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A meta-analysis of beating versus arrested heart isolated tricuspid valve surgery

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ABSTRACT

Objectives: This meta-analysis aimed to compare postoperative outcomes of isolated tricuspid valve surgery with the beating heart and arrested heart techniques.

Materials and methods: A meta-analysis of published studies reporting the comparison of early and late follow-up of isolated tricuspid valve surgery with beating heart and arrested heart techniques was conducted. An analysis of the studies was also performed for each postoperative outcome, observed mortality, and reintervention.

Results: A total of 459 articles were identified. After the removal of duplicate and irrelevant studies and the exclusion of studies due to combined procedures, study design, and the lack of relevant outcomes, five retrospective observational studies with 566 patients were included for meta-analysis. The beating heart technique was used in 303 patients, whereas 263 underwent the arrested heart technique for isolated tricuspid valve surgery. Patients who underwent beating heart surgery had a higher EuroSCORE (European System for Cardiac Operative Risk Evaluation) II (mean difference=6.02, 95% confidence interval [CI]: 2.87-9.16, p=0.0002). No significant differences were observed in in-hospital mortality (odds ratio [OR]=0.96, 95% CI: 0.53-1.73, p=0.88) and permanent pacemaker implantation rate (OR=0.84, 95% CI: 0.49-1.46, p=0.54). Previous cardiac surgery (OR=2.87, 95% CI: 2.03-4.04, p<0.0001) was significantly higher, and infective endocarditis (OR=0.4, 95% CI: 0.26-0.60, p<0.0001) was significantly less in the beating heart group.

Conclusion: Isolated tricuspid valve surgery using the beating heart and arrested heart technique can be performed with no significant difference in postoperative morbidities and mortality. The beating heart technique may be used in more complex patients.

Keywords: Arrested heart, beating heart, surgery, tricuspid valve.

Isolated tricuspid valve surgery (TVS) is the gold standard treatment for patients with right heart failure and symptoms due to tricuspid valve disease.[1-3] Isolated TVS has high operative mortality compared to not only other isolated valve surgeries but also combined valve surgery involving the tricuspid valve.[4,5] Recently, Zack et al.[6] reported an in-hospital mortality rate of 8.8% for isolated TVS despite optimal medical treatment and increase in surgical volume. The authors noted that optimal surgical timing and patient selection is of utmost importance to have better outcomes.

Isolated TVS can be performed with a beating heart (BH) or arrested heart (AH) technique under cardiopulmonary bypass. Although both techniques have been used widely, there is no consensus on the superiority of one technique to the other.[7-12] Russo et al.[11] reported that the 30-day mortality rate was 6.2% *vs.* 5.0% in the AH and BH groups. They also stated that the BH technique was associated with increased long-term survival and freedom from reoperation compared to the standard AH technique. However, Flagiello et al.[10] reported that the BH technique showed comparable outcomes to the AH technique for isolated TV surgery despite a higher risk profile. Surgical advantages of the AH approach include bloodless surgical field and better leaflet exposure during repair or replacement procedures.

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Alternatively, the BH technique decreases the incidence of complications related to aortic clamping, such as myocardial injury and cerebrovascular events. The effect of the suture bites on cardiac rhythm can be simultaneously monitored.

In the literature, there are few retrospective observational studies published, and to date, the advantages of the BH technique have yet to be demonstrated.[7-11] No randomized clinical trial comparing BH and AH approaches have been reported. This study aimed to reveal, through a systematic review with meta-analysis of all published comparative studies, whether the BH technique decreases postoperative mortality, rates of reexploration, permanent pacemaker implantation, or reintervention, compared to the AH technique during isolated TVS.

