Tissue Doppler Assessment of Systolic Right Ventricular Function before and after Balloon Pulmonary Vulvuloplasty

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Abstract

Background: The incidence of valvular pulmonary stenosis has been reported to be 0.6 to 0.8 per 1000 live births, and when associated with other congenital heart diseases as many as 50% of all patient with congenital heart diseases. The magnitude of right ventricular pressure and the pressure across the pulmonary valve are generally proportional to the degree of obstruction. Under usual circumstances, proportional right ventricular hypertrophy maintains normal pulmonary flow. If the normal output isn't maintained, right sided heart failure ensues. This occur in neonates with critical pulmonary stenosis and in patient with severe obstruction that occur in childhood or adulthood.

Aim of Study: To assess the right ventricular systolic function by tissue Doppler in patients with critical valvular pulmonary stenosis before, immediately and three months after successful Balloon Pulmonary Valvuloplasty (BPV).

Methods: This study is a prospective study, it included 20 patients with critical stenosis who attended to the Cardiology Department in Tanta University Hospital and subjected to balloon pulmonary valvuloplastyfrom August 2016 to March 2017. The patients are subjected to balloon valvuloplasty and full echocardiography assessment and tissue Doppler to the right ventricle.

Results: The transcutaneous BPV showed high efficacy in reducing the pressure gradient across the pulmonary valve denoting successful and effective dilatation, where the maximum pulmonary PG ranged from 68-120mmHg. With a mean $\pm$ SD value of 82.47$\pm$16.3 at base line, and 12-30mmHg with a mean value of 20.26$\pm$5.43 immediately after intervention, and 15-35mmHg, with a mean $\pm$ SD value of 22.37$\pm$5.05 mmHg three months after intervention. There was statistically significant decrease in maximum pulmonary PG immediately after BPV (*p*=0.001), but there was no statistically significant difference in the maximum pulmonary PG immediately after intervention and after three months. TAPSE ranged from 11-16mm with a mean $\pm$ SD value of 13.48$\pm$1.43 at base line, and 13-17mm with a mean $\pm$ SD value of 15.87$\pm$1.08 immediately after intervention.and 20-24mm with a mean $\pm$ SD value of 21.74$\pm$1.163 three months after intervention. There

was statistically significance increase in TAPSE immediately after intervention and also three months after intervention. Right Ventricular Systolic wave (RVs) ranged from 8-11cm/s with a mean $\pm$ SD value of 9.24$\pm$0.77 at base line, and 8-11 cm/s with a mean $\pm$ SD value of 9.24$\pm$0.67 immediately after intervention and ranged from 11-14cm/s with a mean $\pm$ SD value of 12.41$\pm$0.67 three months after intervention. There was no statistically difference in RVs before intervention and immediately after intervention but RVs was statistically significance increased after three months from both before intervention and immediately after intervention.

Conclusion: BPV is safe and effective to relieve critical pulmonary stenosis. The balloon promotes advantageous changes in both, pulmonary annulus and pressure gradient across the RVOT, in addition, the Doppler gradient observation during the follow-up support the expectation that BPV is a curative therapy. The right ventricular systolic function changed favorably in children with moderately-severe pulmonary stenosis after successful balloon valvuloplasty. These changes provide a good insight for early intervention in the children with pulmonary stenosis to avoid progression to permanent cardiac deformation and heart failure.

Key Words: Pulmonary stenosis – Tissue Doppler – Balloon valvuloplasty.

Introduction

THE incidence of valvular pulmonary stenosis has been reported to be 0.6 to 0.8 per 1000 live births, and when associated with other congenital heart diseases as many as 50%of all patient with congenital heart diseases [1].

Dysplastic valves consisting of thickened, irregular, immobile tissue often with hypoplasia of the valve annulus and small short pulmonary artery are much less common [2].

The traditional method of treatment of this obstructive lesion was surgical valvotomy up to 1982, when the technique of percutaneous (BPV) was introduced [3].

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The short and mid-term result of BPV have been so good that nowadays became the preferred method of therapy for moderate and severe pulmonary stenosis both in children as well as adults. It is also safe and effective for the relief of pulmonary stenosis in neonates [4].

The anatomic and hemodynamic factors that determine the clinical presentation of infants with critical pulmonary stenosis are not well understood [5].

