




ORIGINAL RESEARCH

A comparative study on the results of beating and arrested heart isolated tricuspid valve surgery: A cross-sectional study

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Abstract

Background and Aims: The isolated tricuspid valve surgery is performed using beating or arrested heart surgery. The present study aimed to evaluate and compare the results of patients who underwent isolated tricuspid valve surgery using the beating and arrested heart techniques.

Methods: In this retrospective observational study, all patients undergoing isolated tricuspid valve surgery between 2011 and 2018 were included. The patient's demographic information, echocardiographic, surgery, and hospitalization results were collected, and the EuroSCORE was calculated from the patient's medical records.

Results: Fifty-three patients were included in the study of which 21 (39.63%) and 32 (60.37%) underwent a beating heart and arrested heart surgeries, respectively. There were no significant differences between the two studied groups in the echocardiographic results before and after the surgery, total hospitalization days ($p = 0.56$), and the mortality in the first 30 days after the surgery ($p = 0.152$). However, the duration of surgery ($p < 0.001$), EuroSCORE ($p = 0.005$), and patients who underwent lateral thoracotomy ($p = 0.007$) were notably lower in the arrested heart than in the beating heart group. In contrast, the duration of cardiopulmonary bypass and hospitalization in an intensive care unit after the surgery was remarkably lower in the beating heart than in the arrested heart group ($p < 0.001$ for both cases).

Conclusion: Although there were some significant differences between the two kinds of surgery techniques, it seems superficial that made a particular decision to consider each method's superiority. Therefore, further studies with larger populations and meta-analyses are required to recommend the preferred method for the surgeons certainly.

KEYWORDS

arrested heart, beating heart, EuroSCORE, isolated tricuspid valve surgery

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1 | INTRODUCTION

Tricuspid valve impairment may lead to heart dysfunction and cause severe and irreversible complications for patients if not appropriately treated.^{1,2} The etiologies of tricuspid valve dysfunction are mainly classified as primary failure and stenosis, including rheumatic diseases, infection of the tricuspid valve, and carcinoid and secondary disorders, primarily due to left-heart pathological problems such as in the left side valve or pulmonary valve.^{3,4} The patients with tricuspid valve impairment are usually clinically asymptomatic for an extended period.⁵ However, patients are typically diagnosed with severe clinical conditions and the symptoms of right ventricular (RV) failure.^{6,7}

The surgery in patients with functional impairment of the tricuspid valve is performed through tricuspid annuloplasty,⁸ and in patients with organic impairment is done by valve replacement.⁹ Two types of mechanical and biological valves are currently available for tricuspid valve replacement.¹⁰ The isolated tricuspid valve surgery is routinely performed by cardiopulmonary bypass with (arrested heart) or without (beating heart) aortic cross-clamp.^{11,12} Surgeons have highly regarded the beating heart method due to its more protection against ischemia and reperfusion. Although its advantages, the beating heart method has important disadvantages, including more incidence of thromboembolic events.^{13,14} The potential benefits of beating heart and arrested heart surgery are still controversial for surgeons.

Therefore, in the present study, we aimed to determine the results and compare the beating heart and arrested heart techniques in patients who underwent isolated surgery of the tricuspid valve in the open heart surgery department of Imam Reza and Ghaem Hospitals affiliated with Mashhad University of Medical Sciences, Mashhad, Khorasan Razavi province, Iran, from 2011 to 2018.

