Exercise echocardiography after tricuspid annuloplasty

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INTRODUCTION

Secondary tricuspid regurgitation is generally treated with tricuspid annuloplasty at the time of left heart valve surgery [1]. The incidence of residual tricuspid regurgitation and its recurrence after annuloplasty is substantial [2]. Tricuspid annuloplasty with ring has a failure rate of 10% to 20% [3]. Hence, many surgeons tend to use smaller or undersized tricuspid rings mirroring the strategy applied for secondary mitral regurgitation, hoping to improve the durability of tricuspid annuloplasty [3]. To our knowledge, the influence of exercise on tricuspid valve gradients after surgical tricuspid annuloplasty has not been studied. We aimed to assess the level of tricuspid stenosis after annuloplasty with different ring sizes during exercise echocardiography.

METHODS

Patients of both sexes who underwent tricuspid and mitral valve repair were subjected consecutively to exercise echocardiography. The first patient was recruited on August 2, 2019 and the last on February 20, 2020. We excluded patients with cardiovascular instability or decompensation within the last 4 weeks, a significant pulmonary disease, pacemaker or cardioverter-defibrillator, and general conditions that prevented exercise testing. The study was approved by the Bioethical Committee of the Medical University of Silesia in Katowice on April 2, 2019 (no. KNW/0022/KB1/42/19), and written informed consent was obtained from every patient. The study complies with the Declaration of Helsinki.

Exercise echocardiography protocol

Exercise echocardiography was performed using an echocardiographic cycloergometer (GE EL Ergometer 1200P). The exercise echocardiography test was performed according to the guidelines of stress echocardiography in non-ischemic patients [4]. The protocol included an initial workload of 25 W which increased every 3 minutes (25 W). The exercise test was terminated at the submaximal heart rate limit, the patient's maximum physical tolerance, or limiting symptoms.

Echocardiographic examinations were performed with the GE Vivid 7 Healthcare echocardiograph and the GE M3S sector transducer. The S' wave velocity within the basal segment of the right ventricular inflow tract on tissue Doppler imaging was used to assess right ventricular function [5]. Subsequently, tricuspid and mitral valve inflows were recorded using a continuous (CW) Doppler to evaluate maximal (mean and peak) transvalvular gradients. Additionally, the flow velocity was measured at the annular level and at the level of the tips of the tricuspid valve leaflets using a pulsed wave (PW) Doppler to assess local mean and peak gradients. The final stage was using Doppler ultrasound to verify the competence of the valves, the presence, and degrees of regurgitation.

Statistical analysis

Data are presented as a median with the interquartile range (IQR); as means and standard deviation (SD) and frequencies (%) as appropriate. Pre- and post-exercise data, as well as different measurements obtained in the same patient, were compared using signed Wilcoxon rank test. Spearman rank-order correlation was used to investigate the relationship between tricuspid valve gradients and various variables of interest. In all cases of statistical analysis, a value of P <0.05 was considered

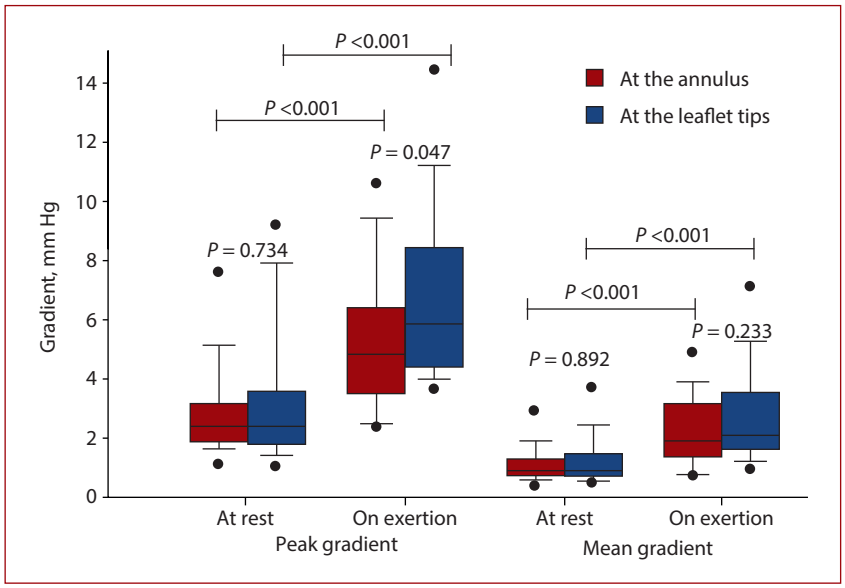

Figure 1. Peak and mean tricuspid valve gradients at the annulus and at the leaflet tips at rest and on exertion. Boxes represent medians with quartiles, whiskers correspond to 10th and 90th percentile

significant. All statistical analyzes were performed using SigmaPlot 12.5 software (Systat Inc.).