MATERIALS AND METHODS

Literature search strategy

An electronic search was performed using the PubMed database (United States National Library of Medicine), Scopus (Elsevier), Ovid Medline, EMBASE (Excerpta Medica Database), Cochrane Database of Systematic Reviews, and ULAKBIM (Turkish National Academic Network and Information Center) database until February 2022. The study was performed in accordance with the MOOSE (Meta-analysis of Observational Studies in Epidemiology) criteria and PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Figure 1).[13,14] To have the most effective search results, the terms "beating heart," "arrested heart," or "tricuspid valve" and "surgery" were used as keywords to find publications conducted in humans. In addition, the reference list of all selected articles was checked to identify potentially relevant articles. Duplicate articles were removed. All results were independently screened for data accuracy. In case of data differences, the relevant data were reexamined.

Study design and selection criteria

Eligible studies for this systematic review and meta-analysis included comparative observational studies that included patients who underwent isolated TVS. Cohort series that did not compare the results of isolated TVS in the BH and AH groups were excluded. Abstracts, case reports, small case series (<20 patients), letters to the editor, conference presentations, editorials, and how to articles were excluded. Review articles were excluded to avoid duplication of results and potential for publication bias. Table 1 shows the characteristics of included studies.

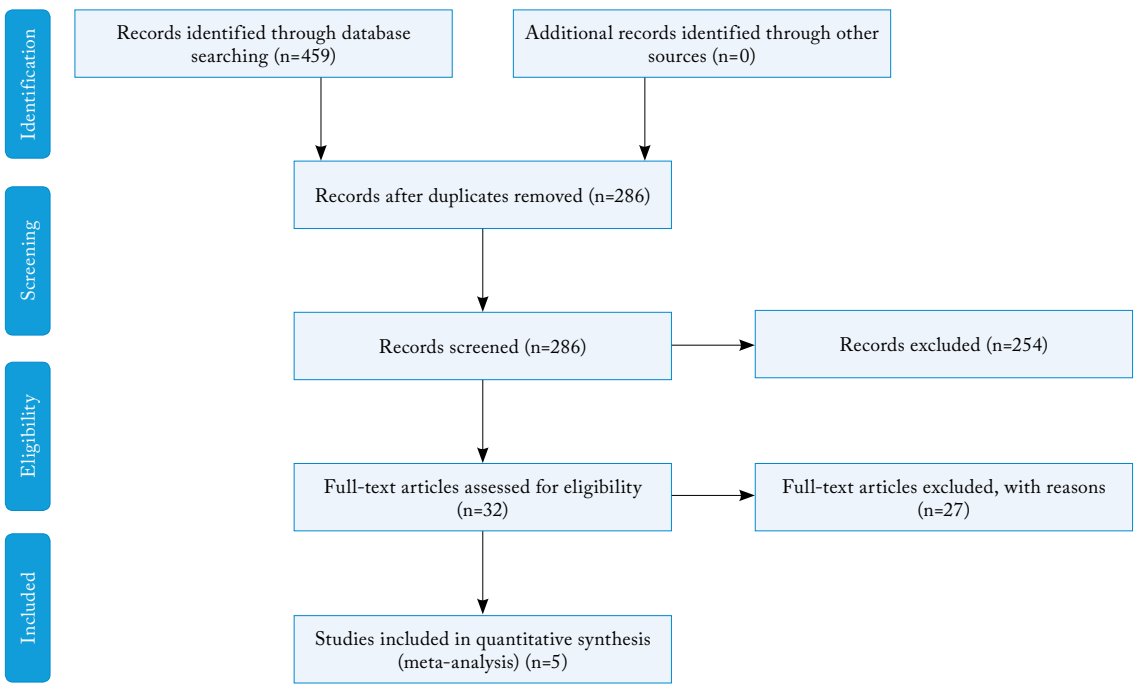

Figure 1. Flowchart of the study.

Data extraction

All data was taken from the main texts, tables, and figures of the relevant studies. Two investigators reviewed the studies and assessed the details of each article, including demographics, interventions, and outcomes. Authors of included trials were contacted when necessary to clarify data and identify multiple publications. The authors of the study reached a consensus by a discussion of the results. The senior investigator reviewed the final outcomes.