2 | MATERIALS AND METHODS

2.1 | Study design

This retrospective observational study was conducted on all (53) patients who underwent isolated tricuspid valve surgery in the open heart surgery department of Imam Reza and Ghaem Hospitals affiliated with Mashhad University of Medical Sciences from 2011 to 2018. The surgery was performed on a beating or arrested heart condition, depending on the surgeon's preference. The arrested heart method was performed by cardioplegia cannula to infusion of the cardioplegic solution.¹⁴ Lateral thoracotomy was operated on in patients who had previously undergone sternotomy twice. Therefore, the third sternotomy operation was high risk. In addition, lateral thoracotomy was performed in patients who had RV adhesion severely to retrosternal in chest X-ray or computed tomography scan. Moreover, the valve selection was based on the discussion with the patient and their preference regarding the age and lifestyle of the

patients. Furthermore, the mechanical valve was performed in patients who were operated on several times to prevent valve refailure.¹⁵

2.2 | Data collection

The demographic patient's information; echocardiographic results before and after the surgery; surgery results including the type of tricuspid valve surgery, duration of surgery, duration of aortic cross-clamp, and cardiopulmonary bypass; and hospitalization results such as duration of hospitalization, mortality within the 30 days after the surgery, and atrioventricular (AV) node conduction disorders were collected from patients' medical records. Furthermore, the EuroSCORE has been calculated according to the patient's history.

2.3 | Statistical analysis

Data were analyzed using the SPSS version.22 statistical software (SPSS Inc.) and expressed according to the nature of parametric and non-parametric as means \pm SD or number with percentage, respectively. The normality of data was assessed using Kolmogorov–Smirnov test. In addition, the comparison between continuous variables was performed using Student's *t*-test for parametric data or Mann–Whitney *U* and Wilcoxon tests for nonparametric data, as appropriate. Finally, the comparison between categorical variables was made using the χ^2 test. The levels of $p \leq 0.05$, 0.01, and 0.001 were considered statistically significant.

3 | RESULTS

In the present study, we divided the patients according to the technique of isolated surgery of the tricuspid valve, including beating and arrested heart surgery. Among the 53 patients who were candidates for the isolated surgery of the tricuspid valve, 21 (39.63%) and 32 (60.37%) underwent the beating heart and arrested heart surgeries, respectively.

3.1 | Baseline characteristics

The baseline characteristics of patients are shown in Table 1. The mean age of patients was 49.5 ± 52.92 and 49.7 ± 52.24 years in the beating heart group and arrested heart group, respectively (Table 1). The beating heart group had 5 (23.8%) males and 16 (76.2%) females, and the arrested heart group had 24 (75%) males and 8 (25%) females. There were no significant differences in age, glomerular filtration rate, pulmonary arterial pressure, heart rhythm, hypertension, diabetes mellitus, chronic obstructive pulmonary disease, dyslipidemia, and ascites between the two groups (Table 1). However, the beating and arrested heart groups had significant

TABLE 1 The baseline characteristic results of the beating and arrested heart surgery groups

Characteristic		BH (N = 21)	AH (N = 32)	p
Age (years, mean ± SD)		49.5 ± 52.92	49.7 ± 52.24	0.97*
GFR (ml/min/1.73 m ² ; mean ± SD)		67.18 ± 1.86	65.17 ± 6.58	0.77*
PAP (mmHg, mean ± SD)		33.98 ± 7	32.8 ± 5.23	0.79*
Sex (N, %)	Male	5 (23.8%)	24 (75%)	0.001**
	Female	16 (76.2%)	8 (25%)	
Heart rhythm (N, %)	Sinus	5 (23.8%)	10 (31.31%)	0.75**
	AF	16 (76.2%)	22 (68.8%)	
History of previous surgery (N, %)		8 (38.1%)	27 (84.4%)	0.001**
Hypertension (N, %)		8 (38.1%)	12 (37.5%)	0.99**
Diabetes mellitus (N, %)		3 (37.5%)	5 (15.6%)	0.99**
COPD (N, %)		4 (19%)	4 (12.5%)	0.69**
Dyslipidaemia (N, %)		5 (23.8%)	8 (25%)	0.92**
Ascites (N, %)		12 (57.1%)	15 (57.1%)	0.46**

Abbreviations: AF, atrial fibrillation; AH, arrested heart; BH, beating heart; COPD, chronic obstructive pulmonary disease; GFR, glomerular filtration rate, PAP, pulmonary arterial pressure.

