



Does Concomitant Tricuspid Annuloplasty Increase the Need for Permanent Pacemaker Implantation Following Mitral Valve Replacement?

Rezan Aksoy¹, Emre Selçuk², Ayhan Küp³, Deniz Çevirme¹, Üzeyir Yılmaz¹, Veysel Başar¹, Furkan Balcı¹, Murat Bülent Rabuş¹

¹ Department of Cardiovascular Surgery, Kartal Kosuyolu High Specialization Training and Research Hospital, Istanbul, Turkey

² Department of Cardiovascular Surgery, Faculty of Medicine, University of Bezmialem Vakif, Istanbul, Turkey

³ Department of Cardiology, Kartal Kosuyolu High Specialization Training and Research Hospital, Istanbul, Turkey

ABSTRACT

Introduction: This study compared the frequency of permanent pacemaker implantation (PPI) following mitral valve replacement (MVR) with tricuspid annuloplasty (TAP) and isolated MVR.

Patients and Methods: This retrospective study analysed 409 patients who had undergone MVR with or without concomitant TAP, from January 2015 through May 2020. Patients were divided into two groups (the isolated MVR group and the MVR plus TAP group). The two groups were compared according to whether PPI was present or not.

Results: A total of 409 consecutive patients [in the isolated MVR group, n= 212 patients; 129 (60.8%) female and in the MVR plus TAP group, n= 197 patients; 138 (70.1%) female] were assessed. The number of female, functional mitral regurgitation, mixed mitral disease, and the use of bio-prosthetic valve was higher in the MVR plus TAP group (p< 0.01). A total of 8 (2%) patients needed a PPI. There was no statistically significant difference between the two groups in terms of PPI (p> 0.01). The frequency of postoperative PPI was 2.2% (7 of 311 patients) in patients with rheumatic etiology and 1.1% (1 of 98 patients) in patients with non-rheumatic etiology (OR: 2.026, 95% CI: 0.24-16.68, p= 0.5). The median time to implantation was seven days [minimum postoperative days (POD) 5, maximum POD 45].

Conclusion: When isolated MVR is considered and if the patient also has tricuspid regurgitation (TR), it is apparent that TAP will be inevitable, because TR inflicts a considerable burden on the patient's quality of life. Recent studies reported varying frequencies of PPI after TAP accompanying left valve surgery. The present study observed no increase in the use of PPI after MVR accompanied by TAP as compared with isolated MVR.

Key Words: Mitral valve replacement; tricuspid annuloplasty; permanent pacemaker implantation.

Mitral Kapak Replasmanına Eşlik Eden Triküspid Annuloplasti Kalıcı Pacemaker İhtiyacını Arttırır mı?

ÖZ

Giriş: Bu çalışmada, mitral valve replasmanı (MVR) ile birlikte triküspid annuloplasti (TAP) ve izole MVR sonrası kalıcı pacemaker implantasyonu (KPI) sıklığı karşılaştırılmıştır.

Hastalar ve Yöntem: Bu retrospektif çalışmada, Ocak 2015 tarihinden Mayıs 2020 tarihine kadar TAP ile birlikte MVR veya TAP olmadan MVR uygulanan 409 hasta analiz edilmiştir. Hastalar izole MVR ve MVR + TAP olarak iki gruba ayrılmıştır. İki grup KPI olup olmasına göre karşılaştırılmıştır.

Bulgular: Çalışmada toplam 409 ardışık hasta [izole MVR grubu: 212 hasta, 129 (%60.8)'u kadın, MVR + TAP grubu: 197 hasta, 138 (%70.1)'i kadın] değerlendirilmiştir. Kadın hasta sayısı, fonksiyonel mitral yetmezliği ve biyoprotez kapak kullanımı MVR + TAP grubunda daha yüksek bulunmuştur (p< 0.01). Toplam 8 (%2) hastanın KPI'ya ihtiyacı olmuştur. İki grup arasında KPI açısından istatistiksel olarak anlamlı bir fark tespit edilmemiştir (p> 0.01). Romatizmal etiyojisi olan hastalar için postoperatif KPI sıklığı %2.2 (311 hastanın yedisi), romatizmal olmayan etiyojisi olan hastalar için %1.1 (98 hastadan biri) olarak saptanmıştır (OR= 2.026, %95 CI= 0.24-16.68, p= 0.5). Ortalama implantasyon süresi yedi gün olarak belirlenmiştir (minimum postoperatif beşinci gün, maksimum postoperatif 45. gün).

