Original Article

Novel Aortic Valve Replacement Technique for Reducing Complete Heart Block

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Abstract

Background: *Aortic valve replacement (AVR) may complicate conduction abnormalities and require permanent pacemaker (PPM) implantation. New techniques that lessen this challenge may lead to the development of new approaches. Our objective was to evaluate the contemporary incidence of early postoperative PPM implantation in patients undergoing isolated AVR and root disease with the standard AVR surgical technique compared with the novel suture AVR technique.*

Methods: *The clinical data of 354 patients (250 male, 104 female) who underwent surgery for isolated AVR and root disease in different referral cardiology departments in Tabriz, Iran, over 4 years were analyzed. Patients with preoperative significant conduction abnormalities were excluded from the study. The patients were evaluated for in-hospital mortality, postoperative PPM implantation, and their stay in the ICU after surgery.*

Results: *The mean age of the patients was 52.46±16.13 years. Totally, 183 patients (51.7%) were operated on with the new suture AVR technique. In-hospital mortality was lower in this group than in the group that underwent the "classic" surgical technique (2.5% vs 3.7%). PPM implantation was required in 3 patients (0.8%) after the novel suture AVR technique, whereas it was needed in 12 patients (3.4%) in the other group (P=0.024). The mortality rate was 9 patients (2.5%) in group 1 and 13 patients (3.7%) in group 2, which was not statistically significant (P=0.296). According to the logistic regression, the survival rate in the group operated on with the classical surgical method was 0.27 times higher than that in the patients operated on with the new method.*

Conclusion: *Permanent complete AV block is a critical complication after AVR surgery. A lower PPM requirement and higher survival in patients operated on with the new method was the main finding of this study. New techniques with lower PPM requirements may be suitable for cardiac surgery.*

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Keywords: *Aortic valve; Replacement; Pacemaker; Heart block*

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Introduction

In most patients, aortic valve replacement (AVR) is the treatment of choice for severe aortic stenosis with left ventricular dysfunction. Standard AVR is performed via a median sternotomy with cardiopulmonary bypass. After aortotomy, the pathological parts of the valve are resected, and the annulus is debrided. A series of interrupted or continuous sutures are placed under direct vision to anchor the new valve (Figure 1).[1,2] This phenomenon progresses with age and restricts the opening of the aortic valve. Overall, AVR results in better functional status and improvement in hemodynamics, especially in patients with severe aortic stenosis or a low transvalvular pressure gradient.[3,4] Despite all these advantages, AVR also has disadvantages, including the need for the implantation of a permanent pacemaker (PPM) due to complete heart block (CHB).[5]

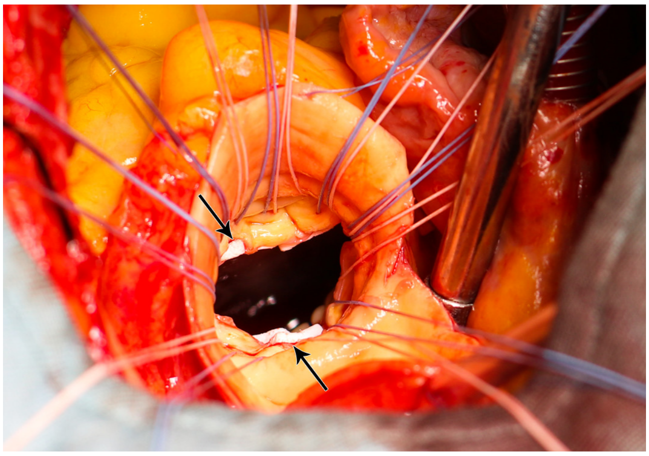

Figure 1. The image illustrates felted sutures in the standard technique. The arrows show the direction of the felted sutures from the inside of the aortic annulus.