The success rate of BPV in infants with critical pulmonary stenosis has been reported to be 55-94%; however restenosis have been reported in 17-36% of these patients [6].

The pulmonary valve annulus and right heart structures have been characterized as hypoplastic in some patients with critical pulmonary stenosis, and growth of these structure relative to somatic growth after BPV has been a subject of controversy [7].

The clinical implications of impaired Right Ventricular function (RV) have been studied widely in recent years, and it has become clear that both RV dysfunction and RV dilatation are strong and independent predictors of adverse cardiac events [8].

At present, conventional two-dimensional (2-D) echocardiography is still considered the cornerstone in evaluation of RV function, however, it is much more challenging compared to evaluation of left ventricular function, mostly due to complex geometry of RV. When used in a qualitative manner, conventional echocardiography is usually able to provide information about RV function, but if more objective (quantitative) information about RV function is required, conventional echocardiography is frequently insufficient [9].

Tissue Doppler Imaging (TDI) has been developed and considered novel technique for quantitative analysis of cardiac function. The major potential advantage of TDI for assessment of RV function over conventional echocardiography is its independence of geometric assumptions and endocardial border tracing [9].

Patients and Methods

The study was conducted as a prospective interventional study from August 2016 to March 2017 with follow-up period of three months, at Cardiovascular Medicine Department, Tanta University Hospitals in Gharbia Governorate, Egypt.

The study included 20 patients with critical stenosis who attended to the Cardiology Department in Tanta University Hospital and subjected to balloon pulmonary valvuloplasty.

Patients included in this study fulfilled all of the following criteria:

A- Echocardiogrphic evidence of moderate to severe pulmonary stenosis.

B- Suitability to trans-catheter balloon valvuloplasty.

C- Age from birth to two years.

D- Successful BPV.

Exclusion criteria were:

A- Patients with associated large Ventricular Septal Defect (VSD) or Atrial Septal Defect (ASD) or any associated anomaly in which dilatation of pulmonary valve would lead to increase risk of development of pulmonary hypertension in future.

B- Patients with multiple levels of Right Ventricular Out-flow (RVOT) obstruction.

C- Patients with active infection.

D- Patients with bad echogenicity.

E- Unsuccessful BPV.

All included patients were subjected to detailed history taking and clinical examination including measurement of vital signs and detection of signs of heart failure/hemodynamic instability according to Killipclassification.

All patients were subjected to the following:

Detailed history talking and clinical examination. Standard 12-lead ECG. Chest X-ray. Full 2D trans-thorathic echocardiography.Transcatheter balloon pulmonary valvuloplasty.

History and clinical examination: Proper history was taken from the parents to detect symptoms suggestive of significant pulmonary stenosis such as dyspnea and cyanosis noticed by the mother and clinical examination was done to document the presence of manifestations suggestive of pulmonary stenosis as congested neck vein and systolic ejection murmur on the left upper sternal border.

Standard 12-lead ECG: Routine 12-lead ECG was done for patients to detect the changes suggestive of pulmonary stenosis such as right ventricular hypertrophy and strain.

Chest X-ray: All patients underwent plain postero-anterior chest X-ray view to detect changes

suggestive of pulmonary stenosis such as prominent main pulmonary artey, decreased pulmonary vascular marking and dilated right side.

Echocardiography: A continuous wave Doppler signal across the area of stenosis is a key component of any examination in pulmonic stenosis. The peak flow velocity across the valve is measured and converted to a peak pressure gradient via the modified Bernoulli equation.

Pulsed wave TDI of the tricuspid annular motion at the lateral free wall was obtained from the apical 4-chamber view using a pulsed wave Doppler. Care was taken to obtain an ultrasound beam parallel to the direction of the tricuspid annular motion. Peak systolic (ST) tricuspid annular velocities were obtained. Evaluating peak systolic velocity, the initial peak that occurs during isometric contraction was ignored TAPSE assumes that the displacement of the basal and adjacent segments is representative of the longitudinal function of the entire right ventricle. Longitudinal myocardial shortening is a significant contributor to the right ventricular function. Systolic excursion of the lateral tricuspid annulus represents the global right ventricular function. TAPSE is assessed with M-mode on an apical four chamber view, placing the M-mode cursor on the lateral tricuspid annulus.

