

Ebstein's anomaly of the tricuspid valve management – the importance of right ventricle assessment

Ebsteinova anomália – význam hodnotenia pravej komory

Klauco F¹, Kaldararova M², Reptova A¹, Valkovicova T¹, Bobocka K¹, Hlavata T¹, Simkova I¹

¹*Slovak Medical University, and The National Institute of Cardiovascular Diseases, ACHD Dept., Cardiology and Angiology Clinic, Bratislava, Slovakia*

Keywords: Ebstein anomaly – imaging – right ventricle – management

Kľúčové slová: Ebsteinova anomália – zobrazovacie metódy – pravá komora – manažment

Background

Ebstein anomaly of tricuspid valve (EA) is a rare congenital heart defect with an incidence of 1 in 200,000 live births (1). It is the most common congenital defect affecting the tricuspid valve, characterized by the distinctive apical displacement of the septal leaflet by more than 8mm/m² compared to the annulus of the mitral valve. This results in a unique morphology of the heart, with a “true” right ventricle (RV), atrialized RV, and right atrium. The tricuspid valve in EA exhibits abnormal morphology with adhesions, fenestrations, and often a redundant and elongated anterior leaflet, leading to severe tricuspid regurgitation and its associated hemodynamic consequences (2, 3).

In recent years, EA has been increasingly recognized as a form of cardiomyopathy rather than just a val-

vular disease. This is because the abnormalities in the RV myocardium are not only secondary to volume overload but also primary, often associated with non-compaction cardiomyopathy of the left ventricle (4). Given these complexities, cardiac magnetic resonance (CMR) imaging has emerged as the gold standard for diagnosing EA. CMR allows for precise evaluation of the function of the “true” RV, measurement of the volumes of the right-sided structures, and identification of associated congenital heart defects. However, CMR availability remains limited, particularly in Central and Eastern European countries.

Therefore, the objective of this study was to identify echocardiographic (ECHO) parameters that correlate with CMR findings and that can serve as suitable alternatives for long-term follow-up of EA patients.

From ¹Slovak Medical University, and The National Institute of Cardiovascular Diseases, ACHD Dept., Cardiology and Angiology Clinic, Bratislava, Slovakia and ²The National Institute of Cardiovascular Diseases, Children's Cardiac Center & ACHD Dept, Cardiology and Angiology Clinic and Slovak Medical University, Bratislava, Slovakia
Manuscript received 12 July 2023; accepted for publication 31 August 2023

Address for correspondence: MUDr. Filip Klaučo, Oddelenie pre vrodené chyby srdca v dospelosti, Národný ústav srdcových a cievnych chorôb, a. s., Pod Krásnou hôrkou 1, 833 48 Bratislava, e-mail: filipklauco@icloud.com

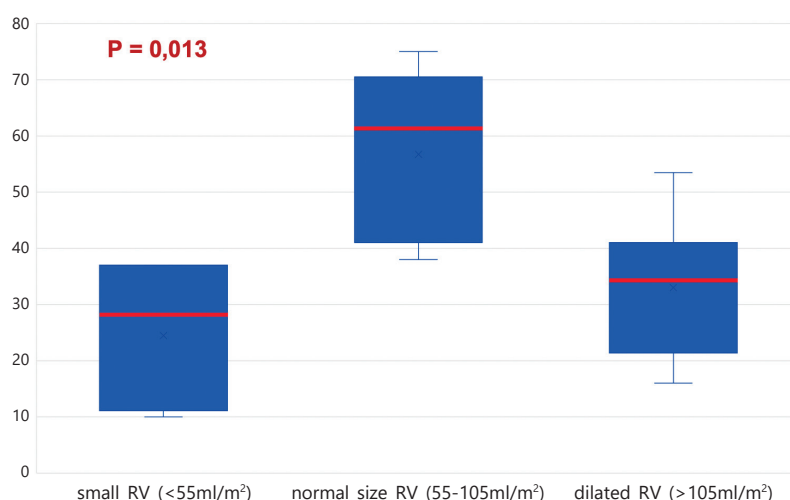


Figure 1 Correlation between CMR derived EF of right ventricle to end-diastolic volume

