. The registry is an initiative of the Club of Polish Cardiac Surgeons in cooperation with the Polish Ministry of Health that commenced in 2006 and collects data from all 37 heart surgery centers in Poland (a list of contributing centers is provided in the Acknowledgment section at the end of the article). Centers enrolling patients in the KROK registry are required to transfer the data concerning every cardiac surgery to the central database in the National Centre for Healthcare Information Systems at the Ministry of Health and are financially liable for data integrity and completeness. Follow-up data regarding mortality were obtained from the National Health Fund—the nationwide, obligatory, public health insurance institution in Poland and incorporated to the registry. A registry module for collecting the data regarding myocardial infarctions (MIs), hospitalizations due to unstable angina, subsequent revascularizations, strokes, and other complications was under construction at the time of analysis.

Data Collection

A detailed questionnaire, defined according to standard definitions, including demographic data, history, physical findings, management, imaging studies, and outcomes, was developed. Data were collected either at presentation or by physician review of the hospital records and were forwarded to the KROK registry. The forms were reviewed for clinical face validity and analytical internal validity.

Study Population and Clinical Variables

Using the KROK participant user file, we identified patients undergoing MV surgery between 2006 and 2017. Of 34,267 MV surgery records, we excluded those without history of AF or AF at time of presentation. Both MV repairs and replacement surgeries were eligible; both MV stenosis and regurgitation could have served as an indication. Regurgitation underlying pathologies encompassed initially rheumatic, functional, degenerative, congenital, endocarditis, calcific, ischemic, and other causes of mitral regurgitation. To better corroborate the results as well as to follow the line of the current guidelines, these were retrospectively categorized into primary and secondary regurgitation according to pertinent definitions.²⁶

For patients undergoing MV surgery, we considered and report 3 categories of variables as potentially influencing the primary end point: baseline demographic characteristics (age, gender, European system for cardiac operative risk evaluation [EuroSCORE] score, diabetes, body mass, hypertension, poor mobility, pulmonary hypertension, chronic kidney disease, vascular disease, chronic lung disease, left ventricle ejection fraction [LVEF], coronary artery disease [CAD], previous MI, previous percutaneous coronary intervention, Canadian Cardiovascular Society, and New York Heart Association functional class), MV pathology (stenosis, regurgitation, and regurgitation grade and category), and surgical characteristics (redo, endocarditis, cardiogenic shock, intra-aortic balloon pump [IABP] use, critical preoperative state, intravenous inotropes/nitrites, and concomitant procedures).

Primary end point assessed was late survival in MV + ablation group versus MV alone group. Analyses of early postoperative mortality (<24 hours) and in-hospital mortality were performed as well. Additionally, operative times, length of intensive care unit (ICU) stay, and hospital stay (HLoS) are reported.

Statistical Analysis

Continuous, normally distributed variables were summarized as mean $\pm$ standard deviation. Variables with nonnormal distributions were summarized as median and interquartile range and compared with the Mann-Whitney *U* test or standard *t* test as appropriate. Categorical variables were expressed as number (%) and compared with the Fisher exact test. Cox proportional-hazards models were used to determine factors related to event-free survival. The ensuing statistical models were used to define the hazard ratios (HRs), point estimate, and 95% confidence interval (95% CI) of the effect size and to evaluate the efficacy of ablation with respect to MV surgery. Respective HRs for the comparison of MV + ablation patients versus MV alone patients were calculated and reported first for the univariate Cox proportional-hazards model taking into account all sets of variables categorized by baseline demographic characteristics, mitral valve pathology, and surgical characteristics. Next, a

multivariate model was built, again stratified on the 3 sets of variables. Interaction between univariate and multivariate variables was assessed with the use of the Cochran-Mantel-Haenszel test. The multivariate model was then tested for multicollinearity.

Propensity score analysis was performed to balance possible confounding between the 2 study groups with regard to selected variables to prevent any bias related to the initial selection of patients for MV surgery. Propensity scores were computed using a multiple logistic regression model in which the dependent variable was concomitant ablation and the independent variables were those for which the given variable returned an estimated effect ≥ 0.1 change in respective HR after multiple logistic regression. Regression adjustment was then fitted, resulting in increased precision for continuous outcome as described by Steyerberg.²⁷ A greedy match using nearest-neighbor method was used and 1 to-1 ratio, without replacement, within a specific caliper width of 0.2 standard deviations of the logit of the estimated propensity score. Propensity scores along with Wald χ^2 test results are reported with corresponding 95% CIs. To verify the balance between the MV + ablation versus and MV alone groups after propensity score matching, the standardized mean differences were computed and were < 0.1 in all cases. For the selected propensity score-matched population, univariate and multivariate Cox proportional hazard models were tested again and statistical differences reported. Overall late mortality was assessed with Kaplan-Meier curves fitted before (unadjusted model) and after propensity score matching. As a sensitivity analysis to assess the survival after concomitant ablation, patients were stratified according to defined subgroups and respective models unadjusted and propensity score match redone. STATA MP version 13.0 software (StataCorp, College Station, Tex) was used for computations.

RESULTS

During the 12-year study period, 34,267 patients undergoing MV surgery were identified. Among them 11,381 initially presented with AF. Subjects were divided into

FIGURE 1. Flow diagram of the current study cohort undergoing mitral valve (MV) surgery with or without concomitant surgical ablation for atrial fibrillation (AF).

MV + ablation (2449 [21.52%]) and MV alone (8932 [78.48%]) groups (see [Figure 1](#)). Median follow-up was 5 years (mean, 4.6 years; interquartile range, 1.9-7.9 years). Baseline characteristics along with clinical and surgical data are listed in [Table 1](#). Patients in the MV + ablation group were significantly younger (63.8 ± 8.7 years vs 66.1 ± 9.0 years; $P < .001$) and were at lower baseline surgical risk (mean EuroSCORE, 2.86 vs 3.69; $P < .001$). Despite similar percentage distribution of patients across ranges of Canadian Cardiovascular Society and New York Heart Association functional classes and LVEF, MV + ablation patients less often had previous MI (10.0% vs 15.4%) and underwent percutaneous coronary intervention (4.5% vs 6.8%). Regarding clinical characteristics at time of procedure, MV + ablation patients less commonly received intravenous inotropes (0.6% vs 3.3%; $P < .001$), or had an IABP inserted (0.4% vs 0.9%; $P = .003$) compared with the MV alone subgroup.