*Comparing the beating and arrested heart groups using an unpaired t-test.

**Comparing the beating and arrested heart groups using a χ^2 test.

differences in sex and history of previous surgery ($p < 0.001$ for both cases, Table 1).

3.2 | Lateral thoracotomy results

In the beating heart group, five (23.8%) patients underwent lateral thoracotomy. However, none of the patients in the arrested heart group had lateral thoracotomy (Table 2).

3.3 | Echocardiographic results

The echocardiographic results of the beating and arrested heart groups before and after the surgery are shown in Table 3. There were no significant differences in the left ventricular ejection fraction (LVEF), right ventricular fractional area change (RVFAC) before the surgery, and RVFAC after the surgery between the two studied groups (Table 3).

3.4 | The type of valve performed for the surgery

As illustrated in Figure 1A, among the beating heart isolated surgery of the tricuspid valve patients, 16 (76.2%) were replaced with a mechanical valve, 3 (14.3%) underwent De Vega tricuspid annuloplasty, and 2 (9.5%) used ring (Figure 1A). Furthermore, the tricuspid valve replacement was performed using the mechanical valve in 16 (50%), biological valve in 5 (15.6%), De Vega tricuspid annuloplasty in 6 (18.8%), and ring in 5 (15.6%) patients who underwent arrested heart surgery (Figure 1B).

TABLE 2 The lateral thoracotomy results in the beating and arrested heart surgery groups

Lateral thoracotomy	BH (N = 21)	AH (N = 32)	p*
Yes	5 (23.8%)	0 (0%)	0.007
No	16 (76.2%)	32 (100%)	

Abbreviations: AH, arrested heart; BH, beating heart.

*Comparing the beating and arrested heart groups using the χ^2 test.

TABLE 3 The echocardiographic results of the beating and arrested heart surgery groups

Characteristic (mean ± SD)	BH (N = 21)	AH (N = 32)	p*
LVEF (%)	39.8 ± 9.47	38.11 ± 1.39	0.57
RVFAC before the surgery (%)	19.5 ± 57.58	21.6 ± 1.15	0.33
RVFAC after the surgery (%)	14.4 ± 14	14.4 ± 8.99	0.59

Abbreviations: AH, arrested heart; BH, beating heart; LVEF, left ventricular ejection fraction; RVFAC, right ventricular fractional area change.

*Comparing the beating and arrested heart groups using an unpaired t-test.

3.5 | Etiological evaluations for the tricuspid valve surgery

Among the beating heart surgery patients, 17 (81%) had functional, and 4 (19%) had rheumatic reasons for replacement of tricuspid valve (Figure 2A). Moreover, in the arrested heart surgery patients, 22 (68.8%)

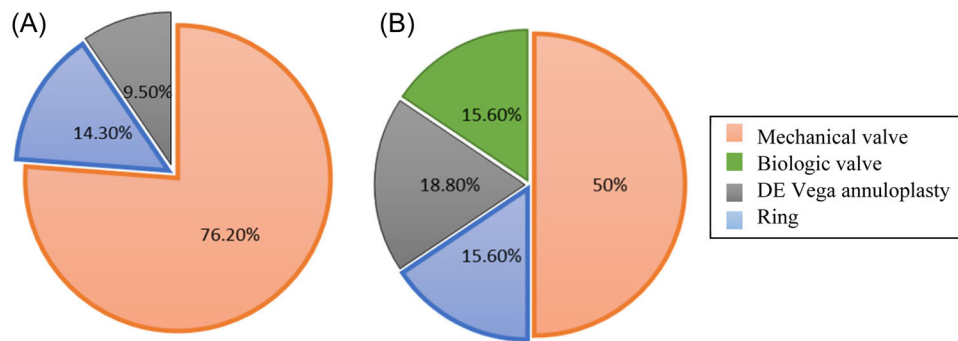


FIGURE 1 The type of valve performed for the tricuspid valve replacement surgery in (A) beating heart and (B) arrested heart technique.