BPV: Transcatheter BPV was done under general anesthesia and through femoral approach In all patients venous access was done using Seldinger's technique and 5-7F sheath was introduced in the femoral vein. Alternative venous access sites were needed in selected cases. An angiographic catheter was placed in the RVOT and straight lateral angiograms were performed (1 cc/kg over one second) to measure the pulmonary valve annulus and assess the RV and valve anatomy. The angiographic catheter was replaced with an endhole catheter which was manipulated in the RV with the tip directed toward the RVOT. The pulmonary valve was crossed and the catheter positioned in the lower lobe branch of either left or right pulmonary arteries.

An exchange wire was placed in the peripheral pulmonary artery and the catheter was replaced with a dilatation balloon. The size of balloon about 120-140% the annulus size. Single balloon may be used, although two balloons side by side may be necessary in large annulus. The balloon was centered across the pulmonary valve annulus and rapidly inflated by hand with diluted contrast solution until the disappearance of the waist. The goal of the procedure is final peak to peak gradient

less than 30mmHg. The deflated balloon was then removed while keeping the guide wire in the pulmonary artery. The guide wire permitted repositioning of an end hole catheter in the pulmonary artery for measurement of the pressure.

The following pressure and hemodynamic measurements were recorded before and immediately after BPV: Right Ventricular Systolic Pressure (RVSP), Right Ventricular Diastolic Pressure (RVDP), Pulmonary Artery Systolic Pressure (PASP), Pulmonary Artery Diastolic Pressure (PADP), Right Ventricular (RV) to Pulmonary Artery (PA) systolic Peak Gradient (PG).

Post catheterization care:

Observation was done for 12 to 24 hours in our catheterization post care unit for most of patients. Re-evaluation of the same parameters taken before the balloon dilatation (the gradient across the valve, TAPSE and pulsed wave TDI of the tricuspid annular motion at the lateral free wall (St)) immediately after the end of the procedure. Further clinical follow-up and echocardiography are undertaken at three months after balloon dilatation.

Statistical presentation and analysis of the present study was conducted, using the mean, standard deviation and Chi-square test by SPSS V.20. Numerical data was presented as mean and Standard Deviation (SD) and categorical data was presented as number and percentage. Chi-squared test was used for comparison of categorical variables. When the Chi-squared test was not appropriate, the likelihood ratio test was applied. The level of significance was adopted at $p<0.05$.

Subjects were informed about the purpose and procedure of the study and benefits of sharing in it. Ethical considerations of the study were carried out according to that of Declaration of Helsinki [10].

Results

This a prospective study including 20 patients with a provisional diagnosis of severe congenital pulmonary stenosis admitted at Cardiology Department of Tanta University Hospital for percutaneous transcatheter balloon pulmonary valvuloplasty during the period from August 2016 to March 2017. All the 20 patients underwent successful BPV.

The age of patients ranged from 3-24 months with a mean value of 13.47 ± 6.75 months with a median value of 18 months. Eleven of the studied patients were girls (55%), while 9 patients were boys (45%) (Table 1). The weight of the studied

cases ranged from 5 to 12Kg with a mean ± S.D 9.03±2.01Kg. The height of the cases ranged from 65 to 84cm with a mean ± S.D 74.35±7.01cm. The Body Mass Index (BMI) ranged from 15 to 17 with a mean ± S.D 16.09±0.68 (Table 2).

Five patients (25%) had a history of palpitation, eight patients (40%) had a history of tachypnea, five patients (25%) gave history of easy fatigability two patients (10%) had a history of cyanosis (Table 3).

Ejection fraction ranged from 63-69% with a mean value 66.68±1.79. Maximum pulmonary pressure gradient ranged from 68 to 120mmHg, with a mean value 82.47±16.3 (Table 4).

The pulmonary valve annulus before the procedure ranged from 1 to 1.2cm with mean ± S.D 0.74±0.21 cm, the annulus size immediately after intervention ranged from 1 to 2cm with mean ± S.D 1.65±0.12cm and the annulus size three months after the procedure 1 to 2cm with mean ± S.D 1.65±0.12cm. There was a significant increase in the annular size after BPV (Table 5).

