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## Association of spectral Doppler cardiac activity in the lower limb veins and echocardiographic findings in patients with tricuspid regurgitation

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### Keywords

tricuspid regurgitation, Doppler echocardiography, spectral Doppler ultrasound, lower limb venous Doppler, right-sided heart failure

### Abstract

**Objective:** To determine the association between spectral Doppler cardiac activity in the lower limb veins and echocardiographic findings in patients with tricuspid regurgitation. **Material and methods:** A cross-sectional analysis was performed in the Gilani Ultrasound Center over a period of 13 months. The total study sample comprised 400 subjects. All individuals referred for abdominal ultrasound having cardiac activities in external iliac vein, popliteal and posterior tibial vein, individuals having normal venous Doppler ultrasound, both genders and all ages, were included, and unwilling and non-cooperative patients were excluded from the study. **Results:** Out of 400 individuals, 200 showed cardiac activity in the lower limb veins on Doppler vascular ultrasound, while 200 did not show cardiac activity. On echocardiography, 204 individuals were diagnosed with tricuspid regurgitation, and 196 individuals had a competent tricuspid valve. According to the independent sample t-test the mean difference in the posterior tibial vein was 25.54 (95% CI: 24.09; 26.98), while the mean difference in the iliac vein was 2.34 (95% CI: 0.64; 4.03) among normal and tricuspid regurgitation. **Conclusion:** A correlation was found between the cardiac activities in the lower limb veins and tricuspid regurgitation.

## Introduction

The most prevalent pathology of the tricuspid valve is tricuspid regurgitation in which the tricuspid valve becomes incompetent<sup>(1)</sup>. There are different causes of tricuspid regurgitation (TR), for example infection including rheumatic fever and infective endocarditis, dilatation of the right ventricle of the heart which in turn causes dilatation of the annulus of the tricuspid valve, and an increased pressure in the tricuspid valve. Other less common causes of tricuspid valve dysfunction include systemic lupus erythematosus,

trauma, Ebstein's anomaly, congenital heart defects, carcinoid disease of the heart, prolapse of the tricuspid valve, and tumor of the heart<sup>(2)</sup>. Patients affected by tricuspid regurgitation present with the following symptoms: fatigue, atrial fibrillation, discomfort especially in the neck region, ascites, liver and renal dysfunction, abdominal discomfort and pain, sleeplessness, swelling in the lower limbs, cardiac activities in the veins of the lower limbs, pleural or cardiac effusion, shortness of breath, and cold skin. These symptoms are most commonly associated with severe heart disease<sup>(3)</sup>. The diagnosis of tricuspid valve disease can be

