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Re-Operation after tricuspid valve surgery: When? How? Why?

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List of abbreviations

ACC/AHA *American College of Cardiology/American Heart Association*
AV *Aortic Valve*
BSA *Body Surface Area*
CMR *Cardiac Magnetic Resonance*
CT *Computed Tomography*
DPG *Diastolic Pressure Gradient*
ECG *Electrocardiogram*
ECMO *Extracorporeal Membrane Oxygenation*
ESC *European Society of Cardiology*
IABP *Intra-Aortic Balloon Pump*
LV *Left Ventricle*
LVOT *Left Ventricle Outflow Tract*
MV *Mitral Valve*
NYHA *New York Heart Association Functional*
OR *Odds Ratios*
PISA *Proximal Isovelocity Surface Area Radius*
RA *Right Atrium*
RV *Right Ventricle*
RVOT *Right Ventricular Outflow Tract*
TA *Tricuspid Annulus*
TAPSE *Tricuspid Annular Plane Systolic Excursion*
TEE *Transesophageal Echocardiography*
TR *Tricuspid Regurgitation*
TTE *Transthoracic Echocardiography*
TV *Tricuspid Valve*

1. Introduction

1.1. Anatomy

The tricuspid valve (TV), localised between the right atrium (RA) and the right ventricle (RV), is the most caudally located heart valve and has the largest opening area (3.5-7 cm2). The valvular apparatus of the TV consists of the annulus and the three leaflets (anterior, posterior and septal) attached by the Chordae tendinae to their specific papillary muscles (Fig. 1). Anterior and posterior leaflets are inserted on the annulus in the area of the free RV wall. The anterior valve leaflet is the largest, it separates the inflow and outflow tract of the right ventricle and is connected to the prominent anterior papillary muscle via chordae tendinae. The septal leaflet is the smallest and arises medially above the membranous interventricular septum.

In contrast to the mitral valve, of which the chordae tendinae are inserted into both leaflets, papillary muscles in the RV are often smaller, multiple and widely separated. The chordae tendinae usually support only one leaflet. In contrast to the left ventricle (LV), chordae tendinae also arise from small papillary muscle heads in the area of the interventricular septum and the free RV wall (Fig. 2).

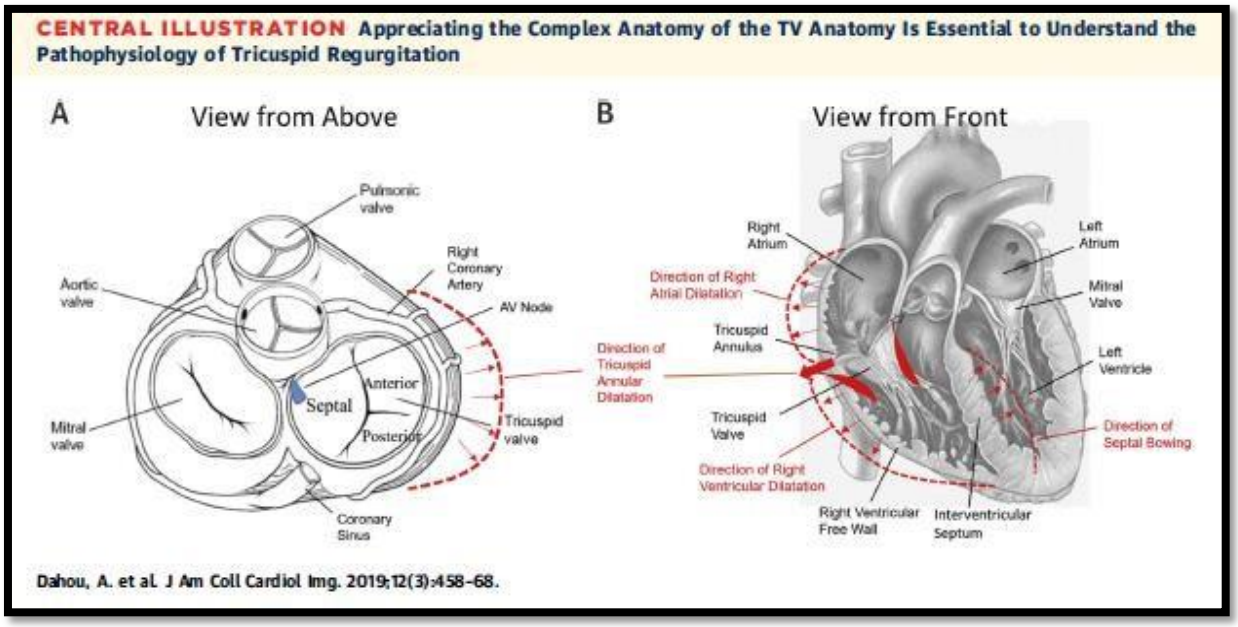

Figure 1 Anatomy of the Tricuspid valve.

The TV annulus has an elliptical, three-dimensional shape with homogeneous contraction [1]. The lowest point of the TV annulus (toward the RV apex from the RA) is in the posteroseptal segment near the ostium of the coronary sinus and the highest point is in the anteroseptal segment with a close positional relationship to the right ventricular outflow tract (RVOT) and to the aortic valve (AV) [2]. The septal leaflet is characteristically inserted ≤ 10 mm more apically than the septal insertion of the anterior mitral valve leaflet. The TV annulus changes its shape and size dynamically during the cardiac cycle due to its close connection with the myocardium and is larger at end systole/early diastole and during atrial systole (up to 30% reduction in annular area) [3].

With the relaxation of the ventricular myocardium at the beginning of the diastole, the diameter of the TV annulus increases and the right ventricular filling is facilitated by the wide open valve (5-7.5 cm2). In the systole, the contraction of the myocardium leads to a reduction in size of the TK annulus (3-4.5 cm2) and improves the coaptation of the leaflets. It has been proven echocardiographically a change in the circumference of the annulus, during systole and diastole, by 19% and of the area by 30%. Normal values for the TV annulus in adults range are 28 ± 5 mm diameter or <21 m/m^2 body surface area (BSA).

Tricuspid, mitral (MV) and aortic (AV) valves are in fibrous continuity with each other. At the base of the AV, the connective tissue combines into two trigona fibrosa. The trigonum fibrosum dextrum is connected to the membranous septum, which separates the left ventricular outflow tract (LVOT) from the right heart cavities. The TV annulus is relatively weak, mainly in the area of the free RV wall, which makes the presence of a closed fibrous ring hardly possible. The dilatation of the TV annulus occurs in the septo-lateral direction. The septal leaflet separates the membranous septum into two parts, an atrioventricular and interventricular part. Alongside in the interatrial septum, at the apex of Koch's triangle, is the atrioventricular node. Koch's triangle is formed by the septal annulus, the Todaro tendon and the confluence of the coronary sinus.

The latter is a fibromuscular ridge that extends between the junctions of the inferior vena cava (with the Eustachian valve) and the coronary sinus (with the Thebesian valve) and the membranous septum. The right coronary artery (A. coronaria dextra) runs in close proximity to the TV annulus in the adipose tissue of the atrioventricular sulcus between the RA and RV.

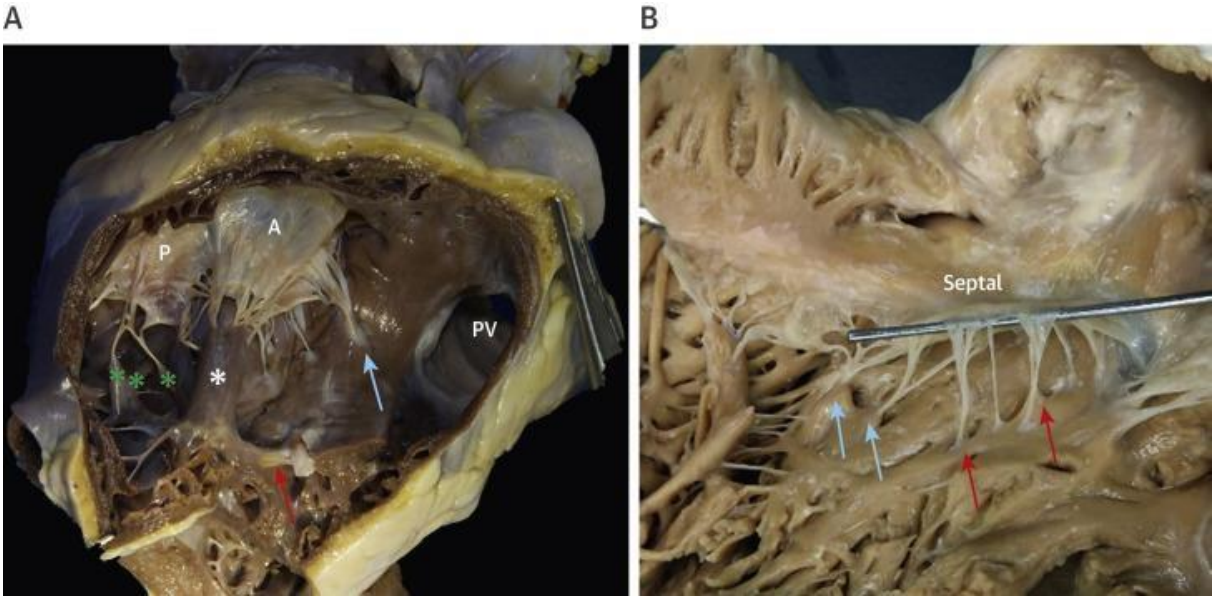

Figure 2 Papillary muscles: *(A) Typical papillary muscle distribution for the tricusid valve. The anterior papillary muscle is typically the largest (white asterisk), which provides chordal support for the A and P leaflets. The moderator band (orange arrows) may join this papillary muscle. The posterior papillary muscle is often bifid or trifid (green asterisks) and lends chordal support to the posterior and septal leaflets. The septal papillary muscle is variable (blue arrow). (B) Septal leaflet chordal attachments to the septal papillary muscle are shown (blue arrows) and directly from the septal myocardium (orange arrows).*

Dahou, Abdellaziz, et al. "Anatomy and physiology of the tricuspid valve." JACC: Cardiovascular Imaging 12.3 (2019): 458-468.

Two anatomical structures close to the annulus are at risk during tricuspid valve surgery: the non- coronary sinus of Valsalva, specially the comissure between the non-coronary and right coronary leaflets of the aortic valve and the bundle of His. The bundle of His crosses the septal leaflet attachement 3 to 5 mm from the anteroseptal comissure and then either perforates or circumscribes the membranous septum before it bifurcates into two branches.