A right ventricle with an end-diastolic volume of less than 55ml/m² has the lowest ejection fraction compared to a normal-sized right ventricle (55-105ml/m² in end-diastole) as well as dilated right ventricle (volume >105ml/m² in end-diastole)

Material and methods

A retrospective cross-section analysis from our registry was performed, which we consider national, as we serve as the only national adult CHD centre. Of the 48 adult patients in the EA national registry, 28 non-operated adults (60% male, median age 39 (18–64) years) with performed CMR were included. Analyzed were ECHO and CMR RV characteristics, NTproBNP and 6-minute walking distance (6MWD). ECHO parameters were evaluated as follows: 1. morphometric [tricuspid valve septal cusp displacement (mm), long-axis RV end-diastolic dimension (RVEDD,mm), long-axis end-diastolic right to left ventricle diameter ratio (RV/LV)] and 2. functional [tricuspid annular plane systolic excursion

(TAPSE, mm), RV fractional area change (FAC,%), RV tissue Doppler myocardial velocity (m/s)]. CMR-derived analyzed parameters were: ejection fraction (EF, %) and end-diastolic volume (EDV, ml) indexed per body surface area (BSA, m²). According to CMR-derived EDV, patients were divided into groups: 1. normal size RV (55–105 ml/m²), 2. dilated RV (>105 ml/m²) and 3. small RV (<55 ml/m²).

Results

For ECHO morphometric measurements, Spearman's correlation (R) showed strong, statistically significant correlation of CMR-derived EDV with ECHO-based RV/LV ratio (R=0.6989, P<0.0001); and moderate, statistically significant correlation with ECHO-based RVEDD (R=0.55, P=0.004); No significant correlations between CMR-derived EF and ECHO parameters were found (Table 1). CMR-derived EF and EDV were independent of the severity of septal leaflet displacement; CMR-derived EF was shown to be conditional to RV EDV, with mean EF in Groups 1/2/3 as follows: 57%/36.5%/25.8% (P=0.0013, Figure 1). CMR-derived Group 3 (small RV) compared to Groups 1 and 2 exhibited worst 6MWD (mean 416m) and highest NTproBNP (mean 1021ng/l), though without statistical significance (Figure 2).

Table 1 Correlation between CMR derived EF of RV and ECHO functional parameters

ECHO – CMR correlation with RV function	
ECHO parameters	P value
TAPSE (mm)	0,84
TDI S (cm/s)	0,60
FAC (%)	0,37

No correlation between echocardiographic functional parameters and CMR derived EF of RV was found. TAPSE – Tricuspid annular plane systolic excursion. TDI S – Tissue Doppler imaging wave S. FAC – Fractional area change