facilitated by using electrocardiogram (ECG), Doppler echocardiography, magnetic resonance imaging (MRI), radionuclide scan, chest X-ray, transesophageal echocardiography, and cardiac catheterization<sup>(4)</sup>. Tricuspid regurgitation is divided into 3 types which are as follows: primary, secondary, and isolated tricuspid regurgitation. Primary tricuspid regurgitation is caused by an anatomical abnormality of the tricuspid valve<sup>(5)</sup>. Secondary tricuspid regurgitation can be due to the dilatation of the right atrium, right ventricle, tethering of the tricuspid valve, and also due to dilatation of the tricuspid annulus. Disease of the left heart, pulmonary hypertension, atrial fibrillation, which is seen in annular dilatation, are among the causes of isolated tricuspid regurgitation<sup>(6)</sup>. The incidence of tricuspid regurgitation in the United States is 0.9%, and no gender or racial differences are noted<sup>(7)</sup>. Tricuspid regurgitation can occur at any stage in life, while Ebstein's anomaly or primary tricuspid regurgitation can be observed during early childhood or at birth. Another common form of tricuspid regurgitation is rheumatic valvular disease which affects patients over the age of 15 years. At present, echocardiography is recognized as the gold standard in the diagnosis of tricuspid regurgitation<sup>(8)</sup>. Transthoracic echocardiography (TTE), transesophageal echocardiography, and 3-D echocardiography, play a key role in the diagnosis of tricuspid regurgitation. In the initial diagnosis, transthoracic echocardiography plays a fundamental role, while transesophageal echocardiography is applied where transthoracic echocardiography shows poor quality, when the patient has an infection from the pacemaker lead or in other cases like endocarditis<sup>(9)</sup>. On the other hand, 3-D echocardiography is far superior to all of these, as it allows visualization of all the leaflets simultaneously<sup>(10)</sup>. In 2012, guidelines were published by the European Association for Cardiothoracic Surgery (EACTS) and the European Society of Cardiology (ESC) for the staging of tricuspid regurgitation<sup>(11)</sup>. The degree of annular dilatation, mechanism of tricuspid regurgitation, and the presence of tethering, can also be diagnosed with the help of echocardiography. When the annular diameter of the tricuspid valve is  $\geq 40$  mm, and the average diameter is approximately 21 mm/m<sup>2</sup> measured at the end-diastole of four-chamber transthoracic view of the heart, this is known as significant tricuspid regurgitation. Significant tethering is attributed to a coaptation distance  $> 8$  mm. Abnormal RV function is attributable to tricuspid annular plane systolic excursion  $< 1.5$  cm or fractional area shortening  $< 35\%$ <sup>(12)</sup>.

Spectral Doppler ultrasound plays a crucial role in providing data about hemodynamic changes in the circulating blood flow. Spectral Doppler information comprises 3 types of variables including time, velocity, and amplitude of sampled circulating blood<sup>(13)</sup>. On the spectral Doppler ultrasound scan, the X-axis depicts the time, y-axis depicts velocity of the moving blood, while the z-axis represents the amplitude. Velocity is the speed at which blood moves in the circulatory system<sup>(14)</sup>. Doppler ultrasound has been used for many years for the diagnosis of various diseases affecting the arteries and veins of the body. Spectral Doppler ultrasound provides additional information about the velocity of the moving blood, and helps in the diagnosis of many lower

limb arterial and venous diseases<sup>(15)</sup>. According to one study, the sensitivity and specificity of Doppler ultrasound in the evaluation of different vascular diseases is 97.9% and 99.5%, respectively<sup>(16)</sup>. On Doppler ultrasound, the blood flow in the veins of the lower limbs is usually phasic, spontaneous, and in the antegrade direction<sup>(17)</sup>. Phasicity in the veins sometimes occurs due to respiratory phasicity which is a normal physiological process, and sometimes cardiac activities are seen in the veins, which is due to pathological conditions including right heart failure, tricuspid regurgitation etc.<sup>(18)</sup> On spectral Doppler ultrasonography, the blood flow will be seen as pulsatile only due to the failure of the right heart<sup>(19)</sup>. Many studies have been published on phasicity in the spectral Doppler waveform, concluding that if the phasicity in the spectral Doppler waveform occurs for 1 second, then it is cardiac phasicity which is due to an increased pressure in the right atrium<sup>(14)</sup>. As there is no valve between the inferior vena-cava and the right atrium, in cases of tricuspid regurgitation blood flow in the veins in the retrograde direction during ventricular contractions<sup>(20)</sup>. Initially, these cardiac activities remain limited to the central veins, but with time chronic venous insufficiency arises, and could be detected in the lower limb peripheral veins. As stated earlier, tricuspid regurgitation is a reversible condition, and it may resolve if the underlying cause is treated in time<sup>(21)</sup>. Typically, such patients are unaware of their heart disease (tricuspid regurgitation)<sup>(22)</sup>, and physicians tend to search for renal or hepatic pathologies responsible for the patient's signs and symptoms<sup>(20)</sup>. The purpose of the study was to assess cardiac activities in the lower limb veins in patients with tricuspid regurgitation confirmed by echocardiography ("gold standard"). Moreover, it could be incorporated and used reliably as sonographic criteria when there is no availability or as an adjunct to echocardiography<sup>(23,24)</sup>.

