Prospective Study of Clinical Outcome of the Patients Undergoing Tricuspid Annuloplasty

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1. Introduction

Heart diseases, or cardiovascular diseases, accounts for 29 percent of deaths worldwide according to the World Health Organization, not to mention the millions of people treated in hospitals for CVD every year which costs the economy billions of Euros annually1. Although valvular heart disease (VHD) is less frequent than coronary disease or heart failure (HF), it causes significant mortality and morbidity. An estimated 20,891 patients died because of VHD in the United States in 20072. Tricuspid valve (TV) disease affects 0.8% of the general population in the United States3,4. Such data regarding the Indian subcontinents are lacking. Because Tricuspid Valve, it works in a low-pressure system, it is difficult to evaluate its preoperative importance and to assess the value of different surgical techniques. These characteristics often lead cardiologists and surgeons to ignore the tricuspid valve with apparent impunity. However, recent developments in diagnostic tools and two-dimensional colour Doppler echocardiography have increased the awareness of this valve, which has been called the “Cinderella of all cardiac valves”.

2. Anatomy

Tricuspid valve is composed of three leaflets (an anterior, a posteriorand a septal leaflet), the chordae tendinae, two discrete papillary muscles, the fibrous tricuspid annulus, and the right atrial and right ventricular myocardium. The anterior leaflet and the septal leaflet are larger, whereas the posterior leaflet is notable for the presence of multiple scallops. TV commissures represent the border between the different leaflets (i.e. antero-septal, antero-posterior, and postero-septal). Because the septal wall leaflet is fixed, there is little room for movement if the free wall of the right ventricular/tricuspid annulus should dilate[7]. Dilatation of the tricuspid annulus therefore occurs primarily in its antero-posterior (mural) aspect, which can result in significant dysfunction of the valve because of leaflet malcoaptation[8,9].

The area of the annular plane to the atrial surface of the leaflets is called the tethering area, this term is often used together with the tethering/coaptation depth which stands for the distance from the annular plane to the begin point of leaflet coaptation (Figure 1.1)[10].

The tricuspid annulus has a complex 3-dimensional structure, which differs from the more symmetric “saddle-shaped” mitral annulus. Healthy subjects normally have a nonplanar, elliptical shaped tricuspid annulus, with the postero-septal portion being “lowest” and the antero-septal portion the “highest” (Figure 1.2). Patients with functional TR generally have a more planar annulus, which has dilated primarily in the antero-posterior direction, resulting in a more circular shape as compared with the elliptical shape in healthy subjects.

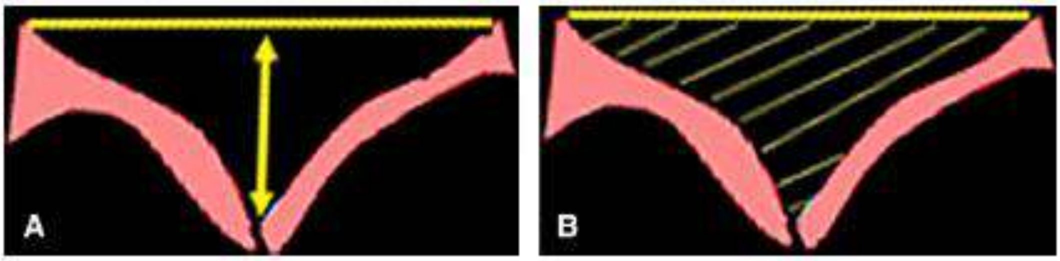

Figure 1.1: T.V Tethering/Coaptation Deapth (A)Tethering Area (B) (10)

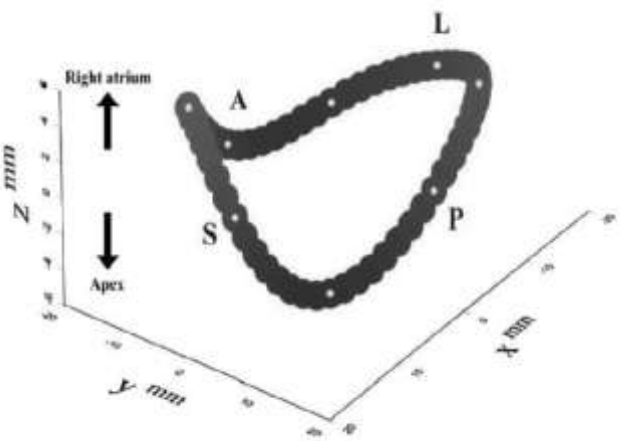

Figure 1.2: Three Dimentional Shape of Tricuspid Annulus, [11] Anterior, Septal, Posterior & Lateral Represented By A, S, P & L.