CHB is a type of arrhythmia in which the atria and ventricles contract independently. It is caused by an obstruction or block in the electrical conduction system.[6] The incidence of CHB as a complication of AVR may be due to the spread of calcium from the aortic valve and ring to the interventricular septum and, thus, the consequent disruption of the conduction tissue (Omran AM. Aortic valve replacement: Could it be a treatment for complete heart block? J Egypt Soc Cardio-Thoracic Surg 2016;24:308–311). Studies suggest that the incidence of CHB requiring the implantation of PPM after AVR is 3% to 6%, depending on the type of surgery.[7]

Nonetheless, we would like to introduce a new trend in AVR with a new technique and focus on its advantages over the standard AVR method. The cardiac conduction system passes posteriorly through the membranous septum between the right coronary and noncoronary cusp commissures.[8-10] In this new procedure, 2 to 3 felted sutures are placed outside the aortic ring. The sutures must emerge from the right part of the aortic valve attachment to the hinge line (annuli). This method has been performed in Tabriz hospitals since May 2009 (Figure 2 & Video 1).

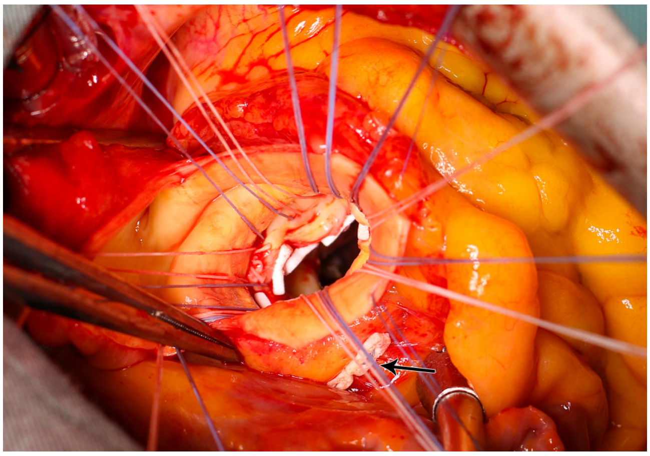

Figure 2. The image demonstrates felted sutures in the novel technique. The arrow shows that the felted sutures run from the outside of the aortic annulus to the inside of the right commissural/noncoronary cusp.

The present retrospective study aimed to investigate the prevalence rates of late PPM implantation (the need for a pacemaker within 6 months to 1 year after surgery), in-hospital mortality, the ICU length of stay, the X-clamp duration, and the bypass duration with the standard and novel methods of AVR.

Methods

We performed a retrospective cohort study of a consecutive series of patients operated on between April 2012 and December 2018 at Shahid Madani Heart Hospital, Tabriz, Iran (a referral cardiac hospital in northwestern Iran) using the standard and our novel suture AVR technique. Inclusion criteria were severe aortic valve and aortic root disease with an indication for valve replacement. Nine different surgeons operated on the included patients. One hundred eighty-three patients were operated on by 1 surgeon using the novel AVR surgical method (group 1), and 171 patients were treated by 8 different surgeons using the classic AVR technique (group 2). Echocardiography was performed on all the patients, which is a prerequisite for referral for surgery.

All the procedures were performed via the conventional midline approach and a complete median sternotomy. Cardiopulmonary bypass with the standard flow rate and perfusion pressure of 60 mmHg to 80 mmHg was utilized in all the procedures. The procedures were carried out in moderate hypothermia. Myocardial protection was provided with cardioplegia, selectively into the coronary ostia or retrogradely via a coronary sinus cannula, depending on the surgeon's preference. The left ventricle was drained via the right upper pulmonary vein vent. The native aortic valve was resected in all the cases, with annular calcification removed.

In the new surgical technique, 2 to 3 felted mattress sutures were placed from the outside of the aortic valve in the commissure between the right and noncoronary cusps. The sutures were placed in such a way that enables the passing of the needle from the outside to the annulus of the aorta for attachment to the hinge line (the attachment place of the leaflets to the aortic annulus) with a view to minimizing the possibility of damage to the conduction system.