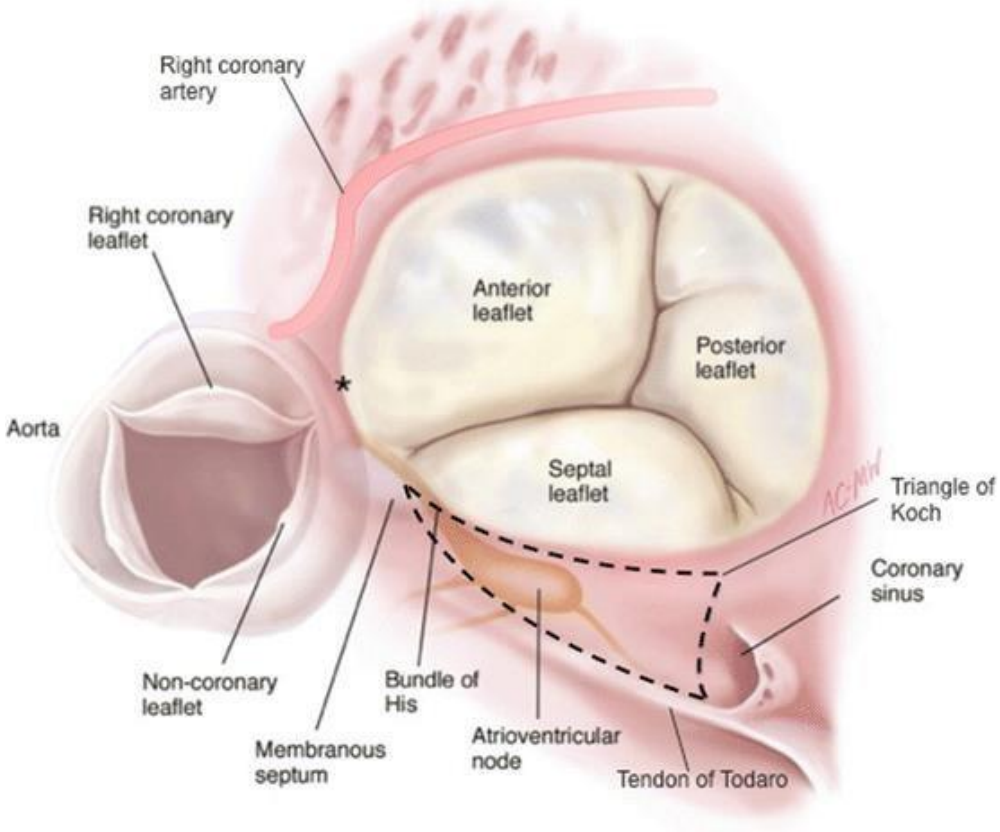

Figure 3 Anatomic considerations for Tricsupid valve

Downs E., Ailawadi G. (2016) Anatomic Considerations for Tricuspid Valve Interventions. In: Ailawadi G., Kron I. (eds) Catheter Based Valve and Aortic Surgery. Springer, New York, NY. https://doi.org/10.1007/978-1-4939-3432-4_23

The tricuspid annulus forms the base of the TV leaflets and distinct itself with two types of segments: a muscular annulus and collagen-rich fibrous annulus. Microscope based study of the tricuspid valve anatomy and histology reveal that the posterior and anterior annulus are composed of myofibers, whereas the septal annulus is composed of collagen bundles [4]. Histologically, the leaflets are completely covered by endothelium, receiving stability from a framework of collagen connective tissue, which is connected to the annulus.

1.2. Aetiology of tricuspid regurgitation

Tricuspid regurgitation (TR) can be divided into primary (organic) and secondary (functional) (Table 1).

Rheumatic fever remains the most common cause of organic TR. It leads generally to the scarring of the valve leaflets and/or chordae tendinae and results with restriction of leaflets mobility. Isolated tricuspid stenosis or isolated TR in this disease are rare, whereas combined stenotic and regurgitant TV are most frequently encountered (often associated with mitral valve disease). The TV annulus is generally dilated [5].

Primary TR results also from congenital origin such as Ebstein's anomaly (the most common form of congenital disease affecting the TV) or acquired disease of the TV such as myxomatous degeneration of the TV leading to leaflet prolaps, connective tissue disorders, endocarditis, carcinoid syndrom, radiation and trauma. Transtricuspid leads can cause TR or significantly worsen the severity of pre-existing TR. Kim et al showed that intracardiac defibrillator can worsen a TR more than pacemakers [6].

Functional TR accounts for 80% to 90% of all severe TR, may be observed in patients with RV pressure overload secondary to cardiac or pulmonary vascular disease and is associated with the severity of RV dysfunction and dilatation. Functional TR results either according to the underlying disease or to the morphologic abnormality. According to the underlying disease functional TR occurs predominantly as a result of left-side heart disease (in particular mitral valve, but also aortic valve increasingly). Pulmonary arterial hypertension from any cause, RV dysfunction, RV ischaemia and idiopatic cause (often associated with atrial fibrillation with tricuspid annular dilatation) can also lead to a functional TR according to the underlying disease.

Table 1.
Causes of Tricuspid Regurgitation

Primary TR

• Congenital
  ◦ Ebstein's anomaly
  ◦ Tricuspid valve tethering associated with perimembranous ventricular septal aneurysm or defect
  ◦ Tricuspid valve dysplasia, hypoplasia, or cleft
  ◦ Double orifice tricuspid valve
  ◦ Other (giant RA)
• Acquired
  ◦ Myxomatous degeneration (Barlow's disease): TV prolapse, flail
  ◦ Endocarditis
  ◦ Carcinoid syndrome
  ◦ Rheumatic disease
  ◦ Trauma (chest wall trauma or TV trauma following intracardiac procedures: RV intramyocardial biopsy, and so on)
  ◦ Pacemaker/device-related

Secondary TR

• According to the underlying disease:
  ◦ Left-sided heart disease (valve disease and/or left ventricular dysfunction)
  ◦ Pulmonary arterial hypertension from any cause
  ◦ RV dysfunction from any cause
  ◦ Idiopathic (no detectable cause) often associated with atrial fibrillation
• According to the morphologic abnormality:
  ◦ Tethering or tenting of TV leaflets
  ◦ Displacement of the papillary muscles
  ◦ RV dysfunction/dilation
  ◦ Annular dilation

RA = right atrium, RV = right ventricle, TV = tricuspid valve.

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RA = right atrium, RV = right ventricle, TV = tricuspid valve.

Table 1 Cause of tricuspid regurgitation

1.3. Pathophysiology of tricuspid regurgitation

The underlying mechanism of TR differs with different aetiologies. Primary TR causes pure volume overload on an initial normal right-sided cardiac chambers, whereas RV enlargement is the main cause of functional TR, resulting with tricuspid annular dilatation and valve tenting.

Primary tricuspid valve leaflet disease can occur from a number of aetiologies. RV size and function along with right atrial size are usually initially preserved without a pulmonary hypertension. RV volume overload causes progressive RA and RV dilatation and over time RV dysfunction.

Conversely, functional TR usually results from an elevation in RV systolic and/or diastolic pressure, RV enlargement, TV annulus dilatation and valve tenting. The severity of secondary TR and RV dilatation is strongly correlated with the presence of leaflet tethering. The increase of RV systolic pressure results usually to pulmonary hypertension, RV overload or pulmonary valve disease. Dilated cardiomyopathy, RV infarction or RV failure lead to diastolic dysfunction of the RV.

The most common causes of secondary TR are left-sided valve disease, LV and RV cardiomyopathy (ischemic and non-ischemic) and RV dilatation due to pulmonary disease. Left-sided heart disease, especially mitral valve disease lead to an increased left atrial pressure, a pulmonary hypertension, a subsequent rise in RV pressure and progressive dysfunction and dilatation of the RV. Progressive RV dysfunction and remodelling exacerbates functional TR through the dilatation of TV annulus dilatation and papillary muscle displacement from RV remodelling. Initially pulmonary arterial pressure and pulmonary vascular resistance are not increased, but a prolonged and chronic post capillary pulmonary hypertension can result in a pulmonary arterial vasoconstriction with increased pulmonary vascular resistance and transpulmonary gradient. A combined post- and pre-capillary pulmonary hypertension is a progressive pathological change and will cause further increases in pulmonary arterial pressure and pulmonary vascular resistance. Diastolic pressure gradient (DPG) is a reliable parameter in suggesting A combined post- and pre-capillary pulmonary hypertension: a DPG $\geq$7 mmHg in combination with Pulmonary vascular resistance > 3 wood. A combined post- and pre-capillary pulmonary hypertension is associated with a worse pulmonary arterial compliance, exercise tolerance and life expectancy, RV and higher surgical risk.

Tricuspid annular dilatation is the major factor for causing functional TR. During initial RV dilatation, the annulus dilates only at its free wall. With further RV expansion the annulus begins to dilate in the septo-lateral direction with an increase in the antero-posterior diameter and changing its form from an elliptical, three-dimensional shape with homogeneous contraction to a more circular and planar form (Fig. 4). As the septal part of the tricuspid annulus is more fibrous and fixed to the interventricular septum, tricuspid annular dilation occurs in the anteroposterior direction along the RV free wall. Once TR has become significant, progressive RV remodelling and dysfunction due to chronic volume

overload result in papillary muscle displacement and leaflet tethering, which will worsen TR and lead to spherical geometry of RV due to progressive RV dilatation.

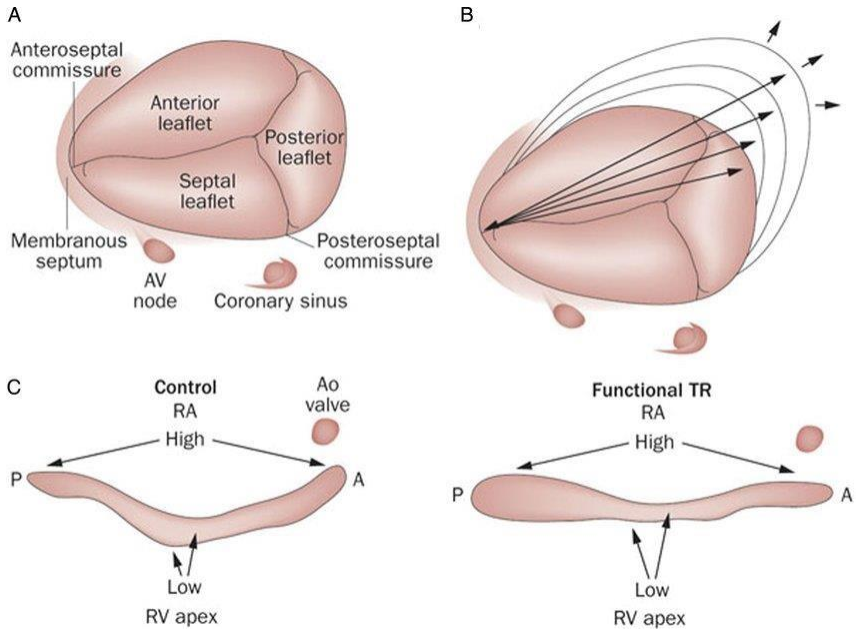


Figure 4 Changes in tricuspid annular geometry in patients with functional TR

(A) Normal tricuspid annulus (C, left image) with a non-planar morphology with highest points in the anteroposterior direction and the lowest in the mediolateral. In patients with functional tricuspid regurgitation, the annulus becomes more planar (C, right image) and dilated in the anteroposterior diameter (B). A: anterior, P: posterior; RA, right atrium; TR, tricuspid regurgitation. Adapted from Shinn and Schaff.11

Mas, Pilar Tornos, José F. Rodríguez-Palomares, and Manuel J. Antunes. "Secondary tricuspid valve regurgitation: a forgotten entity." Heart 101.22 (2015): 1840-1848.

1.4. Epidemiology

Functional TR is frequently observed in the advanced stage of left-sided valvular disease or myocardial disease [7], but 14% of TR may also occur in the absence of structural TV abnormality, pulmonary hypertension or left heart dysfunction.

The Framingham Heart Study evaluated, using the echocardiography, a prevalence of moderate or severe TR of 0.8%. The progression from mild to significant degree of TR is influenced by age and gender. The prevalence of significant TR was more than 4 times greater in women than in men [8]. When trace regurgitation is excluded, the prevalence of TR of a severity ≥ mild was 14.8% in men and 18.4% in women. With increasing age, the prevalence of significant TR increases, and in men and women aged >70 years the prevalence of moderate and severe TR reaches up to 1.5% and 5.6%, respectively [8].