3. Pathophysiology

Tricuspid Regurgitation implies a backflow of blood from the right ventricle to the right atrium during contraction of the right ventricle (Figure 2.1 &2.2). TR is a common echocardiographic finding that is present in 80 to 90% of normal individuals[3]. The cause of TR is more often functional (secondary) rather than morphological (primary). In morphological TR, as the name already predicts, the leaflets themselves are morphologically affected which results in a dysfunctional tricuspid valve[13]. Congenital defects, trauma, carcinoid heart disease, toxic effects of chemicals, tumors, myxomatous degeneration, rheumatism, or endocarditis, possibly together with rupture of chordae or papillary muscles are the main causes of morphological TR.[1-411]

A variety of etiologic factors can induce organic regurgitation, but today, the most frequent cause of organic tricuspid valve disease in urban populations is infective endocarditis. Tricuspid valve endocarditis used to be relatively rare, with an incidence of only 5% to 10% of patients with infective endocarditis. However, its frequency has dramatically increased with the spread of intravenous drug abuse.[13] In this population, the tricuspid valve usually has no pre-existing pathologic change. The lesions vary from isolated vegetation to destruction of the valve, including the annulus. Staphylococcus aureus remains the most common organism found in drug addicts, followed by gram-negative organisms and Candida. Fungal infections are also increasing because of longer periods of invasive monitoring of patients with multiorgan failure in intensive care units. In the developing world, rheumatic fever is the primary cause of organic valvular heart disease. Typical lesions show varying degrees of leaflet thickening and (most often) commissural fusion. In severe cases, the thickened leaflets become diaphragm-like, with a central circular orifice. The sub-valvular apparatus is seldom affected, and calcifications are rare. Although tricuspid valve stenosis is the classic lesion, predominant insufficiency is just as common. In a series of 253 patients with rheumatic heart disease who underwent tricuspid valve surgery, it has been found that organic involvement was present in 45% of the cases and that 45% of them also had annulus dilation.[14] In a classic study of 100 post-mortem hearts with rheumatic disease, Gross and Friedberg[15] found microscopic evidence of inflammation in the annulus of all four valves (in the acute rheumatic attack). Rheumatic tricuspid valve disease is always associated with rheumatic mitral valve or mitral-aortic valve lesions. The incidence of chronic rheumatic tricuspid valve disease associated with rheumatic mitral valve disease varies widely, from 6% in an echocardiographic study16 to 33% in an anatomic series[17] and 11% in a series of 1052 patients undergoing rheumatic valvular surgery.[14] In a Mayo Clinic surgical pathology study of excised tricuspid valves at the time of valve replacement,18 postinflammatory etiology was responsible for 53% of the 363 valves studied. However, this frequency had diminished from 79% during the period from 1963 to 1967 to 24% during 1983 through 1987, reflecting the reduction in the incidence of rheumatic fever in the United States. Leaflet tears and total or partial avulsion of a papillary muscle head occur after closed chest trauma. They are occasionally diagnosed at surgery and only classified postoperatively as traumatic by the patient, who recalls an old accident when prompted by the surgeon.[19-21] An occasional cause of traumatic tricuspid regurgitation is that induced by the bioptome during a right myocardial biopsy in transplanted patients. Leaflet tears or chordal avulsion results in severe regurgitation that requires urgent surgery.[22] Degenerative tricuspid regurgitation associated with mitral valve prolapse is being increasingly observed. This double valve lesion is particularly frequent in Marfan syndrome as a manifestation of a fibrillopathy that also involves the aortic valve and ascending aorta. The reported frequency of tricuspid valve involvement among patients with mitral valve myxomatous disease oscillates between 21% and 52%.[7,23,24] Less common causes include organic tricuspid valve lesions secondary to carcinoid syndrome and appetite-suppressant drugs.[25] In both cases, the leaflets are encased by a fibrous sheath that reduces their mobility, resulting in stenotic and regurgitant lesions.

Functional TR is often called secondary TR because it results most commonly from a left-sided heart disease, right ventricular volume, and pressure overload[9,14,15.]

