

Tricuspid Valve Repair for Treatment and Prevention of Secondary Tricuspid Regurgitation in Patients Undergoing Mitral Valve Surgery

Dr Boris Orlov



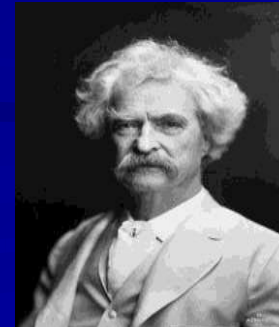
This Presentation

- “What is a problem to prepare this presentation?
There is a lot of information about Tricuspid Valve!”

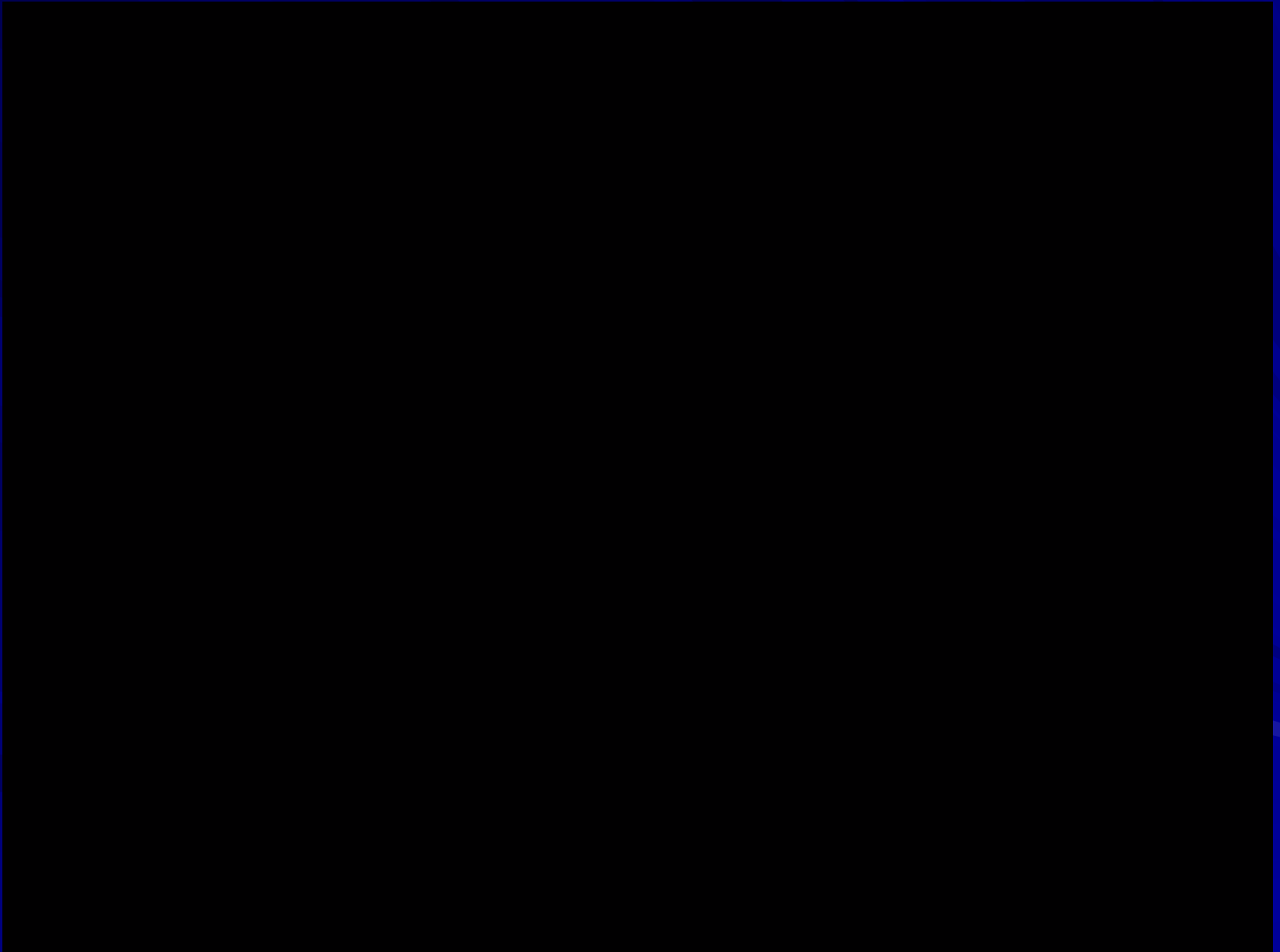


I met two problems:

- “Don't tell fish stories where the people know you;
but particularly, don't tell them where they know the fish.”
- “Not that the story need be long, but it will take a long while to
make it short.”



Say well or be still (deflated?)



Secondary Tricuspid Regurgitation

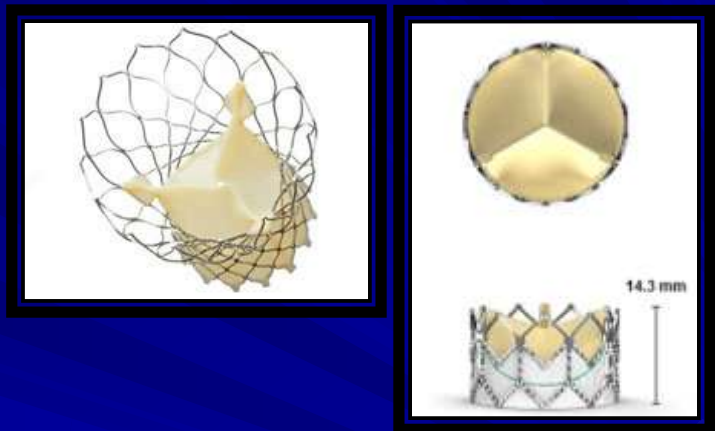
- We have entered an era of renewed interest and enthusiasm surrounding the diagnosis and treatment of valvular heart disease, driven in part by emerging percutaneous therapies for the treatment of aortic, pulmonic, and mitral valve disease.

Longest reported clinical follow-up (Rouen)
Mrs S...88 y-old: > **8 years** with THV



No valve dysfunction

AVA: 1.68 cm², mean gradient 12 mm Hg

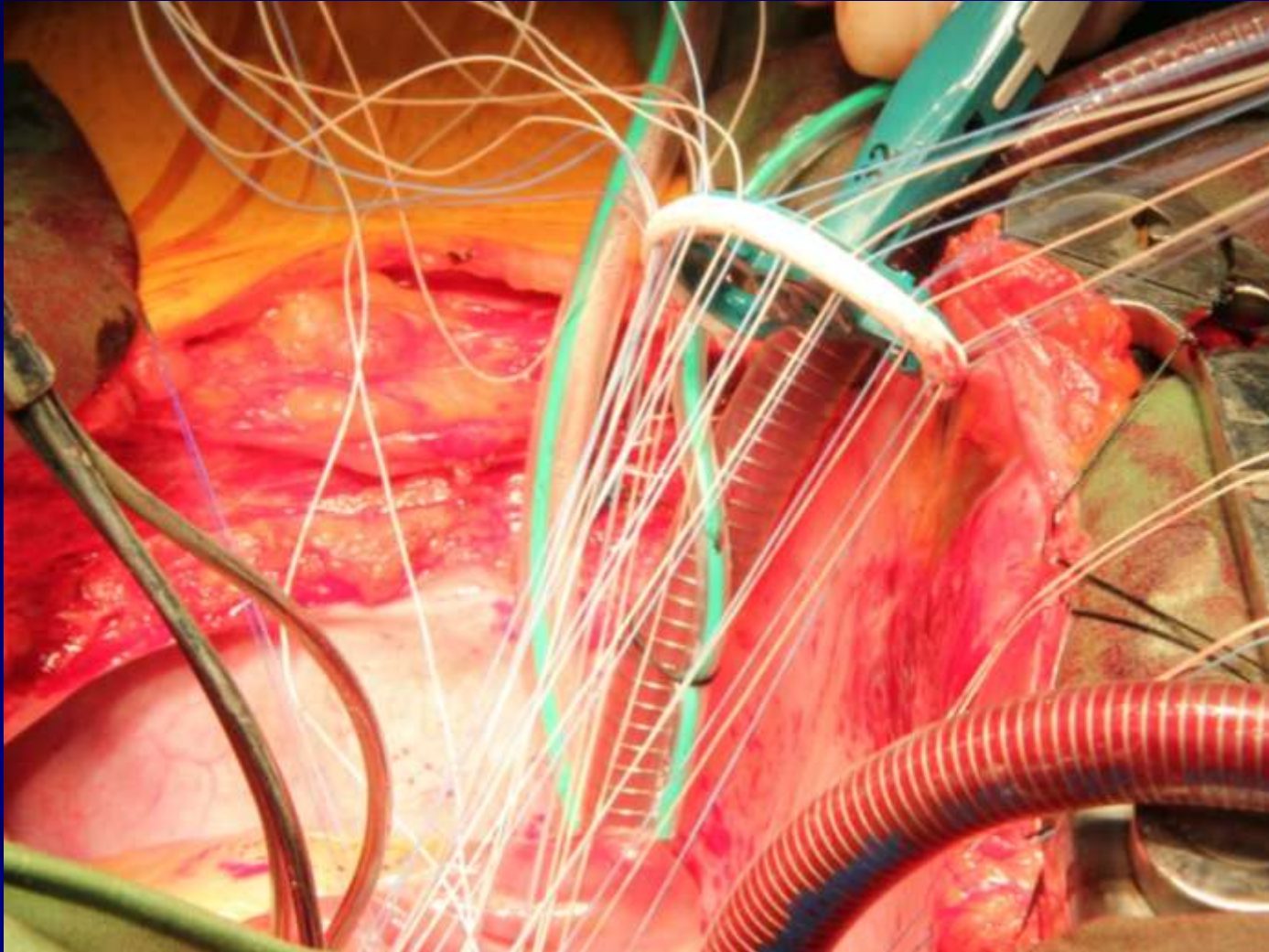


- Despite this wave of investigation, little attention has been given to the treatment of tricuspid valve disease.