Primary mitral regurgitation was reported nearly twice as often in the entire population as secondary regurgitation (65.2% vs 31.0%; $P < .001$) and the proportion was maintained in subgroup comparison of MV + ablation versus MV alone (62.4% vs 66.0%; $P = .001$) and for primary and secondary mitral regurgitation (33.9% vs 31.2%; $P = .011$). Significantly more moderate mitral regurgitation was observed in patients undergoing MV + ablation than MV alone (40.3% vs 30.3%; $P < .001$). The details on operative data are presented in [Table 2](#).

Operative and Long-Term Data

Significantly more patients received MV replacement than MV repair 6843 (60.1%) versus 4538 (39.9%); $P < .001$. In the subgroup analysis, MV replacement was significantly more frequent in the MV alone group (62.1% vs 57.4%; $P < .001$).

Overall average cardiopulmonary bypass time was 128 ± 54 minutes and was 10 minutes shorter in the MV alone group than in the MV + ablation group (125 ± 53 minutes vs 136 ± 55 minutes; $P < .001$). Similarly, average crossclamp time was 83 ± 35 minutes in the overall analysis and was 8 minutes shorter in the MV alone group than the MV + ablation group (82 ± 35 minutes vs 90 ± 35 minutes; $P < .001$).

Average HLoS was 16 ± 22 days and ICU stay was 4.4 ± 11.8 days. There was no difference in either the duration of ICU stay between MV + ablation versus MV alone (4.4 days vs 4.4 days; $P = .941$) or HLoS ($P = .388$).

There was a difference in early postoperative mortality between MV + ablation versus MV alone groups in favor of MV + ablation (risk ratio, 0.58; 95% CI, 0.40-0.81; $P = .005$). In-hospital mortality was reduced as well (risk ratio, 0.72; 95% CI, 0.60-0.88; $P < .001$). Within investigated follow-up, unadjusted HR for long-term survival favored surgical ablation (HR, 0.71; 95% CI 0.63-

0.79; $P < .001$) ([Figure 2](#)). A list of remaining in-hospital outcomes is presented in [Table 3](#).

Propensity Score Analysis

One-to-1 propensity score-matched analysis resulted in 1784 pairs with similar baseline characteristics and operative covariates ([Tables 1](#) and [2](#)). List of variables contributing to propensity score along with respective propensity scores is available in [Table E1](#). Detailed analysis of standardized mean differences before and after propensity score matching comparing covariate values for patients undergoing MV + ablation versus MV alone ([Figure E1](#)) revealed that standard mean differences for the measured covariates were all < 0.1 , suggesting covariate balance across groups. Propensity score-matched late survival was estimated to HR 0.82; 95% CI, 0.70-0.96; $P = .011$. (see [Figure 2](#)). Hospital outcomes adjusted for propensity score are reported in [Table 3](#).

Sensitivity and Subgroup Analyses

A number of subgroup analyses were performed for comparison of MV + ablation versus MV alone before and after propensity score matching ([Figures 3](#) and [4](#)) with respect to the primary end point of long-term survival. In these analyses, several significant interactions with baseline ([Figure 3](#)) or procedure-related ([Figure 4](#)) variables were demonstrated. Before propensity score matching there was significantly higher extent of benefit in the MV + ablation subgroup of patients younger than age 50 years (HR, 0.36; 95% CI, 0.16-0.81; $P = .013$); with EuroSCORE score of 2 through 5 (HR, 0.42; 95% CI, 0.31-0.59; $P < .001$), without pulmonary hypertension (HR, 0.44; 95% CI, 0.31-0.62; $P < .001$), and in those without signs of heart failure (HR, 0.39; 95% CI, 0.19-0.81; $P = .012$). In contrast, there was no evident benefit with ablation in patients presenting with poor mobility (HR, 1.29; 95% CI, 0.74-2.27; $P = .371$), pulmonary hypertension (HR, 1.13; 95% CI, 0.84-1.51; $P = .432$), or decreased LVEF ($< 20\%$) (HR, 1.13; 95% CI, 0.53-2.42; $P = .750$). No significant interactions were observed in subgroup analyses stratified on procedure-related, mitral pathology, and surgery characteristics. Besides, the benefit of ablation was borderline less pronounced in patients undergoing a concomitant coronary artery bypass grafting procedure (HR, 0.81; 95% CI, 0.66-1.00 vs HR, 0.63; 95% CI, 0.55-0.72; $P_{\text{Interaction}} = .049$).

After propensity score matching, the direction of benefit with concomitant ablation was maintained across all subgroups of patients, yet was particularly appraised in patients with lower baseline surgical risk, such as those with EuroSCORE score < 5 and in those without diabetes, hypertension, kidney disease, IABP, intravenous inotropes, or endocarditis.

TABLE 1. Preoperative characteristics before and after propensity score (PS) matching