4. Materials & Methods

This study was conducted at N.R.S Medical College, Kolkata and College of Medicine and Gandhi Memorial Hospital, Kalyani, Nadia for a period of 2014 to 2018 and selected among patients attended O.P.D.Patients who were scheduled for mitral valve surgery (MVP or MVR) and/or TVP were selected out of the database. Possibly, aortic valve surgery and/or coronary artery bypass grafting (CABG) was concomitantly performed with the mitral and/or tricuspid valve surgery since some patients had severe heart problems. Nearly all patients had MR and TVP was routinely performed in case of TA dilatation (echocardiographic: greater than 40 mm or 21 mm/m² apical 4-chamber view end-diastolic) and/or more than moderate (TR>2) functional TR[38]. General data about these patients was gathered out from records. The gathered information included sex, date of birth, date of surgery, risk factors associated with heart problems, lung function results, blood results, medication use before and after the surgery, date of death and rehospitalization due to HF. Information about the surgery itself was collected as well. These parameters included cross clamp time, cardiopulmonary bypass time (CPB), repair/replacement ring size (MV and/or TV ring), repair/replacement ring type, type of cardioplegia, length of stay on intensive care. Short echo reports were added to data by cardiologist after each first or second O.P.D visit.

All consecutive patients who underwent MVP/MVR only or in addition to CABG and/or aortic valve surgery between 2014-2018 in the said Medical Colleges& Hospitals with subsequent clinical follow-up in our center were reviewed for this study. All patients had severe MV regurgitation and TVP was routinely performed in case of TA dilatation (>40 mm apical 4-ch view end-diastolic) and/or more than moderate functional TR[21]. The study complies with the Declaration of the locally appointed ethics committee who has approved the research protocol, and informed consent for has been obtained from all subjects.

5. Surgical Procedure

All surgical procedures were performed through midline sternotomy under mostly normothermic cardiopulmonary bypass with intermittent antegrade warm-blood cardioplegia. Patients with an indication for revascularization underwent first CABG. The mitral valve was exposed through a vertical approach. MVP was performed after thorough intra-operative visual and size of valve analysis. Ring size (St. Jude or Carpentier-Edwards Physioring®, Edwards Lifesciences, Irving, CA) was determined after careful measurement of the height of the anterior leaflet. In case of functional MR, downsizing by two sizes (i.e., size 26 when measuring 30) was applied to ensure a coaptation length of at least 8 mm. Rings were inserted using 12 to 14 deep U-shaped simple horizontal sutures using Ethibond 2-0 (Ethicon®, Inc, Somerville, NJ). **(FIG-2.1)** Additional aortic prosthetic valve replacement (AVR) was performed in patients with aortic lesions, if indicated. Additional TVP was performed in patients with TR exceeding grade 2 on a preoperative transthoracic echocardiogram or patients with a dilated tricuspid annulus exceeding 20 mm on echocardiogram. TVP was performed using mostly a Carpentier-Edwards MC3® ring or by surgical repair **(FIG-2.3)**. The ring size was visually matched to the area of the anterior leaflet. More recently, in presence of a markedly dilated RV resulting in non-coaptation of the leaflet, the anterior leaflet was widely augmented using an autologous pericardial patch.

The restored leaflet coaptation (≥8 mm for mitral valve) was confirmed at the time by filling the ventricles with saline through a disposable syringe and visually inspecting the leaflets. **(FIG-2.2)** This, in conjunction with post-operative echocardiography to assess LV and valve function after discharge. If weaning from Cardio-Pulmonary Bypass criteria were not met, further downsizing was performed.