RESULTS AND DISCUSSION

The median (IQR) time since surgery was 13 (9.5–34.5) months. The majority of patients were in the New York Heart Association (NYHA) class I (18 pts — 72%) and CCS class 0 or 1 (20 pts — 80%), with the rest remaining in NYHA class II. Eleven patients with atrial fibrillation were enrolled in the study. In this setting, gradient and velocity measurements were averaged from 5–10 consecutive beats.

The median (IQR) duration of the exercise test was 6 (3.6–7.8) minutes and the median (IQR) maximal effort performed was 50 (50–70) W. A statistically significant increase in the mean (SD) heart rate was observed during exercise — from 76 (12) bpm to 127 (25) bpm (P <0.001). Mean (SD) systolic blood pressure increased from 136 (16) mm Hg to 152 (19) mm Hg (P <0.001), while mean (SD) diastolic blood pressure did not change: 87 (15) mm Hg vs. 91 (13) mm Hg (P = 0.126). The median (IQR) left ventricular ejection fraction increased from 51 (45–59) % at rest to 58 (55–65.5) % at peak exercise (P <0.001).

The median (IQR) S' wave velocity in the right ventricular inflow tract basal segment was 8.0 (6.25–9.75) cm/s at rest and increased to 12.0 (11.0–14.0) cm/s on exertion (P <0.001).

The tricuspid valve was competent at rest in 13 patients and had only mild incompetence in further 9 patients. In 3 patients (12%) moderate tricuspid regurgitation was present.

The median (IQR) mean gradient at rest through the tricuspid valve as assessed with a CW Doppler was 1.1 (0.9–1.6) mm Hg, and the median (IQR) peak gradient was 3.1 (2.3–4.7) mm Hg. The gradients at the annulus and the leaflet tips are presented in Figure 1. Notably, while the maximal gradients (CW Doppler) and the gradients measured at the leaflet tips (PW Doppler) did not correlate with the tricuspid ring size, there was a significant negative correlation of the tricuspid ring size with the gradient measured at the annular level maximal mean: r = –0.319; P = 0.12; maximal peak: r = –0.260; P = 0.21; mean at theleaflet tips: r = –0.183; P = 0.38; peak at the leaflet tips: r = –0.154; P = 0.46; mean gradient on the annulus: r = –0.467; P = 0.02; peak gradient on the annulus: r = –0.393; P = 0.051.

With exercise, the median (IQR) maximal (CW Doppler) gradient on the tricuspid valve rose significantly for a mean value to 2.7 (1.8–3.6) mm Hg (P <0.001) and a peak value 6.4 (4.5–8.7) mm Hg (P <0.001).

Notably, the peak gradient on exertion on the leaflet tips was higher than at the annular level. Also, mean transtricuspid gradients on exertion, as assessed with a CW Doppler, inversely correlated with the ring size (r = –0.398; P = 0.049).

The maximal peak and mean gradients through the tricuspid valve were significantly lower than those measured on the mitral valve both at rest and on exertion (Supplementary material, *Figure S1*).

Our study is the first, to our knowledge, to assess the transtricuspid valve gradients on exertion in patients after tricuspid annuloplasty with rigid tricuspid annuloplasty rings of various sizes. We have found that although the gradients on exertion are higher with smaller rings, they are generally low especially when compared with the gradients on the mitral valve in the same patients.

There are no generally accepted criteria for grading the severity of tricuspid stenosis. However, a mean gradient of ≥5 mm Hg at a normal heart rate is considered indicative of clinically significant tricuspid stenosis [6]. In our patients,

the mean gradient through the tricuspid valve at rest (i.e. with normal heart rate) was 1.1 mm Hg. The mean gradient at the ring level was higher with the smaller ring size, and the biggest recorded value was 4.1 mm Hg in a patient with the tricuspid ring size of 28. These gradients are comparable with those reported by others after undersized tricuspid annuloplasty [7]. A gradient above 5 mm Hg has also been described in 5 of 85 patients who underwent percutaneous edge-to-edge repair (the TRILUMINATE trial) [8]. In the analysis by Rdzanek et al. relating to the guidelines for performing such procedures, this issue has not been elaborated on, most likely due to the lack of clinical significance in a 6-month follow-up [8, 9].

We and others have noted previously that the gradients on the mitral valve after annuloplasty are generally higher on the leaflet tips in comparison with the annulus [10]. This is related to the fact that mitral annuloplasty renders mitral leaflets restrictive, and their tethering results in a funnel-like inflow channel visible on echocardiography. With tricuspid valve anatomy being different, we expected a wider opening of tricuspid leaflets and, therefore, no increase of the gradient from annular to leaflet tips levels. Indeed, the difference was visible only in the case of peak gradient on maximal exertion and not observed in the case of mean gradients or at rest.

In conclusion, we have shown that stress echocardiography induces an increase of gradients on the tricuspid valve in patients after tricuspid annuloplasty with a prosthetic ring. The exercise gradients inversely correlate with the ring size; however, they are generally low and do not meet the criteria for tricuspid stenosis.

Supplementary material

Supplementary material is available at https://journals.viamedica.pl/kardiologia_polska.

Article information

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