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Comparison of aortic cross-clamping versus beating heart surgery in tricuspid valve repair

Triküspid kapak tamirinde atan kalp ile aortik kros klemp cerrahinin karşılaştırılması

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ABSTRACT

Background: The aim of this study was to evaluate the clinical outcomes of tricuspid valve repair using aortic cross-clamping versus using beating heart surgery.

Methods: A total of 208 patients (67 males, 141 females; mean age 61.5±9.2 years; range, 29 to 81 years) who underwent concomitant cardiac surgery and tricuspid valve repair between January 2007 and January 2016 at a single center were included. Two surgical strategies for tricuspid valve repair with aortic cross-clamping (n=102) or on beating heart (n=106) were compared. Primary endpoints were in-hospital mortality and the rate of permanent pacemaker placement after surgery. Secondary endpoints were cross-clamp and cardiopulmonary bypass times, postoperative inotropic support, temporary pacemaker requirement, and residual tricuspid regurgitation at discharge and at one year.

Results: Overall hospital mortality was 7% (n=14) (cross-clamping 7% vs. beating heart 7%; p>0.05). The mean cross-clamp and cardiopulmonary bypass times were significantly longer in the aortic cross-clamping group (p=0.0001). Also, a higher number of patients in this group needed inotropic support (78/102) than the beating heart group (57/106) (p<0.05). The rate of postoperative left bundle branch block was higher in the cross-clamping group (14% vs. 5%, respectively; p<0.05). The rate of permanent pacemaker placement was also significantly higher in the cross-clamping group than the beating heart group (11.8% vs. 2.8%, respectively; p<0.05). At discharge, residual >2 tricuspid regurgitation was more commonly seen in the cross-clamping group (16% vs. 3%, respectively; p=0.0023). At one year of follow-up, residual >2 tricuspid regurgitation was present in 22 patients (23%) in the aortic cross-clamping group and in eight patients (8%) in the beating heart group (p=0.0048).

Conclusion: Tricuspid valve repair on beating heart offers less inotropic support and a lower rate of postoperative permanent pacemaker placement requirement and residual tricuspid regurgitation, although both techniques yield similar postoperative clinical outcomes. These results support the use of tricuspid valve repair on a beating heart in concomitant left-sided valvular heart surgery.

Keywords: Aortic cross-clamping; beating heart; tricuspid regurgitation; tricuspid valve repair.

ÖZ

Amaç: Bu çalışmada atan kalbe kıyasla aortik kros klemp sırasında triküspid kapak tamirinin klinik sonuçları değerlendirildi.

Çalışma planı: Bu çalışmaya Ocak 2007 - Ocak 2016 tarihleri arasında tek bir merkezde eş zamanlı kalp ameliyatı ve triküspid kapak tamiri yapılan toplam 208 hasta (67 erkek, 141 kadın; ort. yaş: 61.5±9.2 yıl; dağılım, 29-81 yıl) alındı. Aortik kros klemp ile (n=102) veya atan kalpte (n=106) triküspid kapak tamirine yönelik iki cerrahi strateji karşılaştırıldı. Çalışmanın primer sonlanım noktaları hastane mortalitesi ve kalıcı pacemaker implantasyonu gereksinim oranı idi. Sekonder sonlanım noktaları ise, kros klemp ve kardiyopulmoner baypas süreleri, ameliyat sonrası inotrop desteği, geçici pacemaker gereksinimi ve taburculukta ve birinci yılda rezidüel triküspid yetmezliği idi.