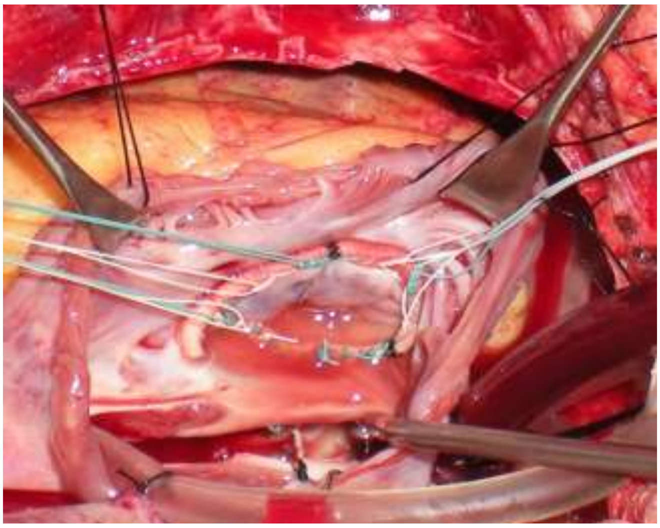

Figure 2.1: Tricuspid Valve Flexible Ring Annuloplasty

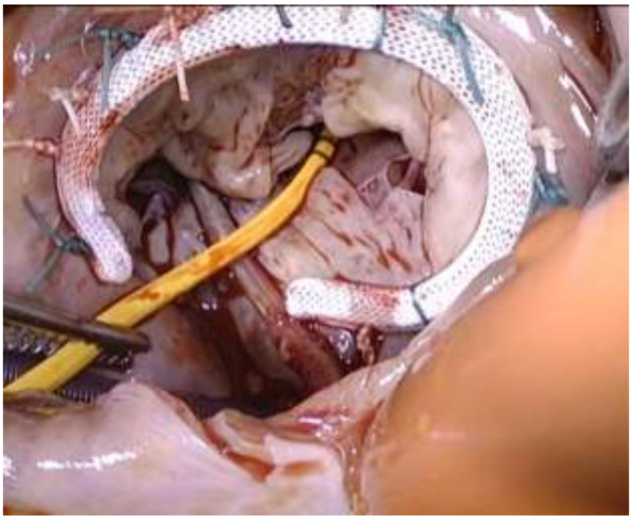

Figure 2.2: Checking of Coaptation after Tricuspid Valve Flexible Ring Annuloplasty

Transthoracic echocardiography
Comprehensive two-dimensional echocardiographic exams were performed with a commercially available system by experienced Diagnostic Cardiac Sonographers. Images were acquired in the left lateral decubitus position and standard two-dimensional and Doppler data, triggered to the QRS complex, were digitally stored in cine loops in DICOM format. **(FIG-3.1 to FIG-3.4)**

The analysis was performed offline by two independent investigators experienced with echocardiographic measurements, blinded to surgical or clinical data at the time of analysis. All reported echocardiographic measurements were averaged from three consecutive cycles and assessed as recommended by the American Society of Echocardiography[39].

From the parasternal view, the left ventricular diameters were measured. The left ventricular ejection fraction (LVEF) was obtained by using Simpson's rule methods from apical 4- and 2chamber views[40]. The RV end-systolic and end-diastolic areas were measured by planimetry. Right ventricular fractional area change (RVFAC) was used to determine the RV systolic function and was calculated by the following formula: FAC = [(diastolic area-systolic area)/diastolic area] x 100%[38]. RV long-axis length and RV short-axis width were measured at the mid-ventricular level and used to calculate the right ventricular sphericity index (RVSI) at end-systole[40]. TV annulus diameter was measured at end-systole and end-diastole as the distance between the midpoints of reflection of the septal and mural endocardium on the anterior and septal tricuspid leaflets, respectively[41]. Color Doppler assessed MR and TR severity flow mapping[3].

Endpoints

The duration of follow-up was defined as the interval from the surgery to all-cause mortality, first HF hospitalization or up-to 8th June 2018. (Fig-2.4) All-cause mortality was analyzed using data documented in the electronic health record. A secondary endpoint was days to first HF hospitalization, defined as an admission of more than 12 hours for worsening HF symptoms requiring parenteral therapy (at our center or at any other facility reported in the medical record). Thirty-day in hospital mortality was also predicted by calculating the Euro SCORE® for each patient.