The maximum pulmonary pressure gradient range from 68-120mmHg. With a mean ± SD value of 82.47±16.3 at base line, and 12-30mmHg with a mean ± SD value of 20.26±5.43 immediately after intervention, and 1 5-35mmHg, with a mean value of 22.37±5.05 three months after intervention. There was statistically significant decrease in maximum pulmonary pressure gradient immediately after BPV. But there was no statistically significant difference in the maximum pulmonary pressure gradient immediately after intervention and after three months. Table (5) Fig. (1).

TAPSE ranged from 11-16mm with a mean ± SD value of 13.48±1.43 at base line, and 13-17mm with a mean ± SD value of 15.87±1.08 immediately after intervention. And 20-24mm with a mean ± SD value of 21.74±1.163 three months after intervention. There was statistically significance increase in TAPSE immediately after intervention and also three months after intervention. Table (5) Fig. (2).

Right Ventricular Systolic wave (RVs) ranged from 8-11cm/s with a mean ± SD value of 9.24±0.77 at base line, and 8-11cm/s with a mean ± SD value of 9.24±0.67 immediately after intervention and ranged from 11-14cm/s with a mean ± SD value of 12.41±0.67 three months after intervention. There was no statistically difference in RVs before intervention and immediately after intervention but RVs was statistically significance increased

after three months from both before intervention and immediately after intervention. Table (5) Fig. (3).

After the pulmonary balloon valvuloplasty just three cases (15%) were developed mild pulmonary regurgitation, while two cases (10%) developed trivial pulmonary regurgitation, and 15 cases (75%) had no pulmonary regurgitation.

Table (1): Demographic data of the study patients.

Characteristics	Study patients (n=20)	
	No.	%
Age (in months):		
<6	3	15
6-12	6	30
12-18	6	30
18-24	5	25
Mean ± S.D	13.47±6.75	
Range	3-24	
Gender:		
Male	9	9
Female	11	11

Table (2): Statistical analysis of the studied cases according to anthropometrics (n=20).

Variables	Study patients (n=20)
Weight/kg:	
Mean ± S.D	9.03±2.01
Range	5-12
Height/cm:	
Mean ± S.D	74.35±7.92
Range	65-84
BMI:	
Mean ± S.D	16.09±0.68
Range	15-17

Table (3): Distribution of cases according to symptoms.

Symptoms	No	%
Palpitation	5	25
Tachypnea	8	40
Cyanosis	2	10
Easy fatigability	5	25

Table (4): Cardiac functions of the study patients.

Cardiac functions	Study patients (n=20)
Left ventriculare (EF):	
Mean ± S.D	66.68±1.79
Range	63-69
Maximum pulmonary pressure gradient:	
Mean ± S.D	82.47±16.3
Range	68-120

Table (5): Comparison of echocardiographic parameters (MMPG, TAPSE and RVs) before the intervention, immediately after intervention, and after 3 months.

	Before	Immediatly	After 3m	*p*-value
MMPG	82.47±16.3	20.26±5.43	22.37±5.05	0.001
TAPSE	13.48±1.43	15.87±1.08	21.47±1.163	0.001
RVs	9.24±0.77	9.24±0.67	12.41±0.67	0.001
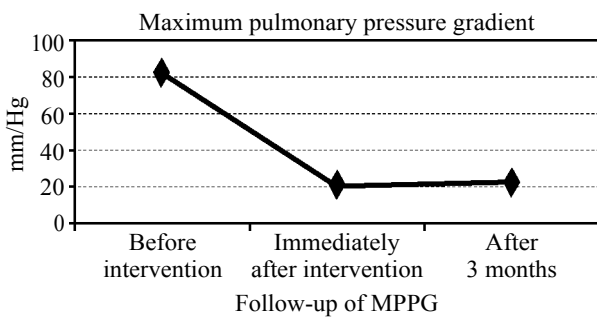
Fig (1): Linear curve showing the progressive drop in the pressure gradient acrossthe pulmonary valve throughout the follow-up period.
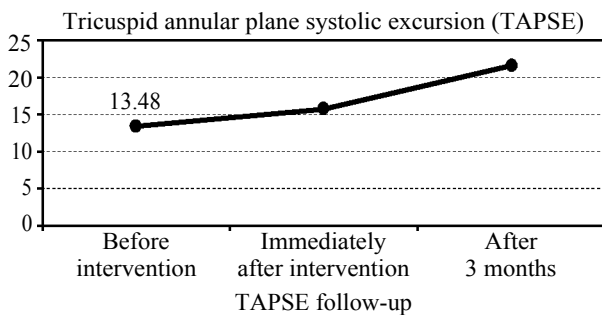