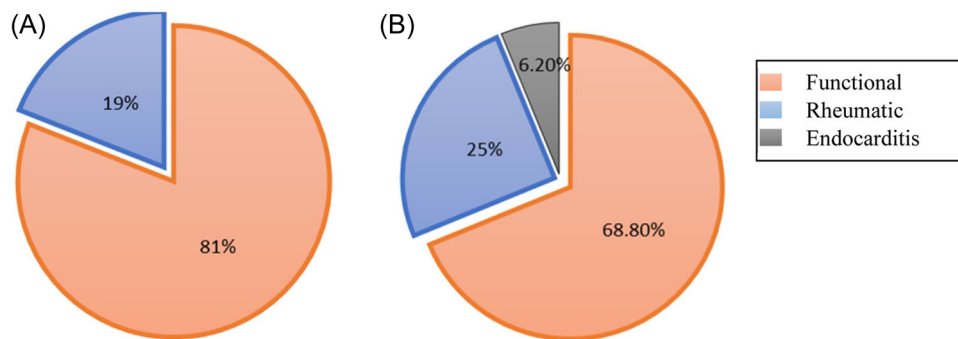


FIGURE 2 The etiological evaluations for the tricuspid valve replacement surgery in (A) beating heart and (B) arrested heart technique.

had functional, 8 (25%) had rheumatic, and 2 (6.2%) had endocarditis aetiologies for the tricuspid valve replacement (Figure 2B).

3.6 | During the surgery and after the surgery results

The surgery duration and the EuroSCORE were notably lower in the arrested heart group than in the beating heart group ($p = 0.001$ and 0.005 , respectively, Table 4). In addition, the duration of cardiopulmonary bypass, and hospitalization in intensive care unit (ICU) were remarkably lower in the beating heart group compared to the arrested heart group ($p = 0.001$ for both, Table 4). There were no significant differences in the total hospitalization time between the two groups ($p = 0.56$). The duration of an aortic cross-clamp in the arrested heart group was 32.1 ± 2.18 min. Moreover, the mortality in the first 30 days after the surgery was two patients in the beating heart group and none in the arrested heart group ($p = 0.152$). Furthermore, no conduction disorders such as AV block was reported in the two studied groups.

4 | DISCUSSION

The current study is the first comparative report on the results of the beating heart and isolated heart techniques in patients who underwent isolated surgery of the tricuspid valve in the open-heart surgery

TABLE 4 During the surgery and after the surgery results of the beating and arrested heart surgery groups

Characteristic (mean \pm SD)	BH (N = 21)	AH (N = 32)	p^*
Operation time (min)	131.9 \pm 12.19	111.2 \pm 11.77	0.001
Cardiopulmonary bypass time (min)	28.2 \pm 3.7	40.1 \pm 4.07	0.001
Aortic cross-clamp time (min)	-	32.1 \pm 2.18	-
ICU stay (day)	2.5 \pm 0.51	3.4 \pm 0.49	0.001
Hospitalization (day)	10.8 \pm 1.33	11.0 \pm 1.37	0.56
EuroSCORE	5.8 \pm 4.8	2.8 \pm 2.64	0.005

Abbreviations: AH, arrested heart; BH, beating heart; ICU, intensive care unit.

