Surgical Outcomes of Repairing Ebstein Anomaly: A Single-Center Experience

Amir Hossein Jalali[1], Aghdas Shadmehr[2], Mozhgan Parsaee[2], Zahra Khajali[1], Sara Adimi[3], Ronak Ahmadi[2], Amir Ghaffari[1] and Sedigheh Saedi[1, *]

[1]Rajaei Cardiovascular Medical and Research Center, Iran University of Medical Sciences, Tehran, Iran
[2]Echocardiography Research Center, Rajaei Cardiovascular Medical and Research Center, Iran University of Medical Sciences, Tehran, Iran
[3]Cardio-Oncology Research Center, Rajaei Cardiovascular Medical and Research Center, Iran University of Medical Sciences, Tehran, Iran

[*]*Corresponding author*: Rajaei Cardiovascular Medical and Research Center, Iran University of Medical Sciences, Tehran, Iran. Email: sedsaedi@gmail.com

Abstract

Background: Ebstein anomaly (EA) is a rare congenital disorder of the tricuspid valve (TV), accounting for about one percent of congenital heart defects. Considering highly variable anatomy, diverse corrective surgical methods are currently utilized. Cone reconstruction provides a near anatomic tricuspid restoration method that has triggered enthusiasm for early repair over recent years.

Objectives: In the current study, we aimed to evaluate the clinical and echocardiographic features and outcomes of patients who underwent surgical correction of EA in our referral center.

Methods: In this study, we reviewed the medical records of 35 patients with EA who underwent cone repair or TV replacement and had accessible echocardiographic data before and at least one year following the corrective surgery. The patients were evaluated for residual tricuspid regurgitation (TR) severity, right ventricular (RV) size, RV fractional area change (FAC), left ventricular end-systolic diameter (LVESD), left ventricular end-diastolic diameter (LVEDD), and 2D left ventricular ejection fraction (LVEF) before and after the operation.

Results: Mean age of the patients was 29.49 ± 9.13 years, and 54.3% of them were female. Twenty-one (60%) patients underwent cone repair, and 14 were subjected to TV replacement. Seven (20%) patients required reoperation; redo TV repair was conducted in three patients (8.6%); two (5.7%) patients underwent biologic TV replacement; mechanical TV replacement was performed in one patient (2.9%) who had degenerative biologic TVs, and one patient (2.9%) was subjected to redo-operation due to mechanical TV malfunction. Positive changes in the means of RV-FAC and 2D-LVEF were statistically significant in all patients irrespective of the type of surgery (P < 0.001), but changes in the means of RV size (P = 0.38) and LVESD (P = 0.302) were not statistically significant. There was a significant increase in functional RV size in both groups of patients who underwent repair (P = 0.063) or replacement (P = 0.02).

Conclusions: The present study revealed satisfactory post-op results for cone TV repair in patients with EA, evidenced by reduced TR severity and improved biventricular functional parameters. Assessing the durability of the outcomes of cone TV repair needs longer-term follow-ups.

Keywords: Ebstein Anomaly, Cone Reconstruction, Tricuspid Valve Replacement, Surgical Procedures

1. Background

Congenital heart disease is a significant cause of heart failure and death due to cardiovascular events in adults younger than 50 years of age. Ebstein's anomaly (EA) is a rare form of right ventricular cardiomyopathy and tricuspid valve dysplasia and accounts for less than 1% of patients with congenital heart diseases (1). This anomaly is characterized by variable levels of tricuspid valve (TV) septal and posterior leaflet displacement due to the abnormal delamination of the underlying right ventricular (RV) myocardium, resulting in severe tricuspid regurgitation (TR) and abnormal atrialized portion of RV, culminating in right-sided heart failure. Variable degrees of leaflet displacement are accountable for numerous anatomic subtypes of EA (2, 3), and clinical presentation ranges from intrauterine or shortly after birth mortality to minimal symptoms in early adulthood. Due to the wide spectrum of clinical and anatomic presentations, finding a

uniform management strategy for EA is often challenging (2, 3).