Variable	All patients				PS-matched patients			
	Total (N = 11,381)	MV + ablation (n = 2449)	MV alone (n = 8932)	P value	Total (N = 3568)	MV + ablation (n = 1784)	MV alone (n = 1784)	P value
Age (y)	66.3 (60.1-72.2)	64.5 (58.7-69.9)	66.8 (60.6-72.7)	<.001	65.2 (60.2-71.1)	64.9 (60.1-70.8)	65.3 (60.2-71.0)	.427
<50	539 (4.7)	171 (7.0)	368 (4.1)	<.001	118 (3.3)	65 (3.6)	57 (3.2)	.461
50-70	6961 (61.2)	1674 (68.4)	5287 (59.2)	<.001	1989 (55.7)	992 (55.9)	992 (55.6)	.999
>70	3881 (34.1)	604 (24.7)	3277 (36.7)	<.001	1461 (40.9)	722 (40.5)	739 (41.4)	.563
Gender								
Male	5298 (46.6)	1080 (44.1)	4218 (47.2)	.006	1638 (45.9)	813 (45.6)	825 (46.2)	.687
Female	6083 (53.4)	1369 (55.9)	4714 (52.8)	.006	1930 (54.1)	971 (54.4)	959 (53.8)	.687
EuroSCORE	1.65 (0.96-3.64)	1.46 (0.88-3.23)	1.70 (0.99-3.78)	<.001	1.55 (0.93-3.42)	1.52 (0.91-3.48)	1.57 (0.96-3.41)	.197
<2	6413 (56.4)	1479 (60.4)	4934 (55.2)	<.001	2088 (58.5)	1039 (58.2)	1049 (58.8)	.734
2-5	2970 (26.1)	631 (25.8)	2339 (26.2)	.674	904 (25.3)	457 (25.6)	447 (25.1)	.700
>5	1998 (17.8)	340 (13.9)	1658 (18.6)	<.001	576 (16.1)	288 (16.1)	288 (16.1)	.999
Diabetes	2689 (23.6)	484 (19.8)	2205 (24.7)	<.001	587 (16.9)	293 (16.4)	294 (16.5)	.964
Insulin dependent	858 (7.5)	154 (6.3)	704 (7.9)	.008	245 (6.9)	116 (6.5)	129 (7.2)	.389
Smoking	5146 (45.2)	1120 (45.7)	4026 (45.1)	.562	1996 (55.9)	992 (55.6)	1004 (56.3)	.686
Hypertension	8023 (70.5)	1595 (65.1)	6428 (71.9)	<.001	1076 (30.2)	535 (30.0)	542 (30.3)	.827
Poor mobility	389 (3.4)	62 (2.5)	327 (3.7)	.007	67 (1.9)	29 (1.6)	38 (2.1)	.266
Pulmonary hypertension	1737 (15.3)	408 (16.7)	1330 (14.9)	.031	799 (22.4)	408 (22.9)	391 (21.9)	.292
Moderate (PA systolic 31-55 mm Hg)	1215 (70.0)	309 (75.6)	906 (68.1)	.003	559 (70.0)	288 (70.1)	273 (69.8)	.490
Severe (PA systolic >55 mm Hg)	523 (30.0)	99 (24.4)	424 (31.9)	.003	220 (30.0)	120 (29.9)	118 (30.2)	.893
Renal impairment	3129 (27.5)	625 (25.5)	2505 (28.0)	.013	741 (20.7)	369 (20.6)	372 (20.8)	.942
Moderate (CC >50 and <85)	2276 (72.7)	497 (79.5)	1779 (71.0)	<.001	593 (80.0)	290 (78.5)	303 (81.4)	.559
Severe (CC <50)	817 (26.1)	125 (20.0)	692 (27.6)	<.001	145 (19.5)	79 (21.4)	66 (17.7)	.270
Dialysis (regardless of CC)	37 (1.2)	3 (0.5)	34 (1.4)	.077	3 (0.5)	1 (0.1)	2 (0.5)	.571
Vascular disease	1746 (15.3)	305 (12.5)	1441 (16.1)	<.001	723 (20.2)	359 (20.1)	364 (20.4)	.835
Extracardiac arteriopathy	1240 (10.9)	196 (8.0)	1044 (11.7)	<.001	291 (8.2)	133 (7.5)	158 (8.9)	.127
History of CVA	722 (6.3)	130 (5.3)	585 (6.6)	.025	245 (6.9)	129 (7.2)	116 (6.5)	.387
Chronic lung disease	931 (8.2)	180 (7.4)	750 (8.4)	.094	294 (8.2)	148 (8.3)	146 (8.2)	.903
Asthma	445 (3.9)	91 (3.7)	353 (4.0)	.593	98 (2.7)	45 (2.5)	53 (2.9)	.413
LVEF (%)	50 (40-60)	50 (45-60)	50 (40-60)	<.001	50 (40-60)	50 (40-60)	50 (40-60)	.746
<20	199 (2.0)	29 (1.4)	170 (2.2)	.013	57 (1.6)	26 (1.5)	31 (1.7)	.505
21-30	837 (8.6)	123 (5.8)	714 (9.4)	<.001	53 (1.5)	25 (1.4)	28 (1.6)	.967
31-50	4385 (45.1)	947 (44.7)	3438 (45.2)	.679	1413 (39.6)	711 (39.9)	702 (39.3)	.758
>50	4307 (44.3)	1021 (48.1)	3286 (43.2)	<.001	2045 (57.3)	1022 (57.3)	1023 (57.3)	.973
CAD	3055 (26.8)	528 (21.5)	2558 (28.6)	<.001	729 (20.4)	353 (19.8)	376 (21.1)	.339
1 VD	1133 (36.7)	221 (41.8)	912 (35.7)	.013	353 (48.4)	180 (51.0)	173 (46.0)	.6947
2 VD	878 (28.5)	158 (30.0)	720 (28.1)	.508	175 (24.0)	78 (22.1)	97 (25.8)	.165
3 VD	1044 (33.8)	149 (28.1)	895 (35.0)	.001	201 (27.6)	95 (26.9)	106 (28.2)	.140
Previous MI	1617 (14.2)	245 (10.0)	1372 (15.4)	<.001	358 (10.0)	179 (10.0)	179 (10.0)	.999
>1	349 (3.1)	57 (2.3)	292 (3.3)	.017	52 (1.5)	27 (1.5)	25 (1.5)	.780
Previous PCI	721 (6.3)	111 (4.5)	610 (6.8)	<.001	200 (5.6)	100 (5.6)	100 (5.6)	.999
CCS								
0	3589 (31.5)	895 (36.5)	2694 (30.2)	<.001	1203 (33.7)	601 (33.7)	602 (33.7)	.971
1	3358 (29.5)	742 (30.3)	2616 (29.3)	.354	1039 (29.1)	526 (29.5)	513 (28.8)	.632
2	3046 (26.8)	567 (23.2)	2479 (27.8)	<.001	910 (25.5)	440 (24.7)	470 (26.3)	.249

(Continued)

