

Original Research Article

Prospective analysis of pacing requirements following cardiac surgery

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ABSTRACT

Background: Post-operative conduction abnormalities are one of the complications occur after cardiac surgery, which can occasionally lead to significant morbidity and mortality. Conduction abnormalities can occur during and immediately after cardiac surgery, most commonly in valve operations. Possible mechanisms include injury to conduction apparatus during decalcification, injury from the sutures, needles and post-operative edema around the conduction system due to injury to surrounding tissues. Most of the pacing requirement is often temporary with only a small proportion of patients requiring permanent pacing. This study was conducted to study incidence of pacing requirements following cardiac surgery and to identify possible risk factors contributing to post-operative cardiac pacing.

Methods: In this study, all relevant data are collected from patients who met the criteria for the study which includes pre-operatively relevant history and routine investigations were done. Intra-operative data were collected and post-operatively – routine blood and cardiac investigations were done on the day of surgery and on alternate days thereafter. The onset of new arrhythmias and the need for pacing are recorded.

Results: In this study, of 350 patients who underwent various types of cardiac surgeries, only 79 (22.6%) patients required temporary pacing of the heart with the temporary pacing wire. Of these, only 1 (0.29%) patient was pacing dependent and requiring permanent pacemaker implantation.

Conclusions: In the study, the factors predicting post-operative pacing requirement were the presence of pre-operative atrial fibrillation, moderate to severe calcification of valves, surgeries performed using cardiopulmonary bypass with prolonged aortic cross-clamp time.

Keywords: Conduction anomalies, Cardiac pacing, Atrial fibrillation, Valvar calcification

INTRODUCTION

Cardiac surgical procedures to treat coronary artery diseases, valvular heart disease and anatomical anomalies of heart which are aimed towards restoration of blood supply to heart, restoration of valvar functions which help in optimal functioning of heart and to preserve heart function. Among cardiac surgical procedures, coronary artery bypass surgery (CABG) and valve replacements (or repairs) are the most commonly performed in adults. Though these procedures are lifesaving, they also have post-operative complications.

Post-operative conduction abnormalities are one of complication occur after cardiac surgery most common after valve operations which can occasionally lead to significant morbidity and mortality.^{1,2} Conduction abnormalities can occur during and immediately after cardiac surgical procedures, most commonly in valve operations.¹⁻⁶ Possible mechanisms include injury to conduction apparatus from the sutures, needles and post-operative edema around the conduction system due to injury to surrounding tissues. Following cardiac surgery, most of the pacing requirement is often temporary with

only a small proportion of patients requiring permanent pacing.

The conduction pathway of the heart lies close to the aortic and mitral valves which is prone for injury during surgery by the sutures and needles.^{3,5,7,8-11} Also, the tissue edema around the suture line caused due to tissue injury leading to post-operative edema can cause post-operative conduction abnormalities which may require pacing of heart. Figure 1 shows the anatomical relation of AV node and the bundle of His to the aortic and mitral valves and its course.¹² Here, the bundle runs below the aortic annulus at the junction of right coronary cusp (RCC) and non-coronary cusp (NCC) along the posterior border of membranous septum before entering the inter ventricular septum (IVS). Injury to the AV node and the bundle of His can happen during decalcification of the aortic valve annulus or by valve sutures and needles passing through the aortic annulus at the RCC and NCC junction. Such injuries are more common in severely calcified annulus due to overzealous decalcification leaving behind deficient annulus for suturing to fix the prosthetic valves.^{5,7,11}