Cite this article as: Aksoy R, Selçuk E, Küp A, Çevirme D, Yılmaz Ü, Başar V, et al. Does concomitant tricuspid annuloplasty increase the need for permanent pacemaker implantation following mitral valve replacement? Koşuyolu Heart J 2021;24(1):8-14.

Correspondence

Rezan Aksoy

E-mail: rezanaksoy@gmail.com

Submitted: 11.01.2021

Accepted: 01.02.2021

Available Online Date: 01.04.2021

© Copyright 2021 by Koşuyolu Heart Journal. Available on-line at www.kosuyoluheartjournal.com

Sonuç: İzole MVR düşünüldüğünde ve hastada triküspit yetmezliği varsa, triküspit yetmezliğinin hastanın yaşam kalitesine önemli bir yük getireceği için TAP'ın kaçınılmaz olacağı açıktır. Son çalışmalar, sol kapak cerrahisine eşlik eden TAP sonrası değişen sıklıklarda KPI bildirmişlerdir. Bu çalışmada, izole MVR'ye kıyasla TAP eşliğinde MVR sonrası KPI kullanımında artış gözlemlenmiştir.

Anahtar Kelimeler: Mitral kapak replasmanı; triküspid annuloplasti; kalıcı pacemaker implantasyonu.

INTRODUCTION

Permanent pacemaker implantation (PPI) is performed with frequencies of 5.6% and 7.9% after dual and triple valve replacements, respectively, leading to an increased risk of PPI requirement, as the number of valves replaced rises. Following valve surgeries, temporary pacemaker (TPA) is usually required⁽¹⁾. PPI does not frequently appear to be necessary, which is 5% after cardiac surgery⁽²⁻⁵⁾. PPI is associated with a long period of mechanical ventilation, intensive care unit (ICU) stay and hospital stay⁽²⁻⁴⁾. Older age (> 60 years of age), male sex, emergency surgery and comorbidities such as diabetes mellitus (DM), heart failure and kidney injury were independent predictors for PPI⁽¹⁾.

PPI is more frequent following multiple valve surgeries^(4,6). Anterior mitral valve leaflet and septal tricuspid valve leaflet are in close proximity to the conduction systems, which can be damaged by surgical trauma^(4,7).

The current study compared the frequency of PPI following mitral valve replacement (MVR) with tricuspid annuloplasty (TAP) and isolated MVR.

PATIENTS and METHODS

This retrospective study analysed 409 patients who had undergone MVR with or without concomitant TAP at the same centre, from January 2015 through May 2020. The data were retrieved from follow-up files and hospital records. A total of 409 consecutive patients who electively had undergone isolated MVR or MVR plus TAP were included into the study, being divided into two groups (the isolated MVR group n= 212 patients; and the MVR plus TAP group n= 197 patients). Additionally, the two groups were compared according to whether PPI was present or not.

The data included the demographics characteristics and past clinical history, types of surgery and specifics, pre- and post-operative electrocardiographic (ECG) features. Additionally, we followed up the patients who had PPI following surgery up to five years.

The exclusion criteria were: emergency surgery, mitral valve repair, pre-operative PPI, concomitant surgical ablation (such as maze procedures), concomitant other cardiac surgeries

(coronary artery bypass grafting, aortic valve surgeries, aortic surgery or adult congenital surgeries), unstable cardiac condition and preoperative infective endocarditis.

Echocardiographic Evaluation

All patients underwent echocardiographic examination before and after the operation. The echocardiographic findings were evaluated by echocardiographic cardiologists. Mitral valve pathologies were assessed with respect to etiology (rheumatic or degenerative etiology). Tricuspid regurgitation was evaluated with color Doppler imaging to assess jet area by using parasternal short axis view, the right ventricular inflow view, and the apical four chamber view.

Outcomes and Follow-up

All patients were observed by echocardiographic examination, evaluation of ECG features, valve functions and the requirement of PPI in the postoperative period. The two groups were compared with respect to post-operative findings and long-term survival rates.

Surgical Procedure

All surgeries were performed using aortic arterial and bi-caval venous cannulations for cardiopulmonary bypass (CPB). Myocardial protection with mild hypothermia was achieved by intermittent antegrade cardioplegia and/or retrograde cardioplegia. While the mechanical prosthetic valve was the most commonly used material as the artificial valve, biological prosthetic valve replacement was performed in elderly patients or women considering pregnancy. Tricuspid annuloplasty was performed through the right atriotomy. The choice of the technique for TAP was left to the surgeons. When the ring annuloplasty was planned for tricuspid valve repair we used a 3D rigid tricuspid ring for all patients. During the postoperative period, warfarin was recommended as a life-long oral anticoagulant treatment to all patients with a mechanical prosthetic valve.