Endpoints

The primary outcome was defined as hospital mortality, which was defined as mortality occurring within 30 days after the operation. The secondary outcome was early postoperative outcomes, including re-exploration and permanent pacemaker implantation. The late secondary outcome was the need for tricuspid valve reintervention.

Statistical analysis

The statistical analyses were performed with R version 4.0.3 (The R Foundation for Statistical Computing, Vienna, Austria). Outcomes were analyzed as dichotomous variables. For dichotomous variables, the odds ratio (OR) was calculated with a 95% confidence interval (CI) for proportions. The weighted mean difference (MD) was calculated with 95% CI for means. Heterogeneity was examined using Cochran's Q test, as well as the I^2 statistic.[15,16] Recognizing that the Q-test is often underpowered to detect statistically significant heterogeneity, particularly when there are few trials in the analysis, the relatively conservative threshold of a p-value <0.10 was chosen to suggest statistically significant heterogeneity across trials. In addition to the Q statistic, the I^2 was calculated to quantify the degree of heterogeneity across trials that could not be attributable to chance alone. As the I^2 indicates the proportion of variability between trials that cannot be attributable to chance alone, it provides an improved measure of heterogeneity between trials and is not limited by power.[15,16] Forest plots were created for primary and secondary outcomes. A funnel plot was also used to examine publication bias in the primary outcome. A p-value <0.05 was considered statistically significant.

RESULTS

Description of the selected studies

Figure 1 demonstrates the search results. No randomized clinical trial or meta-analysis was found.

Table 1
Characteristics of the included studies

Study	Study type	Beating heart	Arrested heart	Follow-up			Hospital mortality	Re-exploration	Permanent pacemaker implantation	Reintervention
		n	n	Mean±SD	Median	Min-Max				
Pfannmüller et al.[7]	ROS	63	42	32.0±32.6 months			Yes	Yes	Yes	Yes
				BHG: 4.2±4.0 years						
Baraki et al.[8]	ROS	48	44	AHG: 5.4±4.3 years			Yes	Yes	Yes	Yes
Atılgan et al.[9]	ROS	16	13		N/A		Yes	Yes	No	No
Russo et al.[11]	ROS	129	129		21	1-131 months	Yes	Yes	Yes	Yes
Flagiello et al.[10]	ROS	47	35	51.2±37.1 months			Yes	Yes	Yes	No

SD: Standard deviation; AHG: Arrested heart group; BHG: Beating heart group; N/A: Not available; ROS: Retrospective observational study.

Table 2
Preoperative and operative data

	Estimate			
	MD	OR	95% CI	*p*
Preoperative data				
Age (year)[7-11]	3.78		1.24-6.3	0.0035*
Ejection fraction (%)[7,9,10]	–0.51		–3.05-2.02	0.6930
EuroSCORE II[7-9]	6.02		2.87-9.16	0.0002*
NYHA Class II-IV[8-11]		1.30	0.9-1.91	0.1610
Infective endocarditis[7,8,10,11]		0.4	0.26-0.60	<0.0001
History of previous cardiac surgery[7-11]		2.87	2.03-4.04	<0.0001*
Operative data				
Valve replacement[7-11]		1.10	0.77-1.57	0.6011
Valve repair[7-11]		0.9	0.64-1.30	0.6011
Thoracotomy incision[7-11]		2.15	1.4-3.3	0.0004*

MD: Mean difference; OR: Odds ratio; CI: Confidence interval; NYHA: New York Heart Association; * p-value <0.05 was considered statistically significant.

A total of 459 articles were identified. After removing duplicate and irrelevant studies, 32 full-text articles were reviewed for eligibility. On further examination of these retrieved studies, 27 were subsequently excluded due to combined procedures, study design, and the lack of relevant outcomes reported, such as 30-day mortality. Of the remaining studies, only five studies including 566 patients were used for meta-analysis.[7-11] All five studies included in the meta-analysis were retrospective observational studies. Table 1 summarizes the characteristics of the included studies.