*Comparing the beating and arrested heart groups using an unpaired t-test.

department of Imam Reza and Ghaem Hospitals affiliated with the Mashhad University of Medical Sciences from 2011 to 2018. The present study's findings indicated that among the total 53 patients, 21 (39.63%) and 32 (60.37%) underwent a beating heart and arrested heart surgeries, respectively. Our statistical analysis showed no significant differences between the two studied groups in the age and echocardiographic results before and after the surgery. However, the duration of surgery, EuroSCORE, and patients who underwent

lateral thoracotomy were notably lower in the arrested heart group than in the beating heart group. In addition, the duration of cardiopulmonary bypass, hospitalization in ICU, total hospitalization, and mortality in the first 30 days after the surgery were remarkably lower in the beating heart group than in the arrested heart group. Furthermore, no conduction disorders such as AV block were reported in the two studied groups. The beating heart group did not need to undergo a cardioplegia cannula to infusion of the cardioplegic solution, which decreased the cardiopulmonary bypass time compared to the arrested heart group. Furthermore, the speed of the surgeon's operation increases in the beating heart method due to the patient's situation than in the arrested heart method.¹⁶

Similarly, Baraki et al.¹⁷ evaluated the results of 92 patients who underwent tricuspid valve surgery at Hannover Medical School, Hannover, Germany, from 1996 to 2011. They reported that among the total 92 patients, 48 and 44 patients had a beating heart and arrested heart surgery, respectively. The EuroSCORE was higher in the beating heart group than in the arrested heart group. In addition, replacement with biological valve replacement was the most frequently performed method, followed by tricuspid valve repair and replacement with mechanical valve; and there were no differences in the type of valve replacement or repaired between the beating heart and arrested heart method. The operation time was significantly longer in the beating heart than in the arrested heart and the aortic cross-clamp time was 41 ± 20 min. However, there were no differences in the cardiopulmonary bypass time, total days of hospitalization, postoperative AV block, days of hospitalization in ICU, and 30-day mortality in the beating heart and arrested heart groups. Following 1, 5, and 10 years of follow-up, patients who underwent beating heart surgery had a lower survival rate than those arrested heart.¹⁷ Furthermore, Buzzatti et al.¹⁸ reviewed the results of 61 patients who underwent isolated tricuspid valve replacement in San Raffaele University Hospital, Milan, Italy, from 1997 to 2012. They demonstrated that 85.2% of patients had to beat heart surgery, and there were no significant differences in the mean cardiopulmonary bypass time of beating heart and arrested heart groups. Additionally, the mean aortic cross-clamp time was 32.0 ± 6.2 min in the arrested heart group. They reported no significant differences in the acute outcomes following the isolated tricuspid valve replacement between the beating and arrested surgery groups, except for days of hospitalization after the surgery. Although the five cases of death following the isolated tricuspid valve replacement using the beating heart technique, there were no significant differences in the survival rate and mortality between the beating and arrested heart groups.¹⁸ Taken together, they could not prove the superiority of a beating heart over the arrested heart surgery method.

Additionally, Pfanmüller et al.¹⁹ determined the results of 105 patients who underwent tricuspid valve surgery at Leipzig Medical School, Leipzig, Germany, from 1997 to 2010. They noticed that 63 patients had a beating heart, and 42 patients had arrested heart surgery. The mean age, previous cardiac surgery, and atrial fibrillation were higher in the beating heart group. The operation time was notably longer in the arrested heart than in the beating heart, and the

aortic cross-clamp time was 44.0 ± 21.8 min. However, there were no differences between the beating heart and arrested heart groups in the cardiopulmonary bypass time, postoperative echocardiographic results, postoperative pacemaker implantations, and neurologic outcomes. Furthermore, no significant differences were reported in the 5-year survival rate and the 5-year event-free survival rate for the beating heart and arrested heart operations, respectively. Collectively, they supported that both beating and arrested heart techniques for tricuspid valve surgery had good results, and they suggested the beating heart method due to its minimally invasive manner.¹⁹ Ricci et al.²⁰ figured out the results of 59 patients who underwent multiple valve surgery using the beating heart technique at Miller School of Medicine, and Jackson Memorial Hospital, Miami, Florida, from 2000 to 2007. They figured out that 16 patients had mitral valve replacement plus tricuspid valve repair and 13 patients had mitral valve repair plus tricuspid repair. Furthermore, early mortality within less than 30 days was observed in five patients, and late mortality within more than 30 days occurred in two patients. The results of a 1-year follow-up showed preserved postoperative LVEF in these patients. Totally, they emphasized the benefits of the beating heart method for multiple valve surgeries.²⁰ However, further studies are necessary to thoroughly understand the superiority of the beating heart over the arrested heart technique in isolated tricuspid valve operation.