Statistical Analysis

Due to the inability of randomization with regard to tricuspid valve intervention, a propensity score (PS) was generated for

each patient from a multivariable logistic regression model based on preoperative and intraoperative covariates as independent variables with isolated MVR versus MVR via TAP as a binary dependent variable. Covariates included in the PS model were age, gender, DM, hypertension, chronic obstructive pulmonary disease, chronic kidney disease, severe pulmonary hypertension (PABs > 55 mmHg), LV dysfunction (ejection fraction < 45%) preoperative medications (beta-blockers, calcium canal blockers, digoxin, other antiarrhythmics) usage, etiology (degenerative, rheumatic, functional), mitral valve pathology (stenosis, regurgitation, mixt), pre-existing rhythm disturbance (atrial fibrillation or any other conduction disorders), and prosthetic valve type. Pairs of patients were derived nearest neighbour 1:1 matching with a calliper of a width of 0.2 SD of the logit of the PS. The quality of the match was assessed by comparing selected variables in PS-matched patients using the standardized mean difference, for this, an absolute standardized mean difference greater than 10% is proposed to represent a significant covariate imbalance. Matching was performed using the “MatchIt” package, and covariate balance was assessed using “cobalt”, balance improvements presented using the “love.plot” command. Categorical variables were presented as counts and frequencies; continuous variables as mean (Standard deviation, SD) or median (Interquartile range, IQR) as appropriate. The Chi-square test or the Fisher’s exact test was used for comparison between categorical variables. The Student t-test or Mann-Whitney U test was used to compare continuous variables. A two-tailed p value of 0.05 was considered statistically significant. R Statistical Software (version 3.6.3; R Foundation for Statistical Computing, Vienna, Austria) was used for all statistical analysis⁽⁸⁻¹⁰⁾.

RESULTS

A total of 409 consecutive patients [in the isolated MVR group: 212 patients; 129 (60.8%) female and in the MVR plus TAP group: 197 patients; 138 (70.1%) female] were assessed. Thirty-nine patients (18.4%) were > 65 years of age in the isolated MVR group, 38 (19.3%) patients were > 65 years age in the MVR plus TAP group (p= 0.81). Patients were stratified according to the presence or absence of TAP. Severe pulmonary hypertension, degenerative mitral disease, regurgitation and stenosis were more pronounced in the isolated MVR group (p< 0.01). The number of women, functional MR, mixed mitral disease, the use of bio-prosthetic valve were higher in the MVR plus TAP group (p< 0.01). After PS matching, the two groups of 120 patients were obtained. Balance improvement after the propensity match is illustrated in Figure 1.

The two groups were comparable for all pre-treatment variables after being matched. Table 1 shows the variables of the patients.

Postoperative TPM was warranted in 95 patients (23%). There was no statistically significant difference between the two groups in terms of TPM and in the PS matched population (p> 0.01). A total of 8 patients (four patients in the isolated MVR group, four patients in the MVR plus TAP group) needed PPI (2%). The frequency of postoperative PPI was 2.2% (7 of 311 patients) in patients with rheumatic etiology and 1.1% (1 of 98 patients) in patients with non-rheumatic etiology (OR: 2.026, 95% CI: 0.24-16.68, p= 0.5) (Table 2).

PPI was implanted in 6 of 8 patients due to a complete AV block. The time to median implantation was 7 days [minimum postoperative days (POD) 5, maximum POD 45]. The PPI and TPM data are presented in Table 3.

DISCUSSION

PPI requirement following heart operation is associated with increased rate of morbidity, longer hospital stay and higher costs^(1,11). We examined whether concomitant TAP increases the frequency for PPI following MVR. Functional MR, mixed mitral disease, the use of bio-prosthetic valve and the number of female patients were higher in the MVR plus TAP group. The frequency of postoperative PPI was 2% and there were no difference between the groups with respect to etiology. Of eight patients who underwent PPI, six had a complete AV block. The two groups showed no statistically significant difference with respect to PPI. Moreover, patients in the two groups who underwent PPI showed no difference with respect to etiology.

The frequency of PPI was about 7% in patients undergoing aortic valve replacement and was about 4% in patients undergoing MVR and 21% in patients undergoing tricuspid valve operations (replacement or repair)⁽¹¹⁻¹⁴⁾. Jouan et al. found that the incidence of PPI was 2.6% following isolated MV repair⁽¹⁵⁾. The current study showed that the frequency of PPI was 2% following MVR with/without TAP. There was no between-group difference at the follow up at five years.