Perioperative characteristics

Table 2 reveals the demographic and operative data of included studies. Patients who underwent BH isolated TVS were significantly older (MD=3.78, 95% CI: 1.24-6.3, p=0.0035) and had a significantly higher EuroSCORE (European System for Cardiac Operative Risk Evaluation) II (MD=6.02, 95% CI: 2.87-9.16, p=0.0002). In the BH group, history of previous cardiac surgery (OR=2.87, 95% CI: 2.03-4.04, p<0.0001) was significantly higher and the incidence of infective endocarditis (OR=0.4, 95% CI: 0.26-0.60, p<0.0001) was significantly decreased in comparison

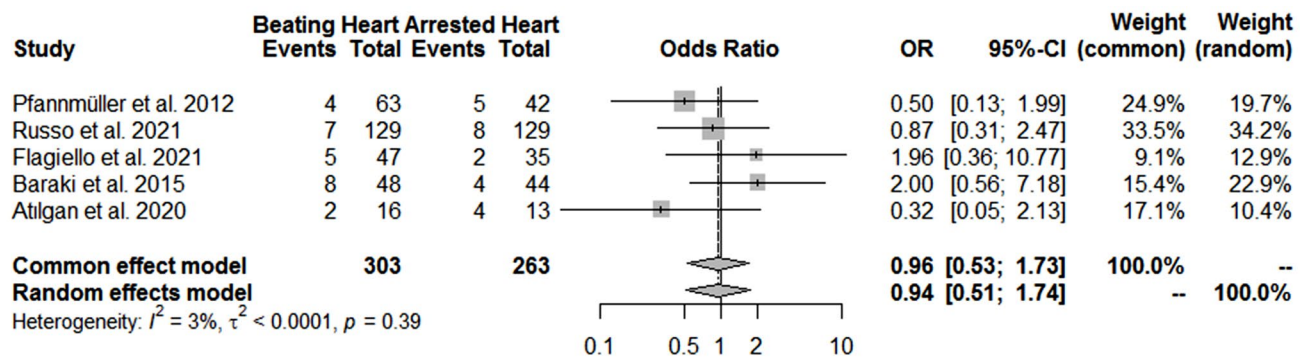

Figure 2. Forest plots for in-hospital mortality.
OR: Odds ratio; CI: Confidence interval.

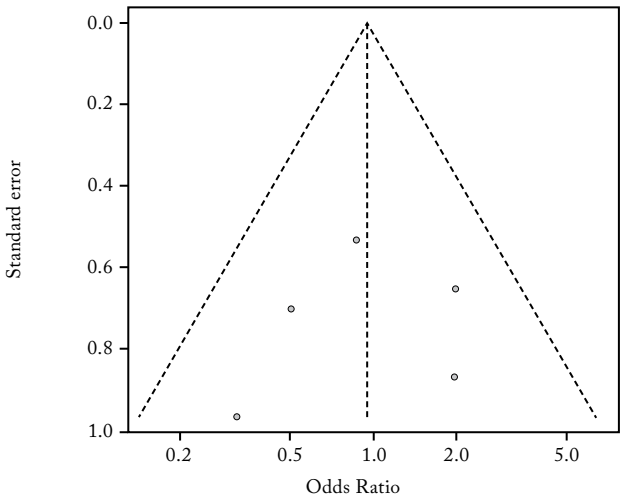

Figure 3. Funnel plot for in-hospital mortality.

to the AH group. Thoracotomy incision (OR=2.15, 95% CI: 1.4-3.3, p=0.0004) was used more in the BH group, and sternotomy was more common in the AH group.

There were no significant differences for the New York Heart Association functional Class III-IV symptoms and tricuspid valve replacement or tricuspid valve repair procedures between the BH and AH groups (p>0.05).