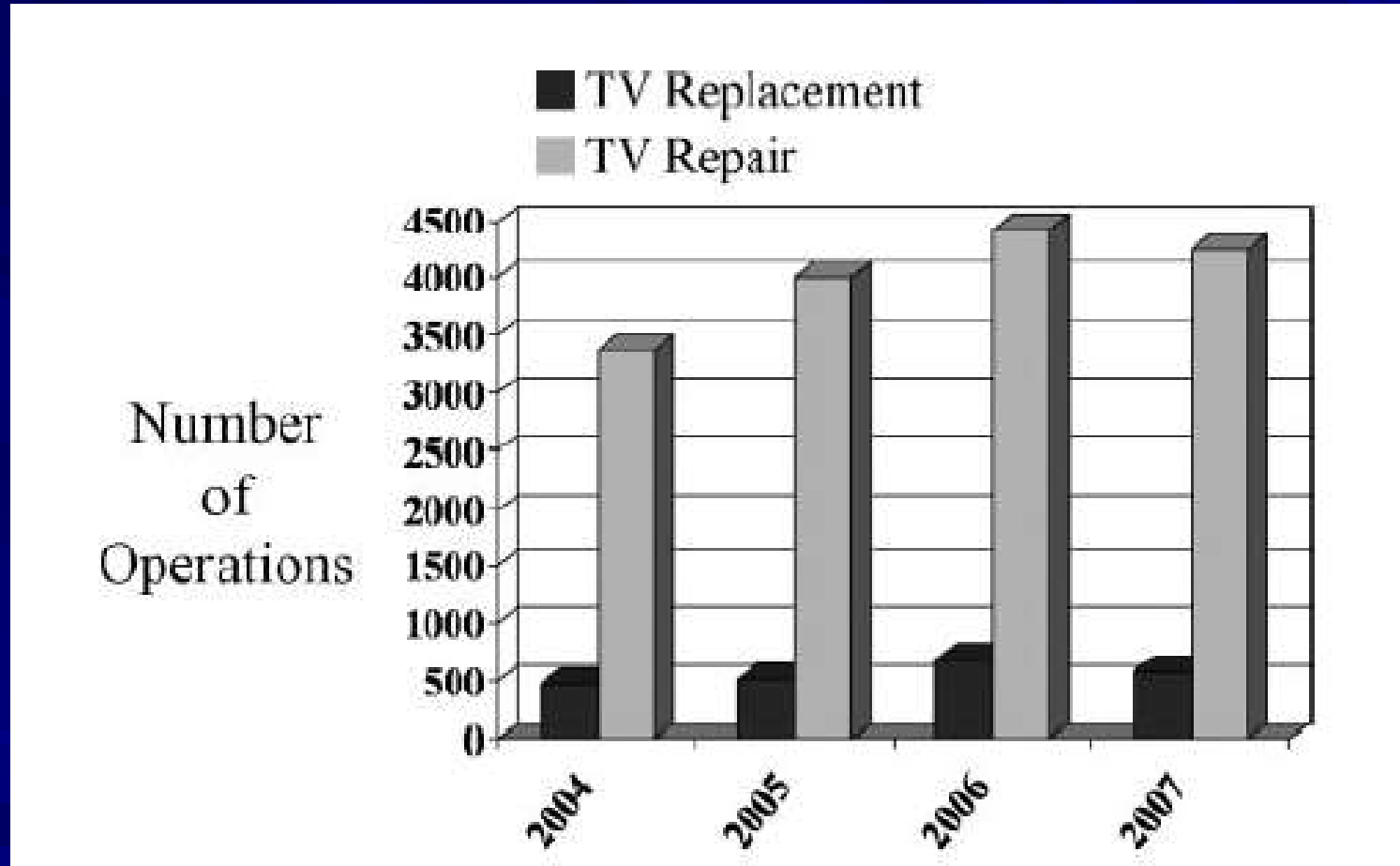
Secondary Tricuspid Regurgitation

- Because significant tricuspid regurgitation appears to be a marker for late-stage myocardial and valvular heart disease, reoperations for recurrent TR are especially high-risk surgical procedures (up to 37% in-hospital mortality).
- TR does not resolve after successful mitral valve surgery.
- If untreated at the time of mitral valve surgery, significant residual TR negatively impacts perioperative outcomes, functional class, and survival.

Forgotten and Neglected Valve



Current TV Repair & Replacement Volumes



- Volumes are clearly a small fraction of the total MV operations yearly, which exceed 40 000.

Tricuspid Regurgitation

Incidence of Intervention



The Society
of Thoracic
Surgeons

Estimated structural heart valve disease (USA)

Valve lesion *	Population	Currently treated
Mitral regurgitation	2,520,000	48,000 (2%)
Aortic stenosis	749,000	79,000 (10%)
Tricuspid regurgitation	1,600,000	< 8,000

"The Forgotten Valve"

* Moderate to severe & severe valvular lesions

Less than 0.5% of cases

Tricuspid Regurgitation

Etiology

■ TR is only rarely caused by primary abnormalities of the tricuspid leaflets. In most cases it is “functional” in nature.

- Primary causes (25%)
 - Rheumatic
 - Myxomatous
 - Ebstein anomaly
 - Endomyocardial fibrosis
 - Endocarditis
 - Carcinoid disease
 - Traumatic (blunt chest injury, laceration)
 - Iatrogenic (pacemaker/defibrillator lead, RV biopsy)
- Secondary causes (75%) “Functional”
 - Left heart disease (LV dysfunction or valve disease) resulting in pulmonary hypertension
 - Pulmonary hypertension (chronic lung disease, pulmonary thromboembolism, left to right shunt)
 - RV dysfunction (myocardial disease, RV ischemia/infarction)

Ventricular interdependence



Pathophysiology of Functional MR



The mitral valve (**anatomically normal**) is caught in a **“tug-of-war”** between the dilated and distorted annulus and the displaced papillary muscles

Pathophysiology of Functional TR



The tricuspid valve (**anatomically normal**) is caught in a **“tug-of-war”** between the dilated and distorted annulus and the displaced papillary muscles

Pathophysiology of Functional MR



- Mitral valve is a Marionette pulled by its Masters, papillary muscles
- The Problem is not with the Marionette, but with its Masters

Pathophysiology of Functional TR



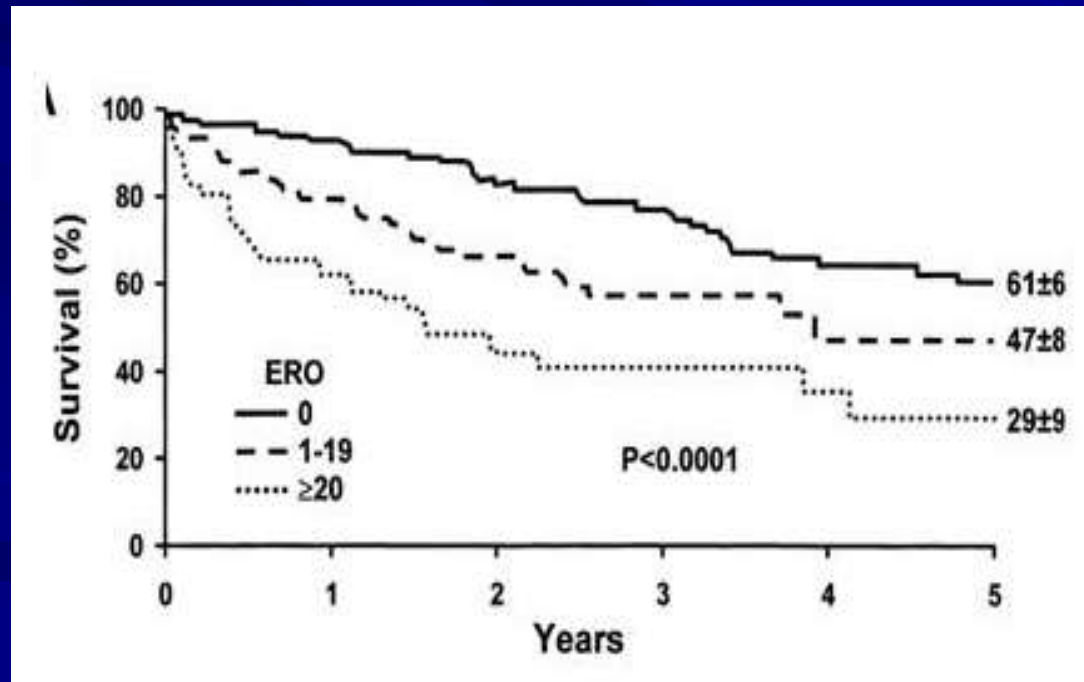
- Tricuspid valve is a Marionette pulled by its Masters, papillary muscles
- The Problem is not with the Marionette, but with its Masters

Ischemic MR

Prognostic Implications

One-year mortality after MI:

No IMR	6%
Mild IMR	10%
Moderate IMR	17%
Severe IMR	40%



Secondary TR

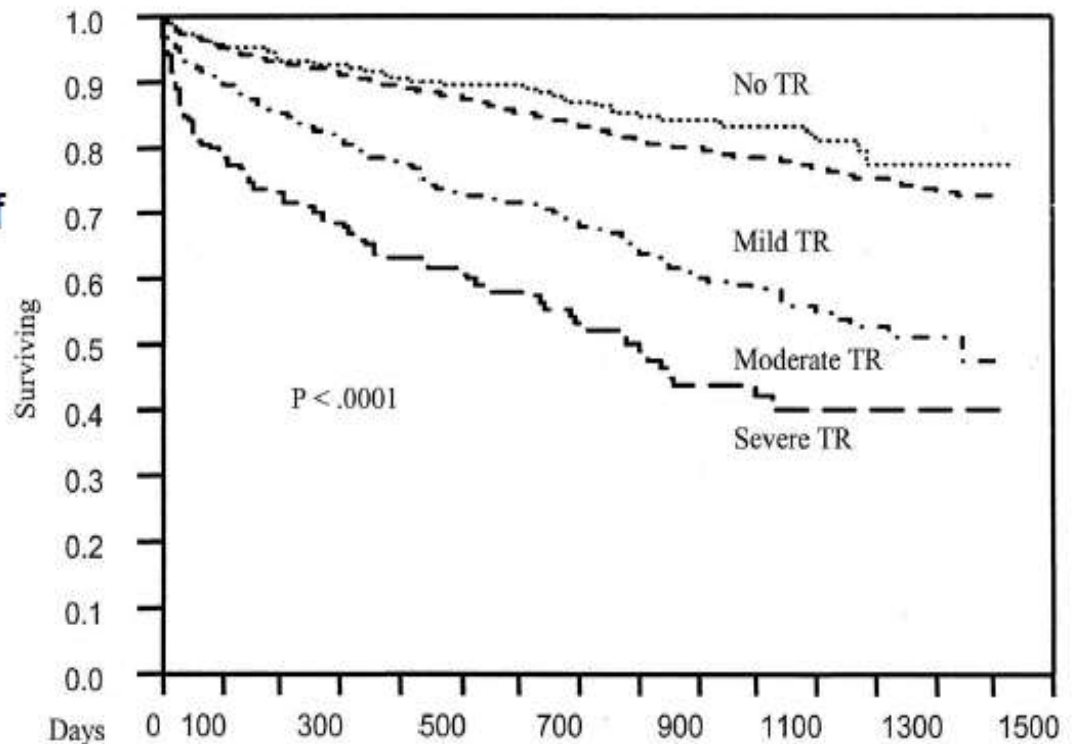
Prognostic Implications

Impact of TR on Long Term Survival

N=5223

Worse Survival Independent of

- Age
- Ventricular Function
- PAP



Ventricular interdependence

- Plays an important role in right ventricular function
- In addition to a shared interventricular septum, there is continuity between the muscle fibers of the left and right ventricles, resulting in a mechanical union whereby left ventricular contraction augments right ventricular free wall contraction
- Experimental models have shown that 20% to 40% of RV systolic pressure and volume outflow results from left ventricular contraction

(This mechanism is responsible for RV Failure after LVAD Implantation, that why IABP improves RV Failure)

Left and Right Ventricles are together forever



Secondary Tricuspid Regurgitation

Historical Excuse

- In the **1960s** with the advent of valve replacement, as surgery's role in managing valvular heart disease expanded rapidly, the thinking at that time was that if regurgitation was “functional,” then it should not require surgical treatment as, by definition, it should improve when the left-sided valve is replaced
- Reduction in severity of tricuspid regurgitation was sometimes observed after mitral valve replacement, prompting Braunwald et al. in **1967** to recommend conservative management of functional tricuspid regurgitation



Secondary Tricuspid Regurgitation

Historical Excuse

- However, in 1974, Carpentier et al. reported excellent results with tricuspid valve repair and argued for systematic repair of functional tricuspid regurgitation during mitral valve surgery

Carpentier A, Deloche A, Hanania G, et al.: *J Thorac Cardiovasc Surg* 1974, **67**:53–65.