Several studies reported that female gender and older age (> 75 years) were predictive risk factors for PPI⁽¹⁶⁻¹⁸⁾. However, some studies showed no difference in the frequency of PPI in two sexes, which is consistent with our findings⁽¹⁸⁾. The preoperative arrhythmia, conduction disturbances and chronic comorbidities were linked to an elevated risk for PPI, which occurred within 30 days after operation⁽¹⁹⁾. We found

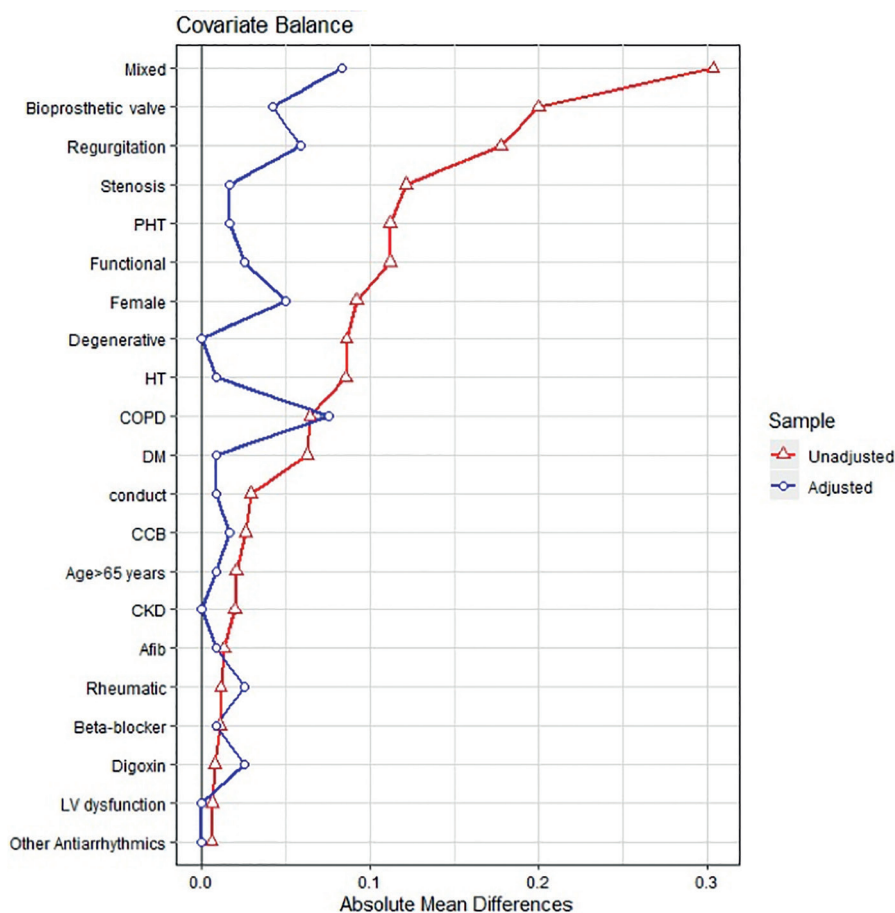


Figure 1. Balance improvements for baseline variables before and after propensity matching.

Pulmonary hypertension (PHT): Severe pulmonary hypertension (PABs > 55 mmHg), HT: Hypertension, COPD: Chronic obstructive pulmonary disease, DM: Diabetes mellitus, CCB: Calcium channel blockers, CKD: Chronic kidney disease, Conduct: Any other conduction disorders, Afib: Atrial fibrillation, LV Dysfunction: Left ventricular dysfunction, ejection fraction < 45%.

that advanced age (> 65 years of age) and gender showed no difference between the two groups.

Several studies reported that preoperative conduction disorders such as right or left bundle branch block and first-degree AV block or left anterior fascicular block warranted PPI^(11,17). The presence of bradycardia further increases the risk for PPI^(20,21). Of eight patients who underwent PPI, six had a complete AV block in this study.

Operative trauma to conduction system has been shown to bring about PPI, posing a risk factor for conduction disorders associated with AV node^(20,23). Following aortic, mitral and tricuspid valve surgeries, PPI are more widely mandated^(5,24). Ghamdi et al. showed that prolonged CBP and cross-clamping time raised the risk for PPI⁽¹⁸⁾. Chronic kidney disease was linked to conduction disturbances and atrial fibrillation based on pathological myocardial remodelling and fibrosis^(25,26). Jouan

et al. showed that prolonged cross clamping time and TAP were independent predictors for conduction disorders, unlike our findings⁽¹⁵⁾. PPI was an increased risk factor for mitral valve surgery with concomitant TAP different from our findings. The frequency of PPI was higher in tricuspid valve replacement than in aortic and mitral valve replacements^(12,27).