TR is frequently present in patients with left-side valve disease (specially mitral valve disease) and more than 30% of patients with mitral stenosis have at least moderate TR [9]. Severe TR has been reported in 23-37% of patients after mitral valve replacement for rheumatic valve disease [10].

Dreyfus et al reported the development of haemodynamically significant TR in 27% of patients with only mild TR at the time of left-sided valve surgery [11]. The 2017 ESC/EACTS Guidelines for the management of valvular disease provide a class I (level of evidence: C) recommendation for tricuspid valve surgery in patients with severe functional TR undergoing left-sided valve surgery and a class IIa (level of evidence: C) recommendation for tricuspid valve surgery in patients with mild or moderate functional TR with a dilatation tricuspid annulus (i.e., ≥40 mm or >21 mm/m² by 2D echocardiography) undergoing left-sided valve surgery [12].

1.5. Clinical presentation

TR is often clinically silent and symptoms are usually related to concomitant left-sided valvular heart disease. When symptoms appear, patients may complain of fatigue, decreased exercise tolerance or asthenia as a result of lower cardiac output. With progressive and significant TR, patients begin to develop signs of right heart failure (signs of elevated right atrial pressure such as ascites, peripheral oedema and congestive hepatomegaly).

On clinical examination, a faint systolic murmur at the lower sternal border and xiphoid process with increasing in intensity during inspiration (Rivero-Carvallo's sign) can sometimes be heard; however it is often inaudible due to the relatively low right-sided pressures.

In advanced stages of TR, signs of right heart failure can be present: systolic jugular distension, pulsatile hepatomegaly and peripheral oedema. In end-stage disease ascites, liver failure and cachexia may be observed.

In patients with severe TR, the v-wave of TR can merge with the c-wave, forming a giant c-v-wave and can be seen in jugular pulse. Atrial fibrillation is common as a result of right atrial enlargement.

Isolated primary TR has a slow evolution and is associated with a high mortality rate. Messika-Zeitoun et al showed that in asymptomatic patients the 10-year incidence of dyspnoea or congestive heart failure was strongly related to RV enlargement and estimated at 57% [13].

Secondary TR is frequently associated with left-sided valvular disease, which is the most important factor of prognosis. However, TR has a prognostic value intrinsically that is proportional to its severity, even after adjustment of the left ventricular function and pulmonary artery pressure. Secondary TR can improve after correction of left-sided valvular disease but can also persist or even worsen. This evolution is unstable and severe late TR remains associated with reduced survival. Isolated secondary TR is a less frequent valvular disease but the prognosis strongly depends on TR severity (10-year survival 38% vs 70% in those with severe and non-severe TR, respectively) [14].

On the electrocardiogram, patients with moderate to severe TR present frequently atrial fibrillation and right bundle branch block. The electrocardiogram can reflect, most of the time, the disease evolution.

The chest X-ray can provide us significant anatomical information regarding the evolution of TR such as a significant cardiomegaly resulting of a right atrial and ventricular enlargement with a spherical geometry of the RV.

1.6. Diagnostics

The evaluation of patients with TR requires the combination of informations from different cardiac imaging techniques. The objectif of imaging are the estimation and evaluation of severity, etiology, the anatomic and hemodynamic consequences (RV size and function, pulmonary artery dimension and pressure, TV gradients) and the detection of concomitant left-sided ventricular heart disease.

1.6.1. Echocardiography

The diagnostic modality of choice to detect TR is transthoracic (TTE) and transesophageal echocardiography (TEE). It is the primary and ideal non-invasive imaging modality to evaluate the etiology of the TR and the valve morphology, to quantify its severity and to determine the annular diameters. Using a 2-dimensional echocardiography, we can evaluate the morphology of the tricuspid valve by seeing only 2 leaflets simultaneously. However, there have been growing indications regarding the 3D imaging, allowing simultaneous visualisation of all 3 leaflets and commissures.

TV morphology can be evaluated by 2D TTE from standard parasternal and apical RV views (RV inflow, parasternal short-axis, parasternal long-axis, apical 4-chamber and subcostal views).

Physiological TR is associated with normal valve leaflet morphology and normal RV and atrial size. The colour jet is thin, central and localized in a small region adjacent to the closure of the tricuspid valve (< 1cm). When TR may be pathological (moderate or severe insufficiency) and detected by colour Doppler, the evaluation of the leaflet morphology and the patho-physiological mechanisms underlying TR is required. 3D TTE may provide in these cases very important information regarding the etiology and determine the mechanism underlying the tricuspid valve dysfunction.

In adults, the normal tricuspid annular diameter is 28 ± 5mm (measured in 4-chamber view in diastole). Secondary TR is characterized by TA dilatation (>40mm) and may also involve leaflet tethering with a tenting distance >8mm. Regarding 3D echocardiography and cardiac magnetic resonance (CMR), TA diameter measured with 2D echocardiography (in 4-chamber view and in parasternal short-axis view) is underestimated [15, 16]. Anwar et al showed that 35% of patients with normal TA diameter at 2D echocardiography presented TR-grade of 1-2 in comparison with 30% of patients with normal TA size with 3D echocardiography [17].

The detection of TR by colour flow uses parasternal, apical or subcostal view. Regurgitant jet area correlates with TR severity, <5 cm^2 in mild, 6–10 cm^2 in moderate, and >10 cm^2 in severe cases. In clinical practice, the basis of TR severity assessment is estimated visually rather than actual planimetry.

A significant apical displacement of the tricuspid leaflets (tethering) is evaluated by measuring the tenting area (area between the atrial surface of the leaflets and the annular plane at maximal systolic closure) and coaptation distance in the 4-chamber view. A severe TR is associated with a tenting area >1cm^2 and a coaptation depth <8mm.

Vena contracta reflect the regurgitant orifice area and being typically imaged in 4-chamber view. A severe TR is characterized by a vena contracta width >6.5mm.

Proximal isovelocity surface area radius (PISA) is a good indicator of severity of TR and usually being measured in 4-chamber view and parasternal long- and short-axis views. A PISA radius <5mm is associated with mild TR, whereas a PISA radius >9mm suggests a severe TR.

Tricuspid annular plane systolic excursion (TAPSE) is measured using M-mode echocardiography in the apical four-chamber as the displacement of the lateral tricuspid annulus toward the apex during systole. Because the septal attachment of the tricuspid annulus is relatively fixed, the major component of longitudinal systolic motion occurs at this point. The greater the displacement, the better is the right ventricular function. A value less than 17 mm suggests a RV dysfunction.

Based on the current ESC/EACTS guidelines, a threshold diameter >40mm (>21mm/m^2) in the 4-chamber view suggests an indication for surgery [12].

1.6.2. Multidetector Computed Tomography

Multidetector computed tomography is an important imaging tool routinely used in pre-procedural planning of transcatheter tricuspid valve intervention but also during follow-up. It has the ability to provide accurate measurement of the TV and surrounding anatomical structures. It is essential for selecting the right patient and the right device to treat TR.

1.6.3. Cardiac magnetic resonance (CMR)

CMR is actually considered the gold standard imaging modality for assessment of the tricuspid valve's anatomy, RV anatomy and RV function. Moreover, CMR has the ability to provide excellent anatomical and morphological assessment such as RV-LV size, dimensions and volumes and precise volumetric quantification of TR. Anwar et al compared measurements between real-time 3D echocardiography and CMR and showed no significant difference in the measurement of TA dilatation, TA area, TA fractional shortening or TA fractional area change between the two imaging.

The current European Society of Cardiology (ESC) guidelines for the management of grown-up congenital heart disease suggests that significant RV enlargement exists when the end-diastolic volume is ≥150 mL/m2 and significant RV dysfunction exists when the EF is ≤45% [12].

1.6.4. Electrocardiogram (ECG)

The ECG can be an important and useful tool in the diagnosis of TR. However, it might have no significant abnormalities. Characteristic ECG of RA enlargement and RV hypertrophy might be present secondary to either pulmonary hypertension or to the hemodynamic consequences of TR itself.

ECG findings of right atrial enlargement include: P wave >2.5 mm (in leads II, III and aVF) and P wave >1.5 mm (in lead V1).

ECG findings of right ventricular hypertrophy include: right axis deviation of +90 degrees or more and an increase of the R amplitude in leads III, aVF, V1 and V2 and deep S spikes in V5, V6, I and aVL (Sokolow-Lyon index RV1 / 2 + SV5 / 6 ≥1.05 mV).

Atrial fibrillation is a common result of right atrial enlargement.

1.6.5. Chest X-Ray

During the initial evaluation, a chest X-ray may be helpful in the diagnosis of TR. Findings on an X-ray suggestive of TR include cardiomegaly, prominent cardiac silhouette, right atrial enlargement, an upward displacement of the diaphragm due to ascites and pleural effusion.

1.6.6. Coronary angiography

A coronary angiography is not necessary for diagnosis and quantification of a TR, but is performed preoperatively to exclude/include a coronary heart disease in mostly older patients presenting cardiovascular risk factors.

In young patients with no cardiovascular risk factors, a calcified coronary artery plaque measured at cardiac computed tomography (CT), is performed preoperatively to predict and assess a coronary heart disease.

1.7. Management of TR

Management of significant TR includes medical management, surgery and transcatheter interventional therapies. Patients with primary TR where tricuspid valve leaflet are pathological, tricuspid valve repair or replacement is the gold standard. Whereas, transcatheter tricuspid valve interventions will be indicated mostly to patients with significant secondary TR and at high surgical risk.

1.7.1. Medical management

Patients with moderate to severe TR begin to develop late symptoms of right heart failure with physical exercise limitation. The underlying etiology needs to be early identified and treated. Patients with symptomatic TR due to ischaemic or non-ischaemic cardiomyopathy are managed according to current heart failure guidelines [18]. The goals of treatment in patients with heart failure are to reduce mortality and to improve their symptoms and quality of life. Nonetheless, McCarthy et al. reported an in-hospital mortality rate of 37% in patients undergoing a reoperation of the tricuspid valve and these patients were managed medically as long as possible before referral to surgery [19]. Although, delayed surgery must be avoid, taking into account the irreversible risk of a decreased right ventricle function, organ failure and a higher in-hospital mortality rate. Combination of diuretics, calcium channel blockers, and mineralocorticoid receptor antagonist (IIa-C) is the most commonly medical treatment for patients with a significant TR and a pulmonary hypertension. Patients who develop atrial fibrillation or progressive dilatation of the right heart chambers due to pulmonary embolism should be treated with oral anticoagulation. An aldosterone antagonist receptor can improve symptoms of volume overload and has its indication if the kidney function is well preserved.

1.7.2. Tricuspid valve surgery

The 2017 ECS/EACTS Guidelines for the management of valvular heart disease provide a class I (level of evidence: C) recommendation for tricuspid valve surgery in patients with severe functional TR undergoing left-sided valve surgery [12]. It has been shown that adding an indicated tricuspid valve repair during a left-sided surgery does not increase

surgical risk, postoperative permanent pacemaker implantation, postoperative morbidity and mortality and provide a reverse remodelling of the RV [11].