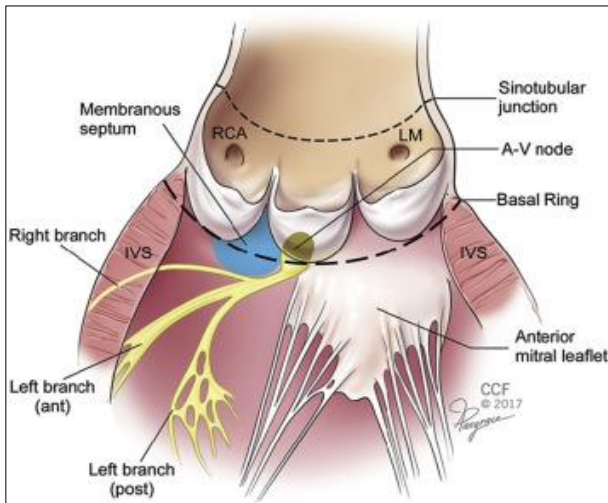


Figure 1: Diagram showing AV node and bundle-of-His in relation to aortic valve and mitral valve.

Figure 2 shows the anatomical relation between the bundle of His to mitral valve which lies close to mitral valve annulus near postero-medial commissure.¹³ The bundle then passes through the central fibrous body and enters IVS where it lies at posterior border of membranous septum before dividing into left bundle branch (LBB) and right bundle branch (RBB). During mitral valve surgery (repair/replacement) the sutures and the needles can injure the conduction bundle or the nodal artery supplying the AV node causing ischemic injury to AV node leading to conduction abnormalities.³ Valve operations are more often associated with post-operative conduction anomalies either due to direct injury to the conduction apparatus, blood supply to nodes or due to edema of surrounding tissues. Such cases may require pacing of heart in the post-operative period which is commonly done by placing

epicardial temporary pacing wires on RA and RV and they can be used to temporarily pace the heart. Conduction abnormalities after valve operations most commonly resolve spontaneously after few hours to days during which time, temporary pacing of heart using the temporary epicardial pacing wires may be required. If there is no return of normal electrical activity suggesting direct injury to conduction system and the patient is completely dependent on pacing for more than 3 to 4 days; or if the pacing threshold of the temporary pacing increases significantly with no underlying ventricular rhythm, implantation of permanent pacemaker (PPM) is considered.¹⁴

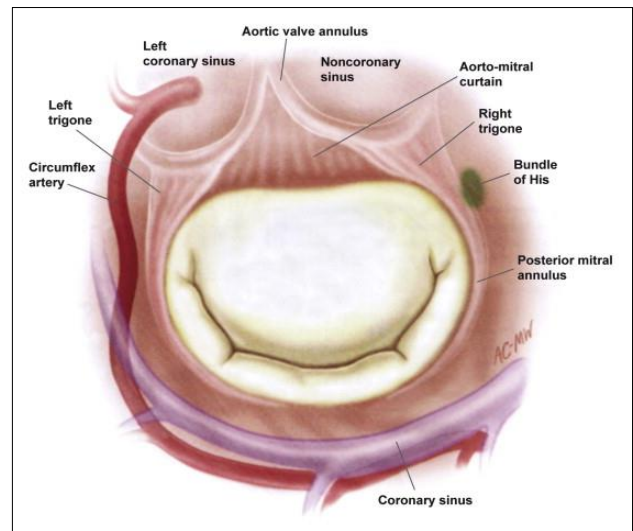


Figure 2: Diagram showing the anatomical relation between bundle of his with aortic and mitral valve.

METHODS

Aim

Aim of the study was to analyse the pacing requirements following cardiac surgery.

Objectives

Objectives of the study were to study incidence of pacing following cardiac surgery and to identify possible risk factors contributing to pacing either temporary or permanent.

Study site

The study was conducted at the department of cardiovascular and thoracic surgery, Apollo Hospitals, Chennai.

Study design

It was a prospective observational study.

Study duration

The duration of the study was for 36 months (January 2018 to December 2020).

Inclusion criteria

All patients undergoing both elective and emergency cardiac surgery. Patients undergoing 1st time and re-operative cardiac surgeries. Patients above age of 18 years.

Exclusion criteria

Patients with pacemakers implanted pre-operatively. Patients with pre-operative AV conduction block and complete bundle branch block.

Sample size

Sample size was 350 patients.