## Materials and methods

A cross-sectional analytical study was performed in the Gilani Ultrasound Center, Lahore, Pakistan, for a duration of 13 months from March 2019 to February 2020. A total sample size of 400 subjects was selected for the purpose of the study. All the individuals referred for abdominal ultrasound having cardiac activities in the external iliac vein, popliteal and posterior tibial veins, individuals having normal venous Doppler ultrasound, both genders of adult age, were included. Unwilling and non-cooperative patients were excluded. Toshiba (Xario), linear transducer with frequency range from 7–14 MHz, and micro-convex transducer with a frequency range of 5 to 9 MHz were used for scanning. Lower limb venous examinations were performed according to the American Institute of Ultrasound in Medicine (AIUM) vascular ultrasound guidelines<sup>(25)</sup>. The lower limb veins were evaluated for cardiac activity based on the spectral Doppler waveform. Then, transthoracic echocardiography was performed with the aid of micro-convex transducer. Transthoracic approach was used in the supine position, as part of full echocardiographic assessment<sup>(26)</sup>. Data were collected in the form of information sheets for all required variables including age, gender,

**Tab. 1.** Descriptive statistics of variables

| Variables  |                         | Frequency | Percent |
|--|-------------------------|-----------|---------|
| Gender   | Female                  | 240       | 60      |
|  | Male                    | 160       | 40      |
| Hypertension   | No                      | 175       | 43.8    |
|  | Yes                     | 225       | 56.3    |
| Diabetes mellitus  | No                      | 201       | 50.3    |
|  | Yes                     | 199       | 49.8    |
| Doppler echo findings                                    | Normal                  | 196       | 49.0    |
|  | Tricuspid regurgitation | 204       | 51.0    |
| Cardiac activity in the iliac and posterior tibial veins | Absent                  | 200       | 50.0    |
|  | Present                 | 200       | 50.0    |
| Total  |                         | 400       | 100.0   |

**Tab. 2.** Comparison of gender and Doppler echo findings

| Crosstab of gender *<br>Doppler echo findings |        | Doppler echo findings |                         | Total        |
|---|--------|-----------------------|-------------------------|--------------|
|   |        | Normal                | Tricuspid regurgitation |              |
| Gender  | Female | 124 (31.0%)           | 116 (29.0%)             | 240 (60.0%)  |
|   | Male   | 72 (18.0%)            | 88 (22.0%)              | 160 (40.0%)  |
| Total   |        | 196 (49.0%)           | 204 (51.0%)             | 400 (100.0%) |

**Tab. 3.** Comparison of diabetes mellitus and Doppler echo findings

| Crosstab          |     | Doppler echo findings |                         | Total       |
|-------------------|-----|-----------------------|-------------------------|-------------|
|                   |     | Normal                | Tricuspid regurgitation |             |
| Diabetes mellitus | No  | 137(34.3%)            | 64(16.0%)               | 201(50.3%)  |
|                   | Yes | 59(14.8%)             | 140(35.0%)              | 199(49.8%)  |
| Total             |     | 196(49.0%)            | 204(51.0%)              | 400(100.0%) |

occupation, tricuspid regurgitation, cardiac activities in the lower limb veins, hypertension, and diabetes. Data analysis was performed with the help of Microsoft Excel 2018 and Statistical Package for the Social Sciences, version 24 (SPSS 24, IBM, Armonk, NY, United States of America). The chi-square test and correlation of tricuspid regurgitation and cardiac activities in the iliac and posterior tibial veins were applied. Qualitative data, e.g. hypertension, diabetes, gender, occupation, cardiac activities in the iliac and posterior tibial veins, and tricuspid regurgitation were presented in the form of frequencies and their respective percentages. Demographic data such as age were presented in the form of mean  $\pm$  standard deviation.