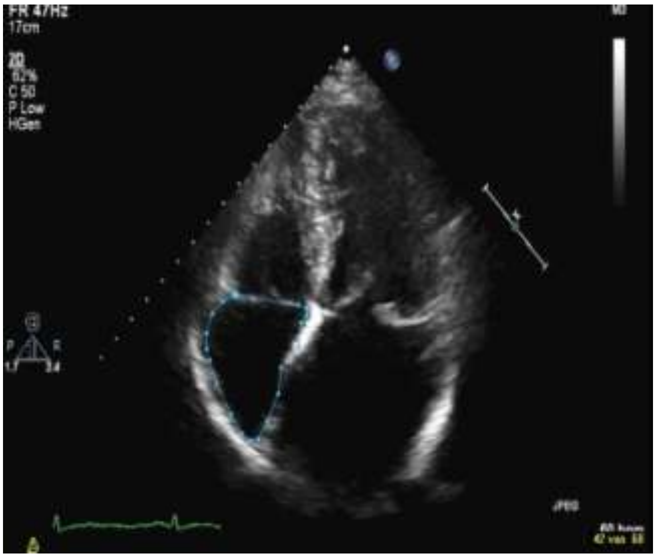

Figure 3.1: Right Atrial Area in Four Chamber Views

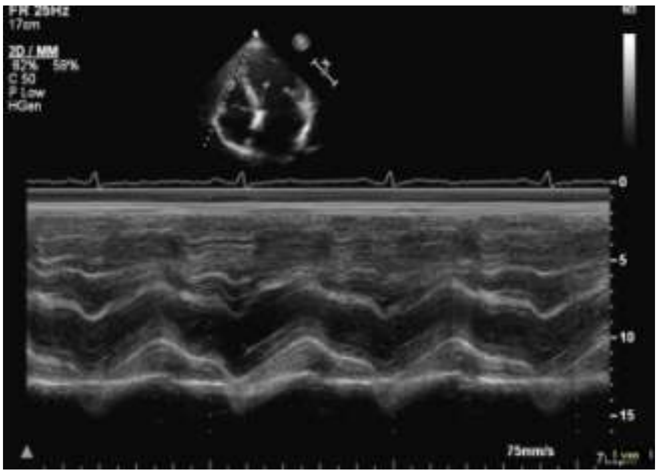

Figure 3.2: Tricuspid Annular Plane Systolic Excursion

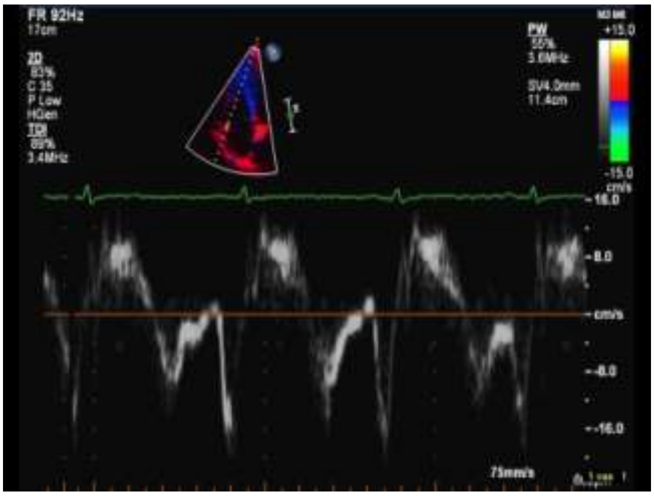

Figure 3.3: Tissue Doppler Imaging of Right Ventricular Free Wall

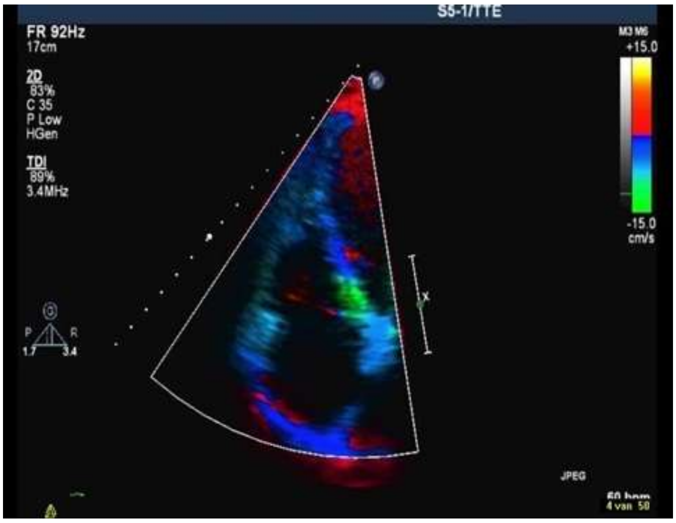

Figure 3.4: Zoomed in Photograph of Framed Area

6. Results and Observations

Among the 116 patients undergoing cardiac surgery, 6 were excluded because of suboptimal baseline echocardiographic image quality and 15 because of missing follow-up data. The final population of this study comprised 95 patients which were divided in two groups. The TVP (-) group consisted of 46 patients who underwent complex left-sided heart surgery without concomitant TVP in contrast to 49 TVP (+) patients who underwent TVP concomitant with complex left sided heart surgery. The preoperative patient demographics are listed as per Table. Baseline characteristics including LVEF, MR gradation and RVSI were similar among both groups. However, the TVP+ had less ischemic but more Barlow and non-ischemic etiology of their MR, a lower RVFAC, higher baseline TR grade and more TA dilatation compared with the TVP- patients. All patients received optimized medical therapy as advocated per guidelines.

All patients underwent successful MVP/MVR and TVP defined as no residual mitral/tricuspid regurgitation and an immediately postoperative coaptation length of the valve leaflets of less than 8 mm. The mean mitral size used was 31.4 ± 4.1 mm and the mean tricuspid ring size used was 31.2 ± 2.4 mm. 30% of the TVPs were performed because of moderate or severe preoperative functional tricuspid insufficiency and 70% because of TA dilatation in absence of significant (>2) TR. CPB time and cross clamp time were comparable between the groups.