TABLE 1. Continued

Variable	All patients				PS-matched patients			
	Total (N = 11,381)	MV + ablation (n = 2449)	MV alone (n = 8932)	P value	Total (N = 3568)	MV + ablation (n = 1784)	MV alone (n = 1784)	P value
3	1174 (10.3)	217 (8.9)	957 (10.7)	.008	360 (10.1)	188 (10.5)	172 (9.6)	.374
4	214 (1.9)	28 (1.1)	186 (2.1)	.003	56 (1.6)	29 (1.6)	27 (1.5)	.788
NYHA functional class								
0	187 (1.7)	45 (1.8)	142 (1.6)	.402	37 (1.0)	19 (1.1)	18 (1.0)	.879
I	567 (5.0)	136 (5.6)	431 (4.9)	.137	176 (4.9)	82 (4.6)	94 (5.3)	.165
II	3605 (31.9)	850 (35.1%)	2755 (31.0)	<.001	1155 (32.4)	568 (31.8%)	587 (32.9)	.497
III	5769 (51.0)	1238 (51.0)	4531 (51.0)	.969	1942 (54.4)	963 (54.0)	979 (54.9)	.141
IV	1180 (10.4)	156 (6.5)	1024 (11.5)	<.001	266 (7.5)	142 (8.0)	124 (7.0)	.329

Values are presented as median (interquartile range) or n (%). PS, Propensity score; MV, mitral valve; EuroSCORE, European system for cardiac operative risk evaluation; PA, pulmonary artery; CC, creatinine clearance; CVA, cardiovascular accident; LVEF, left ventricle ejection fraction; CAD, coronary artery disease; VD, vessel disease; MI, myocardial infarction; PCI, percutaneous coronary intervention; CCS, Canadian Cardiovascular Society; NYHA, New York Heart Association.

The detailed analysis with reporting for both univariate and multivariate Cox proportional hazards model is presented in Table E2.

DISCUSSION

AF, which is common among patients undergoing MV surgery, is a risk factor for death and morbidity.⁵⁻⁹ AF correction performed at the time of index MV surgery procedure is safe and effective in restoring sinus rhythm,

as reflected in the current American guidelines,²¹ which assigned Class I, Level A-recommendation stating that surgical ablation for AF can be performed without additional risk of operative mortality or major morbidity. European Society of Cardiology/European Society of Cardiothoracic Surgery guidelines recommend surgical ablation in patients undergoing cardiac surgery to improve symptoms attributable to AF, balancing the added risk of the procedure and the benefit of rhythm control therapy. A patient's high

TABLE 2. Operative characteristics before and after propensity score (PS) matching

Procedure-related characteristic	All patients				PS-matched patients			
	Total (N = 11,381)	MV + ablation (n = 2449)	MV alone (n = 8932)	P value	Total (N = 3568)	MV + ablation (n = 1784)	MV alone (n = 1784)	P value
Redo surgery	966 (8.5)	64 (2.9)	902 (10.1)	<.001	182 (5.1)	91 (5.1)	91 (5.1)	.818
Endocarditis	379 (3.3)	28 (1.2)	351 (3.9)	<.001	147 (4.1)	71 (3.9)	76 (4.3)	.674
Cardiogenic shock	127 (1.1)	4 (0.2)	123 (1.4)	<.001	6 (0.2)	2 (0.1)	4 (0.2)	.423
Critical preoperative state	233 (2.0)	16 (0.7)	217 (2.4)	<.001	28 (0.8)	12 (0.7)	16 (0.8)	.449
IABP	92 (0.8)	8 (0.4)	84 (0.9)	.003	16 (0.4)	8 (0.4)	8 (0.4)	.999
Intravenous inotropes	313 (2.7)	14 (0.6)	299 (3.3)	<.001	30 (0.8)	13 (0.7)	17 (0.8)	.465
Intravenous nitrates	1087 (9.6)	316 (14.0)	771 (8.6)	<.001	276 (7.7)	138 (7.7)	138 (7.7)	.999
Mitral pathology								
Mitral regurgitation grade								
Trivial	578 (5.1)	81 (3.6)	497 (5.6)	<.001	165 (4.6)	79 (4.4)	86 (4.8)	.436
Mild	1067 (9.4)	247 (11.0)	821 (9.2)	.179	321 (8.9)	172 (9.6)	149 (8.3)	.178
Moderate	3614 (31.8)	907 (40.3)	2708 (30.3)	<.001	1001 (28.0)	492 (27.5)	509 (28.5)	.526
Severe	5607 (49.3)	1113 (49.5)	4495 (50.3)	<.001	1890 (52.9)	940 (52.6)	950 (53.2)	.737
Mitral pathology								
Primary	7425 (65.2)	1527 (62.4)	5898 (66.0)	.001	2497 (65.9)	1254 (70.3)	1243 (69.7)	.688
Secondary	3615 (31.8)	830 (33.9)	2785 (31.2)	.011	1068 (29.9)	534 (29.9)	534 (29.9)	.999
Mitral valve stenosis	3261 (28.7)	721 (32.0)	2540 (28.4)	.331	1020 (28.6)	510 (28.6)	510 (28.6)	.999
Surgery								
MV replacement	6843 (60.1)	1292 (57.4)	5551 (62.1)	<.001	2140 (59.9)	1070 (59.9)	1070 (59.9)	.999
MV + CABG	2621 (23.0)	459 (20.4)	2161 (24.2)	<.001	819 (22.9)	414 (23.2)	405 (22.7)	.720
MV + AV	2145 (18.9)	400 (17.8)	1745 (19.5)	<.001	68 (1.9)	35 (1.9)	33 (1.8)	.806
MV + TV	4890 (43.0)	1190 (52.9)	3700 (41.4)	<.001	1424 (39.9)	714 (40.0)	710 (39.7)	.891

Values are presented as n (%). PS, Propensity score; MV, mitral valve; IABP, intra-aortic balloon pump; CABG, coronary artery bypass grafting; AV, aortic valve; TV, tricuspid valve.