## Results

Four hundred individuals were selected for the study, with the mean age of  $37 \pm 12$  years, ranging from 1 to 97. The total number was divided into two groups: normal individuals and patients with tricuspid regurgitation. Out of the total number of participants, 200 individuals showed cardiac activity in the lower limb vein on Doppler vascular ultrasound, while 200 individuals did not show cardiac activity. Among them, 204 (51.0%) individuals were diagnosed with tricuspid regurgitation, and 196 (49%)

individuals showed competent tricuspid valve (Tab. 1). Out of the total number of included individuals, 240 (60%) were females and 160 (40%) were males (Tab. 2). Details related to diabetes mellitus in normal individuals and patients with tricuspid regurgitation are given in (Tab. 3). In the normal group, the mean age of the individuals was 37.33 with a range of  $5.00\text{--}87.00 \pm 16.29$  Std. D, while the mean age in the patients with tricuspid regurgitation was 55.92 with a range of  $1.00\text{--}97.00 \pm 19.49$  Std. D. In the normal group, the mean velocity in the posterior tibial vein was 5.59 cm/s, with a range of  $3.10\text{--}8.90$  cm/s  $\pm 1.57$  Std. D, while in the patients with tricuspid regurgitation the mean velocity in the posterior tibial vein was 31.13 cm/s, with a range of  $4.20\text{--}59.20$  cm/s  $\pm 10.19$  Std. D. On the other hand, in the normal group the mean velocity in the iliac vein was 39.82 cm/s, with a range of  $30.10\text{--}49.30$  cm/s  $\pm 5.50$  Std. D, while in patients with tricuspid regurgitation the mean velocity in the iliac vein was 42.16 cm/s, with a range of  $10.90\text{--}69.80$  cm/s  $\pm 10.81$  Std. D (Tab. 4). The subjects included in the study represent different professions. Both the healthy group and patients with tricuspid regurgitation have various occupations, which were divided into 4 classes as follows: housewives, students, unemployed and others including a carpenter, clerk, driver, electrician, farmer, gardener, laborer, manager, mason, nurse, office worker, plumber, property dealer, retired, salesman, street hawker, teacher, writer (Tab. 5).

## Discussion

Doppler echocardiography is currently considered to be the most valuable and definitive tool in the assessment of different heart diseases including valvular regurgitation, and its sensitivity and specificity are comparable to cineangiography<sup>(27)</sup>. A literature review shows that Doppler echocardiography is more sensitive than cardiac auscultation, particularly in cases where valvular regurgitation is mild<sup>(28)</sup>. Doppler echocardiography is also able to detect a milder degree of regurgitation in the early stages of the disease, when there are not yet any visible symptoms<sup>(29)</sup>. Lower limb

**Tab. 4.** Velocity in posterior tibial vein (cm/s) and velocity in iliac vein (cm/s)

| Doppler echo findings   |         | Age (years)       | Velocity in posterior tibial vein cm/s | Velocity in iliac vein cm/s |
|-------------------------|---------|-------------------|--|-----------------------------|
| Normal                  | Mean    | 37.33 $\pm$ 16.29 | 5.59 $\pm$ 1.57                        | 39.82 $\pm$ 5.50            |
|                         | N       | 196               | 196                                    | 196                         |
|                         | Minimum | 5                 | 3.10                                   | 30.10                       |
|                         | Maximum | 87                | 8.90                                   | 49.30                       |
| Tricuspid regurgitation | Mean    | 55.92 $\pm$ 19.49 | 31.13 $\pm$ 10.19                      | 42.16 $\pm$ 10.81           |
|                         | N       | 204               | 204                                    | 204                         |
|                         | Minimum | 1                 | 4.20                                   | 10.90                       |
|                         | Maximum | 97                | 59.20                                  | 69.80                       |
| Total                   | Mean    | 46.81 $\pm$ 20.24 | 18.61 $\pm$ 14.74                      | 41.01 $\pm$ 8.70            |
|                         | N       | 400               | 400                                    | 400                         |
|                         | Minimum | 1                 | 3.10                                   | 10.90                       |
|                         | Maximum | 97                | 59.20                                  | 69.80                       |