Bulgular: Genel hastane mortalitesi %7 (n=14) idi (kros klemp grubunda %7 ve atan kalpte %7; p>0.05). Ortalama kros klemp ve kardiyopulmoner baypas süreleri, aortik kros klemp grubunda anlamlı düzeyde daha uzundu (p=0.0001). Ayrıca, atan kalp grubuna kıyasla (57/106), bu grupta daha fazla sayıda hastanın (78/102) inotrop desteğine gereksinimi oldu (p<0.05). Ameliyat sonrası sol dal bloku oranı, aortik kros klemp grubunda daha yüksekti (sırasıyla %5'e kıyasla %14; p<0.05). Kalıcı pacemaker implantasyonu oranı da, atan kalp grubuna kıyasla kros klemp grubunda anlam düzeyde daha yüksekti (sırasıyla %2.8'e kıyasla %11.8; p<0.05). Taburculuk sırasında rezidüel >2 triküspid yetmezlik aortik kros klemp grubunda daha sık görüldü (sırasıyla %3'e kıyasla %16; p=0.0023). Takibin birinci yılında rezidüel >2 triküspid yetmezlik aortik kros klemp grubunda 22 hastada (%23) ve atan kalp grubunda sekiz hastada (%8) gözlendi (p=0.0048).

Sonuç: Atan kalpte triküspid kapak tamiri ile inotrop desteği daha az ve ameliyat sonrası kalıcı pacemaker implantasyon gereksinimi ve rezidüel triküspid yetmezlik oranı daha düşük olmakla birlikte, her iki tekniğin de ameliyat sonrası klinik sonuçları benzerdir. Bu sonuçlar, eş zamanlı sol taraflı kalp kapak cerrahisinde atan kalpte triküspid kapak tamiri yapılmasını desteklemektedir.

Anahtar sözcükler: Aortik kros klemp; atan kalp; triküspid yetmezliği; triküspid kapak tamiri.

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Tricuspid regurgitation (TR) is a common disorder in left-sided valvular heart lesions. Functional or secondary TR due to annular dilatation and increased tricuspid leaflet tethering is commonly encountered in patients with left-sided cardiac valvular disease.[1] After successful surgical correction of left-sided lesions, TR may persist and, even worsening of TR may affect the clinical outcomes. Over the last decade, undertreated tricuspid valve (TV) has been referred as the "neglected or forgotten valve", due to the long-term poor outcomes of less aggressive approaches.[2] Indeed, secondary TR can usually be effectively corrected with ring annuloplasty.[3] The benefit of tricuspid valve repair (TVr) during concomitant mitral valve surgery has been recently well-documented in large-scale observational studies.[4,5] However, despite growing number of studies investigating the evolution of secondary TR, there has been an ongoing debate about the optimum surgical techniques and myocardial protection methods for TR in complex cardiac surgery.

In our earlier practice, reoperation for late tricuspid insufficiency after left-sided valvular surgery was a common surgical challenge. One of the reasons for under-treatment of TR was the assumption that correction of left-sided lesions would eventually lead to regression of TR. Other reason was possible heterogeneity of TVr techniques.[5] To date, several tricuspid annular stabilization techniques have been described, mainly DeVega, Revuelta and Garcia-Rinaldi, Dubost, Sagban, Sarray and Duarte, Kay, Modified Kay, and ring annuloplasty with a flexible or rigid rings.[5] Further leaflet repair techniques can be also added to annular stabilization including the Clover technique, leaflet augmentation, double orifice, or Gore-Tex loops.[5]

Over the past decade, our valvular heart program has liberally included ring annuloplasty for concomitant TV disease either on beating heart (BH) or during aortic cross-clamping (ACC) to avoid irreversible right ventricular (RV) dysfunction. In the present study, therefore, we aimed to compare the clinical outcomes of concomitant TV surgery, mainly ring annuloplasty, with ACC or on BH.

PATIENTS AND METHODS

We retrospectively searched our database for the records of patients who underwent TVr and concomitant cardiac surgery and who had coexistent functional TR between January 2007 and January 2016 at the Heart Center of the Ankara University, Faculty of Medicine. Indications for TVr were moderate-to-severe TR regardless of symptoms, or if there were signs of progressive RV dilatation or RV dysfunction with marked tricuspid annular dilation (>4.0 cm) during concomitant cardiac surgery. Patients with congenital disease of TV or carcinoid disease, previous intra-cardiac defibrillator or permanent pacemaker placement (PPP) and concomitant left ventricular assist device implantation were excluded from the study. A total of 208 patients (67 males, 141 females; mean age 61.5±9.2 years; range, 29 to 81 years) were included. Two surgical strategies for tricuspid valve repair during ACCR (n=102) or on a BH (n=106) were compared. Tricuspid intervention was carried out by the surgical team's preferences. There was no randomization in our study. A written informed consent was obtained from each patient. The study protocol was approved by the institutional Ethics Committee of Ankara University (2018/08-495-18). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Preoperative evaluation