FIGURE 2. Unadjusted and propensity score (PS)-matched Kaplan-Meier survival curves between the 2 groups: mitral valve (MV) + ablation versus MV alone. Hazard ratios (HRs) and respective 95% confidence intervals (CIs) in the MV + ablation compared with MV alone.

baseline risk and reoperation status occasionally triggers the decision not to perform ablation^{21,28} because it may prolong the cardiopulmonary bypass and crossclamp times. Yet, most of the available studies suggest that worse risk profiles are not a contraindication to surgical ablation and others found reduced mortality in high-risk patients.¹⁸ In this contradictory context, demonstration of a

survival benefit in patients with mitral disease after surgical ablation has long been difficult.^{23,29}

The above divergences may be due to limited sample sizes and follow-up duration in randomized controlled trials; indeed, the first Scandinavian randomized controlled trial of 69 patients with permanent AF undergoing MV surgery with or without epicardial left atrial cryoablation found

TABLE 3. In-hospital outcomes before and after propensity score (PS) matching

	All patients				PS-matched patients			
	MV + ablation (n = 2449)	MV alone (n = 8932)	Risk ratio (95% confidence interval)	P value	MV + ablation (n = 1784)	MV alone (n = 1784)	Risk ratio (95% confidence interval)	P value
Early postoperative mortality	31 (1.3)	192 (2.1)	0.58 (0.40-0.81)	.005	25 (1.4)	49 (2.7)	0.51 (0.32-0.82)	.005
In-hospital mortality	124 (5.1)	621 (6.9)	0.72 (0.60-0.88)	<.001	98 (5.5)	138 (7.7)	0.71 (0.55-0.91)	.007
Cardiac tamponade and/or rethoracotomy	290 (11.8)	1031 (11.5)	1.03 (0.91-1.16)	.682	220 (12.3)	243 (13.6)	0.90 (0.76-1.07)	.252
Periprocedural MI	11 (0.4)	64 (0.7)	0.63 (0.33-1.19)	.151	11 (0.6)	15 (0.8)	0.73 (0.34-1.59)	.434
Respiratory failure	216 (8.8)	795 (8.9)	0.99 (0.86-1.14)	.901	209 (11.7)	214 (12.0)	0.98 (0.82-1.17)	.796
Prolonged ICU stay	52 (2.1)	146 (1.6)	1.30 (0.95-1.78)	.102	34 (1.9)	43 (2.4)	0.9 (0.51-1.23)	.301
Neurologic complications	72 (2.9)	313 (3.5)	0.84 (0.65-1.08)	.172	65 (3.6)	89 (5.0)	0.73 (0.53-0.99)	.049
Multiorgan failure	77 (3.1)	358 (4.0)	0.78 (0.62-1.00)	.055	58 (3.3)	91 (5.1)	0.64 (0.46-0.88)	.006
Gastrointestinal complications	27 (1.1)	146 (1.6)	0.67 (0.45-1.01)	.059	25 (1.4)	32 (1.8)	0.78 (0.46-1.31)	.351
Acute kidney failure	65 (2.7)	273 (3.1)	0.87 (0.67-1.13)	.300	54 (3.0)	57 (3.2)	0.95 (0.66-1.37)	.772
Sternal wound infection	30 (1.2)	131 (1.5)	0.84 (0.56-1.24)	.371	29 (1.6)	31 (1.7)	0.93 (0.57-1.55)	.795

Values are presented as n (%), unless otherwise noted. PS, Propensity score; MV, mitral valve; MI, myocardial infarction; ICU, intensive care unit.

FIGURE 3. Hazard ratios (HRs) and 95% confidence intervals (CIs) for death from any cause in the mitral valve (MV) + ablation group compared with MV alone group according to selected preoperative baseline characteristics. *EuroSCORE*, European system for cardiac operative risk evaluation; *LVEF*, left ventricle ejection fraction; *CAD*, coronary artery disease; *VD*, vessel disease; *MI*, myocardial infarction; *PCI*, percutaneous coronary intervention; *CCS*, Canadian Cardiovascular Society; *NYHA*, New York Heart Association. * P value for the treatment effect. ** P value for the interaction between pre- and post propensity score (PS) matching estimates. *** P value for the interaction between subgroup components (after PS matching).

FIGURE 4. Hazard ratios (HRs) and 95% confidence intervals (CIs) for death from any cause in the mitral valve (MV) + ablation group compared with MV alone group according to selected procedural characteristics. IABP, Intra-aortic balloon pump; iv, intravenous; CABG, coronary artery bypass grafting; AV, aortic valve; TV, tricuspid valve. * P value for the treatment effect. ** P value for the interaction between pre- and post propensity score (PS) matching estimates. *** P value for the interaction between subgroup components (after PS matching).

65 patients reached the primary end point of regaining sinus rhythm.³⁰ At 12 months' follow-up, maintenance rate was 73.3% but the study was underpowered for in-hospital complications and did not report longer than 1 year results. In a

Cardiothoracic Surgical Trials Network trial involving 260 patients with persistent or long-standing persistent AF, the addition of surgical ablation at the time of MV surgery significantly increased the rate of freedom from AF at

1 year.⁴ Risk of major cardiac or cerebrovascular adverse events at 1 year was not different (HR, 0.76; 95% CI, 0.32-1.84; $P = .55$) but ablation was associated with a 2.6-fold increased risk of implantation of a permanent pacemaker, which soon after became an argument against performing surgical AF corrections. A meta-analysis of 1900 patients from 22 randomized controlled trials³¹ found individuals undergoing surgical ablation were indeed more likely to need a pacemaker following the procedure (7% vs 4% [only 1.7-fold increase]), whereas in the recent STS analysis of 4449 patients undergoing surgical ablation,³² permanent pacemaker implantation followed in 1.03%, suggesting in turn center/operator success dependence.

In contrast to previous randomized controlled trials, several observational series with larger data sets have shown signs of remote benefits in patients undergoing MV surgery and concomitant ablation¹¹⁻¹⁷ and in particular in patients at high risk; in fact, in the largest-to-date report from STS on multiple valve procedures¹⁸ (predicted mortality 13.1% for 3-valve surgeries), in patients undergoing arrhythmia ablation procedures^{16,32,33} in the aortic valve + MV group and aortic valve + MV + tricuspid valve procedures group, preoperative plus intraoperative models had lower predicted mortality risk than patients not receiving these procedures (odds ratio [OR], 0.85; 95% CI, 0.73-0.98 and OR, 0.77; 95% CI, 0.60-0.99, respectively, for aortic-mitral and aortic-mitral-tricuspid valves). Nevertheless, lack of substantial but first of all, randomized data regarding the long-term success and potential clinical influence of surgical AF correction on hard clinical outcomes (eg, survival and stroke) remains among the most significant gaps in the current literature.