- It was later observed in the 1980s that some patients who had undergone successful mitral surgery returned years later with severe symptomatic tricuspid regurgitation, and when these patients were reoperated on, mortality was very high

King RM, Schaff HV, Danielson GK, et al.: *Circulation* 1984, **119**:3–197

Secondary Tricuspid Regurgitation

Pathophysiological objectives

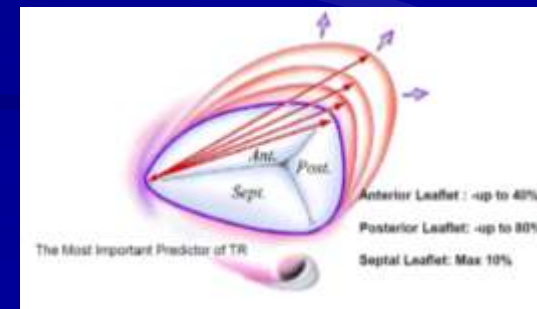
■ Pulmonary Hypertension



■ Papillary Muscle Displacement



■ Tricuspid Annular Dysfunction



Secondary Tricuspid Regurgitation

Pulmonary hypertension

- In patients with left-sided valvular disease a rising left atrial pressure, transmitted through the lungs as pulmonary arterial hypertension, resulting in RV pressure overload and:

- can directly result in tricuspid regurgitation

OR

- more typically causes right ventricular dilatation, which leads to dilatation and distortion of the tricuspid valve annulus (Carpentier type I regurgitation) or/and by tethering of the tricuspid valve leaflets (Carpentier type IIIb regurgitation)



- At least in theory, reduction in degree of pulmonary hypertension (by mitral valve repair) could result in less tricuspid regurgitation, but this would first require reverse remodeling of the previously dilated and deformed right ventricle, which may not be instantaneous

Secondary Tricuspid Regurgitation

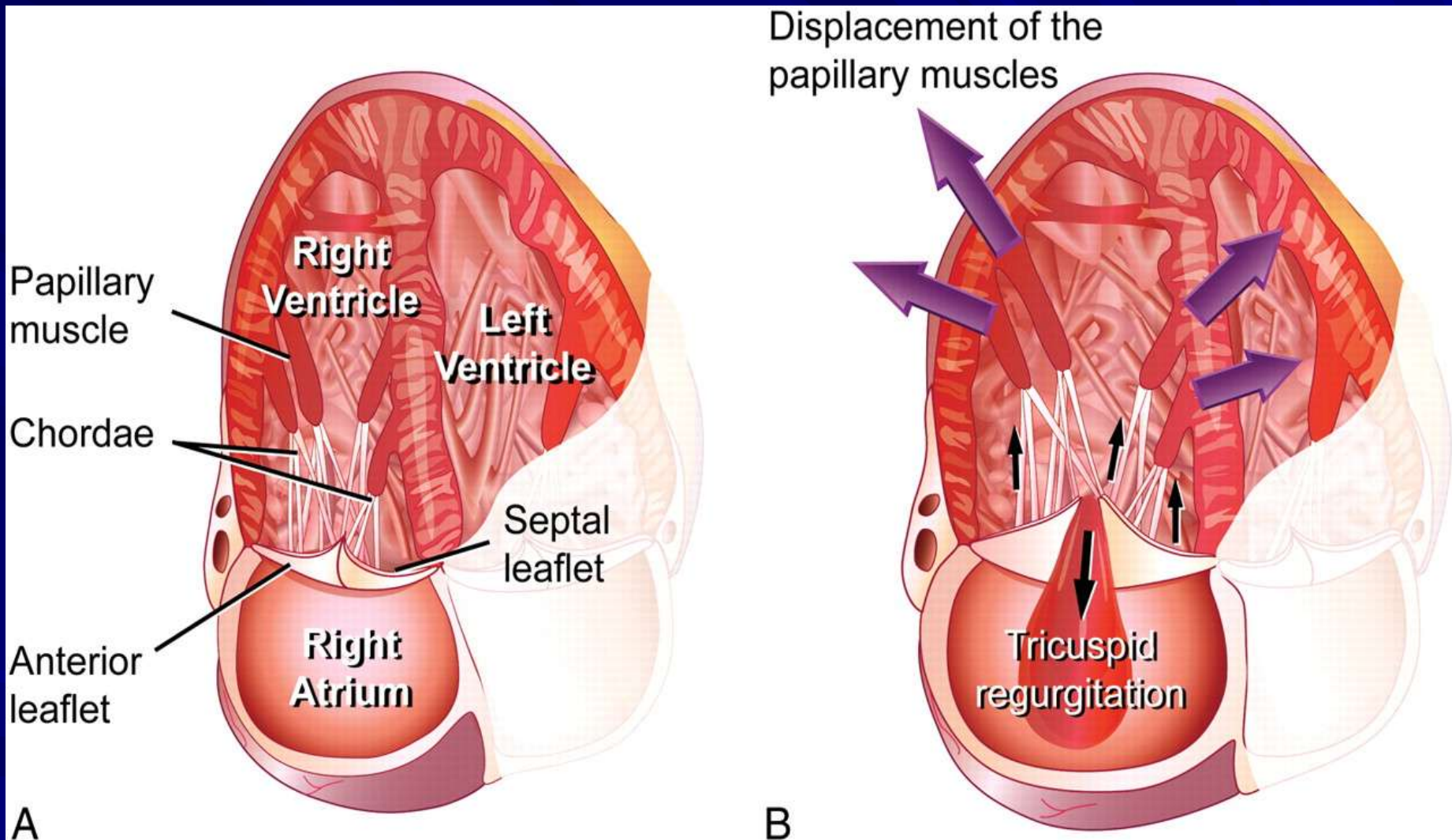
Pulmonary hypertension

- In practice, complete reverse right ventricular remodeling practically not occur, and normalization of pulmonary artery pressures alone will not eliminate tricuspid regurgitation in many patients



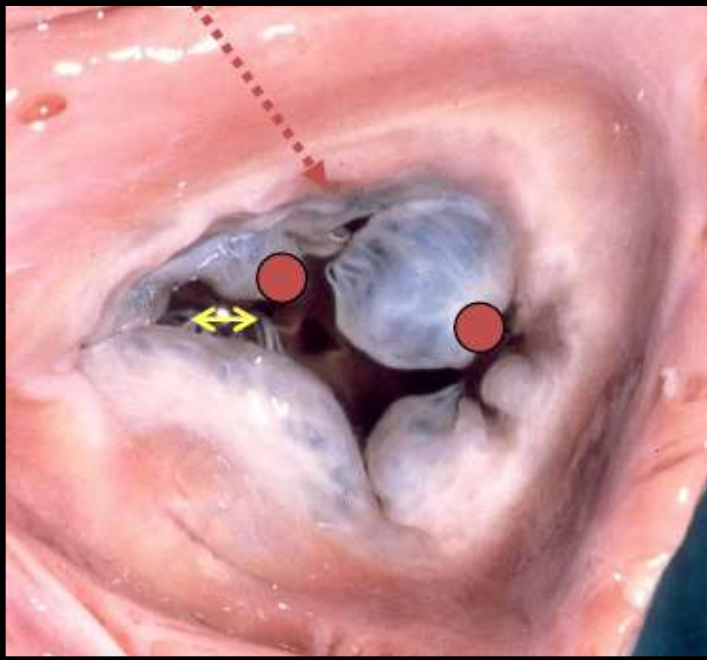
(This is well demonstrated in the pulmonary thromboendarterectomy literature, in which moderate to severe secondary tricuspid regurgitation is reported postoperatively in 30% to 45% of patients despite successful reduction in pulmonary arterial pressure)

Papillary Muscle Displacement



Papillary Muscle Displacement

Tricuspid valve complex

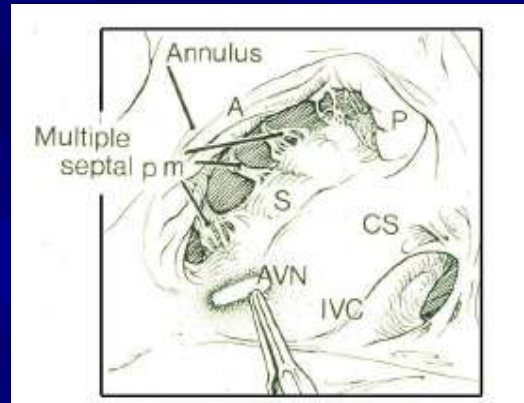


- The anterior leaflet is the largest, whereas the posterior leaflet is notable for the presence of multiple scallops. The septal leaflet is the smallest and arises medially directly from the tricuspid annulus above the interventricular septum.
- The anterior papillary muscle provides chordae to the anterior and posterior leaflets, and the medial papillary muscle provides chordae to the posterior and septal leaflets. The septal wall gives chordae to the anterior and septal leaflets.
- These multiple chordal attachments are important mediators of TR, as they impair proper leaflet coaptation in the setting of right ventricular dysfunction and dilation.

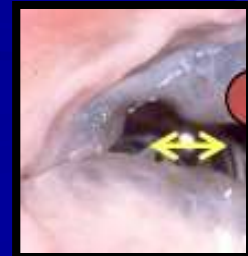
Secondary Tricuspid Regurgitation

Papillary Muscle Displacement

- Modern echocardiographic imaging (particularly real-time 3-D) have observed septal leaflet tethering in patients with secondary tricuspid regurgitation who have normal pulmonary artery pressures



- Because the two ventricles are interdependent at the septum, left ventricular septal dysfunction also causes dysfunction of the right septal wall, the area of origin of the small septal papillary muscles (chords) to the septal and anterior leaflets of the tricuspid valve (*antero-septal commissural gap*).



Secondary Tricuspid Regurgitation Papillary Muscle Displacement

- Such regurgitation can occur irrespective of the size and function of the right ventricle and explains why left ventricular dysfunction is an independent risk factor for secondary tricuspid regurgitation (independent of the effect of pulmonary hypertension)

Fukuda S, Gillinov AM, Song JM, et al.: *Am Heart J* 2006, **152**:1208–1214.