Table 1: Baseline characteristics

	TVP-	TVP+	p-value
n	46	49	
Age (yr.)	68±11	69±12	0.6
Sex, female	46.50%	52.80%	0.405
Diabetes	17.90%	15.70%	0.735
Arterial hypertension	43.30%	57.80%	0.081
Obesity	20.80%	9.20%	0.049
Smokers	22.40%	13.20%	0.147
Hypercholesterolemia	41.80%	40.80%	0.9
Familial predisposition	32.80%	27.60%	0.498
Creatinine	1.2 ± 1.7	1.1 ± 0.3	0.126
LVEF (%)	57.9 ± 13.5	53.8 ± 15.6	0.066
MR grade	2.7 ± 0.9	3 ± 1	0.12
TR grade	0.6 ± 0,6	1.8 ± 1	**<0.001**
TA diameter (cm)	3.0 ± 0.47	3.7 ± 0.61	**<0.001**
RVFAC (c)	0.4 ± 0.1	0.3 ± 0.1	**0.013**
RVSI (cm)	3 ± 0.8	2.8 ± 0.9	0.12
MV pathology			
Degenerative	30.20%	27%	0.633
-Barlow	1.20%	9%	**0.019**
-Fibro-elastic deficiency	29%	18%	0.083
Rheumatic	19.80%	21.30%	0.94
Endocarditis	8.10%	2.30%	0.078
Functional	41.90%	46.10%	0.57
-Ischemic	33.70%	15.80%	**0.006**
-Non-ischemic	8.20%	30.30%	**<0.001**
Others*	0%	3.30%	0.087

Table 2: Perioperative characteristics

	TVP-	TVP+	p-value
n	46	49	
Left-sided procedures			
MVP/MVR	38.30%	51.60%	0.078
MVP/MVR + CABG	48.90%	21.40%	**<0.001**
MVP/MVR + AVR/AVP	4.70%	19.10%	**0.003**
MVP/MVR + CABG	8.10%	7.90%	0.947
Euro Score	9.80%	14.20%	0.063
Cross clamp time (min)	150.6 ± 56.5	151.6 ± 48.9	0.904
CPB (min)	206.7 ± 75.6	201.5 ± 57.7	0.623

Table 3: Results of echocardiographic analysis

Variable	Baseline	Follow-up	p-value
LA area (cm²)	26.2 ± 7.74	22.49 ± 5.79	< 0.001
LA volume (ml)	95.85 ± 37.81	78.7 ± 31.43	0.003
LV end-diastolic volume (ml)	114.98 ± 42.37	113.43 ± 48.13	0.766
LV end-systolic volume (ml)	55.91 ± 33.19	56.68 ± 36.84	0.828
LV ejection fraction (%)	53.76 ± 14.9	52.94 ± 13.23	0.617
LV end-diastolic diameter (mm)	5.05 ± 0.98	4.99 ± 0.88	0.59
LV end-systolic diameter (mm)	3.84 ± 1.06	3.83 ± 0.98	0.925
Mitral regurgitation grade	2.82 ± 1.1	0.51 ± 0.73	< 0.001
RA area (cm²)	20.74 ± 9.02	14.03 ± 3.99	< 0.001
Tricuspid regurgitation grade	2.05 ± 1.06	0.5 ± 0.63	< 0.001
TR gradient (mmHg)	45.12 ± 20.23	38 ± 8.48	0.139
RV end-diastolic area (cm²)	18.26 ± 7.2	19.66 ± 6.08	0.149
RV end-systolic area (cm²)	11.71 ± 5.12	13 ± 4.29	0.032
RV fractional area change (%)	36.2 ± 12.51	33.02 ± 11.99	0.101
RV long-axis (diastolic)	6.08 ± 0.89	6.31 ± 0.72	0.034
RV short-axis (diastolic)	3.54 ± 0.77	3.24 ± 0.48	0.012
RV sphericity index (diastolic)	1.75 ± 0.24	1.97 ± 0.25	< 0.001

LV= left ventricle/ventricular; LA=leftatrium;RV= right ventricle/ventricular; RA= right atrial; TR gradient= trans-tricuspid gradient.