The current study focus was long-term survival after MV surgery in patients with AF undergoing concomitant surgical ablation. The main finding arising from this report is significant survival benefit in the MV + ablation subgroup. The benefit was further maintained after propensity matching and in a number of subgroup analyses performed to support the advantage of ablation across diverse clinical presentations at baseline but also across different surgical scenarios.

KROK is an ongoing, nationwide, multi-institutional registry of heart surgery procedures in Poland. It is among the oldest European heart surgery registries of its kind. There were almost 35,000 patients undergoing MV surgeries in Poland between 2006 and 2017 of whom 11,400 (33%) presented with AF, which is in line also with most recent American observations.^{18,19} Exactly mirroring the overseas trends,²⁸ we observed higher rates of MV replacements in the MV without ablation (62.1%) compared with increasing rates of repairs in MV + ablation subsets (52.6%). Another issue that becomes apparent is a significant underuse of ablation in the current analysis (21.5% [2449 out of 11,381]). Although partially reflecting current

trends, we find this phenomenon disturbing, given that a majority of patients included in both MV + ablation and MV alone groups were in fact at low risk (6413 [56.4%] had EuroSCORE score < 2). Self-explanatory is the fact that prior registry studies reported selection biases toward avoiding ablation in higher-risk patients³³ given the complexity of adding an antiarrhythmic procedure,^{34,35} higher AF recurrence rates in some groups of patients,⁴ and above all time consumption. Indeed, reluctance to perform ablation may reflect concerns about prolonging crossclamp times. In our study, cardiopulmonary bypass time and crossclamp time were on average 10 and 8 minutes longer, respectively, in patients undergoing concomitant ablation. The concern of prolonging operative times is unjustified because there were no differences in ICU stay and HLoS. Ad and colleagues¹⁰ reported that addition of Cox-maze procedure to MV procedures—even with a high degree of complexity—did not increase operative risk and demonstrated acceptable rhythm success, reduced AF burden, and resulted in remarkably low stroke rates in the long-term. Baseline risk and underlying conditions will be clinicians' primary focus in the early postoperative course in higher-risk patients rather than ablation's success itself. It is therefore of great importance to force AF correction surgeries at the time of MV repair or replacement because these patients are more likely to benefit from ablation in the long-term in terms of survival.

It should be noted that individual surgeon experience and training influences significantly the results of long-term surgical ablation for AF, highlighting the potentially crucial role of education and training in increasing implementation and ablation success rates, and thus long-term survival. Ad and colleagues¹⁰ found addition of Cox-maze procedure to MV procedures—even with a high degree of complexity—did not raise the operative mortality; however, correlating with ablation success was surgeon experience (OR, 0.98; 95% CI, 0.96-0.997; $P = .025$). Apparent from Gillinov and colleagues⁴ and reflected in the STS guidelines²¹ is the certain need for appropriate training and education that should be completed before the performance of surgical ablation and we highly recommend surgeons who are new to surgical AF to be proctored by an experienced surgeon in 3 to 5 cases before performing surgical ablation alone.

To better reflect the effect of long-term survival benefit in the present report, hazard analyses were additionally performed across different patient populations. In an unadjusted analysis, significant benefit was still present in higher-risk patients such as those with diabetes, chronic kidney disease, CAD, and chronic obstructive pulmonary disease irrespective of MV underlying pathology. Neither benefit nor harm was demonstrated in subgroups of patients older than age 70 years, with poor mobility, reduced ejection fraction (<20%), and pulmonary hypertension, suggesting these patients may not benefit from concomitant

ablation to the extent of their healthier counterparts in terms of survival. The above trends were mostly retained after propensity score matching, suggesting more pronounced benefit with surgical ablation in lower-risk patients. Unlike Rankin and colleagues,¹⁸ we found that addition of aortic valve or tricuspid valve surgery did not influence the long-term survival between ablation and nonablation groups. Hence, the magnitude and direction of the estimate in favor of ablation was maintained in this group of patients without apparent differences. Proving the robustness and validity of our investigation, the results of subgroup analyses suggest convergent, albeit lower, benefit of ablation in higher burden of CAD, secondary mitral regurgitation and concomitant coronary artery bypass grafting. This finding justifies the role and relevance of ablation in ischemic heart disease as well. Nonsignificant interactions in the survival estimates after ablation were found as well in the comparisons of MV replacement versus MV repair ($P = .167$) and MV regurgitation versus MV stenosis ($P = .254$), in turn suggesting consistent effect across MV underlying pathologies.

Limitations

The current registry was not designed to assess in detail the effectiveness of concomitant ablation; therefore, conversions to sinus rhythm and maintenance rates are not available. In the current literature, these range from 90% to 97% in Cox-maze III and IV procedures, down to approximately 60% in less-established lesions sets and variable energy sources.^{E1,29} A new module of the registry to collect data regarding rehospitalizations and other complications such as stroke is underway and will in the future allow for such analyses. We could not account for left atrial appendage closure rates and ablation durations, techniques, and immediate success rates because these were not obligatory to complete during registry conception.

Whether left atrial appendage may translate into reduced risk of stroke will be shown in ongoing studies,^{E2} but it can be assumed that with higher prevalence of left atrial appendage closures the number of strokes might drop as well as adding to survival benefits. Analysis of permanent pacemaker implantation was not performed because most patients requiring permanent pacemaker were transferred to cardiology departments while receiving temporary epicardial pacing. Because this is performed outside surgery departments, cardiology procedures following surgery were not introduced into the registry.

CONCLUSIONS

Concomitant surgical ablation for AF in patients undergoing MV procedures is safe and feasible. In an unadjusted analysis and after rigorous propensity matching, surgical ablation was associated with improved long-term survival as well.

Conflict of Interest Statement

Authors have nothing to disclose with regard to commercial support.

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Key Words: mitral valve, registry, surgical ablation, long-term results, atrial fibrillation

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FIGURE E1. Standardized mean differences (SMDs) before and after propensity-score matching comparing covariate values for patients undergoing mitral valve (MV) +ablation versus MV alone. The positioning of the estimates within -0.1 to 0.1 suggests good model fit. *iv*, Intravenous; *NYHA*, New York Heart Association; *MI*, myocardial infarction; *CCS*, Canadian Cardiovascular Society; *LVEF*, left ventricle ejection fraction; *EuroSCORE*, European system for cardiac operative risk evaluation.