Most patients with EA require surgery sometime in their lifetime. Historically, there was a tendency to postpone the surgery considering the poor durability of repair techniques and the inherent complications of inserting a prosthetic valve in the right-sided cardiac positions. Hunter and Lillehei first reported a surgical technique to repair EA in 1958 (4). Since then, numerous techniques have been proposed to eliminate TR and restore RV geometry (5-11). Cone repair has shown the most promising results in recent years and is currently the operation of choice in our institution. During cone repair, the severity of TR is reduced by constructing a funnel-like valve similar to the physiologic TV (6, 7, 12-14).

2. Objectives

In the current study, we sought to evaluate the echocardiographic and clinical outcomes of cone repair in EA patients who underwent surgery in our institution.

3. Methods

The current investigation reviewed the records of 56 consecutive EA patients presenting to our referral cardiovascular center between May 2015 and June 2021. Patients with previous palliative surgery or no surgery, individuals with remarkable coronary artery disease, and those who lacked post-op and follow-up echocardiography data were excluded. Ultimately, 35 patients who fulfilled the eligibility criteria were evaluated. All patients underwent follow-up echocardiographic examination at least one year after the operation. Demographic data, including age, sex, and operation details, were extracted from patient records. The primary endpoints of the study were baseline TV anatomy, residual TR severity, and right and left ventricular sizes and function.

Transthoracic echocardiographic examination was performed through echocardiography by adult congenital heart disease fellowship specialists. The Philips Affiniti 70 ultrasound and GE Vivid S60 devices were used to obtain echocardiographic images. Color Doppler echocardiography was used to evaluate tricuspid valve regurgitation. Valvular regurgitation severity was defined based on the guidelines of the American Society of Echocardiography (15). The diameter of the left ventricle (LV) was determined on the parasternal long axis view, and the line used for measurement was oriented perpendicular to the long axis of the left ventricle at the level of the mitral valve leaflet tips. Left ventricle ejection fraction was estimated in the apical four-chamber view using the Simpson method. Right ventricular size was also determined in the apical four-chamber view; RV internal diameter was regarded as the width of the middle one-third of the RV (16). The fractional area change (FAC) was measured by tracing the RV endocardium in an apical four-chamber focused view for RV during diastole and systole (17, 18). The patients were divided into two groups (those undergoing tricuspid valve replacement and those subjected to tricuspid valve repair) to compare the post-op results.

The decision for the patients to undergo TV replacement or cone repair was based on the surgeon's discretion and whether they had expertise in performing cone repair or not. Indications for surgery included desaturation and cyanosis, symptomatic heart failure, atrial or ventricular arrhythmias refractory to other therapies, declining left ventricular systolic function, and progressive RV dilatation and dysfunction. Indications for undergoing corrective surgery were the same in the replacement and repair groups.

The operative strategy consisted of the following steps based on preoperative imaging and clinical findings: (1) Cone reconstruction of the TV or valve replacement (biologic or mechanical); (2) correction of any associated anomalies, such as right ventricular outflow obstruction, pulmonary stenosis, and patent ductus arteriosus; (3) complete or partial closure of ASD or PFO when the right ventricular function was insufficient; (4) plication of the atrialized part of the right ventricle; and (5) bidirectional cavopulmonary shunt when there was severe RV dysfunction, or the functional RV size was small.

Surgical details during cone repair have been reported previously (6, 7). The operation consisted of the circumferential delamination or separation of the leaflet from the underlying right ventricle. The free leaflets were then joined side to side to form a circumferential cone, and the cone of the leaflet tissue was then attached to the anatomic TV annulus. Leaflet augmentation, autologous neochordae, and ring annuloplasty were utilized at the surgeon's discretion during the operation.

The Institutional Ethics Committee approved the study protocol, and the institutional review board waived the requirement for obtaining informed consent because of the retrospective nature of the study.