Table 1 ESC Guidleines for tricuspid valve surgery 2017:

(Falk, Volkmar, et al. "2017 ESC/EACTS Guidelines for the management of valvular heart disease." European Journal of Cardio-Thoracic Surgery 52.4 (2017): 616-664.)
[a]Class of recommendation
[b]Level of evidence
[c]Perkutane Ballonvalvuloplastie als first-line Therapie bei isolierter TS
[d]Perkutane Ballonvalvuloplastie möglich bei PMC

	Class[a]	Level[b]
Surgery is indicated in symptomatic patients with severe TS.[c]	I	C
Surgery is indicated in patients with severe TS undergoing left-sided valve interventions.[d]	I	C
Surgery is indicated in patients with severe primary or secondary TR undergoing left-sided valve surgery.	I	C
Surgery is indicated in symptomatic patients with severe isolated primary TR without severe right ventricular dysfunction.	I	C
Surgery should be considered in patients with moderate primary TR undergoing left-sided valve surgery.	IIa	C
Surgery should be considered in patients with mild or moderate secondary TR with dilated annulus (≥40 mm or ≥21 mm/m2) undergoing left-sided valve surgery.	IIa	C
Surgery should be considered in asymptomatic patients or mildly symptomatic patients with severe isolated primary TR and progressive right ventricular dilatation or deterioration of right ventricular function.	IIa	C
After left-sided valve surgery, surgery should be considered in patients with severe TR who are symptomatic or have progressive right ventricular dilatation/dysfunction, *in the absence* of left-sided valve dysfunction, severe right or left ventricular dysfunction, and severe pulmonary vascular disease.	IIA	C

Patients with mild or moderate functional TR and a dilated tricuspid annulus (≥40 mm or >21 mm/m^2) have a class IIa (level of evidence: C) recommendation for tricuspid valve surgery [12]. Moreover, symptomatic patients with severe TR after previous left-sided surgery, or with progressive right ventricular dilatation and dysfunction have a class IIa (level of evidence: C) recommendation for tricuspid valve surgery.

Late referral surgery is associated with poor outcomes, because of the irreversible RV dysfunction, which is already established in many patients [20].

During the last decade, the number of patients with persisting or progressive functional TR undergoing a TV surgery is constantly increasing [21, 22]. Reoperations for recurrent TR

are high-risk surgical procedures because many such patients have developed multiorgane failure such as pulmonary hypertension with severe right heart, hepatic and renal failure [23, 24]. Therefore TV reoperation for recurrent TR is often delayed and aggravating the right ventricle dysfunction. Recently, several centers have reported reasonable perioperative mortality rates and long-term outcome with reoperation of the tricuspid valve when performed early and before the setting of severe and irreversible RV dysfunction and occurrence of cavity dilatation [14, 25].

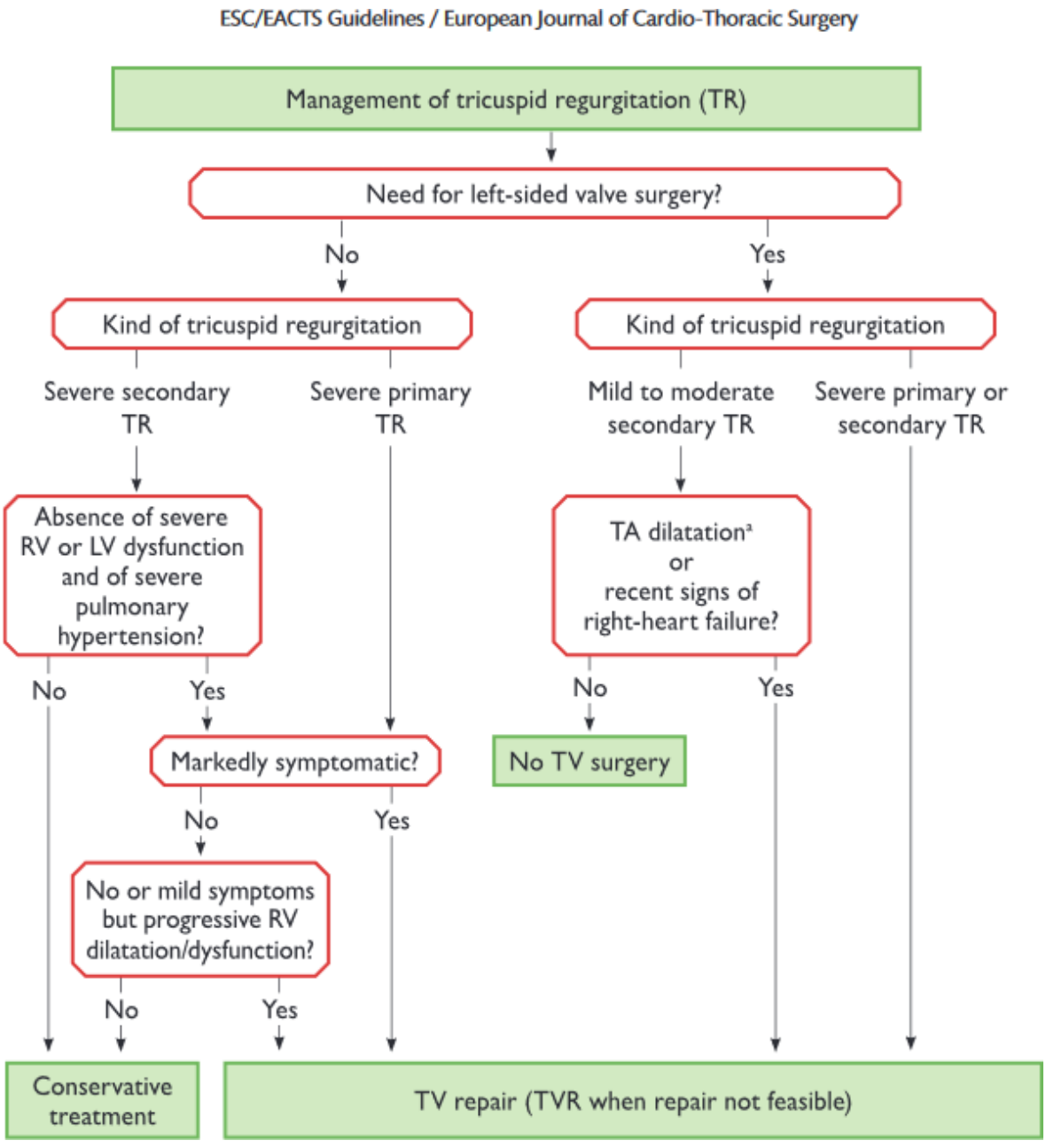


Figure 5 Indications for surgery in TR:

[a]TA ≥40 mm or >21 mm/m2

Falk, Volkmar, et al. "2017 ESC/EACTS Guidelines for the management of valvular heart disease." European Journal of Cardio-Thoracic Surgery 52.4 (2017): 616-664

It is generally believed that the long-term of tricuspid valve repair are more favourable than valve replacement with biological prosthesis or mechanical prosthesis. Annuloplasty techniques are well established and share the goal of narrowing the valve annulus to achieve leaflet coaptation (Fig. 6). Various type of rings have been use to remodel the posterior and anterior segments of the annulus. Currently, several annuloplasty devices with different features are available: flexible, semirigid or rigid combined with a planar or 3D geometry. So far, the choice of device is mainly based on the preference of the surgeon. Veen et al. recently conducted a meta-analysis pooling data from rigid and flexible tricuspid valve repair. They were able to show that overall TR was significantly higher with flexible annuloplasty (7.5%/year) when compared to rigid annuloplasty (3.9%/year) [26]. Pfannmüller et al. weren't able to show any difference in recurrent TR whether using the rigid, planar Carpentier (n=405) ring or the flexible (n=415) Cosgrove band. However, they have shown rigid ring may increase the risk of dehiscence [27].

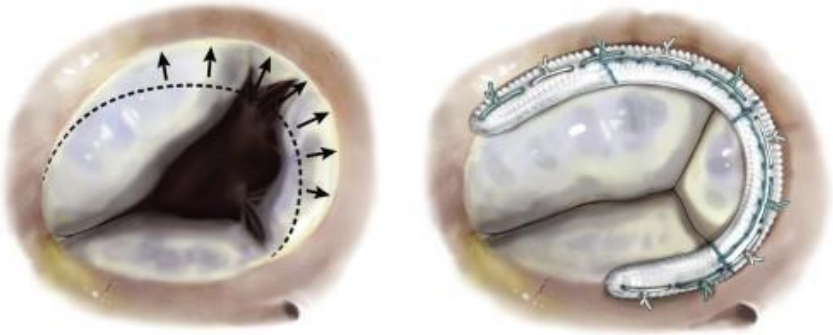


Figure 6 Tricuspid valve annuloplasty:

Milla, Federico, et al. "Rationale and initial experience with the Tri-Ad Adams tricuspid annuloplasty ring." (2012): S71-S73.

Before ring annuloplasty became the technique of choice, suture annuloplasty was commonly used in order to repair the tricuspid valve. in recent years numerous publications showed the superiority of ring annuloplasty compared to suture annuloplasty based on the De Vega or Kay's technique [19, 28]. The De Vega annuloplasty is based on the fact that the tricuspid annulus dilatation occurs mainly in its anterior and posterior segments and remaining unchanged in the septal part. It involves the plication of the tricuspid annulus with two semi-circular purse string sutures that start in the area of the atrioventricular node and the bundle of his (Fig. 7). The Kay's technique (bicuspidization) involve an annulorrhaphy of the posterior segment by obliterating the posterior tricuspid leaflet (Fig. 8).

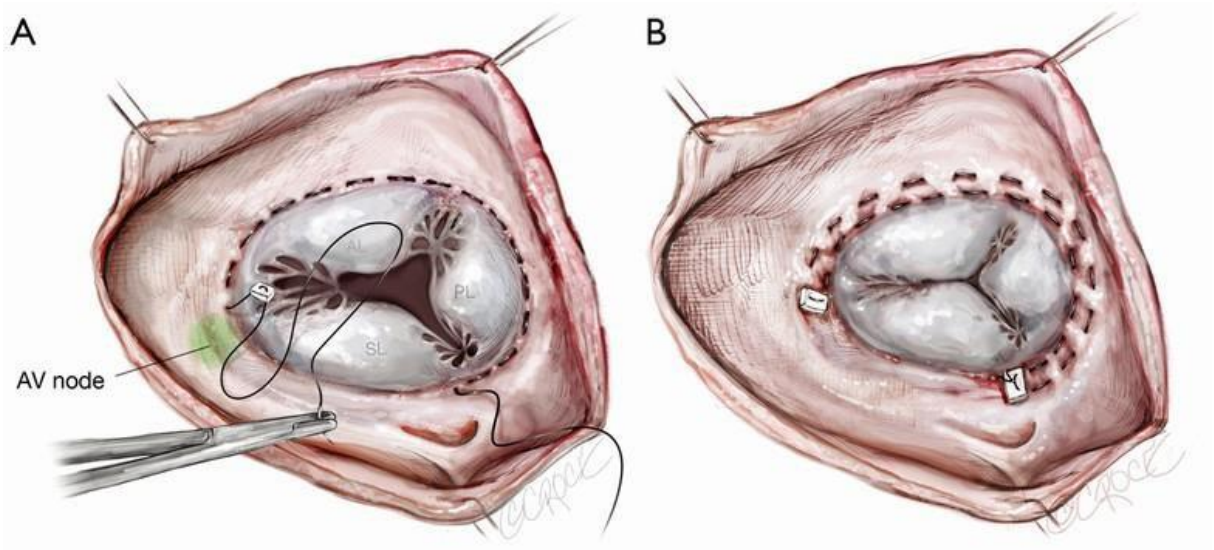


Figure 7 De Vega annuloplasty:

Tchantchaleishvili, Vakhtang, Taufiek K. Rajab, and Lawrence H. Cohn. "Posterior suture annuloplasty for functional tricuspid regurgitation." Annals of cardiothoracic surgery 6.3 (2017): 262.