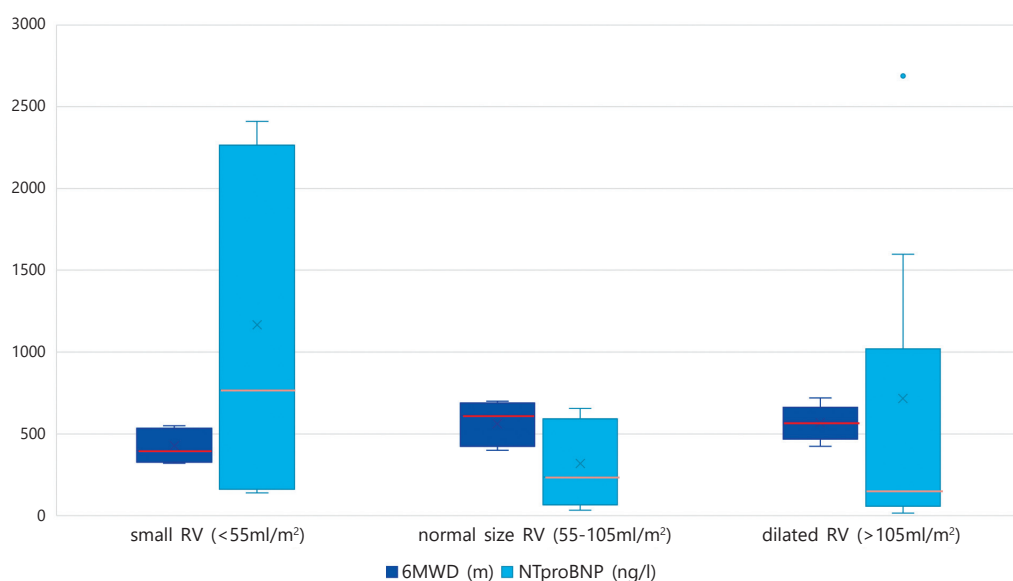


Figure 2 Relationship between 6MWD and NTproBNP with CMR derived EDV

A small RV with end-diastolic volume of <55ml/m² is characterized by shortest distance in 6-minute walking test and highest levels of NTproBNP compared to normal-size RV (55-105ml/m²) and dilated RV (EDV >105ml/m²)

Discussion

Ebstein anomaly (EA) is a rare and complex congenital heart defect characterized by morphological and functional abnormalities in the tricuspid valve, RV myocardium, associated congenital defects (most commonly atrial septal defect), and various arrhythmias. The presentation of EA varies due to the individual extent and severity of these pathologies. RV failure and the risk of sudden cardiac death are common outcomes of EA, leading to significantly worse survival compared to the general population, especially beyond the age of 40 (5). Surgical intervention with valvuloplasty or valve replacement is the primary solution. However, the prognosis for patients with severe but isolated tricuspid regurgitation after surgery is not superior to a conservative approach (6). Multiple risk factors, including reduced RV systolic function, signs of right-sided heart failure, NYHA functional class III-IV, and RV dilation, contribute to the prognosis. These factors are typically present in adult patients with EA. Additionally, the age at the time of surgery is an important determinant of prognosis, emphasizing the need for early intervention, ideally in pediatric patients (7, 8). For adult patients with EA, careful decision-making considering the risk-benefit

ratio of surgery for each individual is crucial, following the current recommendations of the European Society of Cardiology for adult CHD. In addition to symptoms, the severity of tricuspid regurgitation, RV function, and volume and their progressive deterioration should be assessed. Imaging modalities play a central role in the diagnostic algorithm (9). Echocardiography (ECHO) is commonly used initially due to its affordability and efficiency, but it has limitations. The unique characteristics of tricuspid regurgitation in EA patients, such as asymmetric and multiple jets, high compliance of the atrialized RV, and atypical jet direction, often lead to underestimation of its severity. Conversely, evaluation of longitudinal function (TAPSE, TDI wave S) tends to overestimate RV systolic function, as observed in our study (10). Cardiac magnetic resonance (CMR) is considered the gold standard as it provides accurate assessment of “true” RV function, volumes of right-sided structures, exclusion of associated congenital heart defects, and suitability for long-term follow-up. CMR allows for the classification of a heterogeneous group of EA patients based on various parameters, such as the size of the “true” RV. We have demonstrated that RV volume, derived from CMR, correlates with laboratory markers of heart failure (NTproBNP) and patient performance

(6MWD). Paradoxically, patients with a small RV volume exhibit the worst outcomes, which has both prognostic implications and potential for surgical decision-making. However, CMR is not widely available in many countries of Central and Eastern Europe, where ECHO is used as a substitute. We have shown that the ECHO-derived RV/LV ratio correlates well with CMR-derived volumetric parameters. In the absence of CMR, ECHO can be utilized for long-term follow-up of EA patients and aids in the decision-making process for cardiac surgery, particularly when progressive RV dilatation is an indication criteria according to ESC recommendations.