All patients were investigated preoperatively for TV morphology, color flow regurgitant jet, and vena contracta width using Doppler echocardiography. Tricuspid regurgitation was classified on a four-point scale into four grades according to the maximal extent of the regurgitant signal and flow direction in the inferior vena cava or hepatic veins: 1 TR= mild; 2 TR= moderate; 3 TR= moderate-to-severe; and 4 TR= severe. Coronary angiography was also performed in patients who are older than 40 years of age.

Surgery

Transesophageal echocardiography was used in all patients. Standard median sternotomy or resternotomy, bicaval cannulation, and mild hypothermic cardiopulmonary bypass (CPB) was established in all patients. Then, TVr via right atriotomy was performed in the BH group prior to ACC or after cross-clamp removal. All of the concomitant left-sided cardiac procedures were performed under ACC. In the ACC group, following bicaval cannulation and establishment of CPB, ACC and hypothermic cardiac arrest were provided with one fourth of tepid blood cardioplegia. In the ACC group, all surgical procedures (i.e., valve surgery, ablation procedures) were carried out under ACC. Tricuspid ring annuloplasty was performed in all patients using the Carpentier-Edwards Classic annuloplasty ring (Edwards Lifesciences LLC, Irvine, CA, Medtronic Contour 3D 690R; Medtronic Inc., Minneapolis, MN) or a flexible band (Cosgrove-Edwards annuloplasty system; Edwards Lifesciences LLC, Irvine, CA).

Follow-up

Clinical characteristics, operative, and follow-up data were recorded prospectively in a computerized database. Mortality was defined as death within 30 days of operation or within the same hospital admission. Long-term pacemaker dependency was defined by indication for PPP. Postoperative inotrope/vasopressor use including dobutamine (5 μg/kg/min), dopamine (>5 μg/kg/min), norepinephrine (>0.1 μg/kg/min), milrinone, epinephrine, phenylephrine, and vasopressin 24 hours after skin closure was defined as prolonged inotropic dependency.[6] Postoperative daily electrocardiograms, temporary or PPP requirements, duration of mechanical ventilation, and length of the intensive care unit and hospital stay were evaluated. All survivors were seen in the outpatient clinic and echocardiographic evaluation was performed at discharge, at six weeks, at six months, and annually, thereafter. Postoperatively, the patients were given antiplatelet therapy. Warfarin was administered to those who were in atrial fibrillation or who underwent concomitant valve procedures, as indicated.

Statistical analysis

Statistical analysis was performed using the SPSS for Windows version 11.5 software (SPSS Inc., Chicago, IL, USA). Descriptive data were expressed in mean ± standard deviation (SD) and were compared using the Student's t-test. Categoric variables were expressed as frequencies and proportions. The Mann-Whitney U test was used to analyze differences between two independent groups in terms of non-normally distributed variables, whereas the chi-square test was used to examine differences between the categorical variables. The results were given in relative risk with 95% confidence interval (CI). A p value of <0.05 was considered statistically significant.

RESULTS

The preoperative demographic and clinical characteristics of all patients are shown in Table 1.