Sample size calculation

Since our primary objective of study is to find incidence of pacing requirement following cardiac surgery, we assumed 32% as pacemaker dependence percentage for sample size calculation using following formula.¹

$$n = Z^2 pq / d^2$$

Where, Z is the standard normal variable value=1.96, p is pacemaker dependent percentage=32%, q=1-p=68%, and d is clinical allowable error=5%.

Therefore, the required sample size is 334 cases. Considering the drop-out percentage, the required sample size is 350 cases.

'Ethical principles and the guidelines for protection of human subjects of research' of Apollo Hospitals was followed.

Statistical analysis

All the continuous variable was assessed for normality using Shapiro-Wilk's test. If the variables were normally distributed, they are expressed as mean±standard deviation (SD). Non-normally distributed continuous variables are expressed as median (inter quartile range). Categorical variables are expressed as percentage. Comparison of normally distributed continuous variable was done by independent sample – 't' test. Comparison of non-normally distributed continuous variable was done by Mann-Whitney 'U' test. Comparison of categorical variables was done by either Chi-square test or Fischer's exact test, also exploring possibilities of doing Binary-Logistic regression analysis. All 'p' values <0.05 were considered to be statistically significant.

Statistical software used

Data entry was done in Microsoft excel data validation spread sheet and the analysis was carried out using statistical package for the social sciences (SPSS) version 25.0.

Methodology

All consenting patients who met the inclusion and the exclusion criteria were selected for the study. Once a patient was found eligible to participate in the study, an informed consent was obtained and relevant data as listed under was collected. Detailed history of the patient including the risk factors for conduction abnormalities, history of arrhythmias, syncope and palpitations. Complete physical examination will be done. Electrocardiography (ECG), echocardiogram, serum electrolytes, renal function test, thyroid function test and liver function tests with routine clinical investigations are done. Type of surgery (e.g. CABG/valve surgery), duration of surgery, on/off pump surgery, duration of cardio-pulmonary bypass, cardioplegia, conduction abnormalities during surgery and need for pacing intra-op/post-op are noted. On arrival into the intensive care unit (ICU), chest X-ray and ECG, arterial blood gas analysis done to optimize and to correct the electrolyte abnormalities if any. If the patient has been shifted with a temporary pacing, the underlying rhythm is evaluated carefully. The requirement of pacing is assessed every day. During the post-operative period patient was observed for hemodynamic changes and new onset arrhythmias and the medications are optimized. In the post-operative period, ECG and arterial blood gas analysis (ABG) are done on the day of surgery, 1st postoperative day (POD), 3rd POD and 5th POD. The onset of new arrhythmias, electrolytes and need for pacing are recorded. If a patient develops an arrhythmia, immediately an ECG is taken and arterial blood gas is done to look for electrolyte abnormalities and to correct the same. During post-operative period patient will be assessed for New onset conduction abnormalities in ECG, need for temporary pacemaker and duration, need for permanent pacemaker.

The data for study is obtained from tests routinely performed and from investigations that we usually perform when arrhythmia develops.

Ethical clearance

IRB approval was obtained from Institutional Ethical Committee-Bio Medical Research-Apollo Hospitals. Informed consent was obtained from all the patients who met the exclusion criteria.

RESULTS

In this study, of 350 patients who underwent various types of cardiac surgeries, with 267 (76.9%) male and 81 (23.13%) female (Table 1). Only 79 (22.6%) patients required

temporary pacing (TP) of heart with the temporary pacing wire. Of these only 1 (0.29%) patient was pacing dependent requiring permanent pacemaker implantation which was done on 2nd post-operative day.

Table 1: Patients demographic details.

Characteristics	Number (n)	Percentage %
Male	269	76.9
Female	81	23.1
Diabetes mellitus	207	59.1
Hypertension	208	59.4
Hypothyroidism	50	14.3
Smoker	121	34.6

Among 350 patients who underwent cardiac surgery, 79 patients required postoperative cardiac pacing. Analysis of data showed possible risk factors contributing to pacing requirement.