TABLE E1. Propensity scores

Variable	Wald/ χ^2	Standard error	Score	95% Confidence interval	Odds ratio	95% Confidence interval	P value
CCS = 0	66.734	0.155	-1.264	-0.961 to -1.568	0.282	0.209 to 0.382	.000
NYHA = 0	54.732	0.153	-1.134	-0.834 to -1.435	0.322	0.238 to 0.434	.000
CKD = 1	44.955	0.151	-1.013	-0.717 to -1.309	1.363	1.270 to 1.488	.000
AV = 1	13.305	0.157	0.574	0.866 to 0.282	1.563	1.414 to 0.767	.000
CABG = 1	28.450	0.061	0.327	0.447 to 0.207	1.387	1.230 to 1.564	.000
COPD = 1	19.505	0.081	0.359	0.519 to 0.200	1.432	1.221 to 1.680	.000
PCI = 1	16.229	0.091	0.366	0.544 to 0.188	1.442	1.207 to 1.723	.000
REDO = 1	32.274	0.081	0.460	0.618 to 0.301	1.584	1.351 to 1.856	.000
LVEF >50 = 1	6.822	0.049	0.128	0.224 to 0.032	1.136	1.032 to 1.251	.009
Insulin-dependent T2DM = 1	4.065	0.088	0.178	0.351 to 0.005	1.195	1.005 to 1.421	.044
HT = 1	5.923	0.054	0.132	0.239 to 0.026	1.141	1.026 to 1.270	.015
Poor mobility = 1	7.273	0.148	0.399	0.109 to 0.688	1.671	1.502 to 1.897	.007
PHT = 1	347.024	0.049	-0.914	-0.818 to -1.010	1.401	1.364 to 1.441	.000

CCS, Canadian Cardiovascular Society; NYHA, New York Heart Association; CKD, chronic kidney disease; AV, aortic valve; CABG, coronary artery bypass grafting; COPD, chronic obstructive pulmonary disease; PCI, percutaneous coronary intervention; REDO, reoperation; LVEF, left ventricle ejection fraction; T2DM, type 2 diabetes mellitus; HT, hypertension; PHT, pulmonary hypertension.

TABLE E2. Cox proportional hazard univariate and multivariate model estimates before and after propensity score (PS) matching

Model	Univariable				Multivariable				P for interaction	
	Unadjusted hazard ratios		After PS matching hazard ratios		Unadjusted hazard ratios		After PS matching hazard ratios		Unadjusted P interaction	After PS matching P for interaction
	HR (95% CI)	P value	HR (95% CI)	P value	HR (95% CI)	P value	HR (95% CI)	P value		
Baseline characteristics										
Age	1.10 (1.00-1.12)	.002	1.04 (1.01-1.36)	.008	—	—	—	—	—	—
Gender	1.06 (1.04-1.12)	.006	0.87 (0.68-0.97)	.013	0.85 (0.82-0.89)	<.001	—	—	.119	—
EuroSCORE	1.02 (1.01-1.02)	<.001	1.03 (1.02-1.04)	<.001	1.06 (1.06-1.07)	<.001	0.97 (0.96-0.98)	<.001	.089	<.001
Diabetes										
No diabetes/diet	0.83 (0.64-0.99)	.037	1.10 (0.89-1.27)	.322	—	—	—	—	—	—
Oral antihyperglycemic drugs	0.65 (0.36-0.88)	.002	0.79 (0.41-1.09)	.184	—	—	—	—	—	—
Diabetes on insulin	1.15 (1.02-1.27)	.028	1.01 (0.67-1.27)	.921	—	—	—	—	—	—
Smoking	1.10 (1.01-1.19)	.034	1.02 (0.86-1.16)	.745	—	—	—	—	—	—
Hypertension	1.13 (1.05-1.21)	.003	1.19 (1.03-1.31)	.019	—	—	—	—	—	—
Poor mobility	1.62 (1.24-2.11)	<.001	0.66 (0.51-1.28)	.354	—	—	—	—	—	—
Pulmonary hypertension	2.73 (2.50-2.98)	<.001	2.51 (2.14-2.94)	<.001	1.29 (1.24-1.35)	<.001	2.90 (2.47-3.40)	<.001	.365	<.001
Chronic kidney disease	0.94 (0.82-1.08)	.379	1.17 (0.94-1.35)	.145	—	—	—	—	—	—
Vascular disease	1.41 (1.31-1.50)	<.001	1.40 (1.20-1.56)	<.001	—	—	—	—	—	—
Chronic lung disease	1.29 (1.19-1.38)	<.001	1.28 (1.08-1.44)	.009	1.15 (1.08-1.21)	<.001	1.30 (1.16-1.42)	<.001	.903	.051
LVEF (%)										
<20	0.77 (0.28-1.12)	.233	0.96 (0.20-1.40)	.896	—	—	—	—	—	—
20-30	0.89 (0.67-1.07)	.229	0.98 (0.62-1.24)	.877	—	—	—	—	—	—
30-50	0.95 (0.85-1.04)	.278	1.04 (0.88-1.18)	.578	—	—	—	—	—	—
>50	1.05 (0.96-1.12)	.264	0.97 (0.80-1.11)	.677	—	—	—	—	—	—
CAD										
No CAD	1.09 (0.94-1.23)	.224	1.04 (0.83-1.21)	.710	—	—	—	—	—	—
1 VD	1.03 (0.82-1.20)	.775	1.07 (0.78-1.29)	.601	—	—	—	—	—	—
2 VD	1.03 (0.82-1.21)	.760	1.07 (0.69-1.34)	.676	—	—	—	—	—	—
3 VD	0.99 (0.86-1.15)	.934	0.65 (0.06-1.07)	.111	—	—	—	—	—	—
Previous MI	1.06 (0.94-1.20)	.314	1.06 (0.94-1.20)	.089	—	—	—	—	—	—
Previous PCI	1.22 (1.10-1.33)	.001	1.34 (1.14-1.50)	.003	—	—	1.22 (1.01-1.40)	.045	—	.472
CCS										
No signs of angina	0.56 (0.45-0.71)	<.001	0.38 (0.25-0.58)	<.001	0.84 (0.80-0.89)	<.001	—	—	.001	—
1	0.51 (0.41-0.64)	<.001	0.68 (0.56-0.82)	<.001	—	—	—	—	—	—
2	0.45 (0.36-0.56)	<.001	1.88 (1.20-2.95)	.006	—	—	1.23 (1.07-1.37)	.006	—	.078
3	0.32 (0.25-0.40)	<.001	2.00 (1.38-2.58)	<.001	—	—	1.50 (1.36-1.60)	<.001	—	.185
4	1.62 (1.53-1.69)	<.001	2.45 (1.54-3.91)	<.001	—	—	1.59 (1.36-1.74)	<.001	—	.082
NYHA										
No signs of heart failure	0.76 (0.33-1.08)	.163	0.63 (0.29-1.43)	.488	—	—	—	—	—	—
I	0.77 (0.46-1.02)	.078	1.14 (0.81-1.38)	.359	—	—	—	—	—	—
II	0.77 (0.55-0.95)	.011	0.84 (0.63-1.02)	.083	—	—	—	—	—	—