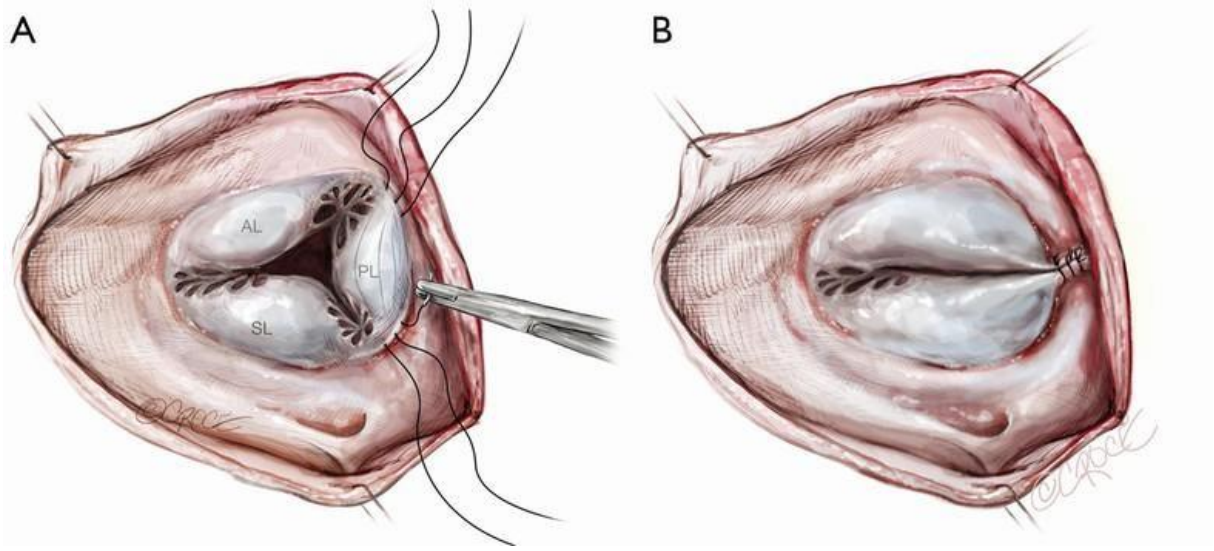


Figure 8 Kay's technique (Bicuspidization):

Tchantchaleishvili, Vakhtang, Taufiek K. Rajab, and Lawrence H. Cohn. "Posterior suture annuloplasty for functional tricuspid regurgitation." Annals of cardiothoracic surgery 6.3 (2017): 262.

If possible, valve repair is preferable to valve replacement because of low surgical risk and the success of this procedure especially for secondary TR with dilated annulus. However, for organic TR, valve replacement may be the treatment of choice. Singh et al. compared the outcome of TV repair and replacement in patients with organic TR. Approximately one third of the patients underwent a TV replacement (mostly with biological prosthesis), both perioperative and mid-term mortalities were significantly higher in the valve replacement group [23]. However, the group of patients who underwent tricuspid valve repair had higher grades of TR on follow-up. Whereas NYHA functional class and reoperation rates were similar between the two groups [23].

Reoperation in patients with recurrent TR is a high risk surgical procedure. Bernal et al demonstrated that reoperation of the TV after previous TV surgery carries a high operative mortality (33.8%), and end-stage heart failure was the most frequent cause of death [29]. The in-hospital mortality was slightly lower for TV re-repair compared to TV replacement [29].

1.7.3. Transcatheter tricuspid valve interventions

Over the last few years, several transcatheter interventions have been developed for the treatment of functional TR. Unlike aortic and mitral valve, there is nowadays, no specific transcatheter for tricuspid valve disease. Although, most of all are still in development or in the clinical application phase, emerging data are promising and suggests their clinical effectiveness and safety. Preliminary results are highlighting the potential benefits of transcatheter treatments over medical therapy. Some devices designed for mitral or aortic valve disease, such MitraClip (Abbott Vascular, Santa Clara, California, United States) or the Edwards Sapien valve (Edwards Lifesciences, Irvine, California, United States), have been successfully adapted for the treatment of TR or its consequences. Furthermore, a large number of percutaneous TV transcatheter devices are currently either under development or under clinical application phase.

We can identify 3 different targets for the current tricuspid transcatheter therapies in the treatment of TR: implants of transcatheter heart valve at the vena cava to reduce reverse backflow (Heterotopic valve), percutaneous tricuspid valve replacement (Orthotopic valve), percutaneous annuloplasty devices shortening annulus dimension, and devices improving leafltet coaptation and reducing the regurgitant orifice. Initial in-human experiences with these devices have been reported, and ongoing and future studies will evaluate the feasibility, safety, and efficacy of these new transcatheter options.

Patients diagnosed with late TR following previous left-sided valve surgery in high-risk patients (with renal and/or hepatic impairment, and severe RV dysfunction) might potentially benefit from less invasive transcatheter therapy

In patients with prior tricuspid repair or replacement and degenerated bioprostheses or annuloplasty ring failure, transcatheter heart valve implantation using transcatheter aortic or pulmonic valves has been reported, becoming a promising novel alternative to redo surgery. Especially considering that reoperation in patients with recurrent TR carries a high operative and in-hospital mortality and morbidity, transcatheter tricuspid valve-in-valve intervention could become the future perspective of treatment.

2. Overview

Functional tricuspid regurgitation (TR), due to right ventricular and tricuspid annular dilatation secondary to left heart disease is the major cause of tricuspid valve (TV) disease. With the increasing number of patients with heart valve disease requiring surgical intervention for left ventricular systolic dysfunction, tricuspid valve surgery gains increasing importance tricuspid annular dilatation due to pulmonary hypertension and left heart disease [30].

The prevalence of significant TR is strongly linked to age and increases with aging. In men and women aged >70 years the prevalence of moderate and severe TR can reach up to 1.5% and 5.6%, respectively [8, 31].

Tricuspid valve (TV) repair with an annuloplasty ring is the therapy of choice and valve replacement is usually required for patients with primary / organic disease with severely destroyed TV.

Tricuspid valve reconstruction at the time of mitral valve intervention is not associated with increased mortality [32] and current guidelines recommend TV surgery at the time of left-sided valve surgery for patients with tricuspid annular dilatation even without significant regurgitation [12].

Reoperations for recurrent TR are high-risk surgical procedures because many such patients have developed pulmonary hypertension with severe right heart, hepatic and renal failure [23, 24]. TV reoperations are associated with a longer stay in the intensive care unit or a longer hospital stay and a poor prognosis in hospital mortality (35.1%) [19, 29].

There are only a limited number of studies available focusing on the incidence and causes of TV reoperations available [25, 29, 33, 34]. The study collectives are small and the follow-up period is short. We investigated the influence of TV's etiology, type of the surgical procedure and the timing of the reoperation on operative mortality and long-term survival.

3. Material and Methods

From January 1975 to February 2017, 1638 patients underwent tricuspid valve surgery at the German Heart Center Munich. Of these patients, 112 patients (6.8%) required a cardiac reoperation. Sixty seven of these patients (4.1%) underwent reoperation of the tricuspid valve and 45 patients (2.7%) underwent another cardiac procedure. This retrospective single-center study focuses only on patients with reoperation of the TV.

Exclusion criteria included patients under 18 years old, patients with Ebstein's disease, patients with neurological events within 6 months preoperatively, patients with porcelain aorta. Patients living outside of Europe were also excluded from the study because of the inherent difficulty of accurate follow-up. This investigation was approved by the Ethics Committee of the Faculty of Medicine of the Technische Universität München (no. 180/14), and patient consent was waived.

3.1. Patients Characteristics

Average age at TV reoperation was 57.82 ±12.9 (range 28-81 years). Forty three patients (64.2%) were women. The mean interval between the initial TV operation and TV reoperation was 6.3 ± 5.6 years. Forty seven (70.1%) patients were in New York Heart Association functional (NYHA) class III/IV, with 42 (62.7%) patients with atrial fibrillation or flutter and 4 patients (6%) pacemaker dependant. Twenty eight patients (41.8%) had a left ventricular ejection fraction <55%.

Thirty seven patients (55%) had functional TR, 12 patients (18%) had an organic TR and 18 patients (27%) had valve-related events (Prosthesis dysfunktion, bioprosthesis degeneration, mechanical prosthesis thrombosis) (Fig 9).

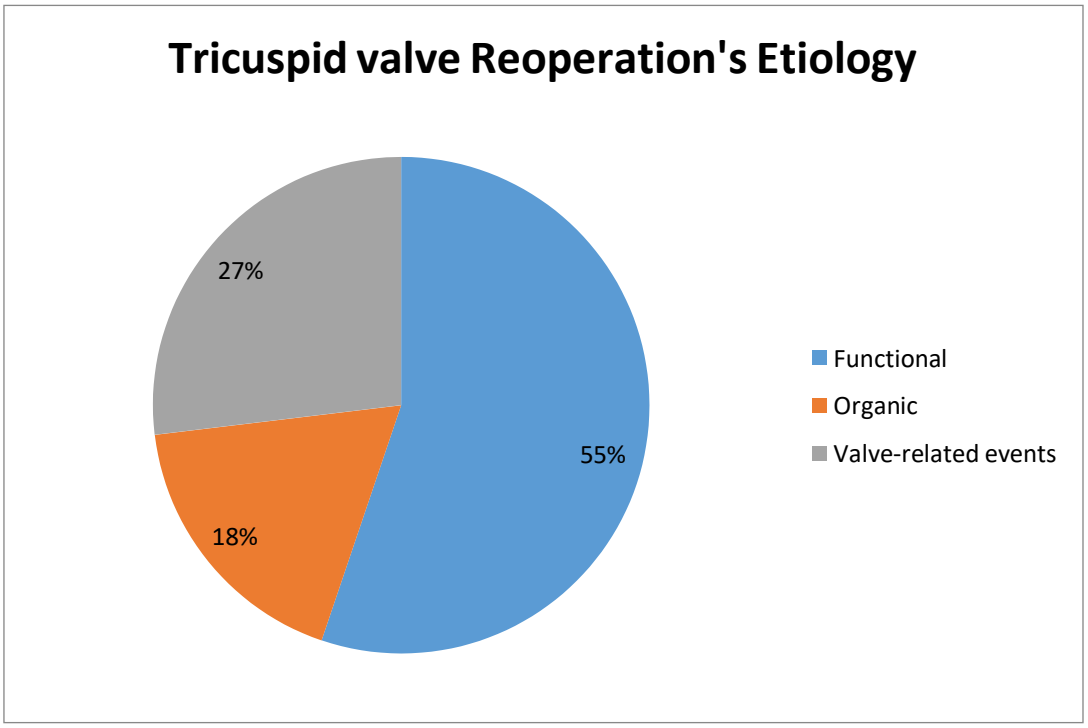


Figure 9 Tricuspid valve reoperation's Etiology

Twelve patients (17.9%) have undergone prior isolated TV surgery and 55 patients (8.1%) have undergone concomitant TV surgery. Patient characteristics are presented in Table 3. The Follow up is 97% complete (mean follow-up: 6.2±7.4 years). Follow up data were retrieved by conducting telephone interviews with the patients and/or the referring physicians, mailed questionnaires and follow-up visits. Valve-related complications are reported according to the Guidelines of the Ad Hoc Liaison Committee of The Society of Thoracic Surgeons and The American Association of Thoracic Surgery [35]. Emergency surgery was defined by patients requiring an immediate surgical intervention usually within 24 hours after admission. An urgent surgery was defined as an operation required within the same hospital stay after diagnosis.