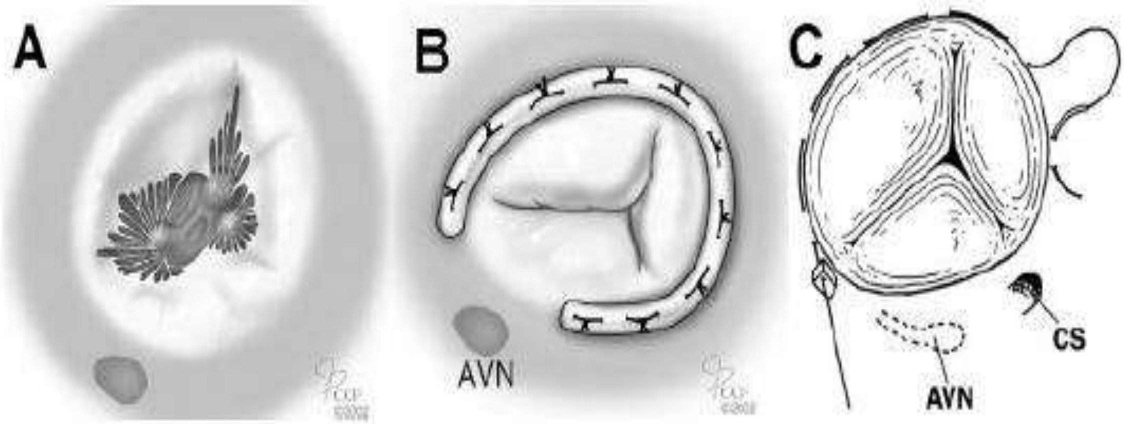

Figure 2.3: Predominant Surgical Repair Techniques for Tricuspid Regurgitationcs: Coronary Sinus[15]

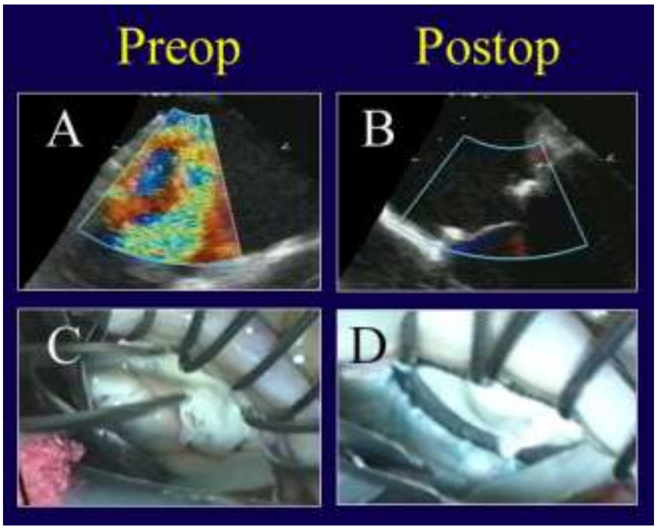

Figure 2.4: Pre-Operative and Post-Operative Echo after Tricuspid Annuloplasty

7. Conclusions

The addition of routine TVP in case of functional TR or TA dilatation, in comparison with standard MVP/MVR during complex left-sided surgery, is associated with a high risk of adverse events, especially with regards to heart failure hospitalizations, even in experienced hands and independent of most preoperative echocardiographic findings. Thereby, provides our study an important rationale for **no** routine addition of TVP in our patient population. Additionally, our observation that the Euro SCORE® more closely predicts 30-day mortality in patients undergoing TVP concomitant with MVP during complex left-sided heart surgery has never been reported before. The closer predictive value of the Euro SCORE® in patients with concomitant TVP is probably a reflection of the fact that the Euro SCORE® only accounts for "valve surgery" as such and not the "amount or complexity" of valve surgeries. Therefore, future risk-stratification models should take into consideration the number and complexity of valvular surgeries as well.

The effect of concomitant TVP on RV size and geometry in patients scheduled for left-sided heart surgery depends on the severity of preoperative TR. In those undergoing TVP because of TA dilatation rather than significant TR, RV sphericity decreases but RV size may increase at follow-up. In patients with more than moderate preoperative TR, RV size will decrease post-TVP, and RV sphericity will decrease even more compared to those with lesser degrees of TR. The preoperative degree of TR has no significant impact on postoperative RV systolic function. Additionally, older patients and those with higher preoperative RVFAC are more likely to develop a decrease in RV contractile function post-TVP.

Obvious limitations inherent to the retrospective study design should be considered when findings are interpreted. Also, our first study i.e. Clinical outcomes was not a comparison of TVP vs. no TVP in patients with TA dilatation and/or more than moderate functional TR and overall surgical interventions did differ between both groups, about additional CABG, aortic valve surgery, and MR etiology. Therefore, even though TVP+ patients had worse outcomes, the addition of TVP might still have prevented an even more infaust prognosis. Nevertheless, the retrospective design, our findings of the second study are interesting because until now the effects of TVP in addition to left-side heart surgery have not been widely studied, particularly not in a population undergoing TVP because of TA dilatation rather than severe TR, or in patients scheduled for left-sided heart surgery other than mitral valve surgery alone. We acknowledge that follow-up duration was relatively short in our study and likely not enough to determine the long-term effects of TVP concomitant with complex left-sided heart surgery. It may also be argued that evaluation of RV function using two-dimensional echocardiography is problematic because of the complex RV geometry and the sometimes-limited definition of the endocardial surface caused by heavy trabeculation. However, analysis was performed on images acquired by experienced personnel, and extreme care was taken to measure RVFAC (a parameter of RV function that is well-validated in many previous studies) from a true non-foreshortened apical 4-chamber view.