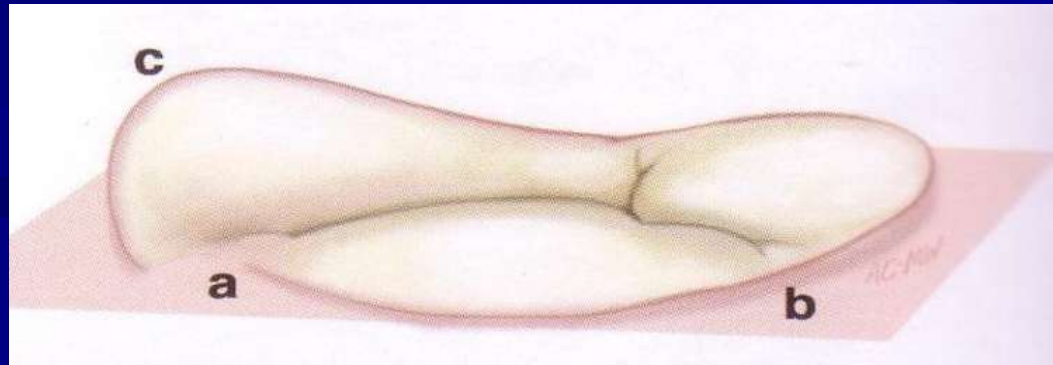
Ventricular Interdependence

Lt & Rt Ventricles are
together forever

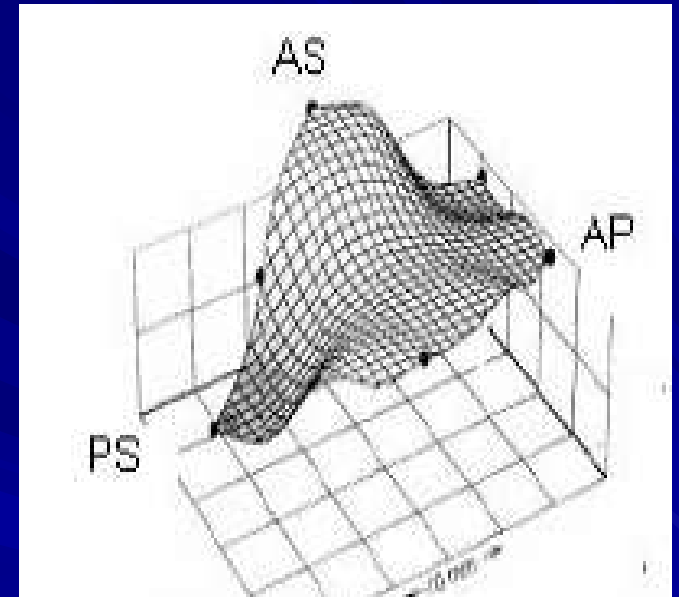
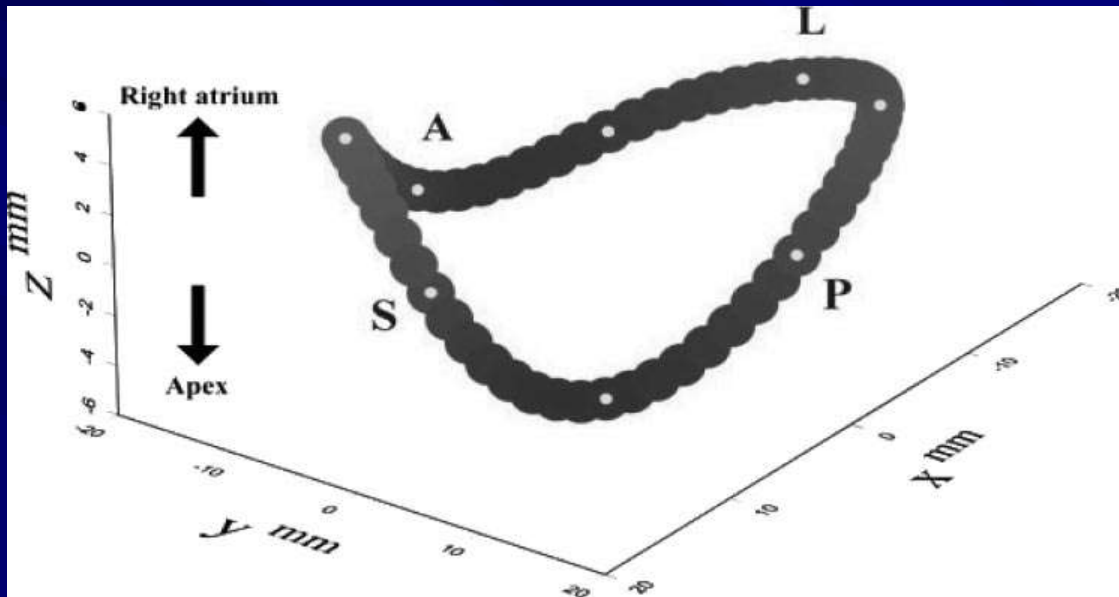
Secondary Tricuspid Regurgitation

Tricuspid Annular Dysfunction

- Tricuspid annular dilatation has long been recognized as a constant feature of secondary tricuspid regurgitation
- Recently, other abnormalities in the annulus have been discovered
 - unlike the saddle-shaped annulus in normal subjects, valves with secondary tricuspid regurgitation are dilated, flattened, and circular
 - an asymmetric reduction in tricuspid annular contraction



Tricuspid valve complex



- The tricuspid annulus has a complex 3-dimensional structure, which differs from the more symmetric “saddle-shaped” mitral annulus.

Rationale for Surgical Correction of Secondary Tricuspid Valve Disease at the Time of Mitral Valve Surgery

Secondary Tricuspid Regurgitation

Prognostic Implications

- **TR After MVR:** Independent Predictor of:
 - NYHA III or IV
 - Heart Failure Death
 - All-Cause Mortality
 - Reduced Exercise Capacity
- **After PBM Valvuloplasty:** TR Do Not Improve in 50-80%

Nonregression or progression of tricuspid regurgitation after MV surgery

- Tricuspid regurgitation is frequently present months or years after isolated mitral valve surgery.
- Although repair of left-sided valve dysfunction may reduce the severity of tricuspid regurgitation, a substantial proportion of patients will go on to develop moderate or severe regurgitation.

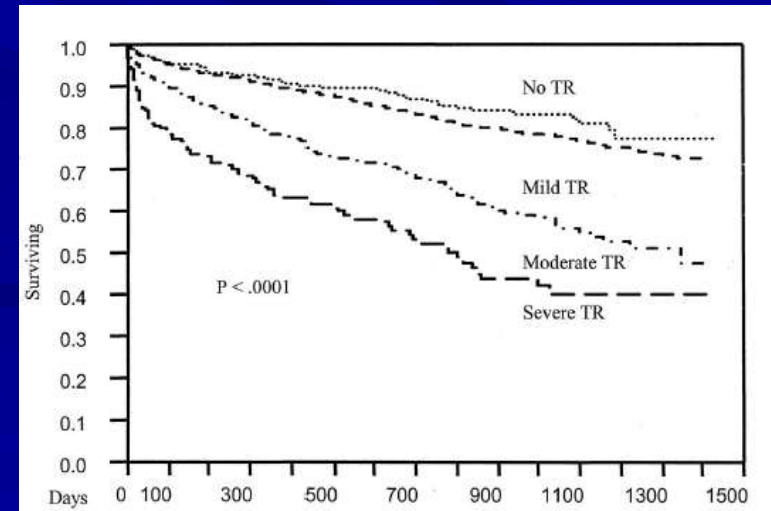
In one series, 43% of patients had severe tricuspid regurgitation at a mean follow-up of 11 years after isolated mitral valve replacement

Porter A, Shapira Y, Wurzel M, et al.: *J Heart Valve Dis* 1999, 8:57–62.

- Although in some patients, significant tricuspid regurgitation will resolve with correction of the left-sided lesion, there is no means of accurately predicting this at the time of mitral surgery

Mortality and morbidity associated with tricuspid regurgitation occurring after MV surgery

- The early mortality, long-term survival, freedom from heart failure, and functional outcome are all significantly worse for patients with severe tricuspid regurgitation compared to those without severe regurgitation
- Moderate tricuspid regurgitation, is also associated with inferior survival, but to a lesser degree than for severe regurgitation (79% 1-year survival for moderate, compared to 64% for severe and 90% to 92% for patients with mild or none, respectively)



Mortality and morbidity associated with tricuspid regurgitation occurring after MV surgery

- Although Re-do surgery can be offered to these patients, it may not improve survival and quality of life at this late stage



Despite resolution of tricuspid regurgitation; the 5- year event-free survival in one series was reported to be 42% , and in another, the 3- year patient survival was 19% .

Staab ME, Nishimura RA, Dearani JA: *J Heart Valve Dis* 1999, **8**:567–574.

McCarthy PM, Bhudia SK, Rajeswaran J, et al.: *J Thorac Cardiovasc Surg* 2004, **127**:674–685.

- The mortality of reoperative tricuspid valve surgery is about 20% to 40% or substantially higher

Kwon DA, Park JS, Chang HJ, et al.: *Am J Cardiol* 2006, **98**:659–661.

Staab ME, Nishimura RA, Dearani JA: *J Heart Valve Dis* 1999, **8**:567–574.

McCarthy PM, Bhudia SK, Rajeswaran J, et al.: *J Thorac Cardiovasc Surg* 2004, **127**:674–685.

Limited (no chance?) effectiveness for second ball



Annular Dilatation

Indicator of functional and structural abnormality of the tricuspid valve and right ventricle, representing the early stages of secondary tricuspid regurgitation.

Secondary Tricuspid Regurgitation

Pathophysiology

- Using echocardiographic analysis of 109 patients, Sagie et al. demonstrated that pulmonary hypertension and right ventricular dilatation per se were not prerequisites for developing functional tricuspid regurgitation.

The most consistent feature they found was tricuspid annular dilatation

Sagie A, Schwammenthal E, Padial LR, et al.: *J Am Coll Cardiol* 1994, **24**:446–453.

Progression of tricuspid valve dysfunction

Dilated annulus

- An association between tricuspid annular dilatation at the time of initial mitral valve replacement and subsequent development of severe tricuspid regurgitation in the long term was demonstrated

Groves PH, Ikram S, Ingold U, Hall RJ: *J Heart Valve Dis* 1993, **2**:273–278. 25.

Colombo T, Russo C, Ciliberto GR, et al.: *Cardiovasc Surg* 2001, **9**:369–377.

- A dilated annulus **is an Indicator** of functional and structural abnormality of the tricuspid valve and right ventricle
- Annular dilatation represents the early stages of secondary tricuspid regurgitation.

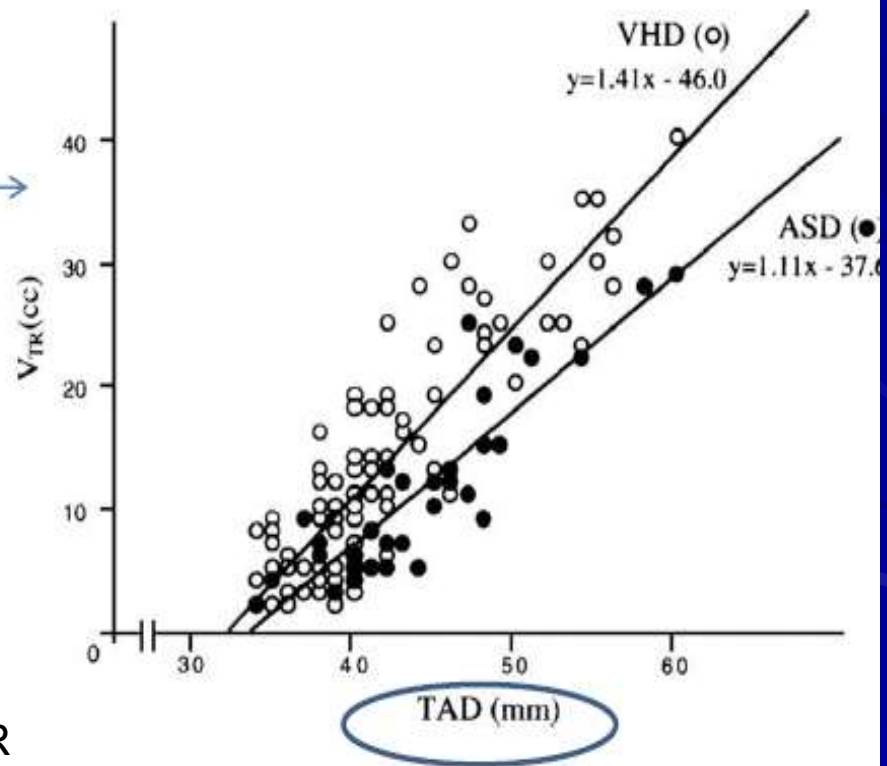
Correlation between Annular Size and Regurgitant Volume

Normal TA Diameter: 2.8 cm

Good Correlation Between Tricuspid Annulus Diameter and Regurgitant Volume



There is a good correlation in both patients with VHD ($r=0.87$) and patients with ASD ($r=0.88$). The correlation lines cross the X-axis at a TAD value of 33-34 mm, which is the threshold for TR



Secondary Tricuspid Regurgitation or Dilatation: Which Should Be the Criteria for Surgical Repair?

N = 311

- Tricuspid annuloplasty if TA diameter > 2x Normal (70 mm) regardless of the grade of regurgitation.
- Group 1 (163 patients, 52.4%): Mitral Valve Repair.
- **Group 2 (148 patients, 47.6%): MVR + Tricuspid Annuloplasty.**
- Tricuspid regurgitation increased > 2 grades:
 - 48% group 1
 - **2% group 2** ($p < .001$).
- NYHA: group 1= 1.6 vs group2=1.1 (p=0.01)

When Should We Operate?

Secondary Tricuspid Regurgitation or Dilatation: Which Should Be the Criteria for Surgical Repair?