3.1. Statistical Analysis

Numerical variables were presented as mean ± standard deviation (SD), and categorical nominal or ordinal variables were expressed as percentages. The assumption of normality was assessed by the one-sample Kolmogorov-Smirnov test. Differences between the

study groups were evaluated using Mann-Whitney U test. When the significance level (P < 0.05) was exceeded, the Bonferroni post-hoc test was utilized to discern the difference between the groups and to rectify multiple comparisons. One-way analysis of covariance (ANCOVA) was performed to adjust the baseline differences between the study groups ($\alpha = 0.05$). The comparisons were made using nonparametric tests, including the Mann-Whitney U test. For data analysis, IBM® SPSS® Statistics version 26 was used, and P values less than 0.05 were considered statistically significant.

4. Results

From May 2015 to June 2021, 35 consecutive patients underwent corrective surgeries for EA. Twenty-one (60%) patients underwent cone repair, and 14 (40%) patients were managed with TV replacement. The mean age of the patients at the time of operation was 29.49 ± 9.13 years (Table 1). Sixteen (45.7%) patients were male, of whom 9 (64.3%) were in the TV replacement group, and 7 (33.3%) were in the cone repair group. Among female patients, 5 (35.7%) underwent TV replacement, and 14 (66.7%) cone repair. The mean ages of the patients in the TV replacement and cone repair groups were 30.1 ± 8 and 28.3 ± 9.2 years, respectively. There were no significant differences in the demographic and clinical characteristics of the patients in the two groups. The decision for the patients to undergo either TV replacement or cone repair was based on the surgeon's discretion and whether he/she had expertise in performing cone repair or not.

Indications for surgery included desaturation and cyanosis, symptomatic heart failure, atrial or ventricular arrhythmias refractory to other therapies, deteriorating left ventricular systolic function, and progressive RV dilatation and dysfunction. Indications for performing corrective surgery were the same in the replacement and repair groups. Sixteen (45.7%) patients had no associated anomalies; 13 (37.1%) patients had atrial septal defects (ASD); 2 (5.7%) patients suffered from right ventricular outflow tract stenosis; 3 (8.6%) patients had ASD and pulmonary valve stenosis, and one patient (2.9%) had patent ductus arteriosus (PDA) (Figure 1).

Among the participants, seven patients (20%) required reoperation during the follow-up. Three patients (8.6%) in the cone repair group, who had previous TV repairs, suffered from severe residual tricuspid regurgitation and underwent redo-surgery. Four patients in the valve replacement group needed reoperation, two of whom underwent biologic TVR (5.7%), and one patient was managed with mechanical TVR (2.9%) due to degenerative changes and destruction of previous biologic TV. Finally,

one patient underwent mechanical TVR (2.9%) due to the malfunction of the previous mechanical TV.

In the cone repair group, 12 patients (34.3%) had mild residual TR; six patients (17.1%) had moderate residual TR, and three patients (8.6%) had severe residual TR. In 14 patients (40%) with TVR, no paravalvular and transvalvular regurgitation was reported.

Mean anatomic RV size increased post-surgery, but this increase was not statistically significant irrespective of the type of operation (P = 0.38 in both). After the operation, the absolute value of RV-FAC significantly increased (P < 0.001).

Changes in the mean left ventricular end-systolic diameter and the mean left ventricular end-diastolic diameter did not reach the statistical significance level (P = 0.302 and P = 0.039, respectively). Changes in the absolute value of the average 2D-LV ejection fraction (2-D LVEF) before and after the operation were statistically significant in both groups (P < 0.001, Table 2).

5. Discussion

The goal of surgery in EA is to restore the entire anatomic RV to a functional ventricle in order to achieve a better effective stroke volume and RV function. In 1988, Carpentier et al. defined a new repair method that comprised the longitudinal plication of the RV, returning the TV to the anatomic level and reinforcing it with a prosthetic ring (8). Danielson et al. subsequently introduced transverse plication of the atrialized RV, right reduction atrioplasty, and posterior tricuspid annuloplasty (9). All these techniques delivered a considerable rate of residual TR, so TV replacement was necessary on many occasions. In 2004, Silva et al. described a new and encouraging surgical technique, namely cone repair, that used some principles of the Carpentier et al.'s method (8, 10). The new approach included moving the tricuspid leaflets to the anatomic tricuspid annulus level, accompanied by the longitudinal plication of the atrialized RV, resembling the normal TV anatomy (10). In addition to improving TR, cone reconstruction better restore RV function and geometry. Long-term outcomes, as reported by da Silva and da Silva, were favorable, with a low mortality rate and satisfactory TV performance (11).