To assess the relationship between pre-operative rhythm and the post-operative pacing, the post-operative pacing data was analysed against rhythm characteristics. The results were assessed for statistical significance. Chi-square test was performed for the same showed following results. Table 2 shows there was a statistically significant relationship between pre-operative atrial fibrillation and need for pacing.

Table 2: Cardiac pacing and pre-operative rhythm.

Rhythm	Temporary	Pacing	Significance (p value)
	Yes (%)	No (%)	
Sinus rhythm	52 (16.4)	265 (83.6)	Not significant
Atrial fibrillation	27 (81.8)	6 (18.2)	Significant (0.000)

To assess the relationship between pre-operative degree of aortic valve calcification and post-operative pacing, the post-operative pacing data was analysed against degree of AV calcification. The results were assessed for statistical significance. Chi-square test was performed for the same showed following results. Table 3 shows there was a statistically significant relationship between moderate to severe calcification of AV and need for pacing.

To assess the relationship between pre-operative degree of mitral valve calcification and post-operative pacing, the post-operative pacing data was analysed against degree of MV calcification. The results were assessed for statistical significance. Chi-square test was performed for the same showed following results. Table 4 shows there was a statistically significant relationship between moderate to severe calcification of mitral valve and need for pacing.

To assess the relationship between different type of cardiac surgery and post-operative pacing, the post-operative pacing data was analysed against type of cardiac surgery.

The results were assessed for statistical significance. Chi-square test was performed for the same showed following results. Table 5 shows there was a statistically significant relationship between valve replacement surgery and need for pacing.

Table 3: Cardiac pacing and aortic valve calcification.

Aortic valve calcification	Cardiac	Pacing	Significance (p value)
	Yes (%)	No (%)	
No calcification	45 (15.3)	249 (84.7)	Not significant
Mild calcification	3 (21.4)	11 (78.5)	Not significant
Mod calcification	4 (100)	0	Significant (0.000)
Severe calcification	27 (71)	11 (29)	Significant (0.000)

Table 4: Cardiac pacing and mitral valve calcification.

Mitral valve calcification	Cardiac	Pacing	Significance (p value)
	Yes (%)	No (%)	
No calcification	47 (20.7)	252 (79.2)	Not significant
Mild calcification	1 (25)	3 (75)	Not significant
Mod calcification	10 (71.4)	4 (28.6)	Significant (0.000)
Severe calcification	21 (63.6)	12 (36.3)	Significant (0.000)

Of the 18 patients who underwent combined valve and CABG, 9 patients required pacing. Of these 7 patients had severe aortic valve calcification and 2 patients had moderate mitral valve calcification and 1 patient had atrial fibrillation. The other 9 patients who did not require post-operative pacing 4 patient had severe aortic valve calcification, 5 patients had moderate mitral valve calcification and 1 patient had atrial fibrillation.

Table 5: Cardiac pacing and type of cardiac surgery.

Type of surgery	Cardiac	Pacing	Significance (p value)
	Yes (%)	No (%)	
CABG	24 (9)	241 (91)	Not significant
Valve replacement	47 (70)	20 (30)	Significant (0.000)
AVR	16 (57)	12 (43)	
MVR	22 (76)	7 (24)	
AVR+MVR	9 (90)	1 (10)	Not significant
CABG + valve replacement	9 (50)	9 (50)	

To assess the relationship between duration of aortic cross clamp and post-operative pacing, the post-operative pacing data was analysed against aortic cross clamp time. The results were assessed for statistical significance. Chi-square test was performed for the same showed following results. Table 6 shows there was a statistically significant relationship between aortic cross clamp time and need for pacing.

Table 6: Cardiac pacing and aortic cross clamp time.