**Tab. 5.** Occupations of patients

| Crosstab   |            | Doppler echo findings |                         | Total        |
|------------|------------|-----------------------|-------------------------|--------------|
|            |            | Normal                | Tricuspid regurgitation |              |
| Occupation | Housewife  | 50 (12.5%)            | 43 (10.8%)              | 93 (23.3%)   |
|            | Unemployed | 21 (5.3%)             | 69 (17.3%)              | 90 (22.5%)   |
|            | Student    | 3 (0.8%)              | 2 (0.5%)                | 5 (1.3%)     |
|            | Others     | 54 (64.4%)            | 76 (67.9%)              | 130 (32.4%)  |
| Total      |            | 196 (49.0%)           | 204 (51.0%)             | 400 (100.0%) |

venous Doppler sonography is recognized as the standard screening test. However, researchers disagree on the nature of phasicity of venous Doppler waveforms. Some think this phasicity is cardiac in origin, reflecting changes in right atrium pressure; others argue that the changes are respiratory; a third group describes the phasicity as sometimes respiratory and sometimes cardiac<sup>(30)</sup>. The disagreement reflects a lack of understanding, which leads to a lack of interest, and consequently a scarcity of reports addressing the significance of the pulsatile flow in these waveforms<sup>(31)</sup>. The aim of the study was to diagnose cardiac abnormalities of the right heart with the help of Doppler ultrasonography of the lower limb veins. The authors attempted to quantify the degree of TR by evaluating the waveform of the femoral vein. The Doppler waveforms of the lower extremity veins were evaluated in 276 patients over a period of 17 months. The abnormal pulsatile Doppler waveforms recorded in these patients were compared with the echocardiography findings. The chest radiographs (CXR) of 104 patients out of 276 were reviewed. According to the findings, abnormal cardiac activity of Doppler waveforms was noted in 9 patients (3.3%), with abnormally high retrograde velocity peaks. These abnormal retrograde velocity peaks were compared with the retrograde velocity peaks in the control group. The retrograde velocity peaks in the diseased group show a statistically significant (Pearson's  $r = 0.9113$ )

correlation with the degree of tricuspid regurgitation observed on echocardiography. All of the 9 patients showed enlargement of the heart on chest radiographs, compared to 16 out of 95 (16.8%) with a normal Doppler waveform. It was concluded that spectral Doppler ultrasound is routinely performed in the hospital radiology departments, and it is a quite simple, reliable, and reproducible method for the evaluation of the veins in lower limbs, and their abnormalities. The sonologist is able to detect the degree of tricuspid regurgitation if cardiac activity is seen within the veins of the lower limbs<sup>(23)</sup>. In the reported study, 400 individuals were included, of which 200 individuals showed cardiac activity in the lower limb vein on Doppler vascular ultrasound, while 200 individuals did not show cardiac activity. Among 400 subjects, 204 were diagnosed with tricuspid regurgitation, and 196 subjects showed a competent tricuspid valve. The results of the study were also statistically significant, having the  $p$ -value = 0.00 and  $<0.001$ . According to the results of previous studies, age is weakly correlated with tricuspid regurgitation. However, according to the present study, the correlation is strong, with more identified patients at an advanced age compared to young individuals<sup>(32)</sup>.

## Conclusion

An association was found between the cardiac activities in the lower limb veins and tricuspid regurgitation.

## Conflict of interest

*Authors do not report any financial or personal connections with other persons or organizations which might negatively affect the contents of this publication and/or claim authorship rights to this publication.*

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