Primary outcome

In-hospital death occurred in 26 of 303 patients in the BH group and 23 of 263 patients in the AH group in the five studies included in the analysis. Overall, the analysis showed that the risk of hospital mortality was similar in both groups (OR=0.96, 95% CI: 0.53-1.73, p=0.88). Forest plots and funnel plots for in-hospital mortality are shown in Figures 2 and 3, respectively.

Secondary outcomes

A total of 42 patients undergoing isolated TVS required reexploration. No statistically significant difference was found in the need for reexploration in the BH and AH groups (OR=0.89, 95% CI: 0.48-1.67, p=0.72). Figure 4 displays the forest plot for postoperative reexploration.

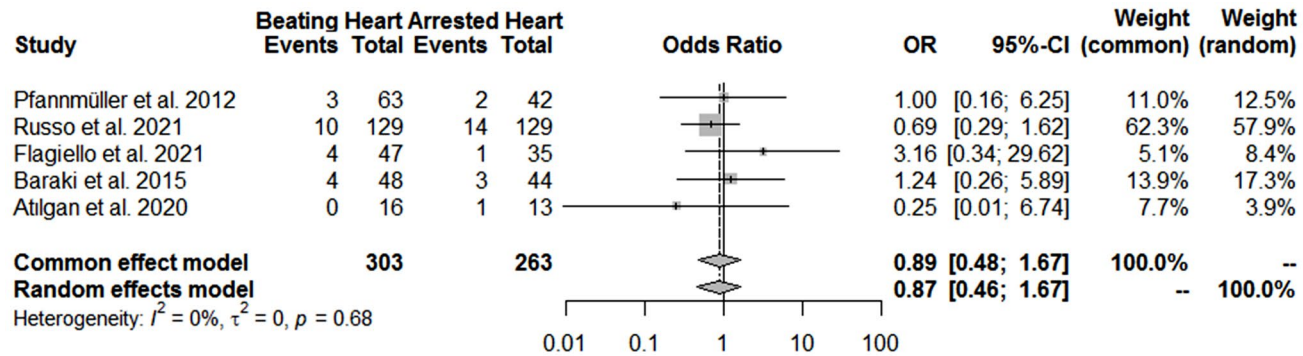

Figure 4. Forest plots for reexploration.
OR: Odds ratio; CI: Confidence interval.

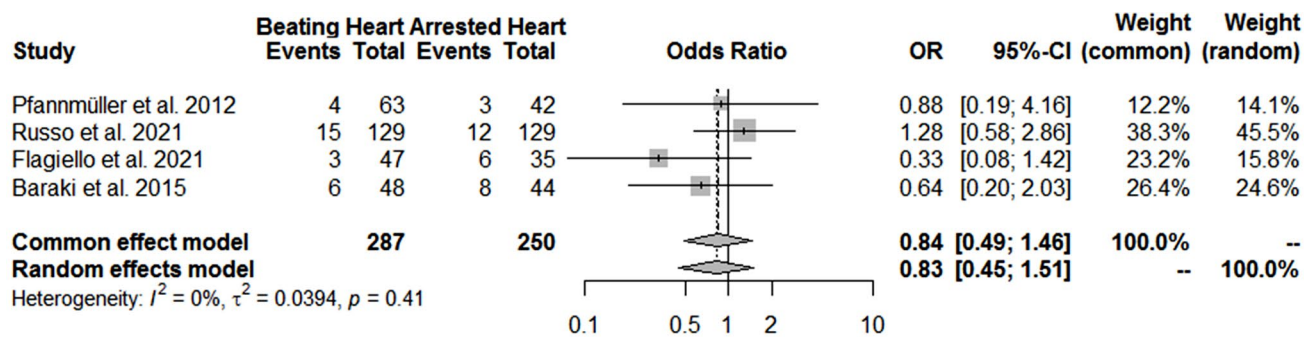

Figure 5. Forest plots for pacemaker implantation.
OR: Odds ratio; CI: Confidence interval.