Aortic cross clamp time	Cardiac	Pacing	Significance (p value)
	Yes (%)	No (%)	
<60 min	6 (54.5)	5 (45.5)	Not significant
>60 min	54 (68.4)	25 (31.6)	Significant

In this study group of 350 patients, only 1 patient required permanent pacemaker. He had severe aortic valve calcification and was completely pacing dependent post-operatively most probably due to injury to AV node and or bundle of his during decalcification and annulus suturing. In view of his complete dependence on pacing with no underlying rhythm and persistence of 3rd degree AV block he underwent permanent pace maker implantation on 2nd post-operative day.

The risk factors which contributed to pacing dependence in patient who required permanent pacemaker implantation in our study are, severe valvular calcification and prolonged aortic cross clamp duration.

DISCUSSION

The post-operative conduction abnormalities requiring cardiac pacing can occur after cardiac surgical procedures and lead to morbidity and mortality. This contributes to prolonged hospital stays and financial burden on the patients. Among the patients requiring post-operative cardiac pacing, AV conduction blocks and bradycardia are the most common indications for pacing. This study showed significant association of cardiac pacing with various pre-operative and peri-operative factors which contribute to post-operative cardiac pacing. Of the 350 patients in our study, 79 patients required post-operative cardiac pacing.

Among these, only one patient required permanent pacing and the remaining 78 patients required temporary cardiac pacing.

The only patient who underwent permanent pacemaker implantation on 2nd post-operative day was completely pacing dependent with no underlying native rhythm.

The duration of pacing requirement varied in different patients. In our study group, 79 patients required cardiac pacing which was initiated on the day of surgery and the duration of cardiac pacing was as under, forty-five patients required temporary pacing up to 24 hours, twenty-eight

patients required temporary pacing from 25 to 48 hours, three patients required temporary pacing form 49 to 72 hours, two patients required temporary pacing form 73 to 96 hours, and one patient required temporary pacing form 96 to 120 hours.

Cardiac pacing and pre-operative cardiac rhythm

Of the 350 patients in our study, 317 patients were in sinus rhythm pre-operatively and 33 patients had pre-operative atrial fibrillation. Among these 52 (16.4%) patients with pre-operative sinus rhythm and 27 (81.8%) patients with atrial fibrillation required post-operative cardiac pacing which was significant in our study. It was found that requirement of post-operative cardiac pacing was increased if the patient had pre-operative atrial fibrillation. A retrospective study by Onalan et al, on 13,751 patients of which 197 (1.43%) had permanent pacemaker implantation.⁴ Their study showed atrial fibrillation, sinus node dysfunction and post-operative AV block are independent predictors of pacemaker dependence. A study by Schurr et al on 3534 patients who underwent AVR, 234 (6.6%) had permanent pacemaker implantation.⁵

Postoperative RBBB is a predictors of pacemaker implantation. A retrospective audit by Elahi et al on 2392 patients who underwent valve surgery, 118 (4.93%) patients had pacemaker implantation.⁶ Their analysis showed preoperative arrhythmias (AF, LBBB; p<0.001) was a risk factor for post-operative pacemaker requirement. A study by Dawkins et al on 342 patients, 29 (8.5%) patients required permanent pacemaker.⁷ Their analysis showed pre-operative conduction disease (atrial fibrillation) and post-operative AV block were independent risk factors for pacemaker requirement. A retrospective analysis by Merdad et al of 6113 patients who underwent cardiac surgery, of these 145 (1.85%) required pacemaker implantation.⁸ Their analysis showed pre-operative atrial fibrillation and sinus node dysfunction are a risk factor for post-operative pacing requirement.