Table 2 Patient Characteristics: Tricuspid Valve Reoperation

Patient Characteristics for TV reoperation	**Number (%)**
Age (years)	57.82 ± 12.896
Sex	
Male	24 (35.8%)
Female	43 (64.2%)
ECG preoperative	
SR	21 (31.3%)
AF/flutter	42 (62.7%)
Pacemaker	4 (6%)
NYHA (class):	
NYHA ≤II	20 (29.9%)
NYHA ≥III	47 (70.1%)
Left ventricular ejection fraction (%)	
<55	28 (41.8%)
≥55	39 (58.2%)
Etiology of reoperation	
Functionel TR	38 (56.7%)
Non-functional	29 (43.3%)
Type of the initial TV surgery	
TV repair	49 (73.1%)
TV replacement	18 (26.9%)
TV replacement with bioprosthesis	14 (20.9%)
TV replacement with mechanical prosthesis	4 (6%)

Isolated TV surgery Combined procedures	12 (17.9%) 55 (82.1%)
Mean Time between first and reoperation of TV (years)	6.3 ± 5.57
Mean Follow-up Time (years)	12.1 ± 8.07

AF: Atrial fibrillation, ECG: Electrocardiogram, LVEF: Left ventricular ejection fraction, NYHA: New York Heart Association functional, SR: Sinus rhythm, TR: Tricuspid regurgitation, TV: Tricuspid valve

3.2. Operative Data

Eight reoperations (12%) were performed on an emergent or urgent basis.

Cardiopulmonary bypass mean time was 140 ± 58 minutes and cross-clamp time was 83 ± 35 minutes. Myocardial protection was achieved using either cold (4°C) antegrade crystalloid (Custodiol®, Koehler Chemie, Alsbach-Haehnlein, Germany) or antegrade blood cardioplegia

Twenty two patients (32.8%) underwent a re-repair of the TV, 20 patients (29.9%) underwent a TV replacement with bioprosthesis and 25 patients (37.3%) underwent a TV replacement with mechanical prosthesis. Types of surgery were classified according to TV etio-pathology in Fig 10.

Thirty eight patients presented with functional TR. Thirty two (32/38= 84.2%) of these patients have undergone previous TV repair. At reoperation TV re-repair was possible in 16 patients (50%). Twenty nine patients had non-functional TR. Of these patients 17 (59%) had initial TV repair. In 6/17 patients (35%) re-repair was possible.

None of these patients required neither an intra-aortic balloon pump (IABP) nor an extracorporeal membrane oxygenation (ECMO). Operative Data are summarized in Table 4.

Sixty six patients were operated through a median sternotomy and 1 patient underwent an interventional catheter procedure on the tricuspid valve, through a transapical access. Types of TV prosthesis or repair techniques after TV surgery are classified in Table 5.

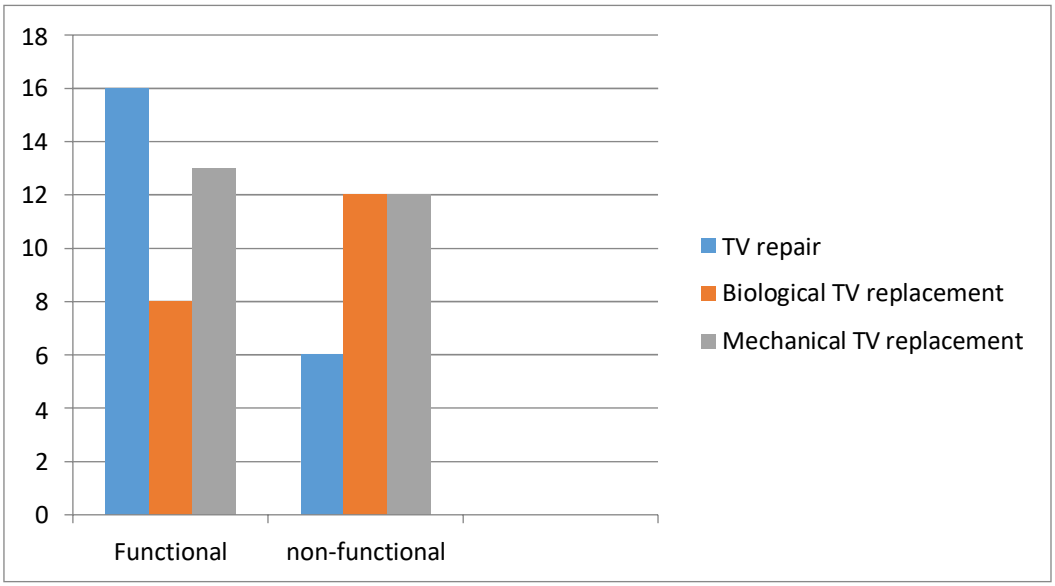


Figure 10 Type of surgery according to Tricuspid valve etio-pathology

Table 3 Operative Data

Operative Data	**Number (%)**
Timing of surgery	
Elective-OP	59 (88.1%)
Emergencies-OP	5 (7.5%)
Urgent-OP	3 (4.5%)
Cardiopulmonary bypass time (Minutes)	139.957 ± 57.7507
Cross-clamp time (minutes)	83.26 ± 34.818
Type of surgery	
TV repair	22 (32.8%)
TV replacement with bioprosthesis	20 (29.9%)
TV replacement with mechanical prosthesis	25 (37.3%)
Isolated TV surgery	19 (28.4%)
Combined procedures	48 (71.6%)

Table 4 Types of Tricuspid Valve Prosthesis or Repair techniques after TV surgery

Technique of TV Repair		**N**
De Vega Annuloplasty		7
Duran	Medtronic, Inc. Minneapolis, Minn. USA	1
Repair without ring		4
Carpentier Edwards	Edwards Lifesciences, Irvine, CA, USA	8
Contour 3D	Medtronic, Inc. Minneapolis, Minn. USA	2
Total of TV repair		*22*
Type of Prosthesis		
Björk-Shiley	Shiley, Inc., Irvine, Calf., USA)	12
St. Jude	St. Jude Medical, Inc., St..Paul, Minn. USA	5
Perimount	Edwards Lifesciences, Irvine, CA	4
Hancock II	Hancock Extracorporeal, Inc., Anaheim, Calif,. USA	8
Mosaic	Medtronic, Inc. Minneapolis, Minn. USA	2
Carbomedics	CarboMedics Inc, Austin, TX	1
Omnicarbon	Medical Inc., Inver Grove Heights, Minn.	3
Medtronic Hall	Medtronic, Inc. Minneapolis, Minn. USA	1
SJM Biocor	St. Jude Medical, Inc., St..Paul, Minn. USA	1
ATS Medical	ATS Medical, Minneapolis, Minnesota	3
Intact	Medtronic, Inc. Minneapolis, Minn. USA	4
Sapien	Edwards Lifesciences, Irvine, CA, USA	1
Total of Prosthesis		*45*
TOTAL		**67**

3.3. Statisical Analysis

The data are expressed as proportions or as the mean ± standard deviation. The Kaplan-Meier method was used to study patient and event-free survival probability. The log-rank-test was used to ascertain differences between groups. The chi square test (for categorical variables) and Mann-Whitney test (for continuous variables) were used to determine statistical significance. Significant factors were entered into a multiple logistic regression model to assess the independent impact of potential risk factors. Predictors of survival were identified in a multivariable analysis with Cox proportional hazards modelling. Results were considered significant if p values were less than 0.05. Computations were carried out using the IBM-SPSS 25 software (SPSS Inc, Chicago, IL).

4. Results

4.1. 30 day mortality and morbidity

The overall 30 days mortality was 14.9% (n=10). 30-day mortality after TV re-repair and TV replacement was 4.5% (3/67) and 10.4% (7/67), respectively. There was no difference in 30 day mortality of patients, who underwent isolated (21%) vs combined (12.5%) TV reoperation.

Four patients (6%) required a re-operation for postoperative bleeding. In five patients a postop pacemaker implantation was necessary. None of the patients experienced a thromboembolic event.

4.2. Survival after TV reoperation

Late Mortality >30 day was 64.2% (n =43). Overall causes of death were cardiac in 20.9% of cases (n=14). The 5 and 10-year survival rates were 47.3% and 31.2%, respectively.

Regarding patients who underwent a TV re-repair, the 5 and 10-year survival rates were 49.2% and 38.8%, respectively, compared with 46.4% and 30.5% in patients who underwent a TV replacement (p=0.684) (Fig 11).

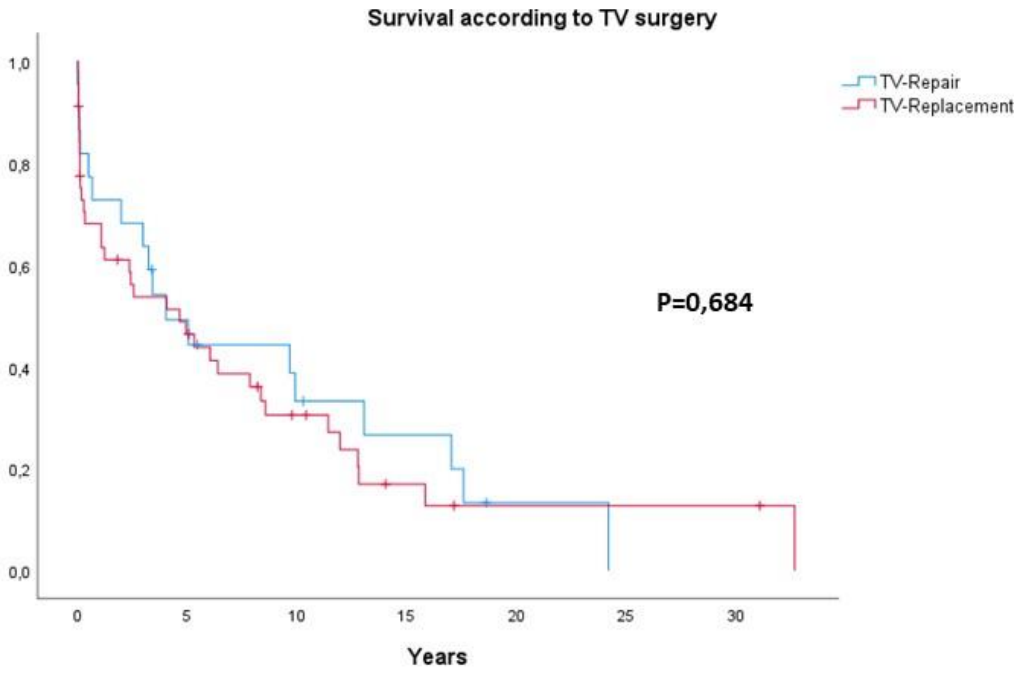
The 5-, 20-year survival rates were 38.4%, 23% and 11.5% respectively in patients with reoperation of the TV with biological TV replacement compared with 52%, 35.2% and 13.4% in patients with reoperation of the TV with mechanical TV replacement (p=0.330) (Fig 13).