Following the surgery, the patients were managed in the ICU. Standard monitoring included the following vital parameters: 5-lead electrocardiography, central venous pressure, oxygen saturation, and blood pressure by invasive measurement. Electrolyte levels were controlled. All the patients were protected with an epicardial lead, and external pacing was used in case of complete atrioventricular (AV) blocks or other bradyarrhythmias. The indication for PPM implantation was the persistence of a complete AV block exceeding 7 to 10 days after the operation in accordance with the recommendations of the Electrophysiology Studies (EPS) group. Acquired AV blocks, such as the complete third-degree AV block with or without symptoms or the high-degree AV block, and CHB are considered the salient reasons for PPM implantation.[11]

In the current retrospective study, the entire study population signed informed consent before surgery. In the data gathering stage, anonymized data provided by sampling centers were drawn upon. All patient information was kept confidential.

The Kolmogorov-Smirnov goodness-of-fit test was conducted to evaluate the normality of data distribution. Quantitative data were expressed as the mean (±standard error of the mean [SEM]), and qualitative data were reported as frequencies (percentages). The independent sample *t* and χ^2 tests were used to compare the 2 study groups. The Mann-Whitney *U* test was applied to compare differences between nonparametric variables. The statistical software SPSS (SPSS Inc, IL, Chicago, USA), version 24, was employed for data entry and analysis. A *P* value of less than 0.05 was considered significant.

Results

The present study evaluated 354 patients, of whom 183 (51.7%) underwent the novel technique (cases) and 171 (48.3%) the standard AVR technique (controls). Additionally, 338 patients (95.5%) did not have a late pacemaker, whereas 15 (4.2%) needed PM implantation. Before surgery, aortic stenosis was not observed in 171 patients (48.6%), while 136 patients (38.4%) had severe aortic stenosis. Aortic insufficiency was not observed in echocardiography in 58 patients (16.4%), as opposed to 200 patients (56.5%) who had severe aortic insufficiency. The Bentall-De Bono operation was performed on 70 patients (19.8%).

Table 1 presents the baseline characteristics of the study population. No significant differences existed regarding the mean age and height between the 2 groups. The prevalence rates of right bundle branch block (RBBB), chest pain, hypertension, smoking, and hyperlipidemia were higher in group 2, whereas left bundle branch block (LBBB), dyspnea, fatigue, and diabetes mellitus were significantly more frequent in group 1. The frequency of coronary artery bypass graft surgery (CABG) history was higher in group 2 (66.7%) than in group 1 (33.3%). Whereas the mean values of systolic blood pressure, fasting blood sugar, triglycerides, and high-density lipoprotein were higher in group 1, the mean values of diastolic blood pressure, total cholesterol, and the low-density lipoprotein were higher in group 2.

A comparison between quality and quantity indicators is shown in Table 2. The mortality rate was 9 patients (2.5%) in group 1 and 13 (3.7%) in group 2, which was not significantly different (P=0.296). There were no significant differences between the 2 groups regarding aortic stenosis (P=0.080) and aortic insufficiency (P=0.337). The type of Bentall-De Bono operation had a nonsignificant difference between the groups (P=0.199). The Bentall-De Bono operation had no adverse effects in terms of mortality in the 2 study groups.

The mean total bypass time was 152.18±58.04 (23-435) minutes. The mean duration of the X-clamp was 112.24±45.45 (11-300) minutes. The average ICU length of stay was 6.11±6.43 days, and the lengthiest stay in the ICU was 78 days. The 2 groups were also compared concerning the mean values of these variables (Table 2). The comparisons between the bypass duration, the X-clamp duration, and the ICU length of stay in the 2 groups are given in Table 2. The mean duration of the X-clamp was significantly higher in group 2 (P=0.002).

The relationships between PPM implantation, surgery type (the Bentall-De Bono operation), aortic stenosis, aortic insufficiency, and mortality are shown in Table 3. PPM implantation had a significant relationship with mortality (P=0.004) and aortic stenosis (P<0.001).

As shown in Table 4, the relationships between in-hospital mortality, the Bentall-De Bono operation, aortic stenosis, and aortic insufficiency were not statistically significant.