Table 1. Clinical characteristics of the patients at baseline

	Total (n=208)			ACC group (n=102)			BH group (n=106)			95% CI	
	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	Median	*p*
Age (year)			61.5±9.2			61.4±9.3			61.7±9.2	0.95-1.03	0.81
Gender											
Male	67	32		35	34		32	31			0.55
Body surface area (kg/m^2)			1.80±0.16			1.79±0.19			1.81±0.17	0.96-1.01	0.68
Body Mass Index (kg/m^2)			25.1±3.5			25.0±3.5			25.2±3.4	0.95-1.03	0.67
EuroSCORE II			5.5±1.5			5.5±1.5			5.5±1.5	0.93-1.08	0.92
EuroSCORE risk scale											
Low-risk	33	16		16	16		17	16			1.00
Intermediate-risk	139	66		70	68		69	65			
High-risk	36	18		16	16		20	19			
Hypertension	87	42		44	43		43	41			0.77
Diabetes mellitus	62	30		31	30		31	29			0.88
Liver disease	6	3		2	2		4	4			0.68
Current tobacco use	112	54		53	52		59	56			0.67
COPD	35	17		18	18		17	15			0.85
Hyperlipidemia	73	35		33	32		39	37			0.56
History of peripheral vascular disease	8	4		4	4		4	4			1.00
Previous stroke	12	6		7	7		5	5			0.56
Serum creatinine (mg/dL)			1.7±1.0			1.7±1.0			1.7±1.0	0.85-1.19	0.88
Renal failure	12	6		6	6		6	6			1.00
NYHA Functional Class III and IV	116	56		55	54		61	58			0.67
Previous IABP support	8	4		4	4		4	4			1.00
Infective endocarditis	4	2		2	2		2	2			1.00
Reoperative cardiac surgery	12	6		6	6		6	6			1.00
History of atrial fibrillation/flutter	127	61		61	60		65	61			1.00

ACC: Aortic cross-clamping; BH: Beating heart; CI: Confidence interval; SD: Standard deviation; EuroSCORE: European System for Cardiac Operative Risk Evaluation; COPD: Chronic obstructive pulmonary disease; NYHA: New York Heart Association; IABP: Intra-aortic balloon pump.

Table 2. Concomitant cardiac pathologies and echocardiographic characteristics

	Total (n=208)			ACC group (n=102)			BH group (n=106)			95% CI	
	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	Median	*p*
Concomitant mitral regurgitation	133	64		63	62		70	66			0.56
Concomitant mitral stenosis	91	44		46	45		45	42			0.78
Concomitant aortic regurgitation	32	15		17	17		15	14			0.70
Concomitant aortic stenosis	11	5		5	5		6	6			1.00
Concomitant coronary artery disease	32	15		15	15		17	16			0.84
Concomitant congenital heart disease	3	1		2	2		1	2			0.61
LVEF			52±8.7			51.9±8.7			52.1±8.6	0.95-1.04	0.86
Pulmonary artery pressure (mmHg)			59.1±7.2			58.7±7.5			59.4±6.9	0.96-1.02	0.48
Tricuspid regurgitation 3+ and 4+	186	89		91	89		95	90			1.00
Tricuspid annulus diameter (mm)			44.8±3.6			44.9±3.8			44.6±3.5	0.98-1.03	0.55
Basal right ventricular end-diastolic diameter (mm)			51.6±5.1			51.8±5.2			51.4±4.9	0.98-1.04	0.56
Basal right ventricular end-systolic diameter (mm)			43.3±4.0			43.5±4.2			43.1±3.9	0.98-1.04	0.47
Mid right ventricular end-diastolic diameter (mm)			45.2±4.2			44.9±4.1			45.3±4.4	0.97-1.02	0.49
Mid right ventricular end-systolic diameter (mm)			35.5±4.5			35.2±4.4			35.7±4.5	0.95-1.02	0.41

ACC: Aortic cross-clamping; BH: Beating heart; CI: Confidence interval; SD: Standard deviation; LVEF: Left ventricular ejection fraction.

Fifty-six percent of the patient cohort was in the New York Heart Association (NYHA) Class III or IV. Sinus rhythm was present in 81 patients (39%) and 61% had a history of atrial fibrillation/flutter. Left ventricular function was preserved in most patients, although the mean pulmonary artery pressure was 59.1±7.2 mmHg. There was no statistically significant difference between the two groups in terms of age, gender, body mass index, operative risk profiles, preoperative atrial fibrillation, left ventricular function, and NYHA functional class. Preoperative cardiac pathologies and echocardiographic data of the patients are shown in Table 2.