Patients with functional TR and NYHA Class I/II had a 5-year survival rates of 53.1% compared with 17.9% in patients with NYHA Class III/IV (p=0.004) (Fig 14).

The 5-, 10- and 20-year survival rates were 48.7%, 33.5% and 11.2% respectively in patients with functional TR compared with 45.4%, 28.2% and 15.4% in patients non-functional TR (p=0.988).

Overall 6 out of 9 patients, who received an initial TV replacement with a bioprosthesis, were reoperated because of valve degeneration within 9.5±4.6 years after the initial operation.

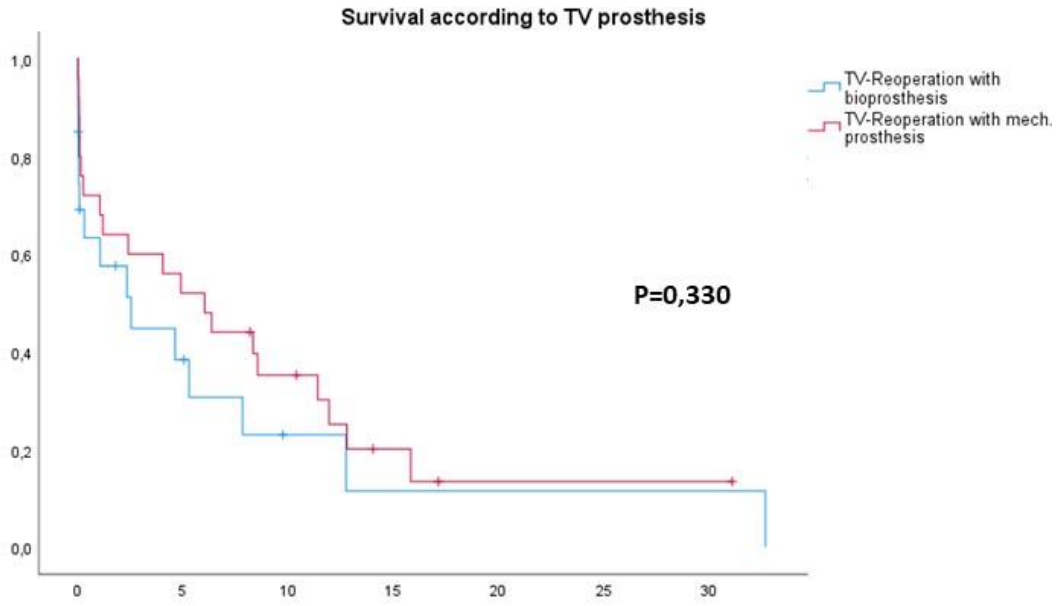
Three patients (with Omnicarbon, Lillehei-Kaster and Björk-Shiley) out of 4 who received an initial TV replacement with a mechanical prosthesis, had to be reoperated because of valve thrombosis after 6.6±6.9years.



Patients at risk

TV-Repair	21	10	6	4	1		
TV-Replacement	44	19	10	4	2	2	2

Figure 11 Survival according to tricuspid valve surgery



Patients at risk							
Re-OP with bioprosthesis	20	6	2	1	1	1	1
Re-OP with mech. prosthesis	25	13	8	3	1	1	1

Figure 12 Survival according to tricuspid valve prosthesis

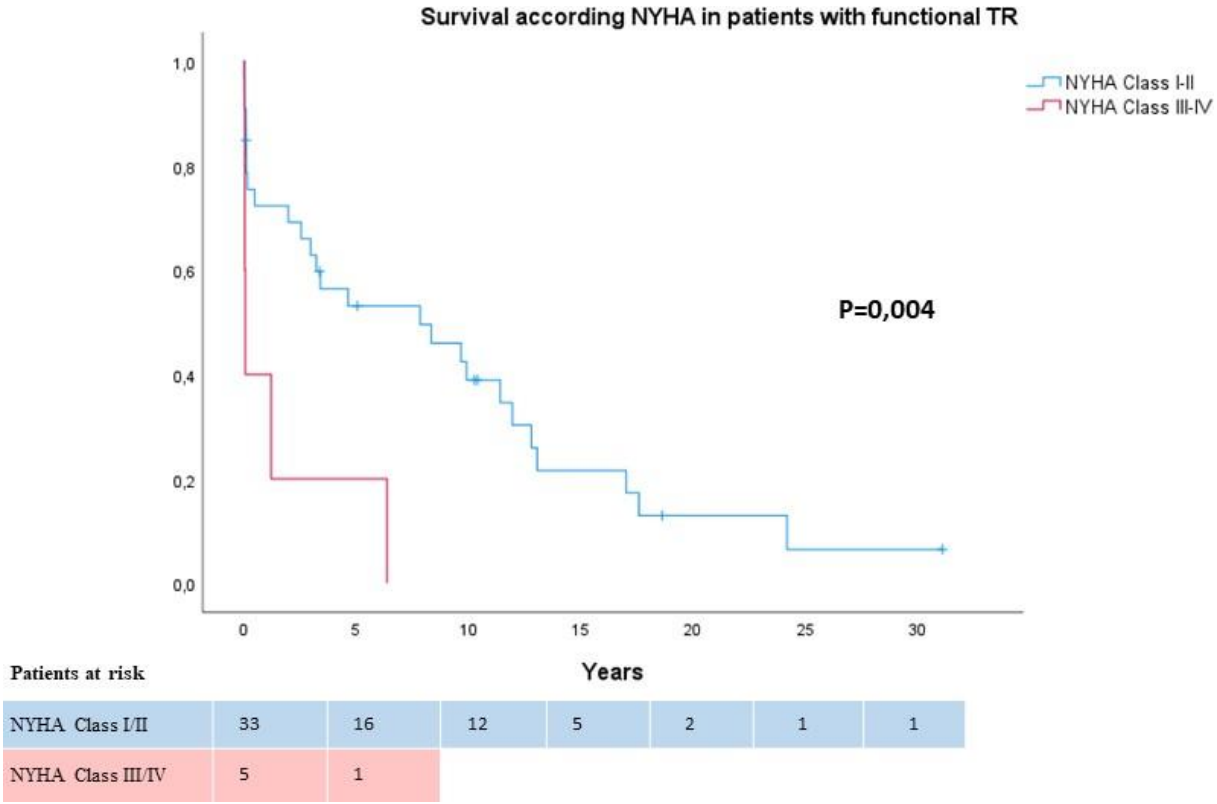


Figure 12 Survival according to functional NYHA class

4.3. Analysis of risk factors for long-term mortality

Univariate analysis for patients with functional TR in NYHA class ≥III showed a significant lower long-term survival probability as compared to patients with NYHA class <III (p=0.004). Other factors as sex (male vs female) (p=0.24), combined procedure (p=0.06), timing of surgery (elective vs non elective) (p=0.90), aetiology at initial TV surgery (functional vs non-functional) (p=0.28), aetiology at reoperation (p=0.99) and reoperation's technique (repair vs replacement) (p=0.68) had no significant impact.

Multivariate analysis of risk factors on long-term survival revealed age ≥60 years as the only predictor of long-term survival (p=0.01). Neither combined procedure, aetiology at initial TV surgery, reoperation's aetiology, timing of surgery nor the reoperation's technique had a significant impact.

5. Discussion

Functional tricuspid valve regurgitation, as the result of a left-sided valve disease, is the most common cause of tricuspid regurgitation. Many studies have shown that significant TR does not improve after surgical correction of mitral valve disease and therefore TR should be addressed at the time of left-sided valve surgery [11, 36].

Furthermore, tricuspid valve reconstruction at the time of mitral valve intervention is not associated with increased mortality [32].

Tricuspid valve repair with ring annuloplasty is the treatment of choice in patients with functional TR, while patients with non-functional TR require more often TV replacement [12, 37]. However, tricuspid valve repair is associated with a high rate of recurrent TV regurgitation [19]. Various authors reported a considerable rate of recurrent TR during follow-up in patients after initial TV-repair (15-35%) [19, 38].

Despite this high rate of recurrent TR, tricuspid valve reoperation is usually rare. In various studies the reoperation rate ranges between 3-12% over 8 and 5 years, respectively [19, 27].

Reoperation of the tricuspid valve is associated with a high operative mortality and morbidity [29, 39]. Therefore, reoperations of the tricuspid valve are often postponed for a long time and TR is treated medically. The average time interval between the initial TV operation and the reoperation ranges between 7-9 years [29, 33, 34].

Tricuspid valve disease entity is a marker of late-stage myocardial and valvular heart disease. According to the literature, 56-90% of the patients (in our series 70.1%), who require TV reoperation are in a poor clinical condition with NYHA functional class ≥III [25, 29, 33, 34]. Therefore the need for TV reoperation reflects an end-stage valvular heart disease often associated with severe RV-dysfunction and secondary hepato-renal dysfunction.

There are only a limited number of studies available reporting long-term results after TV reoperation. The follow-up period in these studies ranges between 2.6 and 14.2 years [25, 27, 29, 33]. The patient collectives presenting with a recurrent TR after an initial TV surgery and requiring a reoperation are small [25, 29, 33].

Due to the small number of these patients and the relatively short follow-up time, reliable statements are difficult to make. A number of questions remain without concrete answer, e.g. why should we reoperate a patient with recurrent TR after initial TV surgery and not treat him medically? When should we reoperate patients with recurrent TR? Which surgical procedure should be considered (repair vs replacement) and which type of prosthesis should preferably be used in the case of valve replacement?

Therefore we investigated the influence of TV's etiology, type of the surgical procedure and the timing of the reoperation on operative mortality and long-term survival. We analyzed data of 67 patients requiring TV-reoperation over 42-year period.

30-day mortality

The 30-day mortality in our series was 14.9%. Other studies report an in-hospital mortality of 13- 37% [25, 29, 33]. The high mortality can be explained by a considerable percent of patients who were operated on an urgent or emergency basis (45.6%) [25]. In our study 12% of the patients underwent non elective TV surgery. By multivariate analysis we could identify age as a significant risk factor for mortality (p=0.038). The mean age of the patients in our study was 57.8±12.9 years. The mean age of the patients in other studies reporting higher mortality rates (18-37%) ranges between 58-65 years [19, 33, 34].

Late referral of patients to surgery presenting with advanced symptoms and organ dysfunction may also be associated with an increased in-hospital mortality up to 37% [19]. The average time interval between the initial TV operation and the reoperation in our series was 6.3±5.6 years. Bernal et al and Chen et al report a mean time interval of 8.2 and 7.8 years, respectively. In both studies the in-hospital mortality ranged between 18-33%. The earlier intervention in our series may have contributed to the lower in-hospital mortality and morbidity after reoperation by preventing the onset of significant and irreversible LV dysfunction.

The mean preoperative EF in our study was 56.5±10.5%. Jeganathan et al showed a significant correlation between operative mortality and left ventricle EF <40%. Therefore, to achieve improved clinical outcomes, surgeons should consider early surgical intervention before the development of left ventricular dysfunction.

In our study the type of surgery (repair vs replacement) didn't influence the mortality rate of patients who underwent TV reoperation.