The results of the logistic regression performed for the in-hospital mortality rate showed that only the ICU length of stay and group variables were significant, meaning that the chance of survival in the group undergoing the classical surgical method was lower than that in the group operated on with the novel surgical method (Table 5).

Table 1. Baseline Characteristics

Variable	Group 1	Group 2
Age (y)	52.88±17.02	52.02±15.16
Height (cm)	166.7612.25	166.4±10.86
Weight (kg)	70.73±13.54	74.87±16.89
Sex		
Male	128 (51.2)	122 (48.8)
Female	55 (52.9)	49 (47.1)
RBBB	7 (43.8)	9 (56.3)
LBBB	14 (73.7)	5 (26.3)
Dyspnea	102 (51.3)	97 (48.7)
Fatigue	21 (75)	7 (25)
Chest pain	27 (38)	44 (62)
HTN	78 (4.6)	86 (52.4)
Smoking	24 (33.8)	47 (66.2)
HLP	1 (6.7)	14 (93.3)
DM	27 (56.3)	21 (43.8)
CABG. history	2 (33.3)	4 (66.7)
SBP (mmHg)	123.55±55.75	120.33±16.93
DBP (mmHg)	71.71±10.51	73.72±10.12
FBS	110.89±59.32	99.06±34.26
TC mg/dL)	153.51±44.05	162.04±43.42
TG (mg/dL)	138.44±86.03	124.07±72.62
LDL (mg/dL)	92.65±37.17	94.18±33.54
HDL (mg/dL)	43.64±19.71	39.81±18.02

*Data are given as means±SEM and frequencies (percentages).
Group 1, New AVR surgical method; Group 2, Classic AVR technique; RBBB, Right bundle branch block; LBBB, Left bundle branch block; HTN, Hypertension; HLP, Hyperlipidemia; DM, Diabetes mellitus; SBP, Systolic blood pressure; DBP, Diastolic blood pressure; FBS, Fasting blood sugar; TC, Total cholesterol; LDL, Low-density lipoprotein; HDL, High-density lipoprotein

Table 2. Comparison between Quality and Quantity Indicators between the 2 Groups (frequencies (%))

	Groups		P
	Group 1	Group 2	
Mortality	9 (2.5)	13 (3.7)	0.296†
AS			0.08†
No	87 (25.1)	84 (24.2)	
Severe	79 (22.8)	57 (16.4)	
Moderate	11 (3.2)	20 (5.8)	
Mild	3 (0.9)	6 (1.7)	
AI			0.337†
No	35 (10.1)	23 (6.2)	
Severe	104 (30)	96 (27.7)	
Moderate	29 (8.4)	36 (10.4)	
Mild	11 (3.2)	13 (3.7)	
Bentall-De Bono operation	41 (11.6)	29 (8.2)	0.199†
Bypass time	157.85±59.33	146.15±56.19	0.060*
X-clamp time	120.56±45.41	103.37±43.92	0.002**
ICU stay	6.22±6.71	5.97±6.13	0.712*

†χ^2 test
*Independent samples t test
**Mann-Whitney U test
Group 1, New AVR surgical method; Group 2, Classic AVR technique; AS, Aortic stenosis; AI, Aortic insufficiency

Table 3. Relationship between PPM and Quality Indicators (frequencies (%))

	PPM (No)	P
Mortality	18 (5.1)	0.004
AS		<0.001
No	168 (48.4)	
Severe	128 (36.9)	
Moderate	28 (8.1)	
Mild	8 (2.3)	
AI		0.920
No	55 (15.9)	
Severe	191 (55)	
Moderate	62 (17.9)	
Mild	24 (6.9)	
Bentall-De Bono operation	65 (18.4)	0.359

AS, Aortic stenosis; AI, Aortic insufficiency; PPM, Permanent pacemaker implantation

Table 4. Relationship between Mortality and Quality Indicators (frequencies (%))