In mitral valve surgery, the valve lesion was regurgitation in 64%, stenosis in 44%, and mixed in 17%. Overall, concomitant mitral valve repair/replacement and TVr was the most common procedure (65%), as shown in Table 3. Mitral valve repair/replacement (MVR) was performed in 95 patients

Table 3. Surgical procedures

	Total (n=208)		ACC group (n=102)		BH group (n=106)		
	n	%	n	%	n	%	
TRA + MVR	135	65	65	64	70	66	0.77
TRA + AVR	7	3	4	3	3	3	0.71
TRA + CABG	6	3	2	2	4	4	0.68
TRA + MVR + AVR	31	15	16	16	15	14	0.84
TRA + AVR + CABG	3	1	1	1	2	2	1.00
TRA + MVR + CABG	23	12	12	12	11	10	0.82
TRA + MVR + ASD repair	3	1	2	2	1	1	0.61
Types of tricuspid ring annuloplasty							
Medtronic contour 3D 690R	98	47	47	46	51	48	0.78
Carpentier-Edwards Classic annuloplasty ring	92	44	45	44	47	44	1.00
Flexible band (Cosgrove-Edwards annuloplasty system)	18	9	10	10	8	8	0.62

ACC: Aortic cross-clamping; BH: Beating heart; TRA: Tricuspid ring annuloplasty; MVR: Mitral valve replacement; AVR: Aortic valve replacement; CABG: Coronary artery bypass grafting; ASD: Atrial septal defect.

Table 4. Operative characteristics, primary and secondary outcomes

	Total (n=208)			ACC group (n=102)			BH group (n=106)			95% CI	
	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	Median	*p*
Aortic cross-clamp time (min)			86.5±22.8			97.8±21.6			75.2±18.1	1.22-1.39	0.0001
Cardiopulmonary bypass time (min)			120.8±18.4			140.7±17.3			101.6±15.7	1.33-1.44	0.0001
Selected annuloplasty ring size			31.6±1.6			31.5±1.6			31.6±1.6	0.98-1.01	0.65
Prolonged inotropic dependency*	135	65		78	76		57	54			0.0008
Re-exploration for bleeding	10	5		4	4		6	6			0.74
Postoperative RBBB	16	8		9	9		7	7			0.60
Postoperative LBBB	19	9		14	14		5	5			0.03
Need for temporary pacemaker	36	17		20	20		16	15			0.46
Duration of mechanical ventilation (h)			10.6±4.8			10.4±4.7			10.8±4.8	0.85-1.09	0.57
Postoperative length of ICU stay (days)			2.4±1.99			2.42±2.01			2.37±1.97	0.81-1.28	0.85
Postoperative length of hospital stay (days)			8.31±2.53			8.35±2.62			8.27±2.41	0.92-1.09	0.81
In-hospital mortality	14	7		7	7		7	7			1.00

	Discharged patients						
	n=194		n=95		n=99		
	n	%	n	%	n	%	*p*
Permanent pacemaker requirement	15	8	12	13	3	3	0.0143
Indication for permanent pacemaker implantation							0.5165
High degree AV block	12	80	10	83	2	67	
Sinus node dysfunction	3	20	2	17	1	33	
>2+ TR (at discharge)	18	9	15	16	3	3	0.0023
>2+ TR (at first year)	30	15	22	23	8	8	0.0048

ACC: Aortic cross-clamping; BH: Beating heart; CI: Confidence interval; SD: Standard deviation; RBBB: Right bundle branch block; LBBB: Right bundle branch block; ICU: Intensive care unit; TR: Tricuspid regurgitation; * Postoperative inotrope/vasopressor use including dobutamine (5 μg/kg/min), dopamine (>5 μg/kg/min), norepinephrine (>0.1 μg/kg/min), milrinone, epinephrine, phenylephrine, and vasopressin 24 hours after skin closure was defined as prolonged inotropic dependency.