70mm Surgical=
=40 mm Echo

- Considerable Tricuspid Dilatation Can Be Present Even in The Absence of Substantial TR.
- Tricuspid Dilatation Is an Ongoing Disease Process that will, with time, lead to severe TR

Secondary Tricuspid Regurgitation

Irrational & Rational

- Despite these observations, only a minority of cardiologists and surgeons embraced using tricuspid valve repair for functional tricuspid regurgitation, and surgical abstention continues in many centers to the present day
- This strategy has been increasingly scrutinized since Dreyfus et al. reported that patients having tricuspid valve repair at the time of mitral valve surgery did better in the long term compared with patients who did not.

Dreyfus GD, Corbi PJ, Chan KM, Bahrami T: *Ann Thorac Surg* 2005, **79**:127–132.

Indications for Surgery

When Should We Operate?

- **No consensus to guide decision making**
- **TV repair is often dictated by team or surgeon predisposition**
- **Lack of a clear guideline on TV repair indications**

Indications for Intervention in TV Disease

Table 2. 2006 ACC/AHA Guidelines Pertaining to the Surgical Management of Tricuspid Valve Disease/Regurgitation

Class I

Tricuspid valve repair is beneficial for severe TR in patients with MV disease requiring MV surgery. (*Level of Evidence: B*)

Class IIa

1. Tricuspid valve replacement or annuloplasty is reasonable for severe primary TR when symptomatic. (*Level of Evidence: C*)
2. Tricuspid valve replacement is reasonable for severe TR secondary to disease/abnormal tricuspid valve leaflets not amenable to annuloplasty or repair. (*Level of Evidence: C*)

Class IIb

Tricuspid annuloplasty may be considered for less than severe TR in patients undergoing MV surgery when there is pulmonary hypertension or tricuspid annular dilatation. (*Level of Evidence: C*)

Class III

1. Tricuspid valve replacement or annuloplasty is not indicated in asymptomatic patients with TR whose pulmonary artery systolic pressure is less than 60 mm Hg in the presence of a normal MV. (*Level of Evidence: C*)
2. Tricuspid valve replacement or annuloplasty is not indicated in patients with mild primary TR. (*Level of Evidence: C*)

ACC indicates American College of Cardiology; AHA, American Heart Association; TR, tricuspid regurgitation; and MV, mitral valve.

Indications for Intervention in TV Disease

	Class
Severe TR in a patient undergoing left sided valve surgery	IC
Severe primary TR and symptoms despite medical therapy without severe right ventricular dysfunction	IC
Severe TS (\pm TR), with symptoms despite medical therapy*	IC
Severe TS (\pm TR) in a patient undergoing left sided valve intervention*	IC
Moderate organic TR in a patient undergoing left-sided valve surgery	IIaC
Moderate secondary TR with dilated annulus (> 40 mm) in a patient undergoing left sided valve surgery	IIaC
Severe TR and symptoms, after left-sided valve surgery, in the absence of left sided myocardial, valve, or right ventricular dysfunction and without severe pulmonary hypertension (systolic pulmonary artery pressure > 60 mmHg)	IIaC
Severe isolated TR with mild or no symptoms and progressive dilation or deterioration of right ventricular function	IIbC

* Percutaneous technique can be attempted as a first approach if TS is isolated

TR: tricuspid regurgitation

TS: tricuspid stenosis

VHD Guidelines ESC 2007



EUROPEAN
SOCIETY OF
CARDIOLOGY®

When Should We Operate?



Surgical Armamentarium

Secondary Tricuspid Regurgitation

Implications for Surgical Therapy

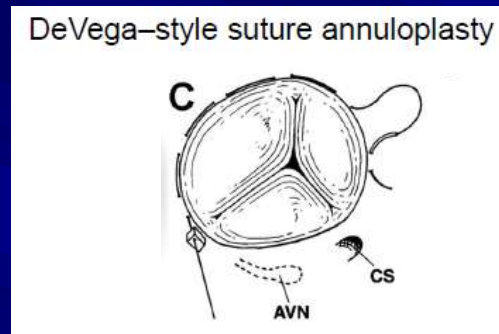
- Based on current understanding of pathophysiology, principles of surgical therapy for secondary tricuspid regurgitation include the following:
 - Elimination of increased afterload to the right ventricle by correction of left-sided valve dysfunctions and optimization of left ventricular function
 - Maximization of right ventricular remodeling by reducing pulmonary hypertension. Correction of left-sided lesions often suffices, but in cases in which pulmonary hypertension persists, oral pulmonary vasodilators such as sildenafil and bosentan may be helpful in promoting reverse remodeling of the right ventricle

Mogollon MV, Lage E, Cabezon S, et al.: *Transplant Proc* 2006, **38**:2522–2523.

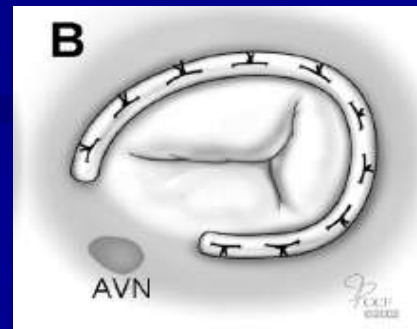
- Correct tricuspid annular dilatation and dysfunction - a tricuspid valve annuloplasty to restore annular size and geometry

Surgical Techniques for Tricuspid Valve Repair

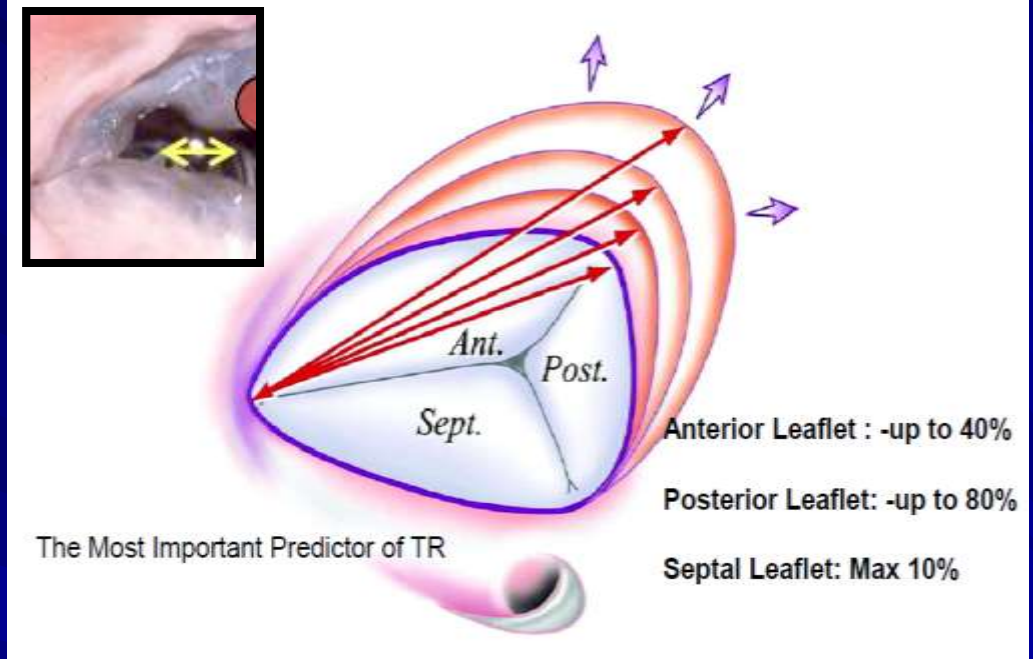
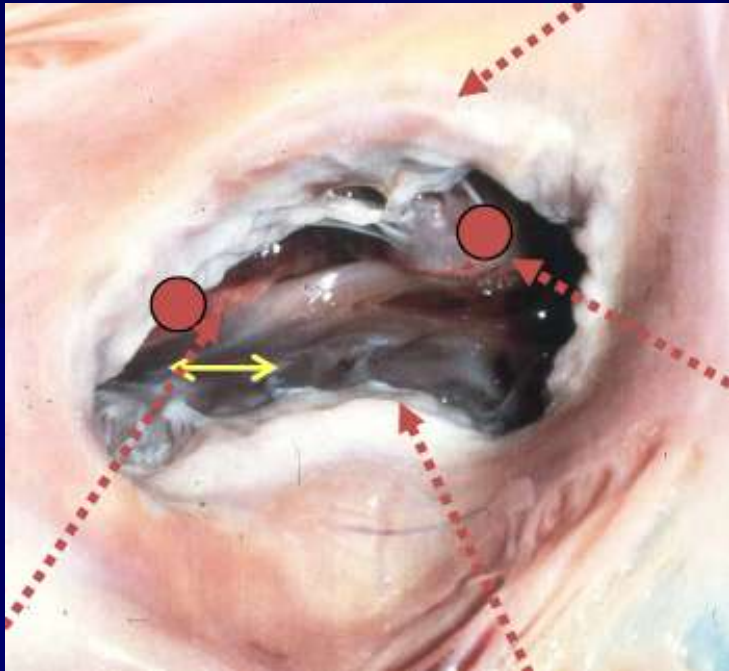
- Two principal surgical methods are used to treat or prevent secondary tricuspid regurgitation:
the ring annuloplasty - method introduced by Carpentier
and the suture annuloplasty method described by De Vega



- With the ring annuloplasty technique, the annulus is permanently fixed in a systolic position by suturing in a rigid or semirigid ring



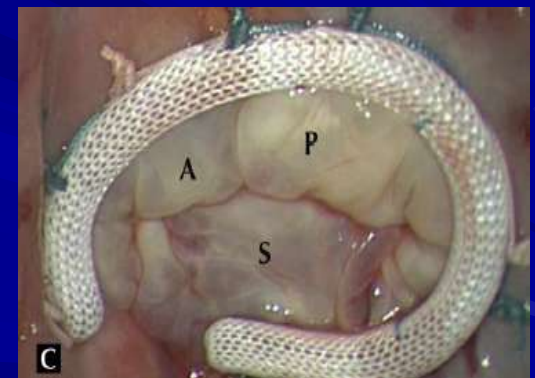
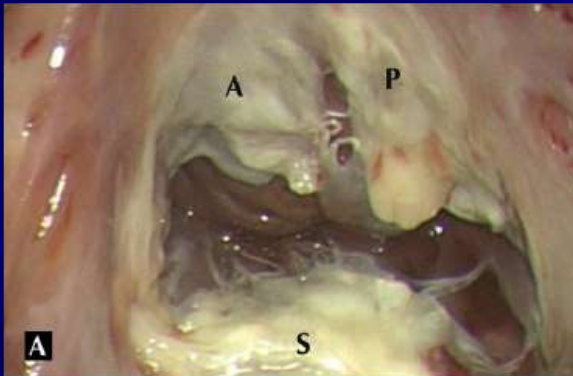
Surgical perspective of the tricuspid valve complex



- Because the small septal wall leaflet is fairly fixed, there is little room for movement if the free wall of right ventricular/ tricuspid annulus should dilate.
- Dilatation of the tricuspid annulus occurs primarily in its anterior/posterior (mural) aspect, which can result in significant functional TR as a result of leaflet malcoaptation
- The septal aspect of the tricuspid annulus is considered to be analogous to the intertrigonal portion of the mitral annulus in that it is relatively spared from annular dilation

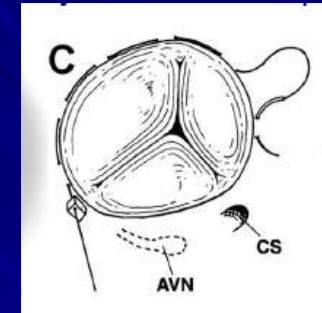
Surgical perspective of the tricuspid valve complex

- Because of this property, tricuspid annular sizing algorithms have been based on the dimension of the base of the septal leaflet.
- The ring size must be at least one size smaller than the distance between the antero-septal and septo-posterior commissures, or at least one size smaller than the surface area of the anterior leaflet