Cardiac pacing and type of cardiac surgical procedures

In our study, of the 350 patients 265 patients underwent isolated CABG (of which 5 were ONCABG and 260 were OPCABG), 18 patients underwent combined valve + CABG operations (10 AVR+ CABG and 8 MVR+ CABG) and 67 patients underwent isolated valve operations (28 isolated AVR, 29 isolated MVR and 10 combined AVR+MVR). In our study, 24 (9%) patients of 265 patients who underwent isolated CABG required post-operative pacing. Also, 9 (50%) patients of the 18 patients who underwent combined valve + CABG operations required post-operative pacing. Of the 67 patients, who underwent isolated valve surgeries 47 (70%) patients required post-operative pacing. Among this 16 (57.1%) of 28 patients who underwent isolated AVR, 22 (75.9%) of 29 patients who underwent isolated MVR and 9 (90%) of 10 patients who underwent combined AVR+ MVR surgery required postoperative cardiac pacing. In this current study, it was

observed that requirement of post-operative cardiac pacing was more in patients who underwent valve operations when compared to patients who underwent CABG. A study by Ferrari et al on 1102 patients of which 187 (17%) patients required temporary pacing and 17 (7.5%) patients required permanent pacemaker implantation, their analysis showed association between temporary pacing and valve operations ($p=0.002$).¹ A study by AlWaqfi et al on 400 patients of which 55 (23.9%) patients required temporary pacing, their study revealed multiple valve operations ($p=0.21$) as a predictive factor for temporary cardiac pacing.² A study by Schurr et al on 3534 patients who underwent AVR, 234 (6.6%) had permanent pacemaker implantation.⁵ The predictors of pacemaker implantation were, multiple valve replacements and combined CABG + valve operations. A retrospective audit by Elahi et al on 2392 patients who underwent valve operations, 118 patients had pacemaker implantation.⁶ Their analysis showed multiple valve operations ($p<0.001$) is a risk factor for post-operative pacemaker requirement. A retrospective analysis by Merdad et al of 6113 patients who underwent cardiac surgical procedures, 145 (1.85%) required permanent pacemaker implantation.⁸ Their analysis showed double valve replacement is a risk factor for post-operative pacing requirement.

Cardiac pacing and valve operations

There was a well-known association between need for post-operative cardiac pacing and valve replacement surgeries. Higher incidence of pacing in valve operations is due to, injury to conduction bundle during de-calcification of annulus and suturing, ischemic injury to conduction during on pump arrested heart, tissue edema surrounding the conduction system.

Of the 67 patients who underwent isolated valve operations, 47 (70%) patients required post-operative cardiac pacing. Of the 18 patients who underwent combined CABG and valve operations, 9 (50%) patients required post-operative cardiac pacing. In our study, it was reconfirmed that group of patients who underwent valve operations required post-operative cardiac pacing. A study by Ferrari et al on 1102 patients of which 187 (17%) patients required temporary pacing and 17 (7.5%) patients required permanent pacemaker implantation, their analysis showed association between temporary pacing and mitral valve surgery ($p=0.002$).¹ A study by AlWaqfi et al on 400 patients of which 55 (23.9%) patients required temporary pacing, their study revealed multiple valve operations ($p=0.21$) as a predictive factor for temporary cardiac pacing.² A study by Schurr et al on 3534 patients who underwent AVR, 234 (6.6%) had permanent pacemaker implantation.⁵ The predictors of pacemaker implantation were, severe mitral valve insufficiency, combined CABG + valve operations and sub aortic resection. A retrospective audit by Elahi et al on 2392 patients who underwent valve operations, 118 patients had pacemaker implantation.⁶ Their analysis showed multiple valve operations ($p<0.001$) is a risk factor for post-operative

pacemaker requirement. A study by Dawkins et al on 342 patients, 29 (8.5%) patients required permanent pacemaker, their analysis showed pre-operative valvular regurgitation is an independent risk factors for pacemaker requirement.⁷ A retrospective analysis by Merdad et al of 6113 patients who underwent cardiac surgery, of these 145 (1.85%) required pacemaker implantation. Their analysis showed double valve replacement is a risk factor for post-operative pacing requirement.