(93%) in the ACC group and 97 patients (92%) in the BH group.

Overall hospital mortality was 7% (n=14): seven (7%) in the ACC group and seven (7%) in the BH group. The causes of death were heart failure in five, pneumonia in four, ventricular arrhythmias in one, and multi-organ dysfunction in four patients. There was no statistically significant difference between the two groups in terms of in-hospital mortality (p>0.05), as presented in Table 4.

Prolonged inotropic dependency was observed in 78 patients (76%) in the ACC group and in 57 patients (54%) in the BH group. The ACC group required prolonged inotropic support, indicating statistical significance (p<0.05) (Table 4).

Electrocardiograms were also evaluated in the early postoperative period. The number of patients who had right bundle branch block (RBBB) in both groups were similar (9 patients (9%) in the ACC group and 7 patients (7%) in the BH group); however, the postoperative left bundle branch block (LBBB) rates were higher in the ACC group, compared to the BH group (14% vs. 5%, respectively; p<0.05) (Table 4).

Postoperative temporary pacemaker was used in 20 (20%) of 102 patients in the ACC group. Temporary pacemaker was used in 16 (15%) of 106 patients in the BH group, indicating no statistically significant difference between the two groups (p>0.05) (Table 4). However, postoperative PPP was performed in 12 patients (13%) in the ACC group, while only three patients (3%) required PPP in the BH group (p<0.05). Overall, the most common indication for PPP was high-degree atrioventricular (AV) block in 80% of the patients (Table 4).

Re-exploration was performed in four patients (4%) in the ACC group and six patients (6%) in the BH group. There was no statistically significant difference between two groups in terms of the re-exploration rates (p>0.05).

Table 5. Operative and postoperative outcomes of mitral valve replacement + tricuspid ring annuloplasty subgroups

	Total (n=135)		ACC group (n=65)		BH group (n=70)		
	n	%	n	%	n	%	
Prolonged inotropic dependency*	89	66	50	77	39	56	0.0112
Postoperative RBBB	12	9	6	9	6	9	1.00
Postoperative LBBB	13	10	10	15	3	4	0.04
Need for temporary pacemaker	24	18	13	20	11	16	0.65
In-hospital mortality	8	6	4	6	4	6	1.00

	Discharged patients						
	n=127		n=61		n=66		
	n	%	n	%	n	%	*p*
Permanent pacemaker requirement	11	8	9	13	2	3	0.0259
Indication for permanent pacemaker implantation							1.00
High degree AV block	7	64	6	67	1	50	
Sinus node dysfunction	6	36	3	33	1	50	
> 2+ TR (at discharge)	12	9	10	16	2	3	0.0136
> 2+ TR (at first year)	19	15	14	23	5	8	0.0235

ACC: Aortic cross-clamping; BH: Beating heart; RBBB: Right bundle branch block; LBBB: Right bundle branch block; AV: Atrioventricular; TR: Tricuspid regurgitation; * Postoperative inotrope/vasopressor use including dobutamine (5 μg/kg/min), dopamine (>5 μg/kg/min), norepinephrine (>0.1 μg/kg/min), milrinone, epinephrine, phenylephrine, and vasopressin 24 hours after skin closure was defined as prolonged inotropic dependency.

In addition, MVR + tricuspid ring annuloplasty was the most performed procedure, and we also analyzed this subgroup (Table 5). The patients who underwent MVR + tricuspid ring annuloplasty in both groups were compared and the postoperative outcomes were found to be similar.

Furthermore, echocardiography performed at discharge was defined as early period echocardiography. The number of patients with >2 TR in the ACC group was 15 (16 %). This number was 3 (%) in the BH group. When the early period echocardiographic findings for two groups were compared, a statistically significant difference was found for >2 TR in favor of the BH group ($p<0.05$) (Table 4).

Echocardiography performed at the end of the postoperative first year was defined as late period echocardiography. The number of the patients with >2 TR in the ACC group was 22 (23%) and eight (%8) in the BH group. A statistically significant difference was found for >2 TR in favor of the BH group ($p<0.05$) (Table 4).