Conceptual Classification of TV Annuloplasty

■ Suture Annuloplasty



■ Flexible Band



■ Undersized Ring Annuloplasty

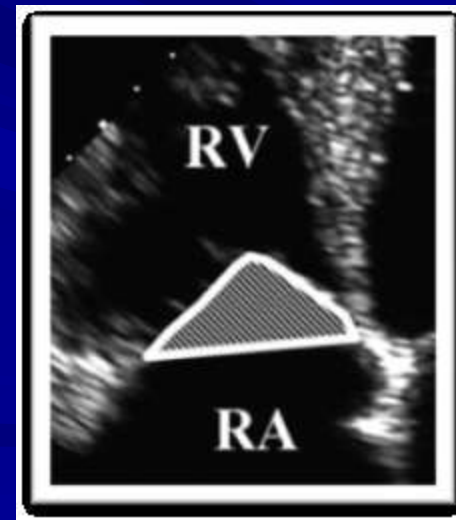
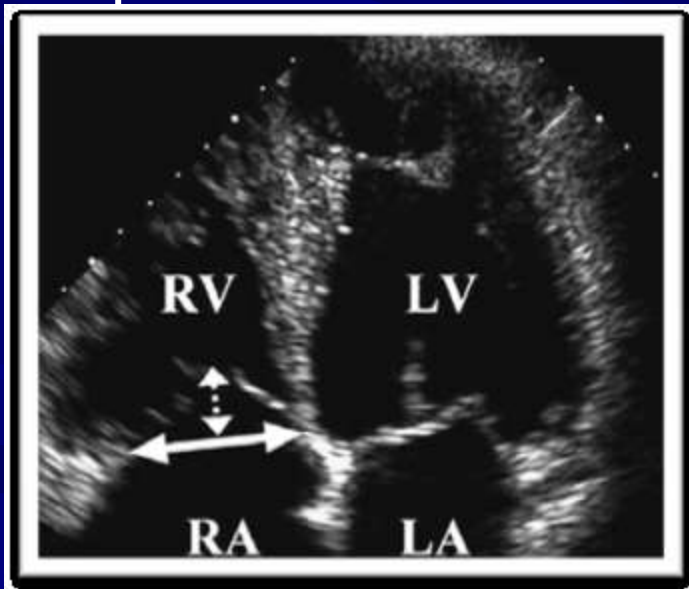


■ Remodeling 3-D Ring Annuloplasty



Surgical Techniques for Tricuspid Valve Repair















- Annular remodeling strategies should be tailored in the setting of mechanism and severity of Secondary TR
- Probably, patients with extensive leaflet tethering (>1.0 cm) required additional maneuvers to ensure valve competence.



E. M. Spinner,, D. H. Adams, and A. P. Yoganathan

In Vitro Characterization of the Mechanisms Responsible for Functional Tricuspid Regurgitation

Circulation, August 23, 2011; 124(8): 920 - 929.

Tricuspid Valve	Medtronic	Edwards	St Jude	Sorin	Peters Surgical
Rigid Rings	 Contour 3D Ring	 MC3  Classic			
	 Tri-Ad Ring				 UniRing
Flexible Rings/ Bands	 Duran AnCore Ring	 Cosgrove Band	 Tailor Ring	 AnnuloFlex Ring	
	 Simulus FLX-O Ring		 Tailor Band		
	 Duran AnCore Band				
	 Simulus FLX-C Band				
	 Simplici-T Band				

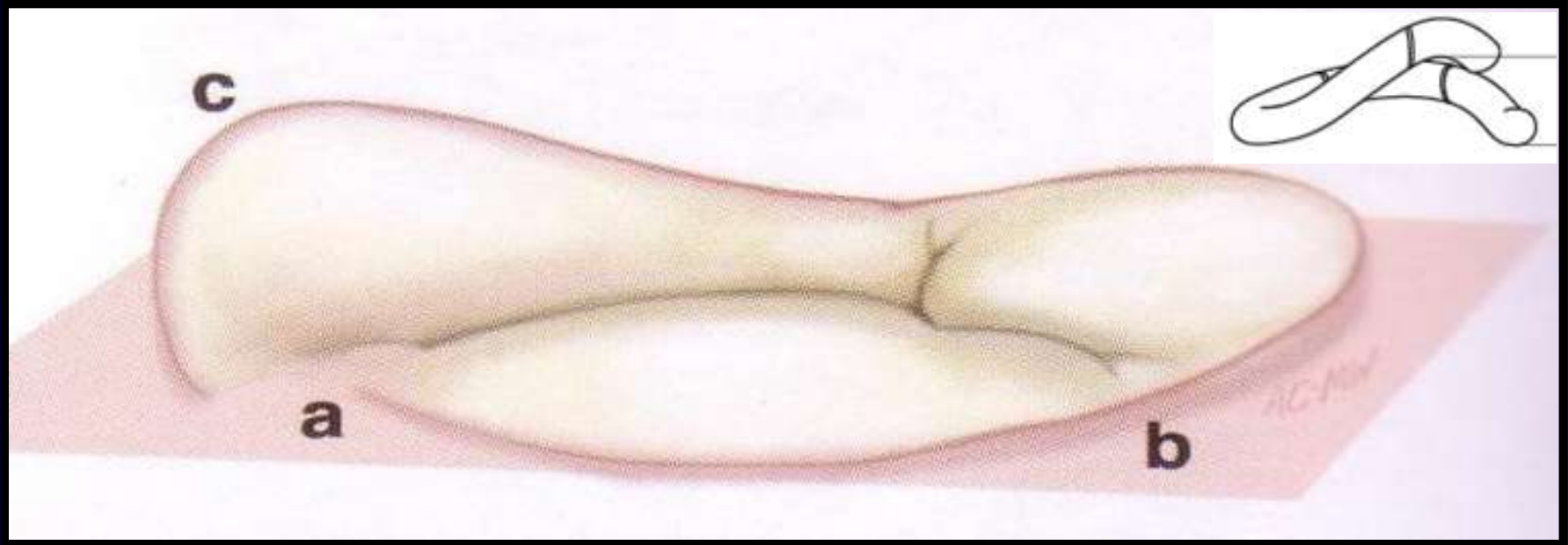
Carpentier-Edwards Classic Ring



Cosgrove-Edwards Annuloplasty Band



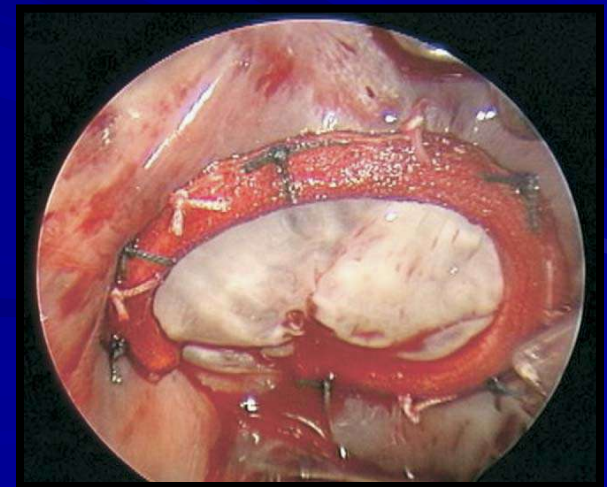
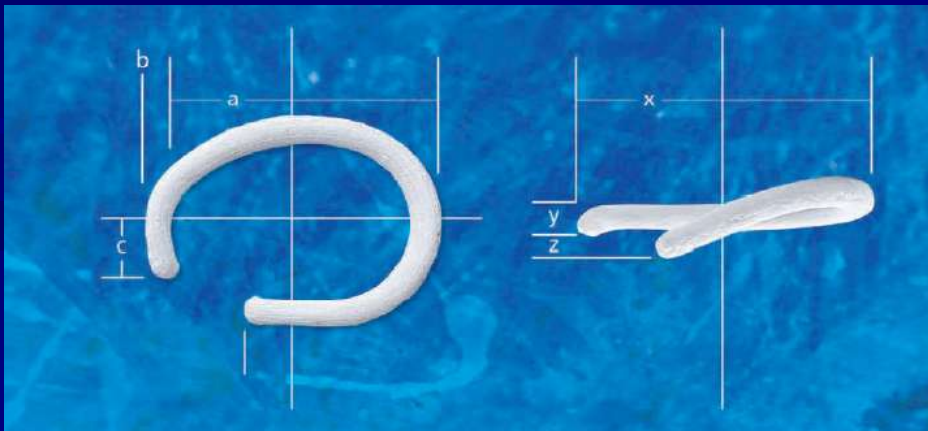
Remodeling 3-D Ring Annuloplasty



Types of TV repair rings

Edwards MC3

- The MC3 TV annuloplasty ring (Edwards Lifesciences, Irvine, CA, USA) is the first TV annuloplasty ring anatomically designed to conform to the three-dimensional shape of the normal TV and minimize stress on sutures
- Progressive flexibility is created from the unique processing of the titanium band
- The Edwards MC3 annuloplasty ring is covered with material that encourages host tissue ingrowth



Contour 3D™ Ring



- Remodeling annuloplasty ring (rigid)
 - Unique asymmetrical 3D ring design (nonplanar)
 - Ring design based upon scientific evidence on normal tricuspid annular geometry
- Launched in 2010
- Developed with Drs. Aubrey Galloway, Eugene Grossi, Rüdiger Lange and Hugo Vanermen
- Polyester knit covering with titanium/silicone core
- Six sizes, 26 – 36 mm
- Tricuspid



Medtronic

Alleviating Pain • Restoring Health • Extending Life

Tri-Ad™ Ring

- Remodeling annuloplasty ring (semi-rigid)
 - Targeted remodeling with semi-rigid stiffener and flexible segments that adapt to the nonplanar annular geometry
 - Large suture free area to avoid the conduction area
- Launched in 2010
- Developed with David Adams, MD
- Braided polyester covering and MP-35N/silicone core
 - Closed-coil spring
- 6 sizes, 26 – 32mm
- Tricuspid



Medtronic

Alleviating Pain • Restoring Health • Extending Life

Surgical Techniques for Tricuspid Valve Repair

- Recent long-term studies suggest that ring annuloplasty repairs are more durable than suture annuloplasty repairs

Tang GH, David TE, Singh SK, et al.: *Circulation* 2006, **114**(1 Suppl):I577–I581.

- More than 85% of patients having a ring annuloplasty will be free from moderate or severe tricuspid regurgitation 10 years after the surgery

McCarthy PM, Bhudia SK, Rajeswaran J, et al.: *J Thorac Cardiovasc Surg* 2004, **127**:674–685.

Echocardiographic Follow-up of Tricuspid Annuloplasty with a New Three-Dimensional Ring in Patients with Functional TR

- The TV annuloplasty with the new physiologic MC3 ring is effective for the management of TR and may be superior to conventional techniques.
- However, patients with extensive leaflet tethering (>1.0 cm) require additional maneuvers to ensure valve competence.





Tricuspid Valve Repair With Various Annuloplasty Rings

Department of Cardiac Surgery, The Leviev Heart Center, Sheba Medical Center, ISRAEL

Dan Spiegelstein, Probal Ghosh, Leonid Sternik, Rafael Koperstein, Micha S. Feinberg, Ehud Raanani

We compared clinical outcomes for different tricuspid valve (TV) annuloplasty ring types, in patients requiring surgical intervention for TV disease with or without concomitant disease of the mitral valve.