Fig. (2): Linear curve showing improvement of the systolic right ventricular function as measured with tricuspid annular systolic excursion during the follow-up period.
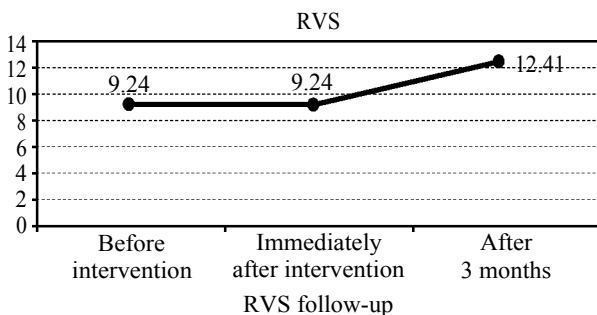

Fig. (3): A linear curve showing the progressive improvement of systolic right ventricular function as measured with tissue Doppler during the follow-up period.

Discussion

Critical pulmonic stenosis is a life-threatening condition in the neonate because of inadequate antegrade pulmonary flow through the Right Ventricular Outflow Tract (RVOT) [11]. Currently,

balloon valvuloplasty is the procedure of choice, as it is as effective as surgical correction and is less invasive [12].

Tissue Doppler imaging is a useful echocardiographic technique to evaluate global and regional myocardial systolic as well as diastolic function. It can also be used to quantify right ventricular function. Recent studies have demonstrated its utility as a diagnostic as well as prognostic tool in different cardiac conditions [13].

In this study,our aim was to assess the systolic right ventricular function in patients with pulmonary stenosis before and after the balloon pulmonary valvuloplasty using tissue Doppler.

This study was a prospective study that included 20 ptients with severe pulmonary stenosis admitted to Cardiology Department at Tanta University Hospital for pecutaneous balloon pulmonary valvuloplasty in period from August 2016 to March 2017.

The age of patients ranged from 3 to 24 months with a mean value of 13.47±6.75 months, and a median value of 18 months. Eleven of the studied patients were girls (55%), while 9 patients were boys (45%).

Eight patients presented with tachypnea while 5 patients complaining from easy fatigability, 5 patients were complaining from palpitation and the minority 2 patients were complaining from cyanosis. Heart rate ranged from 108-125bpm with a mean value of 113.95±5.03.

In our study, we demonstrated that pulmonary stenosis causes a significant degree of impairment of the systolic right ventricular function as it was assessed by tissue Doppler and TAPSE and these parameters significantly returned to near the normal values after balloon pulmonary valvuloplasty.

In the current study: The transcutaneous pulmonary balloon valvuloplasty showed high efficacy in reducing the pressure gradient across the pulmonary valve denoting successful and effective dilatation, where the maximum pulmonary pressure gradient range from 68-120mmHg. With a mean value of 82.47±16.3 at base line, and 12-30mmHg with a mean value of 20.26±5.43 immediately after intervention, and 1 5-35mmHg, with a mean value of 22.37±5.05 three months after intervention. There was statistically significant decrease in maximum pulmonary pressure gradient immediately after BPV (*p*=0.001). But there was no statistically significant difference in the maximum

pulmonary pressure gradient immediately after intervention and after three months.

Similarly, Mahfouz et al., [14] study, where forty eight pediatric patients were enrolled in this study, they were diagnosed with moderate to severe pulmonary stenosis and they all underwent successful BPV. This study found that the maximum pulmonary pressure gradient ranged from 62.8 ±16.2mmHg before pulmonary valvuloplasty and 23±13.5mmHg after three months of pulmonary valvuloplasty with statistically significant decrease between the maximum pressure gradient after three months.

Also, in agreement with the current study, Holzer et al., [15] study, where 211 cases were included, all of them were diagnosed as isolated pulmonary stenosis and underwent balloon pulmonary valvuloplasty. Procedure success was achieved in 91%, being defined as post-BPV peak systolic valvular gradient to <25mmHg (88%), decreased in gradient by 50% (79%).