The European Society of Cardiology guideline recommends an observation of seven days for AV block and from five days to several weeks for sinoatrial dysfunction after cardiac surgery prior to PPI^(28,29). Permanent pacemaker was reported to be implanted at day five postoperatively after valve surgery⁽²⁸⁾. However, Jouan et al. recommended that, prior to performing PPI, patients should be observed up to 14 days following mitral valve surgery with TAP⁽¹⁵⁾. In this study, PPI was implanted, on average, on the 7th postoperative day (ranging from 5 to 45 days postoperatively). In early

Table 1. Baseline characteristics of study population

Variables	Before Match			After Match			Before	After
	Isolated MVR	MVR + TAP	p value	Isolated MVR	MVR + TAP	p value		
Number of patients	212	197		120	120			
Female gender, n (%)	129 (60.8)	138 (70.1)	0.02	84 (70.0)	78 (65.0)	0.4	0.092	-0.05
Age > 65 years, n (%)	39 (18.4)	38 (19.3)	0.81	70 (58.3)	71 (59.2)	0.89	-0.05	0.0083
DM, n (%)	94 (44.3)	75 (38.1)	0.19	51 (42.5)	52 (43.3)	0.86	-0.0627	0.0083
COPD, n (%)	89 (42.0)	70 (35.5)	0.18	43 (35.8)	52 (43.3)	0.235	-0.0645	0.075
HT, n (%)	27 (12.7)	42 (21.3)	0.02	19 (15.8)	20 (16.7)	0.86	0.0858	0.0083
CKD, n (%)	12 (5.7)	15 (7.6)	0.42	6 (5)	6 (5)	1	0.0195	0
PHT, n (%)	84 (39.6)	56 (28.4)	0.01	36 (30.0)	38 (31.7)	0.78	-0.112	0.0167
LV dysfunction, n (%)	3 (1.4)	4 (2.0)	0.63	2 (1.7)	2 (1.7)	1	0.0062	0
Beta-blocker, n (%)	144 (67.9)	136 (69.0)	0.8	85 (70.8)	84 (70.0)	0.88	0.0111	-0.0083
CCB, n (%)	27 (12.7)	20 (10.2)	0.41	15 (12.5)	13 (10.8)	0.68	-0.0258	-0.0167
Digoxine, n (%)	20 (9.4)	17 (8.6)	0.88	15 (12.5)	12 (10)	0.54	-0.008	-0.025
Other antiarrhythmics, n (%)	12 (5.7)	10 (5.1)	0.79	8 (6.7)	8 (6.7)	1	-0.0058	0
Rheumatic, n (%)	166 (78.3)	152 (77.2)	0.78	99 (82.5)	96 (80)	0.62	-0.0114	-0.025
Degenerative, n (%)	29 (13.7)	10 (5.1)	0.004	8 (6.7)	8 (6.7)	1	-0.086	0
Functional, n (%)	14 (6.6)	35 (17.8)	0.001	13 (10.8)	16 (13.3)	0.55	0.1116	0.025
Regurgitation, n (%)	127 (59.9)	79 (40.1)	0.001	70 (58.3)	63 (52.5)	0.36	-0.1777	-0.0583
Stenosis, n (%)	58 (27.4)	20 (10.2)	0.001	24 (20)	22 (18.3)	0.74	-0.1213	-0.0167
Mixed, n (%)	25 (11.8)	98 (49.7)	0.001	25 (20.8)	35 (29.2)	0.13	0.3034	0.0833
Afib, n (%)	19 (9.0)	15 (7.6)	0.62	10 (8.3)	9 (7.5)	0.81	-0.0135	-0.0083
Other conduction disorders, n (%)	11 (5.2)	16 (8.1)	0.233	10 (8.3)	11 (9.2)	0.81	0.0293	0.0083
Bioprosthetic valve, n (%)	34 (16.0)	71 (36.0)	0.001	30 (25)	25 (29.2)	0.46	0.2	0.0417

MVR: Mitral valve replacement, TAP: Tricuspid annuloplasty, DM: Diabetes mellitus, COPD: Chronic obstructive pulmonary disease, HT: Hypertension, CKD: Chronic kidney disease, PHT: Pulmonary hypertension, LV: Left ventricle, CCB: Calcium channel blocker, Afib: Atrial fibrillation.