In our center, the cone reconstruction technique has been used increasingly in recent years. In this study, we found that cone repair significantly reduced TR severity post-surgery and led to a significant increase in RV-FAC and LVEF. These results were similar to that reported by Silva et al. (19) and Nihat and Kara (20), who reported good RV function and a low incidence of recurrent severe TR

Table 1. Characteristics of Patients with Ebstein Anomaly Undergoing Corrective Surgery [a]

Variables	Before Operation	After Operation	P-Value
Age (y)	29.49 ± 9.13		
Displacement (cm)	3.16 ± 1.38		
RV size (cm)	4.160 ± 0.39	4.33 ± 0.41	0.38
FAC (%)	36.03 ± 6.649	43.31 ± 7.475	< 0.001 [b]
LVESD (cm)	2.00 ± 0.211	2.03 ± 0.162	0.302
LVEDD (cm)	4.12 ± 0.383	4.02 ± 0.309	0.039 [b]
2D-LVEF (%)	41.11 ± 7.39	47.57 ± 6.45	< 0.001 [b]

Abbreviations: RV, right ventricle; FAC, fractional area change; LVESD, left ventricular end-systolic diameter; LVEDD, left ventricular end-diastolic diameter; LVEF, left ventricular ejection fraction.

[a] Values are expressed as mean ± SD.

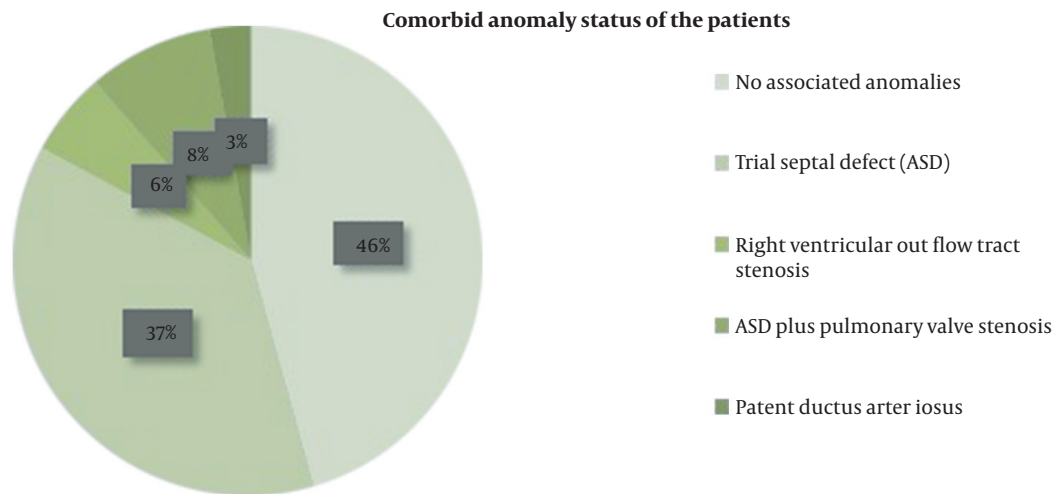[b] P values less than 0.05 were considered statistically significant.

Figure 1. Associated anomalies in the study population

Table 2. Echocardiographic Findings in Patients with Ebstein Anomaly Before and After Corrective Operation [a]

Variables	TV Replacement (n = 14)			Cone Repair (n = 21)			Between-Group Comparison
	Before Operation	After Operation	P-Value	Before Operation	After Operation	P-Value	P-Value
RV size (cm)	4.18 ± 0.43	4.50 ± 0.33	0.020 [b]	4.14 ± 0.37	4.23 ± 0.43	0.48	0.063
FAC (%)	33.00 ± 7.83	40.07 ± 8.50	< 0.001 [b]	38.05 ± 4.95	45.48 ± 5.97	< 0.001 [b]	0.355
LVESD (cm)	2.00 ± 0.21	2.05 ± 0.16	0.548	2.00 ± 0.21	2.01 ± 0.16	0.827	0.475
LVEDD (cm)	4.11 ± 0.35	4.14 ± 0.27	0.818	4.12 ± 0.41	3.94 ± 0.32	0.029 [b]	0.050 [b]
2D-LVEF (%)	38.50 ± 6.35	45.36 ± 6.34	< 0.001 [b]	42.86 ± 7.67	49.05 ± 6.25	< 0.001 [b]	0.472

Abbreviations: TV, tricuspid valve; RV, right ventricle; FAC, fractional area change; LVESD, left ventricular end-systolic diameter; LVEDD, left ventricular end-diastolic diameter; LVEF, left ventricular ejection fraction.