Conclusions

The assessment of RV in EA seems more critical than the morphology of the tricuspid valve itself. Therefore, as in the context of our results, more emphasis needs to be placed on RV size. In particular, small-capacity RV, as we found, showed a strong relation to reduced RV function and some (though not significant) to NTproBNP and 6MWD. CMR-derived EDV and EF are accepted as the gold standard method for RV evaluation. Since we detected significant correlation of CMR with simply gained ECHO parameters (RV/LV ratio and RVEDD), we assume that easily accessible ECHO remains a pertinent method in routine follow-up, able to reflect the complex hemodynamic situation in EA.

The authors declare that there are no conflicts of interest.

Presented at the ESC Congress 2022, Barcelona, Spain. Original publication was published in supplement: F Klauco and others, Ebstein's anomaly of the tricuspid valve management – the importance of right ventricle assessment, *European Heart Journal*, Volume 43, Issue Supplement_2, October 2022, ehac544.1856

References

1. Dearani JA, Danielson GK. Surgical Management of Ebstein's Anomaly in the Adult. *Seminars in Thoracic and Cardiovascular Surgery*. 2005;17:148-154. doi: 10.1053/j.semtcvs.2005.02.008
2. Stephens EH, Dearani JA, Qureshi MY, Ammash N, Maleszewski JJ. The Congenital Tricuspid Valve Spectrum: From Ebstein to Dysplasia. *World J Pediatr Congenit Heart Surg*. 2020;11:783-791.
3. Singh DP, Hussain K, Mahajan K. Ebstein Anomaly and Malformation. 2023 May 25. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan–. PMID: 30521245.
4. Attenhofer Jost CH, Connolly HM, Scott CG, Burkhart HM, Warnes CA, Dearani JA. Outcome of cardiac surgery in patients 50 years of age or older with Ebstein anomaly: survival and functional improvement. *J Am Coll Cardiol* 59:2101-2106.
5. Eckerström F, Eriksson P, Dellborg M, Lappas G, Rosengren A, Hjortdal VE, et al. Mortality burden in patients born with Ebstein's anomaly: a 40-year nationwide cohort study. *Eur Heart J Qual Care Clin Outcomes*. 2021;7:312-319. doi: 10.1093/ehjqcco/qcz069. PMID: 31917406.
6. Axtell AL, Bhambhani V, Moonsamy P, Healy EW, Picard MH, Sundt TM 3rd, et al. Surgery Does Not Improve Survival in Patients With Isolated Severe Tricuspid Regurgitation. *J Am Coll Cardiol*. 2019;74:715-725. doi: 10.1016/j.jacc.2019.04.028. Epub 2019 May 6. PMID: 31071413; PMCID: PMC8890054.
7. Dreyfus J, Audureau E, Bohbot Y, Coisne A, Lavie-Badie Y, Bouchery M, et al. TRI-SCORE: a new risk score for in-hospital mortality prediction after isolated tricuspid valve surgery. *Eur Heart J*. 2022;43:654-662. <https://doi.org/10.1093/eurheartj/ehab679>
8. Mrad Agua K, Burri M, Cleuziou J, Beran E, Meierhofer C, Nagdymann N, et al. Preoperative predictability of right ventricular failure following surgery for Ebstein's anomaly. *Eur J Cardiothorac Surg* 2019;55:1187-1193.
9. Baumgartner H, De Backer J, Babu-Narayan SV, Budts W, Chessa M, Diller GP, et al. 2020 ESC Guidelines for the management of adult congenital heart disease: The Task Force for the management of adult congenital heart disease of the European Society of Cardiology (ESC). Endorsed by: Association for European Paediatric and Congenital Cardiology (AEPC), International Society for Adult Congenital Heart Disease (ISACHD). *Eur Heart J* 2021;42:563-645.
10. Kühn A, Meierhofer C, Rutz T, Rondak IC, Röhlig C, Schreiber C, et al. Non-volumetric echocardiographic indices and qualitative assessment of right ventricular systolic function in Ebstein's anomaly: comparison with CMR-derived ejection fraction in 49 patients. *Eur Heart J Cardiovasc Imaging*. 2016;17:930-935. doi: 10.1093/ehjci/jev243. Epub 2015 Oct 8. PMID: 26453545.