Table 2. Postoperative PPI and TPM requirements according to the type of operation in the overall study cohort and PS-matched population

	Unmatched (n= 409)	MVR (n= 212)	MVR + TAP (n= 197)	p value	Matched (n= 240)	MVR (n= 120)	MVR + TAP (n= 120)
PPI, n (%)	8 (2)	4 (1.9)	4 (2.0)	0.36	4 (2.1)	2 (1.7)	3 (2.5)
TPM, n (%)	95 (23.2)	46 (21.7)	49 (24.9)	0.44	55 (22.9)	26 (21.7)	29 (24.2)

MVR: Mitral valve replacement, TAP: Tricuspid annuloplasty, PPI: Permanent pacemaker implantation, TPM: Temporary pacemaker, PS: Propensity score.

postoperative period TPM was warranted in 23% of patients. However, after postoperative seven days, PPI was required in 2% of patients, of whom four were in the isolated MVR group and four in the MVR plus TAP group. The two groups did not differ with respect to PPI.

Jouan et al. showed that requirement for PPI was enhanced after concomitant TAP, different from our results⁽¹⁵⁾. Jokinen

and colleagues followed up 136 consecutive patients undergoing tricuspid valve operations for nearly eight years and they reported that PPI may prevent from fatal bradyarrhythmia following tricuspid surgery in the long term follow-up. However, PPI appears to have a risk for endocarditis and thromboembolic complications⁽¹⁴⁾. Several studies examined TAP with left sided valve surgeries and found that concomitant

Table 3. The PPI and TPM data presentation

Patients	Age (years)	Sex	Pathology	Operation	Indication for PPI	Postoperative day of PPI
1	48	F	Rheumatic-Stenosis	MVR (mechanical)	3 rd degree AV block	5
2	37	F	Rheumatic-Stenosis	MVR (mechanical)	3 rd degree AV block	8
3	48	F	Functional-Regurgitation	MVR (mechanical) + Tricuspid ring annuloplasty	3 rd degree AV block	7
4	64	F	Rheumatic-Stenosis	MVR (mechanical)	3 rd degree AV block	5
5	54	M	Rheumatic-Regurgitation	MVR (mechanical) + Tricuspid de vega annuloplasty	2 nd degree AV block	45
6	35	M	Rheumatic-Regurgitation	MVR (mechanical)	3 rd degree AV block	5
7	55	F	Rheumatic-Stenosis	MVR (mechanical) + Tricuspid ring annuloplasty	3 rd degree AV block	24
8	55	F	Rheumatic-Regurgitation	MVR (bioprotesis) + Tricuspid ring annuloplasty	2 nd degree AV block	27

PPI: Permanent pacemaker implantation, TPM: Temporary pacemaker, F: Female, M: Male, MVR: Mitral valve replacement, AV block: Atrioventricular block.

TAP with left sided surgeries did not increase the incidence of PPI or other morbidities such as bleeding, low cardiac output syndrome and kidney diseases^(30,31). We found no difference in the frequency of PPI between the two groups.

It is vital to protect patients from adverse effects of late TR, because it is known that elevated TR is associated with increased morbidity and mortality following mitral valve surgery^(32,33).

CONCLUSION

When isolated MVR is considered and if the patient also has TR, it is apparent that TAP would be inevitable, because TR inflicts a considerable burden on the patient's quality of life. Recent studies reported varying frequencies of PPI after TAP accompanying left valve surgery. This study did not observe an increased use of PPI after MVR operations accompanied by TAP as compared with isolated MVR operations.

STUDY LIMITATIONS

There are many limitations in this study because, it has a retrospective design and included observational data from a single-center with a relatively small cohort and short follow up period. Further prospective and multi-center studies are needed to clarify the frequency for PPI following MVR plus TAP.

Ethics Committee Approval: This study was approved by Kartal Kosuyolu High Specialization Training and Research Hospital, Clinic of Cardiovascular Surgery Ethics Committee (2020/8/358).

Informed Consent: Informed consent was obtained.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept/Design - RA, DÇ; Analysis/Interpretation - ES, VB; Data Collection - AK, ÜY, FB; Writing - RA, ES; Critical Revision - MR; Final Approval - RA; Statistical Analysis - ES; Overall Responsibility - RA, MR.

Conflict of Interest: The authors have no conflicts of interest to declare

Financial Disclosure: The authors declared that this study has received no financial support.