Morbidity

TV reoperations are associated with a longer stay in the intensive care unit and a longer hospital stay [19, 29]. Low morbidity rate were demonstrated in our study for patients who underwent TV reoperation with exploration for postoperative bleeding (n=4), thromboembolic events (n=0) and pacemaker implantation (n=5). Our postoperative results were better than those in the former study.

Many authors reported a high incidence of postoperative bleeding complications, renal failure, low cardiac output, strokes and pacemaker implantations [14, 25]. Jeganathan et al. demonstrated a high morbidity rate with 9 postoperative bleeding, 11 postoperative low cardiac output syndrome, 5 renal failure requiring dialysis, 3 strokes and 13 pacemaker implantation. Pfannmüller et al. demonstrated a rate of postoperative pacemaker implantation of 10.4%, 4.2% with a new-onset neurologic deficits postoperatively and 12.5% who required a postoperative rethoracotomy for bleeding complications. This could support the notion that a growing experience of the operators directly affect into a net clinical benefit for the patient.

Late mortality

The overall 5-, 10- and 20-year survival rates were 47.3%, 31.2% and 12% respectively. Other studies reported a similar poor long-term survival. Jeganathan et al report a 15 year survival rate of 33.2% and Bernal et al report a 26 year survival probability of 11.8% [25, 29]. The timing of the reoperation has a significant impact on long-term survival. We found that patients with functional TR and with NYHA class ≥III had a significant higher long-term mortality compared to patients with NYHA class<III. Therefore, delayed referral to surgery of severely symptomatic patients should be avoided. LV dysfunction often leads to organ dysfunction, which has a significant impact on long-term survival. Ratschiller et al have shown that renal failure with GFR less than 60 mL/minute is associated with a significantly lower actuarial survival probability at 2 years [40]. Jeganathan et al reported also that patients with renal failure requiring dialysis are significantly associated with higher long-term mortality [25].

Reoperation's technique

Patients with functional TR are treated primarily with TV repair, while patients with non-functional TR more often require TV replacement [12, 37, 38].

The re-repair and replacements rates at reoperation are also influenced by the TV's etio-pathology. Patients with functional TR do have a higher probability for re-repair. In our series overall 42% (16/38) of the patients with functional TR requiring a reoperation could be treated with TV repair compared to 21% (6/29) of the patients with non-functional TR. For those patients requiring valve replacement there is no clear recommendation which prosthesis to choose.

Tricuspid valve reoperation with biological prosthesis have shown promising results in long-term durability by many authors [41, 42]. Kawachi et al reported an actuarial freedom from structural valve failure of a Hancock tricuspid bioprosthesis at 10 years of 94% [41]. However, Nakano et al have showed 35% of the patients, who underwent a biological TV replacement at reoperation developed prosthetic valve dysfunction within 5 Years [43]. In our study, 6 patients out of 9 who received an initial biological TV replacement, were reoperated because of bioprosthetic dysfunction within 9.5±4.6 years.

It is known that mechanical prostheses in tricuspid position may be associated with an increased risk of valve thrombosis. Many mechanisms were involved to explain the higher rate of mechanical valve thrombosis in the right heart such as the lower pressure on the right chambers, the anatomy and histological characteristics of the right ventricle and a low prostacyclin concentration of venous blood [44].

Furthermore, many studies have demonstrated a higher incidence of thrombogenicity with earlier-generation mechanical prosthesis compared with the new bileaflet mechanical valves[45]. Another disadvantage of the mechanical prostheses remains the lifelong necessity of anticoagulation, with the increased risk of haemorrhage and thromboembolism. The most important prevention of bleeding and thrombotic complications remains the education of the patients and the strict control of anticoagulation levels. In our series three patients (with Omnicarbon, Lillehei-Kaster and Björk-Shiley) out of 4 who received an initial TV replacement with mechanical prosthesis, had to be reoperated because of valve thrombosis after a mean time interval of 6.6±6.9years.

There are no comparative benefits demonstrated between biological and mechanical prosthesis, either in terms of early- and long-term survival or reoperation. In the study of Garatti et al, early- and long-term survival were not affected by the type of implanted tricuspid prosthesis [46]. Rizzoli et al showed also that the risk of mechanical valve thrombosis was not significantly different than that of bioprosthesis dysfunction [43]. Ratnatunga et al reported similar survival and rate of reoperation between patients with biologic and mechanical prostheses [47]. In our series the patients who underwent TV replacement with a biological or a mechanical prosthesis had a 15 year survival rate of 11.5% and 20.1%, respectively. There was non-significant difference in long-term survival.

In addition, we perceive a growing trend toward recommending bioprosthetic valves to younger patients (<65 years). One patient (62 years of age) received a successful transcatheter tricuspid valve implantation as a reoperation of the TV due to high risk for surgery. This interventional technique could be the future perspective for patients in the need of TV reoperation and with high surgical risk. The rationale for this strategy is based on the promising endorsements on transcatheter valve-in-valve (VIV) techniques targeting TR and pushing surgeons to reoperate the tricuspid valve with biological prosthesis. However, most of the available studies are mainly focusing on the treatment of bioprosthesis degeneration of the aortic valve [48]. More experience in transcatheter tricuspid VIV are required and may open a new clinical prospect in the near future for these patients.

6. Limitations

Our study is limited by its retrospective design and the small study population. Patients, who require tricuspid valve reoperation, are a very heterogeneous group. Therefore, the comparison of surgical results is difficult. Furthermore, as with all studies of clinical experience, the data may be subject to selection bias. Symptomatic patients might have been more likely to receive follow-up echocardiography than asymptomatic patients.

7. Conclusions

Tricuspid valve reoperation is associated with a high operative mortality. The long-term survival is poor with 10-15 year survival rates of approximately 30%. Considering the poor results of patients with NYHA class ≥III requiring TV reoperation, intensive surveillance of patients after TV surgery is primordial for early identification of patients with recurrent TR and appropriate timing of the reoperation. The probability of TV repair at reoperation depends on the aetiology of TV disease. Re-Repair is more common in patients with functional TR. For those patients requiring valve replacement, we recommend the use of a biological prosthesis, because there is no significant difference in long-term survival as compared to mechanical prostheses and anticoagulation can be avoided. Transcatheter tricuspid valve in valve implantation is a valid option for further treatment and could be the future perspective for patients in the need of TV reoperation with high surgical risk.

8. Abstracts

Englisch:

Objectives:

Reoperations for recurrent tricuspid regurgitation (TR) after previous tricuspid valve (TV) surgery are high-risk surgical procedures, associated with a poor long-term survival. There are a limited number of studies available reporting long-term survival rates. We investigated the influence of TR etiology, type of the surgical procedure and timing of the reoperation on operative mortality and long-term survival.

Methods:

Between January 1975 to February 2017, 1638 patients underwent tricuspid valve surgery at the German Heart Center Munich. Overall, 67 (4.1%) patients required a TV reoperation after a mean time of 5.6 years after previous TV repair (n=49) or replacement (n=18). The follow-up was 97% complete, with a mean follow-up time of 6.2±7.4 years.

Results:

38 (56.7%) patients presented with functional TR and 29 (43.3%) patients had non-functional TR. Overall, 30 day mortality was 14.9% (n=10). The 5 and 10 year survival rates were 47.3% and 31.2%, respectively. There was no significant difference in the survival rate of patients, who underwent TV re-repair (38.8% at 10 years) or TV replacement (30.5% at 10 years) (p=0.684). Patients who underwent repeat TV replacement with a biological or a mechanical prosthesis showed a 10-year survival rate of 23%, versus 35.2% respectively (p=0.330). The patients with functional TR and NYHA Class <III had a 5-year survival rate of 53.1%, compared with 17.9% in patients with NYHA Class ≥III (p=0.004). Age ≥60 years had a significant influence on long-term survival (p=0.01).

Conclusions:

30 day mortality after TV reoperation is high. Patients with functional TR and NYHA Class ≥III requiring TV reoperation are at increased risk. Therefore intensive surveillance of patients after TV surgery is primordial for early identification of patients with clinical deterioration due to recurrent TR. This might lead to earlier intervention and improved results. When valve replacement is necessary we recommend using a biological prosthesis.

Keywords:

Tricuspid valve reoperation, recurrent tricuspid valve regurgitation, tricuspid valve repair, tricuspid valve replacement

Deutsch:

Hintergrund:

Reoperationen Aufgrund rezidivierender Trikuspidalklappeninsuffizienz (TR) bei Zustand nach Trikuspidalklappenoperation (TV) sind chirurgische Eingriffe mit hohem Risiko, die mit einem reduzierten Langzeitüberleben verbunden sind. Es gibt eine begrenzte Anzahl von Studien, die Langzeitüberlebensraten berichten. Wir untersuchten den Einfluss der TR-Ätiologie, der Art des chirurgischen Eingriffs und des Zeitpunkts der Reoperation auf die operative Mortalität und das Langzeitüberleben.

Methodik:

Zwischen Januar 1975 und Februar 2017 wurden am Deutschen Herzzentrum München 1638 Patienten einer Trikuspidalklappenoperation unterzogen. Insgesamt benötigten 67 (4.1%) Patienten eine TV-Reoperation nach einer mittleren Zeit von 5.6 Jahren nach vorheriger TV-Reparatur (n = 49) oder Ersatz (n = 18). Das Follow-up war zu 97% vollständig, mit einer mittleren Follow up von 6.2±7.4 Jahren.

Resultate:

38 (56,7%) Patienten stellten sich mit funktioneller TR und 29 (43.3%) Patienten mit nicht-funktioneller TR vor. Insgesamt betrug die 30-Tage-Mortalität 14.9% (n = 10). Die 5- und 10-Jahres-Überlebensraten betrugen 47.3% bzw. 31.2%. Es gab keinen signifikanten Unterschied in der Überlebensrate von Patienten, die sich einer erneuten TV-Reparatur (38.8% nach 10 Jahren) oder einem TV-Ersatz (30,5% nach 10 Jahren) unterzogen (p=0.684). Patienten, die sich einem wiederholten TV-Ersatz mit einer biologischen oder einer mechanischen Prothese unterzogen, zeigten eine 10-Jahres-Überlebensrate von 23% gegenüber 35.2% (p = 0.330). Die Patienten mit funktioneller TR und NYHA-Klasse < III hatten eine 5-Jahres-Überlebensrate von 53.1%, verglichen mit 17.9% bei Patienten mit NYHA-Klasse ≥ III (p=0.004). Das Alter ≥60 Jahre hatte einen signifikanten Einfluss auf das Langzeitüberleben (p=0.01).

Schlussfolgerungen:

30-Tage-Mortalität nach Reoperation der Trikuspidalklappe ist hoch. Patienten mit funktioneller TR und NYHA-Klasse ≥III, die eine TV-Reoperation erfordern, haben ein erhöhtes Risiko. Daher ist eine intensive Überwachung von Patienten nach einer TV-Operation von grundlegender Bedeutung, um Patienten mit einer klinischen Verschlechterung aufgrund einer rezidivierenden TR frühzeitig zu identifizieren. Dies könnte zu einer früheren Intervention und besseren Ergebnissen führen. Wenn ein Klappenersatz erforderlich ist, empfehlen wir die Verwendung einer biologischen Prothese.

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10. Appendix

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10.2. List of tables

TABLE 3 PATIENT CHARACTERISTICS: TRICUSPID VALVE REOPERATION

TABLE 4 OPERATIVE DATA

TABLE 5 TYPES OF TRICUSPID VALVE PROSTHESIS OR REPAIR TECHNIQUES AFTER TV SURGERY