Early Results

	Flexible n=134	Classic n=46	3 ^D n=104	p value
Mortality	7(5%)	4(9%)	5(5%)	0.61
CVA	2(2%)	0(0%)	0(0%)	0.32
TIA	3(2%)	1(2%)	3(3%)	0.94
Low C.O.	2(2%)	8(17%)	6(6%)	<0.01
ARF/Dias	12(9%)	7(15%)	11(11%)	0.49
New Dialysis	2(1%)	2(4%)	2(2%)	0.50
IABP	1(1%)	3(7%)	5(5%)	0.07
Pacemaker	7(5%)	4(9%)	2(2%)	0.16
Length of stay	10±8	10±8	11±7	0.62

Echo Results

	Flexible n=127	Classic n=42	3 ^D n=99	p value
Mean TR	1.6±0.7	1.9±0.7	1.7±0.6	0.05
TR None/Trivial	60(53%)	10(26%)	30(33%)	0.01
TR Mild	44(39%)	24(63%)	53(59%)	
TR Moderate	5(4%)	3(8%)	6(8%)	
TR Severe	4(4%)	1(3%)	0(0%)	
Freedom from Mild+ TR	60(53%)	10(26%)	30(33%)	0.002
Freedom from Moderate+ TR	104(92%)	34(89%)	83(92%)	0.86

Late Results

	Flexible n=127	Classic n=42	3 ^D n=99	p value
Follow up (month)	23 ± 19	34 ± 22	9 ± 8	<0.01
Late Death	9(7%)	8(19%)	2(2%)	<0.01
Re-operation on TV	3(2.4%)	0(0%)	0(0%)	0.18
Mean NHYA FC	1.6 ± 0.8	1.8±0.9	1.7± 0.8	0.50
NYHA I	54(59%)	15(52%)	41(51%)	0.49
NYHA II-IV	37(40%)	14(48%)	40(49%)	0.49

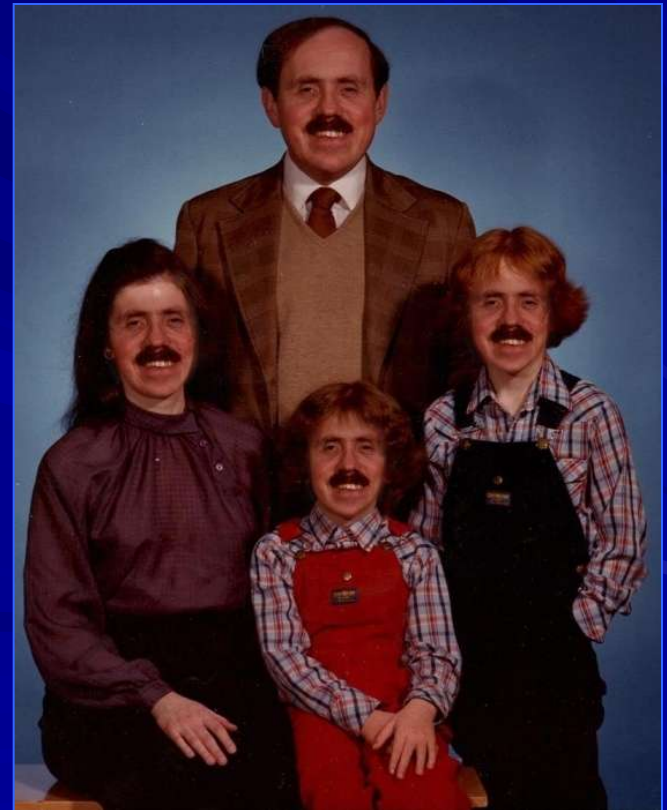
Summary and Conclusions

Early results are similar between rigid and flexible rings
Flexible ring may have less rate of recurrent TR
TV intervention should be more liberal and early
Selection of the "suitable" ring is still unknown

Our strategy

- The systematic and consistent performing TV Annuloplasty for all patients undergoing any open heart surgery and having TV dilatation (> 38 mm) or moderate to severe TR !

Consistency



Advanced thinking

Moderate tricuspid regurgitation

Rationale for Surgical Correction

- Patients with moderate degrees of tricuspid regurgitation require careful consideration, because of the possibility that the severity may have been underestimated

(vasodilators, diuretics, inotropes, fasting, and general anesthesia may result in downgrading of severe tricuspid regurgitation)

- Any patient who has any prior documentation of severe regurgitation should undergo tricuspid valve repair, as severe regurgitation at any point infers an abnormally functioning valve
- Coexisting pulmonary hypertension is an indication for tricuspid valve repair, and if present in the setting of moderate regurgitation, it should alert the clinician to the possibility that regurgitation severity is being underestimated

Moderate tricuspid regurgitation

Rationale for Surgical Correction

- Because of the secondary tricuspid regurgitation's dynamic nature, patients with mild or moderate degrees of tricuspid regurgitation may still have severe valvular dysfunction
- Regardless of severity, any degree of tricuspid regurgitation other than trivial is undesirable

Nath J, Foster E, Heidenreich PA: *J Am Coll Cardiol* 2004, **43**:405–409.

- Evidence from surgical series suggests that the severity of mild to moderate tricuspid regurgitation occurring after mitral valve surgery increases over time and is associated with poorer long-term survival and higher reoperation rates

Tricuspid Annular Dilatation Assessment

- Measurement of the annular diameter should be part of pre-/ intraoperative transesophageal echocardiographic assessment
- An abnormal intercommissural annular diameter recorded on any view of more than 35 mm likely represents a dilated annulus
- *Currently in Mount Sinai Hospital, 70% of mitral valve repair patients receive concurrent tricuspid valve repair for annular dilatation or valve regurgitation*

Incremental Risks Associated with Tricuspid Valve Repair

- In the present era, the risk of tricuspid valve repair at the time of mitral valve surgery is probably negligible, as patients usually do not have associated end-organ dysfunction, which increases perioperative risk as was historically seen in patients having tricuspid valve surgery
- Two groups who liberally applied tricuspid valve repair for annular dilatation at the time of mitral valve repair reported an operative mortality of 0.7% and 2%

Secondary Tricuspid Regurgitation



Tricuspid Annuloplasty

Let's do this!



It is fast, simple, effective and beneficial

Secondary Tricuspid Regurgitation

Conclusions

- Secondary tricuspid regurgitation commonly occurs in combination with left-sided valvular heart disease and will often not improve despite correction of the left-sided valve dysfunction
- Because tricuspid regurgitation occurring after prior mitral surgery carries a poor prognosis, surgical repair of the tricuspid valve at the time of mitral valve surgery is recommended for treating and preventing secondary tricuspid regurgitation
- Assessing the tricuspid valve annular dimensions must be a part of all mitral valve operations, and annuloplasty strongly considered in patients with tricuspid annular dilatation or moderate to severe tricuspid regurgitation
- Future randomized trials will determine whether there is a role for prophylactic tricuspid valve repair in all patients undergoing mitral valve surgery

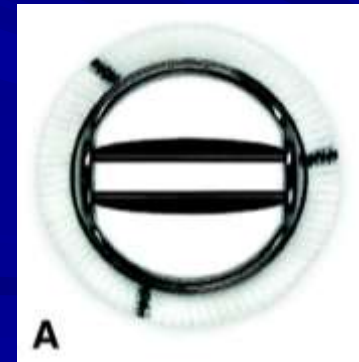
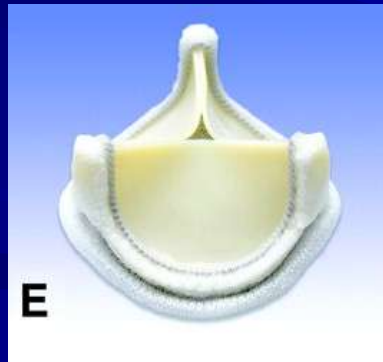
Our message is:



To be liberal in the indications for Tricuspid Annuloplasty

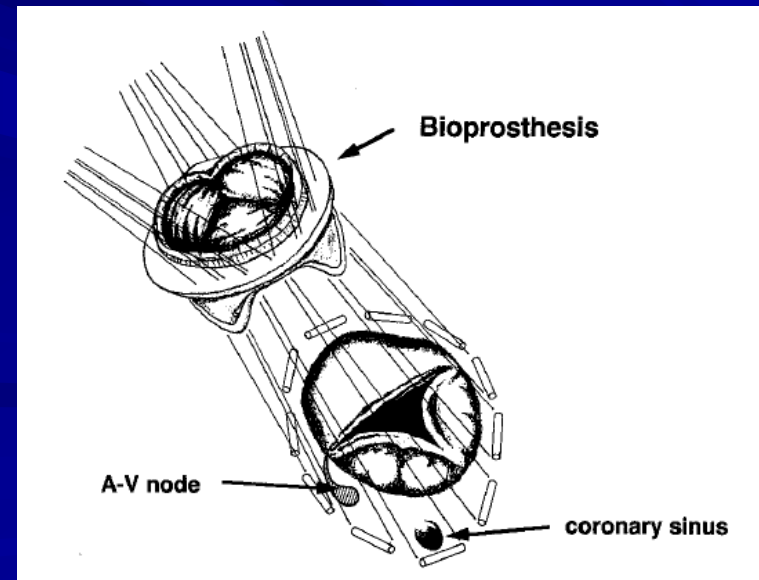
TV Replacement

- Although repair is preferred, valve replacement is necessary when the valve leaflets themselves are diseased, abnormal, or destroyed. Thrombosis with mechanical tricuspid valves is rare (1% per year)
- Overall survival has been shown to be equivalent between bioprosthetic and mechanical valves in a recent large metaanalysis



TV Replacement

- TV repair appears to result in improved mid-term survival (up to 10 years after surgery, primarily as a result of higher perioperative mortality with replacement) as compared with tricuspid valve replacement
- Higher perioperative mortality with replacement may have been due to a rigid object (tricuspid valve), that leads to loss of tricuspid annular contraction which finally impedes right ventricular function.
- TV supra-annular implantation avoids this phenomenon



Collaboration - Heart Team



*If you want to go fast, go alone;
If you want to go far, go together*

old African proverb

Secondary Tricuspid Regurgitation



Thank You

SURGEON'S VIEW

*Secondary TR
Patients*



Secondary TR

Different Mechanisms

- Pulmonary arterial hypertension, resulting in pressure overload on the right ventricle and can directly result in tricuspid regurgitation.
- Left ventricular septal dysfunction also causes dysfunction of the right septal wall, the area of origin of the papillary muscles(chords) to the septal leaflet of the tricuspid valve.
- Geometric change of the RV, characterized or by homogenous, or by heterogenous dilatation in the septal-lateral direction, has much effect on coaptation of the TV leaflets as a result of displacement of the papillary muscles
- A stretched RV wall and subsequent loss of RV contraction surrounding the TV annulus (dilated, flattened, and circular annulus)
- Combination of mechanisms