Also, in agreement with the current study, Saad et al., [16] study, where seventy six patients with severe pulmonary stenosis were subjected to balloon pulmonary valvuloplasty. Immediately after the procedure patients had a significant reduction in peak gradient from 82.5±23.76mmHg to 17.35± 8.96mmHg, ($p<0.001$).

In the current study: We found a good correlation between between successful BPV and improvement of the systolic right ventricular function. According to assessment the systolic right ventricular function with TAPSE, which ranged from 11 to 16mm with a mean value of 13.48±1.43mm at base line, and 13 to 17mm with a mean value of 15.87±1.08mm immediately after intervention, and 20 to 24mm with a mean value of 21.74±1.163mm three months after intervention. There was statistically significance increase in TAPSE immediately after intervention, and also at three months after intervention. (p=0.001).

This agree with Mahfouz et al., [14] who showed TAPSE ranged from 15.2±3.2mm in children with pulmonary stenosis before valvuloplasty, to 22.2± 2.8mm three months after the procedure ($p<0.001$).

In the current study: We found that patients with pulmonary stenosis showed significantly impairment of systolic right ventricular function as assessed with tissue Doppler and restored to near normal values after success BPV. Right Ventricular systolic wave (RVs) ranged from 8 to 11 cm/s with a mean value of 9.24±0.77 at baseline,

and 8 to 11cm/s with a mean value of 9.24 ±0.67 cm/s immediately after intervention and ranged from 11 to 14cm/s with a mean value of 12.41 ±0.67 three months after intervention. There was no statistically difference in RVs before intervention and immediately after intervention but RVs was statistically significance after three months from both before intervention and immediately after intervention. This agree with Mahfouz RA et al., (2017) [14] who showed RVs 9.3±2.3cm/s in children with pulmonary stenosis before balloon valvuloplasty and 13.2±2.6 three months after valvuloplasty.

In the current study, as regard to the pulmonary valve regurgitation after the valvuloplasty, just three cases (15%) developed mild pulmonary regurgitation, two cases (10%) with trivial pulmonary regurgitation, and 15 cases (75%) had no pulmonary regurgitation.

In Alsawah et al., study [17], sixty eight pediatric patients with severe pulmonary stenosis were enrolled in this study and underwent BPV. Echocardiography follow-up revealed trivial to grade I pulmonary valve regurgitation in 45.4%, grade II pulmonary regurgitation in 16.6%.

Also in Parent et al., [18] who evaluated the outcomes of BPV for isolated pulmonary valve stenosis in children, fifty three patients were enrolled in this study. They were diagnosed as isolated pulmonary stenosis, and underwent successful balloon valvuloplasty. The study found that 25% of the patients had trivial or no pulmonary regurgitation, 49% of the patients had mild regurgitation, 22% of the patients had mild to moderate regurgitation, and 4% of the patients had moderate regurgitation.

Limitations:

The study had some limitations. This is a single-centre experience and represents a limited number of patients. The follow-up period was only 3 months; longer follow-up periods may show different results.

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تقييم كفاءة البطين الآيمن بإستخدام دوبلر الآنسجة قبل وبعد توسيع البالونى الصمام الرئوى

إشتملت الرسالة على ٢٠ مريض ضيق بالصمام الرئوى وتم التوسيع البالونى فى قسم القلب بمستشفيات جامعة طنطا فى الفترة من آغسطس ٢٠١٦ إلى مارس ٢٠١٧ وتم تقييم كفاءة البطين الآيمن بعد موافقة لجنة آخلاقيات البحث العلمى، والحصول على الموافقة المسبقة من جميع آولياء الآمور للآطفال المشاركين فى هذا البحث. وجميع بيانات المرضى بصورة سرية مع وجود ملفات خاصة لكل مريض.

وكما إتضح تحسن فى معايير ووظائف القلب بعد التوسيع البالونى للصمام الرئوى.

ونستنتج من ذلك آن ضيق الصمام الرئوى تؤدى إلى خلل فى وظائف القلب وإجهاد لعضلة القلب الآيمن وإن التوسيع البالونى بإستخدام القسطرة هو الحلال آفضل لعلاجها وإن دوبلر الآنسجة يعتبر طريققة مثلى فى تقييم كفاءة البطين الآيمن.