REFERENCES

- Leyva F, Qiu T, McNulty D, Evison F, Marshall H, Gasparini M. Long-term requirement for pace-maker implantation after cardiac valve replacement surgery. *Heart Rhythm* 2017;14:529-34. [Crossref]
- Limongelli G, Ducceschi V, D'Andrea A, Renzulli A, Sarubbi B, De Feo M, et al. Risk factors for pacemaker implantation following aortic valve replacement: a single centre experience. *Heart* 2003;89:901-4. [Crossref]
- Emlein G, Huang SKS, Pires LA, Rofino K, Okike ON, Vander Salm TJ. Prolonged bradyarrhythmias after isolated coronary by-pass graft surgery. *Am Heart J* 1993;126:1084-9. [Crossref]
- Chung MK. Cardiac surgery: postoperative arrhythmias. *Crit Care Med* 2000;28(Suppl):N136-N144. [Crossref]
- Elahi M, Usmaan K. The bioprothesis type and size influence the postoperative incidence of permanent pacemaker implantation in patients undergoing aortic valve surgery. *J Interv Card Electrophysiol* 2006;15:113-8. [Crossref]

6. Zakhia Doueihy R, Leloux MF, De Roy L, Kremer R. Permanent cardiac pacing for prolonged second and third degree atrioventricular block complicating cardiac valve replacement. *Acta Cardiol* 1992;47:157-66. [\[Crossref\]](#)
7. Wiggins NB, Chong DT, Houghtaling PL, Hussein, AA, Saliba W, Sabik JF, et al. Incidence, indications, risk factors, and survival of patients undergoing cardiac implantable electronic device implantation after open heart surgery. *Ep Europace* 2017;19:1335-42. [\[Crossref\]](#)
8. Ho KI D, King G, Stuart EA. MatchIt: nonparametric preprocessing for parametric causal inference. *J Stat Softw* 2011;42:1-28. [\[Crossref\]](#)
9. Greifer N. Covariate balance tables and plots: a guide to the cobalt package. Accessed March 2020;10.
10. Imai K, Ratkovic M. Covariate balancing propensity score. *J R Stat Soc Series B Stat Methodol* 2014;76:243-63. [\[Crossref\]](#)
11. Schurr UP, Berli J, Berdajs D, Hausler A, Dzembali O, Emmert M, et al. Incidence and risk factors for pacemaker implantation following aortic valve replacement. *Interact Cardiovasc Thorac Surg* 2010;11:556-60. [\[Crossref\]](#)
12. Scully HE, Armstrong CS. Tricuspid valve replacement. Fifteen years of experience with mechanical prostheses and bioprostheses. *J Thorac Cardiovasc Surg* 1995;109:1035-41. [\[Crossref\]](#)
13. Meimoun P, Zeghdi R, D'Attelis N, Berrebi A, Braunberger E, Deloche A, et al. Frequency, predictors, and consequences of atrioventricular block after mitral valve repair. *Am J Cardiol* 2002;89:1062-6. [\[Crossref\]](#)
14. Jokinen JJ, Turpeinen AK, Pitkanen O, Hippelainen MJ, Hartikainen JEK. Pacemaker therapy after tricuspid valve operations: implications on mortality, morbidity, and quality of life. *Ann Thorac Surg* 2009;87:1806-14. [\[Crossref\]](#)
15. Jouan J, Mele A, Florens E, Chatellier G, Carpentier A, Achouh P, et al. Conduction disorders after tricuspid annuloplasty with mitral valve surgery: implications for earlier tricuspid intervention. *J Thorac Cardiovasc Surg* 2016;151:99-103. [\[Crossref\]](#)
16. Sachweh JS, Vazquez-Jimenez JF, Schondube FA, Dae-britz SH, Dorge H, Muhler EG, et al. Twenty years experience with pediatric pacing: epicardial and transvenous stimulation. *Eur J Cardiothorac Surg* 2000;17:455-61. [\[Crossref\]](#)
17. Erdogan O, Augustini R, Saliba W, Juratli N, Wilkoff BL. *Pacing Clin Electrophysiol* 2006;29:1055-62. [\[Crossref\]](#)
18. Al-Ghamdi B, Mallawi Y, Shafquat A, Ledesma A, AlRuwaiti N, Shoukri M, et al. Predictors of permanent pacemaker implantation after coronary artery bypass grafting and valve surgery in adult patients in current surgical era. *Cardiol Res* 2016;7:123-9. [\[Crossref\]](#)
19. Moskowitz G, Hong KN, Giustino G, Gillinov AM, Ailawadi G, DeRose JJ Jr, et al. Incidence and risk factors for permanent pacemaker implantation following mitral or aortic valve surgery. *J Am Coll Cardiol* 2019;74:2607-20. [\[Crossref\]](#)