Regarding the limitations, careful interpretation of our findings should guide further prospective studies to examine the safety and efficacy of routine TVP in this vulnerable population, and to better characterize which patients might benefit most. Additionally, longer follow-up prospective studies using more sophisticated parameters than RVEDA or RVFAC (e.g. cardiac magnetic resonance imaging for serial assessment of RV volume and systolic function) are needed to evaluate the exact effect of TVP on RV size or function.

By this means, our hypothesis is only partly confirmed since the Euro SCORE® has a closer predictive value in patients with concomitant TVP, more preoperative echocardiographic parameters were expected to be found in relation to clinical outcomes and concomitant tricuspid valve surgery did not lead not to a reduction in RV size and systolic function at short-term follow-up in our overall study population.

In the past 20 years, we have witnessed the booming of minimal access surgery, which is an established approach to the surgical therapy of cardiac disease. Current trends in sick patients are moving toward decreasing the size of the access and the invasiveness of the procedures, aiming at decreasing the effects on physiology.[201-203] In tricuspid valve surgery, the main drivers for failure are the long-standing disease, the preoperative condition of the patient, and the number of prior operations. They are clearly interrelated.

Cardiac surgery has changed as imaging has greatly improved preoperative diagnosis. The advent of two-dimensional echocardiography and Doppler velocity analysis represented a step forward helping physicians in better understanding heart valve disease.[68] Atrioventricular valve physiology is better known because of Doppler echocardiography,[204] and accurate estimates of valve regurgitation are the consequence of the input given by Doppler analysis and color-mapping. Doppler echocardiography has been shown to have higher sensitivity than contrast echocardiography.[205] Color-flow was shown early to be quick and simple in the interpretation of continuous wave Doppler and was an appropriate companion to Doppler, although there were historically some doubts about the investment needed to purchase the equipment.[206]Doppler echocardiography and color-flow mapping has become the most useful tool in diagnosis and quality assessment in surgery. We do not understand an operating room without echocardiography. Postoperative evaluation of any cardiac surgical patient heavily relies on echocardiography. The preoperative assessment of valve lesions and ventricular function before the initiation of an operation and the intraoperative evaluation after completion of cardiopulmonary bypass or after off-pump operations are of utmost importance in adult and pediatric cardiac surgery as, of course, information on morphology and function is required for all types of procedures.[207-208] As we move toward increasing use of technology, monitoring is a key requirement for improving quality.[209] Therefore, imaging and technology are going to play an important part in the future of cardiac surgery.

Two- and three-dimensional echocardiography and cardiac magnetic resonance are currently the most important imaging techniques for assessment of valve heart disease. The rapid evolution of echocardiography as a diagnostic tool has led to the implementation of newer techniques like strain imaging. Therefore, we are learning newer definitions, formulas, and calculations from speckle tracking echocardiography.[210-213] As it happened almost three decades ago, the incorporation of these techniques into clinical practice are to revolutionize our knowledge and approach to tricuspid valve disease.

The morphology of the right ventricle is shaped in a crescent and truncated manner, and it has separated inflow and outflow sections. This complex anatomy plays a role in the prognosis of heart disease, the development of functional tricuspid regurgitation, and the interpretation of pulmonary hypertension. It is generally agreed that the variability in the tricuspid annulus diameter plays a role in the indication for tricuspid annular remodeling through annuloplasty. The measurements of the annular diameter at mid-systole and early diastole and right ventricular volumes are part of the surgical strategy.[212]

It is then time to gain knowledge in the new quantitative methods in two-dimensional and three-dimensional echocardiography. Ongoing research confirms that there are a number of variables that influence diameters in normal volunteers; therefore, this has to be taken seriously in the consideration of diseased individuals for appropriate surgical planning.[212] The use of different planes of right ventricular analyses is also useful in estimating the clinical effects of pulmonary hypertension. Transverse and longitudinal right ventricular function are reliable markers for cardiac function and high pulmonary artery pressure, respectively.[213] The assessment of tricuspid regurgitation is of utmost importance for the surgeon because of the complexity of a nonplanar structure such as the tricuspid valve annulus. Surgical treatment of tricuspid valve disease is still a challenge as per the decision and execution; however, surgeons have higher-quality preoperative information to navigate more accurately through a complex decision-making process.

The accumulated knowledge on tricuspid valve surgery indicates that tricuspid regurgitation secondary to left heart disease is the most common cause of insufficiency of the right atrioventricular valve. The controversy is still alive as to the superiority of ring versus non–ring repair. According to recent information, it seems that ring repair[199] might have better long-term outcomes regarding survival and freedom from reoperation; the remaining question is whether improving the design of rings might lead to even better outcomes. It is likely that technology comes into aid in the future.

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