[a] Values are expressed as mean ± SD.

[b] There was no significant correlation between the degree of apical displacement of septal tricuspid valve leaflets and postoperative RV size and FAC.

in the long-term follow-up. Some studies evaluating the outcomes of cone operation in EA patients by cardiac magnetic resonance imaging have demonstrated a marked reduction in TR, RV end-diastolic volume index (EDVi), RV end-systolic volume index (ESVi), and RV stroke volume index (SVi), however, RVEF remained unchanged (12, 21). In 2018, Perdreau et al. reported that RV-FAC was significantly reduced post-operation (22). These studies evaluated the patients early after the operation (less than seven months post-op), whereas we followed patients up for at least one year after the operation, encompassing the necessary time required for RV recovery and positive remodeling. In accordance with our findings, Ibrahim et al., using serial echocardiographic assessment of RV function, showed improved RV systolic function after 24 to 36 months of surgery and hypothesized that the eradication of TR and improved forward flow in the pulmonary artery could present as enhanced RV myocardial performance several years after the repair (23). It has been noted that tricuspid regurgitation is remarkably reduced after cone reconstruction; however, RV function typically takes longer to improve (24).

The present research revealed a statistically significant increase in LVEF and a decline in LVEDD; however, LVESD remained unchanged. Ibrahim et al. showed that global LV function remained unchanged and within normal limits (23). In the recent study, systolic LV eccentricity index and LV shortening function did not significantly change as well post-surgery. However, cardiovascular magnetic resonance analysis showed that cone reconstruction improved LV filling due to the enhanced forward blood flow following a significant reduction in TR severity (23). Moreover, Rotar and Kron found no changes in the left-sided ejection fraction, global circumferential, and longitudinal strains (24). However, basal septal circumferential strain improved with a median of 2.8 years after cone reconstruction. These researchers attributed the reduction in RV end-diastolic volume to the increase in LV end-diastolic volume mediated via ventricular-ventricular interactions (12, 24).

5.1. Limitations

Studies on EA are generally limited by the small sample size as this anomaly is a rare condition. Analysis of pre- and postoperative data from the same individuals helped us perform comparative analysis on a wide range of patient demographics. Almost all readily applicable measures of RV and LV systolic function are load-dependent and can be affected by alterations in preload and afterload volumes following surgery. Improved TR severity seems to be a more reliable marker for evaluating surgical outcomes.

5.2. Conclusions

Durable TV repair is an important issue in young patients with EA. Cone repair is a safe and effective method to resolve tricuspid regurgitation and restore near-anatomic RV geometry. Follow-up echocardiography in our study showed a low incidence of residual severe tricuspid regurgitation and improved biventricular functional parameters after the corrective surgery. The learning curve for cone reconstruction is steep, with a difficult initial learning process, but it is essential for surgeons working in institutions dealing with congenital heart disease patients to master the skill.

Footnotes

References

1. Gilboa SM, Devine OJ, Kucik JE, Oster ME, Riehle-Colarusso T, Nembhard WN, et al. Congenital Heart Defects in the United States: Estimating the Magnitude of the Affected Population in 2010. *Circulation*. 2016;**134**(2):101–9. [PubMed ID: 27382105]. [PubMed Central ID: PMC4942347]. https://doi.org/10.1161/CIRCULATIONAHA.115.019307.

2. Qureshi MY, Sommer RJ, Cabalka AK. Tricuspid Valve Imaging and Intervention in Pediatric and Adult Patients With Congenital Heart Disease. *JACC Cardiovasc Imaging*. 2019;**12**(4):637–51. [PubMed ID: 30947906]. https://doi.org/10.1016/j.jcmg.2018.10.036.