20. Nm VM, Sj H, Jong W, Domburg RT, Pw S, Jaegere PP. Persistent annual permanent pacemaker implantation rate after surgical aortic valve replacement in patients with severe aortic stenosis. *Ann Thorac Surg* 2012;94:1143-9. [\[Crossref\]](#)
21. Baraki H, Al Ahmad A, Jeng-Singh S, Saito S, Schmitto JD, Fleischer B, et al. Pacemaker dependency after isolated aortic valve replacement: do conductance disorders recover over time? *Interact Cardiovasc Thorac Surg* 2013;16:476-81. [\[Crossref\]](#)
22. Koplan BA, Stevenson WG, Epstein LM, Aranki SF, Maisel WH. Development and validation of a simple risk score to predict the need for permanent pacing after cardiac valve surgery. *ACC Curr J Rev* 2003;12:88. [\[Crossref\]](#)
23. *Cardiac Pacemakers - Biological Aspects, Clinical Applications and Possible Complications*. In: Min M (ed). BoD-Books on Demand, 2011.
24. Raza SS, Li JM, John R, Chen LY, Tholakanahalli VN, Mbai M. Long-term mortality and pacing outcomes of patients with permanent pacemaker implantation after cardiac surgery. *Pacing Clin Electrophysiol* 2011;34:331-8. [\[Crossref\]](#)
25. Kestenbaum B, Rudser KD, Shlipak MG, Fried LF, Newman AB, Katz R, et al. Kidney function, electrocardiographic findings, and cardiovascular events among older adults. *Clin J Am Soc Nephrol* 2007;2:501-8. [\[Crossref\]](#)
26. Mathew J, Katz R, St John Sutton M, Dixit S, Gerstenfeld EP, Ghio S, et al. Chronic kidney disease and cardiac remodeling in patients with mild heart failure: results from the Resynchronization Reverses Remodeling in Systolic Left Ventricular Dysfunction (REVERSE) study. *Eur J Heart Fail* 2012;14:1420-8. [\[Crossref\]](#)
27. Do QB, Pellerin M, Carrier M, Cartier R, Hebert Y, Page P, et al. Clinical outcome after isolated tricuspid valve replacement: 20-year experience. *Can J Cardiol* 2000;16:489-93. [\[Crossref\]](#)
28. Epstein AE, DiMarco JP, Ellenbogen KA, Mark Estes 3rd NA, Freedman RA, Gettes LS, et al. ACC/AHA/HRS 2008 guidelines for device-based therapy of cardiac rhythm abnormalities: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the ACC/AHA/NASPE 2002 Guideline Update for Implantation of Cardiac Pacemakers and Antiarrhythmia Devices) developed in collaboration with the American Association for Thoracic Surgery and Society of Thoracic Surgeons. *J Am Coll Cardiol* 2008;51:2085-105. [\[Crossref\]](#)
29. Brignole M, Auricchio A, Baron-Esquivias G, Bordachar P, Boriani G, Breithardt OA, et al. 2013 ESC Guidelines on cardiac pacing and cardiac resynchronization therapy: the Task Force on cardiac pacing and resynchronization therapy of the European Society of Cardiology (ESC). Developed in collaboration with the European Heart Rhythm Association (EHRA): The Task Force on cardiac pacing and resynchronization therapy of the European Society of Cardiology (ESC). Developed in collaboration with the European Heart Rhythm Association (EHRA). *Eur Heart J* 2013;34:2281-329. [\[Crossref\]](#)
30. Zhu TY, Wang JG, Meng X. Does concomitant tricuspid annuloplasty increase perioperative mortality and morbidity when correcting left-sided valve disease? *Interact Cardiovasc Thorac Surg* 2015;20:114-8. [\[Crossref\]](#)
31. Dreyfus GD, Corbi PJ, Chan KMJ, Bahrami T. Secondary tricuspid regurgitation or dilatation: which should be the criteria for surgical repair? *Ann Thorac Surg* 2005;79:127-32. [\[Crossref\]](#)
32. Koelling TM, Aaronson KD, Cody RJ, Bach DS, Armstrong WF. Prognostic significance of mitral regurgitation and tricuspid regurgitation in patients with left ventricular systolic dysfunction. *Am Heart J* 2002;144:524-9. [\[Crossref\]](#)
33. Kwak JJ, Kim YJ, Kim MK, Kim HK, Park JS, Kim KH, et al. Development of tricuspid regurgitation late after left-sided valve surgery: a single-center experience with long-term echocardiographic examinations. *Am Heart J* 2008;155:732-7. [\[Crossref\]](#)