DISCUSSION

Aggressive approach to TV surgery has been increasingly performed in Turkey in accordance with the guidelines from the European Association for Cardiothoracic Surgery and European Society of Cardiology.[7] In our center, TV annuloplasty is the gold standard surgical therapy for functional TR and liberally performed in left-sided valvular heart disease. Our study findings shows that TVr on a BH is associated with less permanent pacemaker requirement, lower inotropic support, and fewer rates of LBBB and residual TR, compared to the ACC in TV surgery concomitant with other cardiac surgeries.

The primary advantage of BH cardiac surgery without the use of cross-clamp is the shortened cross-clamp and CPB times, minimizing the deleterious effects of extracorporeal circulation and systemic inflammatory response which may increase morbidity and mortality.[8] In their randomized study involving 50 patients who underwent left cardiac valve surgery, Matsumoto et al.[9] compared the methods between BH and arrested heart techniques and reported that shorter CPB times significantly decreased catecholamine release, although there was no statistically significant difference, and also resulted in lower creatine kinase-MB and troponin release during the postoperative period. Romano et al.[10] included a total of 316 patients who underwent redo mitral valve surgery on a BH and 134 patients underwent the same operation at ventricular fibrillation arrest state and reported that surgery on BH yielded better results such as shorter operation and CPB times, less transfusion need, and shorter extubation times. The most important advantage of cardiac surgery on a BH is that there is no need for cardioplegic arrest which may cause myocardial hypoxemia, malnutrition, and electronic

imbalance.[9,11-16] This advantage is particularly important for patients with preoperative myocardial hypertrophy and poor ventricular functions who need longer ACC times.[13]

Tricuspid valve repair can be performed prior to ACC or after cross-clamp removal in patients undergoing surgery on a BH. Furthermore, assessment of TV coaptation is easy, reliable, and reproducible on a BH.[12,13] Several centers advocate performing TVr before mitral valve surgery to avoid tricuspid annular distortion and geometry.[13,14] However, easier surgical exposure and bloodless operative field are the main advantages of ACC.[12]

On the other hand, the most important disadvantages of valve surgery on a BH include limited surgical vision due to the BH, making surgical manipulation more difficult, aortic root fullness, potential tissue injury due to traction of the contracting heart, and excessive amount of blood in the heart.[14] The advantages of refraining from cardioplegic arrest may become clearer with increased cross-clamp times. Hence, patients with multivalve disease or complex TV disease are the most suitable candidates for TV surgery on a BH.

In particular, TV surgery has been shown to increase the risk of developing bradyarrhythmias requiring PPP postoperatively due to the close proximity of the valve to the AV node.[17-19] In recent years, growing evidence has supported early TVr or tricuspid valve replacement (TVR) for medically refractory functional TR associated with severe RV dysfunction.[20,21] Mar et al.[19] carried out a study to evaluate the predictors of PPP following TV surgery. In the aforementioned study, concomitant mitral valve and TV surgery was the most common procedure (42%) with a significantly greater proportion occurring in the PPP group versus the non-PPP group (54% vs. 38%, p=0.028). The most common indication for PPP was high-degree AV block (78%), followed by sinus node dysfunction (13%), and atrial fibrillation with slow ventricular response (8%). The other result of this study was about postoperative rhythms. The incidence of postoperative RBBB was similar. In this study, multivariate regression analysis revealed a cross-clamp time of >60 min (OR 4.1, 95% CI: 1.3-12.9, p=0.015) and concomitant mitral valve surgery (OR 3.8, 95% CI: 1.2-12.2, p=0.026) as independent predictors for PPP following TVR. None of the electrocardiographic findings was found to be independent risk factor for PPP. Cross-clamp time, not unexpectedly, is a critical predictor of permanent pacing following valve surgery, as it indicates cardiac ischemic time. A prolonged period of cardiac ischemia with subsequent ischemic injury of the conduction system has been proposed to be an important mechanism leading to bradyarrhythmias following cardiac surgery. Longer cross-clamp times have historically been associated with increased mortality following cardiothoracic surgery.[11,13,15,16] Previous studies which evaluated permanent pacing after cardiothoracic surgery did not find cross-clamp time to be an independent predictor of permanent pacing based on the regression analysis results. Furthermore, Gordon et al.[17] reported that a cross-clamp time of >60 min conferred a four-fold risk of pacemaker implantation.[17] In our study, the rate of PPP was higher in the ACC group (13% vs. 3%). Overall, indications for PPP were high-degree AV block (80%) and sinus node dysfunction (20%). Although postoperative RBBB rates were similar between the groups (9% in the ACC group and 7% in the BH group), postoperative LBBB rates were higher in the ACC group (14% vs. 5%).