3. Saedi S, Pashapour P, Houshmand G. Case Report of a 33-year-old with Ebstein malformation of tricuspid valve and hypertrophic cardiomyopathy. *Cardiol Young*. 2022;**32**(4):674–5. [PubMed ID: 34496998]. https://doi.org/10.1017/S1047951121003644.

4. Hunter SW, Lillehei CW. Ebstein's malformation of the tricuspid valve; study of a case together with suggestion of a new form of surgical therapy. *Dis Chest*. 1958;**33**(3):297–304. [PubMed ID: 13512138]. https://doi.org/10.1378/chest.33.3.297.

5. Holst KA, Dearani JA, Said S, Pike RB, Connolly HM, Cannon BC, et al. Improving Results of Surgery for Ebstein Anomaly: Where Are We After 235 Cone Repairs? *Ann Thorac Surg*. 2018;**105**(1):160–8. [PubMed ID: 29174783]. https://doi.org/10.1016/j.athoracsur.2017.09.058.

6. da Silva JP, Baumgratz JF, da Fonseca L, Franchi SM, Lopes LM, Tavares GM, et al. The cone reconstruction of the tricuspid valve in Ebstein's anomaly. The operation: early and midterm results.

J Thorac Cardiovasc Surg. 2007;**133**(1):215–23. [PubMed ID: 17198815]. https://doi.org/10.1016/j.jtcvs.2006.09.018.

7. Dearani JA, Bacha E, da Silva JP. Cone Reconstruction of the Tricuspid Valve for Ebstein's Anomaly: Anatomic Repair. *Oper Tech Thorac Cardiovasc Surg.* 2008;**13**(2):109–25. https://doi.org/10.1053/j.optechstcvs.2008.03.003.

8. Carpentier A, Chauvaud S, Mace L, Relland J, Mihaileanu S, Marino JP, et al. A new reconstructive operation for Ebstein's anomaly of the tricuspid valve. *J Thorac Cardiovasc Surg.* 1988;**96**(1):92–101. [PubMed ID: 3386297].

9. Danielson GK, Driscoll DJ, Mair DD, Warnes CA, Oliver WC. Operative treatment of Ebstein's anomaly. *J Thorac Cardiovasc Surg.* 1992;**104**(5):1195–202. [PubMed ID: 1434695].

10. Silva JP, Baumgratz JF, Fonseca L, Afiune JY, Franchi SM, Lopes LM, et al. [Ebstein's anomaly: results of the conic reconstruction of the tricuspid valve]. *Arq Bras Cardiol.* 2004;**82**(3):212–6. Portuguese. [PubMed ID: 15073647]. https://doi.org/10.1590/s0066-782x2004000300002.

11. da Silva JP, da Silva Lda F. Ebstein's anomaly of the tricuspid valve: the cone repair. *Semin Thorac Cardiovasc Surg Pediatr Card Surg Annu.* 2012;**15**(1):38–45. [PubMed ID: 22424507]. https://doi.org/10.1053/j.pcsu.2012.01.008.

12. Beroukhim RS, Jing L, Harrild DM, Fornwalt BK, Mejia-Spiegeler A, Rhodes J, et al. Impact of the cone operation on left ventricular size, function, and dyssynchrony in Ebstein anomaly: a cardiovascular magnetic resonance study. *J Cardiovasc Magn Reson.* 2018;**20**(1):32. [PubMed ID: 29783986]. [PubMed Central ID: PMC5963144]. https://doi.org/10.1186/s12968-018-0452-0.

13. Lianza AC, Rodrigues ACT, Mercer-Rosa L, Vieira MLC, de Oliveira WAA, Afonso TR, et al. Right Ventricular Systolic Function After the Cone Procedure for Ebstein's Anomaly: Comparison Between Echocardiography and Cardiac Magnetic Resonance. *Pediatr Cardiol.* 2020;**41**(5):985–95. [PubMed ID: 32335735]. https://doi.org/10.1007/s00246-020-02347-6.