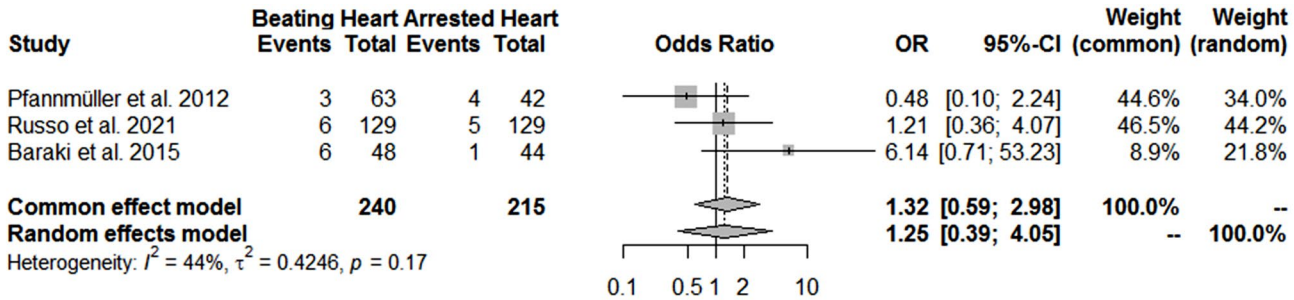

Figure 6. Forest plot for tricuspid valve reintervention.
OR: Odds ratio; CI: Confidence interval.

Four studies collected postoperative permanent pacemaker implantation data.[7,8,10,11] Permanent pacemakers were implanted in 28 of 287 patients in the BH group and in 29 of 250 patients in the AH group. The risk of permanent pacemaker implantation in the postoperative period was similar in both groups, as shown in Figure 5 (OR=0.84, 95% CI: 0.49-1.46, p=0.54).

There were three studies that collected data on patients requiring tricuspid reoperation at long-term follow-up.[7,8,11] Tricuspid valve reoperation was required in 25 of 455 patients. No statistically significant difference was found in the need for reoperation in the BH and AH groups (OR=1.32, 95% CI: 0.59-2.98, p=0.50). Figure 6 shows the forest plot for tricuspid valve reoperation.

DISCUSSION

No previous meta-analysis has studied the effect of the BH versus AH technique for isolated TVS in randomized or nonrandomized trials. A few retrospective observational studies have reported the outcomes of the comparison of the two techniques for isolated TVS.[7-11] The study by Russo et al.[11] suggested that the BH technique was associated with significant benefits in terms of long-term survival and reintervention. However, early mortality and postoperative outcomes were comparable in all published studies.[7-11] Isolated TVS remains challenging due to high mortality rate. In the articles included in this meta-analysis, the operative mortality of isolated tricuspid surgery ranged from 5.8 to 20.7%.[9,11]

Previously published studies on TVS techniques have mostly focused on tricuspid valve replacement or tricuspid valve repair.[17,18] Although the BH and AH techniques for right-sided cardiac surgery have been described for a long time, there are few studies in the literature comparing the BH technique with the AH technique in isolated TVS.[19,20] The first article was published by Pfannmüller et al.[7] in 2012. However, the number of patients included was limited, as in all subsequent articles. We performed this meta-analysis due to the limited number of available studies. To the best of our knowledge, this is the first meta-analysis to examine the postoperative outcomes of BH and AH techniques in TVS.

The main findings of this study were that there was no difference between the postoperative results of BH and AH techniques in isolated TVS. The mortality of tricuspid valve repair is lower than that of tricuspid valve replacement.[17] Since the replacement and repair patients were homogeneously distributed in the meta-analysis groups, it is not expected to affect the mortality analysis. In this analysis, we think that the BH technique was mostly used in more complex patients since EuroSCORE II, the most widely used risk scale in cardiac surgery, was higher in the BH patients. The preoperative clinical condition of isolated TVS patients is one of the most important factors in terms of postoperative mortality, as well as in patients undergoing acute aortic dissection surgery.[21] Therefore, the hospital mortality results of this meta-analysis should be carefully considered so as not to reach a definitive conclusion.