The present study showed that the tricuspid valve replacement was more frequently performed using the mechanical valve than a biological valve in beating heart and arrested heart patients. Recently, Negm et al.²¹ reviewed the results of 23 studies with tricuspid valve replacement and reported a total number of 945 mechanical and 1332 biological tricuspid valve replacements. Furthermore, no significant differences were observed between the mechanical and biological groups in the 30 days and late mortality, reoperation, and 5-year valve failure.²¹ Another study also determined that biological and mechanical valves were used in 76.2% and 23.8% of patients, respectively, and there were no significant hemodynamic differences between these two types of valves.²² Similarly, Cho et al.²³ evaluated that among 104 patients who underwent tricuspid valve replacement, 59 had mechanical and 45 had a biological valve replacement. In fact, they reported that no significant differences were observed in the mortality rate and event-free survival between the two types of valves.²³ Thus, collectively, there was no superiority between the mechanical and biological valves, and it should be chosen according to the patient's condition.

Our results also revealed that tricuspid valve replacement was more frequently performed than tricuspid valve repair in beating heart and arrested heart groups. In contrast, Moraca et al.²⁴ figured out that among the 315 patients who underwent tricuspid valve surgery, 93 replacements and 222 repairs have been done. Moreover, the 30 days of mortality, days of hospitalization, and 1, 5, and 10-year survival rates were similar between the valve replacement and repair.²⁴ A meta-analysis of 17 studies and 4561 patients recently determined that 3432 and 1129 patients underwent tricuspid valve repair and replacement, respectively. Additionally, they reported a

higher mortality risk in the tricuspid valve replacement group than in tricuspid valve repair.²⁵ Taken together, the tricuspid valve replacement should be considered in patients with who there is a reasonable chance for recurrence of impairment after repair.

5 | CONCLUSION

In summary, among the 53 patients, the duration of surgery and EuroSCORE was notably lower in the arrested heart group than in the beating heart group. In addition, the time of cardiopulmonary bypass, hospitalization in ICU, and total hospitalization after the surgery were remarkably lower in the beating heart group compared to the arrested heart group. However, there were no significant differences in mortality in the first 30 days after the surgery between the two studied groups. Although there were some significant differences between the two kinds of surgery techniques, it seems superficial that made a particular decision to consider each method's superiority. Therefore, further studies with larger populations and meta-analyses on reports are required to recommend the preferred method for the surgeons certainly.

AUTHOR CONTRIBUTIONS

Leila Bigdelu: Conceptualization; funding acquisition; investigation; and methodology. **Ali Azari:** Conceptualization; investigation; and methodology. **Zarrin Mashayekhi:** Data curation and investigation. **Maliheh Dadgarmoghaddam:** Data curation and formal analysis. **Vafa B. Rahimi:** Formal analysis; writing–original draft; and writing–review and editing.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data are available from the corresponding author upon reasonable request.

ETHICS STATEMENT


This study was confirmed by the ethics committee of Mashhad University of Medical Sciences (approval code. IR.MUMS.fm.REC.1395, 269). The need to obtain written informed consent was waived because of the retrospective design of the study by the Mashhad University of Medical Sciences Ethics Committee. Indeed, we made no further interventions in the diagnosis and treatment of patients during this study.

TRANSPARENCY STATEMENT

This manuscript is an honest, accurate, and transparent account of the study being reported; no important aspects of the study have been omitted, and any discrepancies from the study as planned have been explained.

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