Although most TV surgeries occur in the setting of concomitant left-sided valve surgery, untreated isolated TR has been associated with significant long-term mortality. Literature in the field encourages early surgical intervention of isolated secondary TR in patients refractory to medical treatment with evidence of progressive RV dysfunction. Therefore, the number of TV surgery in the absence of left-sided valve surgery may increase in the coming years.[3-5,13]

Furthermore, in cardiac surgeries carried out under prolonged cross-clamp times, myocardial failure is observed more frequently. Baisden et al.[22] carried out a study on 113 patients in which they highlighted that renal and myocardial failure findings were observed less following surgical operations on a BH.[22] Consistent with this finding, in our study, the intra- and/or postoperative inotropic support requirement was higher for patients in the ACC group. This finding suggests that shorter cross-clamp and CPB times using the BH technique are associated with less inotropic support and less pacemaker requirement postoperatively.

The first report which demonstrated a correlation between the increasing severity of TR and mortality was a retrospective, five-year follow-up study in which TR severity was associated with a worse outcome (26% mortality among patients medically treated), irrespective of age, biventricular systolic function, RV size, and inferior vena cava dilation; however, in the aforementioned study, limited characteristics of the patients such as age and gender were considered.[23] Although not significant, a lower five-year survival rate was also documented for patients who underwent

TV surgery, compared to medically treated patients. In our study, the rate of in-hospital mortality was 7% (n=14). The causes of death were heart failure in five, pneumonia in four, ventricular arrhythmias in one, and multi-organ dysfunction in four patients.

Several studies have demonstrated that significant residual TR has a negative impact on clinical outcomes, functional class, jeopardizing survival. Tricuspid valve surgery on a BH has various advantages, such as the evaluation of the annular diameter in contracting apparatus and more accurate observation of the TV coaptation. Therefore, it is particularly recommended that TVR can be performed on a BH for functional TR cases.[23-25] Our study also confirms that the prevalence of early and late TR in the ACC group is higher, indicating a statistically significant difference. At early echocardiographic assessment after discharge, >2 TR was more common in the ACC group (n=15, 16%) than the BH group (n=3, 3%). At late follow-up, >2 TR was present in 22 patients (23%) in the ACC group, whereas only 8% of the BH group had >2 TR. We believe that assessment of TV coaptation is easy, reliable, and reproducible on a BH technique.

Nonetheless, our study has some limitations, many of which are inherent to any retrospective analysis and single-center design of an observational nature. The number of patients with TVr groups with ACC and BH is also limited. In addition, as with any retrospective study, the present series is susceptible to selection bias which makes it difficult to generalize our findings.

In conclusion, tricuspid valve repair on a beating heart can be performed safely in complex cardiac surgery before or after aortic cross-clamping. In this study, we demonstrated that tricuspid valve repair on a beating heart was associated with less inotropic and postoperative permanent pacemaker requirement, although both techniques yielded similar postoperative outcomes. Of note, residual tricuspid regurgitation after surgery was more commonly seen in the aortic cross-clamping group. These results support the use of tricuspid valve repair on a beating heart for concomitant left-sided valvular heart surgery. However, further, large-scale, prospective, randomized studies are warranted to confirm these findings.

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