A permanent pacemaker may be required after isolated TVS.[22] In TVS performed with the BH technique, the theoretical effect of sutures passed through the annulus of the tricuspid valve on the

heart rhythm can be directly monitored. It is expected that severe heart blocks will not be encountered by taking precautions when the stitch disruption of the rhythm is noticed. However, according to the results of the meta-analysis, we can say that this advantage of the BH technique has no effect on the reduction of permanent pacemaker implantation in the early postoperative period.

Freedom from reoperation after TVS demonstrates the success of the surgical technique and is reported in most series on the tricuspid valve.[23] Saran et al.[24] showed that tricuspid valve replacement increased the need for reoperation in the long term compared to repair. In the BH technique, placement of annular sutures is challenging due to the movement of the heart and may increase ring and valve dehiscence. Such situations may cause the need for reoperation for the tricuspid valve in the long-term follow-up. However, in this meta-analysis, there was no difference between the need for reoperation in the long-term follow-up of patients who had TVS with the BH technique and the AH technique.

As demonstrated in our meta-analysis, the preoperative demographic data of patients operated with the BH and with AH techniques were different. The main reason for this might be that all five studies included in the analysis were retrospective, and the choice of AH and BH technique might be biased according to patient characteristics. It was found that patients who underwent TVS with the BH technique were older and had a higher EuroSCORE II. However, the New York Heart Association functional classification of both patient groups was similar. The BH technique was preferred more in patients with a history of previous cardiac surgery. In the AH technique, an aortic cross clamp must be placed. The BH technique may have been preferred in most patients with a history of previous cardiac surgery to avoid the removal of periaortic mediastinal adhesions and to prevent possible aortic injuries. Tricuspid valve surgeries can be performed with right mini-thoracotomy or sternotomy.[25,26] Right mini-thoracotomy was preferred more in the BH technique than in the AH technique. Furthermore, right mini-thoracotomy may have been preferred in isolated TVS in cardiac reoperations to reduce sternal reentry injuries.[27,28]

Beating heart surgery was preferred less in patients operated for tricuspid valve infective endocarditis. The leaflets are mobile, and it is more difficult to examine the ventricular faces of the leaflets in the BH technique. The most common cause of tricuspid valve endocarditis is intravenous drug use.[29] Other causes include cardiac implantable electronic devices, long-term central venous access catheters, and congenital heart disease.[30,31] Slaughter et al.[32] reported that postoperative mortality in tricuspid valve infective endocarditis was 2% in repair patients, 3% in replacement patients, and 16% in valvectomy patients.

There are some limitations to this study. This study is based on a low level of evidence from five observational studies (one adjusted and four unadjusted). A single study provided 45.6% of the patients included in the analysis. This can be associated with a potential selection bias related to the type of surgical approach, such as repair or replacement, as well as the techniques used during those procedures. The data showed that the BH technique was mostly used in more complex patients. Publication bias, which is the common limitation of all meta-analyses, is probably valid for this meta-analysis. This study was performed to make a current data analysis and to have a conclusion for clinicians and future studies.

In conclusion, isolated TVS with beating and AH techniques are associated with similar postoperative outcomes. From available data, the BH technique generally tends to be used in more complex patients.

Ethics Committee Approval: Since this is a meta-analysis study, there is no ethics committee requirement. The data used in the study are publicly available. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Concept/design: Z.M.D.; Data analysis/interpretation: Z.M.D., M.B., E.Y., D.A., S.Ş.; Drafting article: Z.M.D., B.T.; Critical revision of article: B.O., Approval of article: B.O.; Statistics and data collection: Z.M.D., E.Y., A.R., D.A., S.Ş.

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