14. Brown ML, Dearani JA, Danielson GK, Cetta F, Connolly HM, Warnes CA, et al. The outcomes of operations for 539 patients with Ebstein anomaly. *J Thorac Cardiovasc Surg.* 2008;**135**(5):1120–36. 1136 e1-7. [PubMed ID: 18455593]. https://doi.org/10.1016/j.jtcvs.2008.02.034.

15. Otto CM, Nishimura RA, Bonow RO, Carabello BA, Erwin JP, Gentile F, et al. 2020 ACC/AHA Guideline for the Management of Patients With Valvular Heart Disease: Executive Summary: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. *Circulation.* 2021;**143**(5):e35–71. [PubMed ID: 33332149]. https://doi.org/10.1161/CIR.0000000000000932.

16. Lang RM, Badano LP, Mor-Avi V, Afilalo J, Armstrong A, Ernande L, et al. Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. *J Am Soc Echocardiogr.* 2015;**28**(1):1–39 e14. [PubMed ID: 25559473]. https://doi.org/10.1016/j.echo.2014.10.003.

17. Anavekar NS, Skali H, Bourgoun M, Ghali JK, Kober L, Maggioni AP, et al. Usefulness of right ventricular fractional area change to predict death, heart failure, and stroke following myocardial infarction (from the VALIANT ECHO Study). *Am J Cardiol.* 2008;**101**(5):607–12. [PubMed ID: 18308007]. https://doi.org/10.1016/j.amjcard.2007.09.115.

18. Khoo NS, Young A, Occleshaw C, Cowan B, Zeng IS, Gentles TL. Assessments of right ventricular volume and function using three-dimensional echocardiography in older children and adults with congenital heart disease: comparison with cardiac magnetic resonance imaging. *J Am Soc Echocardiogr.* 2009;**22**(11):1279–88. [PubMed ID: 19815382]. https://doi.org/10.1016/j.echo.2009.08.011.

19. Silva G, Miana LA, Caneo LF, Turquetto ALR, Tanamati C, Penha JG, et al. Early and Long-Term Outcomes of Surgical Treatment of Ebstein's Anomaly. *Braz J Cardiovasc Surg.* 2019;**34**(5):511–6. [PubMed ID: 31364344]. [PubMed Central ID: PMC6852467]. https://doi.org/10.21470/1678-9741-2018-0333.

20. Cine N, Kara KA. New trend: Surgical correction of Ebstein's anomaly using modified cone repair and a combination of different techniques. *J Card Surg.* 2022;**37**(7):1842–8. [PubMed ID: 35307869]. https://doi.org/10.1111/jocs.16382.

21. Yu S, Yang K, Chen X, Lu M, Zhao K, Yang S, et al. Cardiac remodeling after tricuspid valve repair in Ebstein's anomaly: a magnetic resonance study. *Eur Radiol.* 2023;**33**(3):2052–61. [PubMed ID: 36284004]. https://doi.org/10.1007/s00330-022-09190-8.

22. Perdreau E, Tsang V, Hughes ML, Ibrahim M, Kataria S, Janagarajan K, et al. Change in biventricular function after cone reconstruction of Ebstein's anomaly: an echocardiographic study. *Eur Heart J Cardiovasc Imaging.* 2018;**19**(7):808–15. [PubMed ID: 28950308]. https://doi.org/10.1093/ehjci/jex186.

23. Ibrahim M, Tsang VT, Caruana M, Hughes ML, Jenkyns S, Perdreau E, et al. Cone reconstruction for Ebstein's anomaly: Patient outcomes, biventricular function, and cardiopulmonary exercise capacity. *J Thorac Cardiovasc Surg.* 2015;**149**(4):1144–50. [PubMed ID: 25702323]. https://doi.org/10.1016/j.jtcvs.2014.12.074.

24. Rotar EP, Kron IL. Commentary: Predictors of postoperative adverse events after cone reconstruction for Ebstein's anomaly. *J Card Surg.* 2021;**36**(3):1018–9. [PubMed ID: 33503679]. [PubMed Central ID: PMC8115025]. https://doi.org/10.1111/jocs.15376.