Cardiac pacing and degree of valvular calcification

In our study, there was an association between post-operative cardiac pacing requirement and valvular calcification. In our study, of 350 patients 56 (16%) patients had aortic valve calcification (14 mild aortic valve calcification, 4 moderate aortic valve calcification and 38 severe aortic valve calcification). Of these 48 patients underwent aortic valve replacement. Among the patients who underwent aortic valve surgery, 3 (21.4%) patients with mild aortic valve calcification, 4 (100%) patients with moderate aortic valve calcification and 27 (71%) patients with severe aortic valve calcification required post-operative cardiac pacing. Also of the 350 patients, 51 (14.5%) patients had mitral valve calcification (4 mild mitral valve calcification, 14 moderate mitral valve calcification and 33 severe mitral valve calcification). Among these 47 patients underwent mitral valve replacement. The patients who underwent mitral valve surgery, 1 (25%) patient with mild mitral valve calcification, 10 (71.4%) patients with moderate mitral valve calcification and 21 (63.6%) patients with severe mitral valve calcification required post-operative cardiac pacing. In our study, it was observed that incidence of post-operative cardiac pacing was more if the patient has aortic and mitral valve calcification. And the pacing requirement is more if the patient has moderate to severe valvular calcification when compared to patients with mild or no valvular calcification. A study by AlWaqfi et al on 400 patients, 55 (23.9%) patients required temporary pacing, their study revealed heavy annular calcification ($p=0.003$) as a predictive factor for temporary cardiac pacing.²

Cardiac pacing and aortic cross clamp duration

In our study, pacing requirement was more in surgeries where aortic cross clamp time was more than 60 min. This is probably due to, ischemic injury to the conduction system and tissue edema, cold injury caused due to cold cardioplegia. Inadequate cardioplegia to the right coronary artery where AV nodal artery arises from right coronary artery.

Of the 90 patients who underwent surgery on pump, 85 surgeries were performed after applying aortic cross clamp with cardioplegic arrest of heart. Among these, 67 operations were isolated valve surgeries and 18 surgeries were combined CABG + valve operations. Among these surgeries which required cross clamping of aorta, 6

patients required aortic occlusion for less than 60 min and 79 required aortic occlusion for more than 60 min. Of this, 1 (16.6%) patient with aortic cross clamp duration less than 60 min and 54 (68.4%) patients with aortic cross clamp duration more than 60 min required post-operative cardiac pacing which was significant. A study by AlWaqfi et al on 400 patients of which 55 (23.9%) patients required temporary pacing, it revealed aortic cross clamp duration >60 min ($p=0.01$) was a predictive factor for temporary cardiac pacing.² A study by Schurr et al on 3534 patients who underwent AVR, 234 (6.6%) had permanent pacemaker implantation.⁵ Their analysis showed prolonged cross clamp time is a predictors of pacemaker implantation. A retrospective audit by Elahi et al on 2392 patients who underwent valve operations, 118 patients had permanent pacemaker implantation.⁶ Their analysis showed prolonged cross clamp time ($p<0.001$) is a risk factor for post-operative pacing requirement.

Limitations

This study is a single center study which includes a heterogeneous group of population undergoing different cardiac procedures.

CONCLUSION

In this study we found, the incidence of post-operative temporary cardiac pacing was 22.6% and permanent pacing requirement was 0.28%. and the factors predicting post-operative pacing requirement were, presence of pre-operative atrial fibrillation, moderate to severe calcification of valves, isolated valve operations, combined CABG + valve operations, surgeries performed using cardiopulmonary bypass, prolonged aortic cross clamp time.

There was no increase in pacing requirement in patients undergoing isolated CABG (both OPCABG and CABG using CPB).

Recommendations

Pre-operatively, the patients who are at high risk of conduction system injury during surgery need to be counselled and informed consent for pacemaker implantation must be obtained. Intra-operatively, meticulous decalcification of valve annulus to avoid injury to conduction system and careful suturing of annulus adjacent to conduction bundle must be undertaken. To place a temporary cardiac pacing wire in, patients with pre-existing arrhythmias and bradycardia, patients who had prolonged cardio pulmonary bypass time and aortic cross clamp time. Patients undergoing valve operations.

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Ethical approval: The study was approved by the Institutional Ethics Committee

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