	Mortality		P*
	Yes	No	
AS			0.388
No	11 (3.2)	160 (46.1)	
Severe	10 (2.9)	126 (36.3)	
Moderate	0	31 (8.9)	
Mild	0	9 (2.6)	
AI			0.684
No	3 (0.9)	55 (15.9)	
Severe	11 (3.2)	189 (54.5)	
Moderate	6 (1.7)	59 (17)	
Mild	1 (0.3)	23 (6.6)	
Bentall-De Bono operation	9 (2.5)	61 (17.2)	0.016

*P value based on the χ^2 test.
AS, Aortic stenosis; AI, Aortic insufficiency

Table 5. Logistic Regression for the Mortality Rate

	OR (95% CI)	P*
ICU (d)	0.88 (0.79-0.99)	0.047
Group	0.27 (0.080-0.91)	0.036

*P value based on the logistic regression test

Discussion

Following aortic valve surgery, the incidence rate of bradycardia is approximately 2% to 7%, which is usually caused by persistent, complete AV block and requires PPM implantation.[12] PPM is the major reason for prolonged in-hospital stays and increased hospital mortality. The main risk factors for PPM implantation after AVR have not been elucidated, but risk factors such as preoperative conduction disturbances (eg, LBBB and RBBB) and redo operations are very likely. Small aortic roots, bicuspid aortic valve surgery, and concurrent operations (CABG and mitral valve replacement lengthening the X-clamp and cardiopulmonary bypass duration) increase the likelihood of PPM implantation.[13, 14] Bagur et al[15] assessed 780 older individuals who had undergone surgery and reported that 3.2% of the patients had PPM within 30 days following AVR. The authors recognized LBBB and RBBB based on preprocedural electrocardiography as the leading independent PPM predictors following AVR. Additionally, the mortality and survival rates in a 5-year follow-up were similar between the patients who underwent AVR and received PPM and those who did not need PPM following AVR. Another study involving 101 patients in Harefield Hospital in London showed that the PPM incidence rate after AVR varied between 0.8% and 3.4%.[16] Another study reported that PPM implantation was performed on 6.6% of 3534 patients undergoing isolated AVR. Furthermore, the in-hospital mortality rate was 4.2% in the patients undergoing PPM implantation. The mortality rate for remote AVR patients with PPM was 1.4%. On the other hand, the PPM group underwent additional cardiac procedures (CABG, mitral valve replacement, subaortic stenosis resection, and re-operations) compared with the patients without PPM implantation.[17] Klapkowski et al[18] reported that PPM implantation was associated with prolonged cardiopulmonary bypass and aortic cross-clamp duration and larger implanted valve size.

We aimed to reduce the incidence of CHB by decreasing the hospital stay, cost, and mortality in patients undergoing AVR. Fortunately, we managed to confer long-term survival and improved quality of life to our patients by assessing the leading cause of CHB and the relationship between the cardiac conduction system and the anatomical structure of the aorta in the membranous septum area. Our results showed lower PPM requirements and mortality rates in patients undergoing new surgery technique. Furthermore, we did not observe any complications (eg, leakage) in patients undergoing new surgical technique. The bypass duration, the X-clamp duration, and the ICU length of stay after the new technique were longer; nevertheless, these results may be due to the high number of Bentall operations in this group.

Our study has noteworthy limitations, the most prominent of which is its retrospective design. Secondly, we could not investigate factors such as the causes of death, arrhythmia-related deaths, and postmortem examinations. Further prospective studies may confer more robust results in this realm.

Conclusion

Reduced PPM and in-hospital mortality rates after AVR surgery with our new suture technique were the principal findings of the present study. The introduction of new techniques with reduced PPM needs is safe and could be suitable for all AVR operations.

Acknowledgments

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To watch the following videos, please refer to the relevant URLs:

https://jthc.tums.ac.ir/index.php/jthc/article/view/1659/1079

Video 1. The video shows suturing steps with a new technique. In this technique, 2 to 3 felted sutures are inserted from the outside of the aorta and passed out of the hinge lines of the aortic cusp.