(Continued)

TABLE E2. Continued

Model	Univariable				Multivariable				P for interaction	
	Unadjusted hazard ratios		After PS matching hazard ratios		Unadjusted hazard ratios		After PS matching hazard ratios		Unadjusted P interaction	After PS matching P for interaction
	HR (95% CI)	P value	HR (95% CI)	P value	HR (95% CI)	P value	HR (95% CI)	P value		
III	0.95 (0.78-1.10)	.548	1.17 (1.04-1.29)	.014	—	—	1.20 (1.07-1.32)	.003	—	.772
IV	1.08 (0.94-1.24)	.292	0.74 (0.36-1.03)	.085	—	—	—	—	—	—
Procedural characteristics										
Redo surgery	1.31 (1.21-1.40)	<.001	1.35 (1.13-1.52)	.005	1.10 (1.02-1.19)	.014	1.29 (1.06-1.46)	.018	.770	.139
Endocarditis	1.08 (0.84-1.39)	.526	0.92 (0.39-1.28)	.716	—	—	—	—	—	—
Cardiogenic shock	1.13 (0.69-1.87)	.620	1.02 (0.22-1.46)	.944	—	—	—	—	—	—
Critical preoperative state	0.83 (0.31-1.20)	.417	0.95 (0.30-1.35)	.841	—	—	—	—	—	—
IABP	1.31 (0.93-1.56)	.095	1.37 (0.82-1.66)	.148	—	—	1.50 (1.07-1.74)	.030	—	.514
Intravenous inotropes	1.09 (0.74-1.34)	.574	0.93 (0.40-1.29)	.757	—	—	1.35 (1.11-1.52)	.006	—	.736
Intravenous nitrates	1.20 (1.08-1.31)	.003	0.94 (0.58-1.21)	.693	—	—	—	—	—	—
Mitral pathology										
Mitral regurgitation grade										
No regurgitation	0.88 (0.72-1.08)	.227	1.04 (0.62-1.32)	.842	—	—	—	—	—	—
Trivial	0.97 (0.80-1.17)	.752	1.13 (0.81-1.37)	.388	—	—	—	—	—	—
Mild	0.92 (0.79-1.06)	.249	1.13 (0.88-1.32)	.276	—	—	—	—	—	—
Moderate	0.97 (0.88-1.06)	.493	1.11 (1.07-1.39)	.04	—	—	1.23 (1.00-1.40)	.046	—	.299
Severe	0.97 (0.90-1.06)	.525	1.06 (0.90-1.19)	.451	—	—	—	—	—	—
Mitral regurgitation										
Primary	0.90 (0.79-1.00)	.062	0.94 (0.75-1.11)	.512	—	—	0.78 (0.55-0.97)	.021	—	.368
Secondary	1.10 (1.00-1.21)	.062	1.06 (0.89-1.25)	.512	—	—	—	—	—	—
Mitral valve stenosis	1.19 (0.84-1.44)	.674	1.03 (0.50-1.39)	.857	—	—	—	—	—	—
Surgery										
MV repair	0.92 (0.84-1.01)	.072	1.01 (0.84-1.15)	.911	0.94 (0.90-0.98)	.004	—	—	.675	—
MV replacement	1.08 (0.99-1.16)	.072	0.99 (0.85-1.16)	.911	—	—	—	—	—	—
Concomitant procedure										
MV + CABG	1.26 (1.18-1.33)	<.001	2.48 (1.56-3.94)	<.001	—	—	—	—	—	—
MV + AV	1.18 (1.05-1.32)	.004	0.92 (0.10-1.39)	.803	—	—	—	—	—	—
MV + TV	1.08 (0.99-1.17)	.091	1.02 (0.87-1.18)	.843	1.04 (1.00-1.08)	.039	—	—	.514	—
Status										
Elective	0.67 (0.43-1.04)	.072	0.98 (0.79-1.14)	.797	—	—	—	—	—	—
Urgent	0.82 (0.53-1.28)	.384	1.05 (0.88-1.20)	.517	1.05 (1.00-1.11)	.042	—	—	.271	—
Emergency	1.16 (0.77-1.75)	.466	1.36 (1.26-1.42)	.191	—	—	2.30 (1.08-4.87)	.031	—	.172
Late survival	0.71 (0.63-0.79)	<.001	0.82 (0.70-0.96)	.011	0.92 (0.87-0.96)	<.001	0.72 (0.51-0.90)	.002	<.001	.484

PS, Propensity score; HR, hazard ratio; CI, confidence interval; EuroSCORE, European system for cardiac operative risk evaluation; LVEF, left ventricle ejection fraction; CAD, coronary artery disease; VD, vessel disease; MI, myocardial infarction; PCI, percutaneous coronary intervention; CCS, Canadian Cardiovascular Society; NYHA, New York Heart Association; IABP, intra-aortic balloon pump; MV, mitral valve; CABG, coronary artery bypass grafting; AV, aortic valve; TV, tricuspid valve.