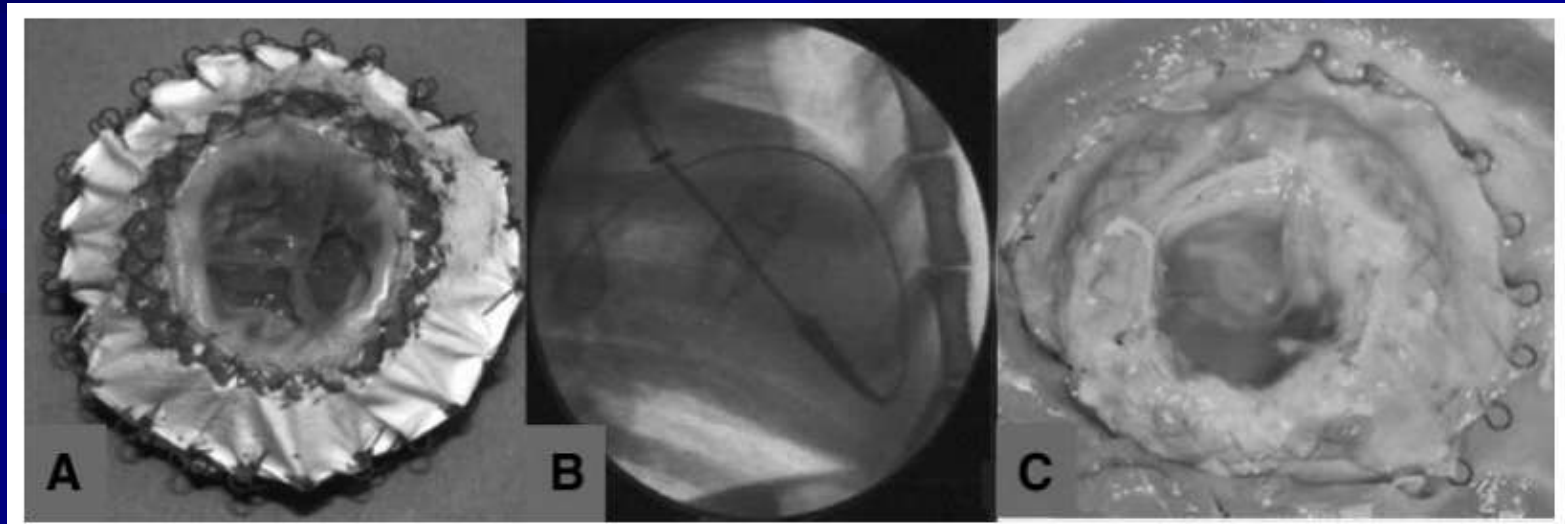


רפואה – זה אומנות
לעבוד על החולה בזמן שהטבע עושה את שלו

TV Percutaneous

Relevance in the Percutaneous Era

- To date, there have been few reports describing percutaneous approaches to tricuspid valve disease
- In 2005, Boudjemline et al. described a novel percutaneous tricuspid valve consisting of a bovine jugular venous valve mounted to a self-expanding nitinol frame consisting of 2 disks
- The device was implanted in seven normal sheep, but no further work has been done with this device



Relevance in the Percutaneous Era

- Nitinol stent with a self-expandable super-absorbent polymer (SAP), composed of right atrial anchoring elements, a right ventricular tubular stent, and a trileaflet bovine pericardial valve. The stent is coated with a waterproof material, and a pouch containing SAP for minimizing paravalvular leakage
- Twin valve caval stent for functional replacement

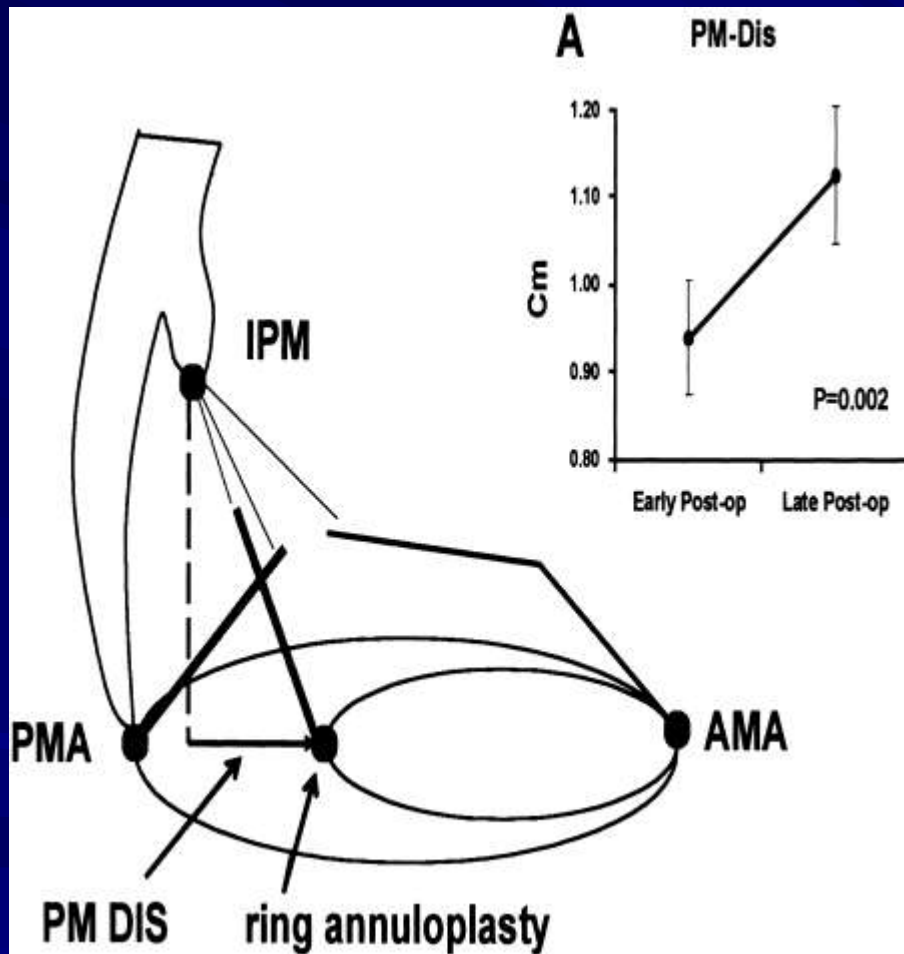
Unanswered Questions

Functional Mitral & Tricuspid Regurgitation

The Same Main Discussion Issue

Is Functional MR/TR just a marker of poor LV/RV function or this is a major contributor to decreased survival rates?

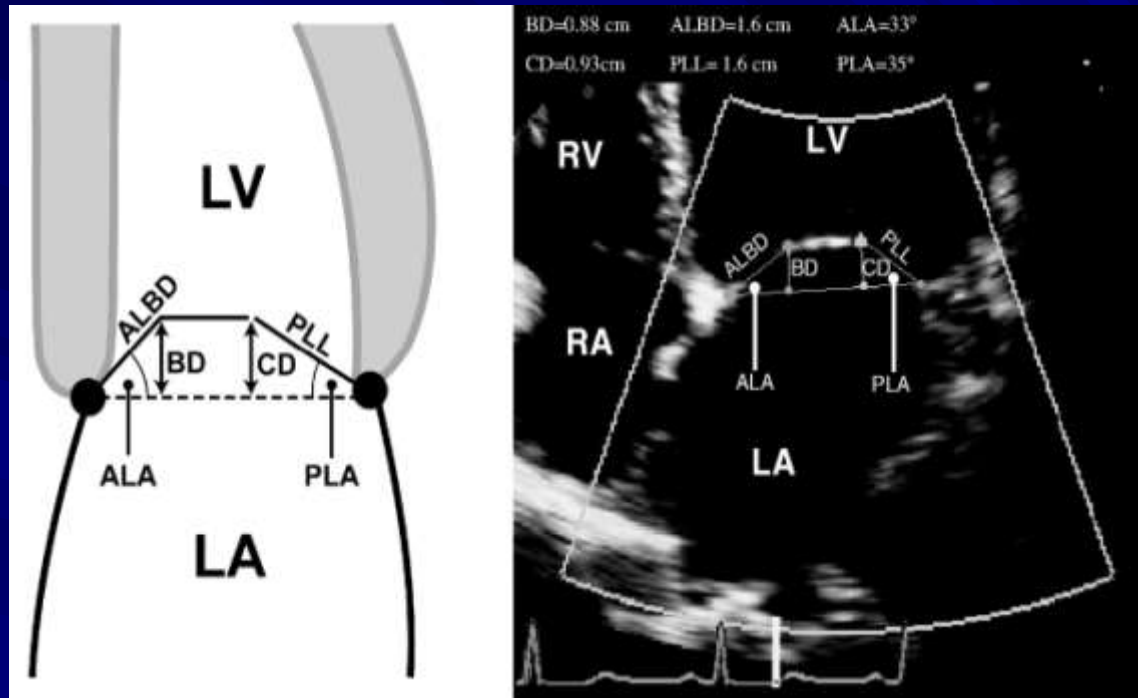
Restrictive Ring Annuloplasty



- Addresses only the annular end & does not address tethering
- Exacerbates papillary muscle displacement by increasing distance from the papillary muscle to the mitral annulus
- Converts the valve into unicuspid valve with rigid posterior and restricted anterior leaflet

Restrictive Ring Annuloplasty

Extremely poor candidates

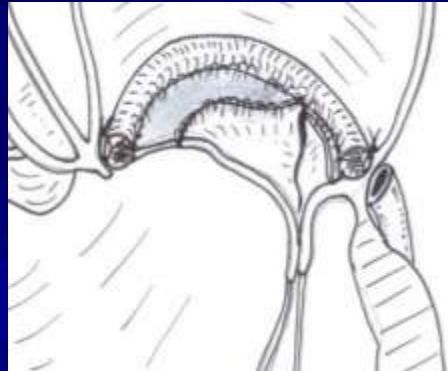


- Posterior leaflet angle $\geq 45^\circ$
- Tenting area $\geq 2.5 \text{ cm}^2$
- Coaptation distance $\geq 1 \text{ cm}$

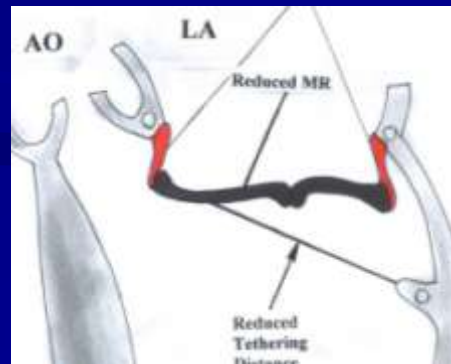
Those are patients with advanced Ischemic MR required an advanced MV Repair

Advanced surgical approaches for Advance Ischemic MR patients

- Mitral valve leaflets augmentation



- Mitral valve leaflets relocation



Indications for TV Surgery

- TR does not simply “go away” after mitral valve surgery
- Tricuspid valve repair currently appears underutilized

Indications for TV Surgery

- Given the adverse consequences of allowing TR to progress to severe (such as worsening symptoms of right heart failure), it would seem logical that earlier intervention for TR, especially in the presence of ongoing right atrial and right ventricular enlargement, would be beneficial

Postulates



- Reduction in degree of pulmonary hypertension (by mitral valve repair) could result in less tricuspid regurgitation, but this would first require reverse remodeling of the previously dilated right ventricle, which may not be instantaneous
- Two ventricles are interdependent at the septum, left ventricular septal dysfunction also causes dysfunction of the right septal wall, the area of origin of the papillary muscles to the septal leaflet of the tricuspid valve
- Patients having tricuspid valve repair at the time of mitral valve surgery did better in the long term compared with patients who did not
- Although in some patients, significant tricuspid regurgitation will resolve with correction of the left-sided lesion, there is no means of accurately predicting this at the time of mitral surgery
- For survivors of reoperative surgery because of a high rate of persistent or recurrent heart failure and continued elevated risk of death despite resolution of tricuspid regurgitation
- The poor prognosis for tricuspid regurgitation occurring after mitral valve surgery
- Limited effectiveness of surgical therapy at this late stage
- Annular dilatation represents the early stages of secondary tricuspid regurgitation

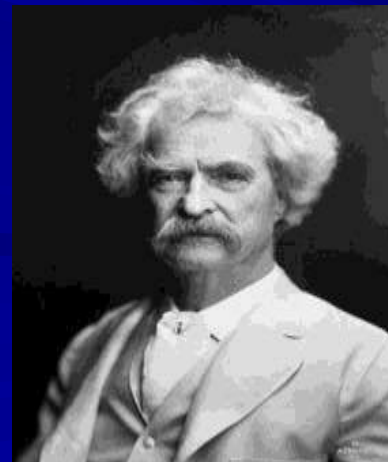
CUT BY ME 27.10.11

CUT BY ME 27.10.11

This Presentation

I met two problems:

- “Don't tell fish stories where the people know you; but particularly, don't tell them where they know the fish.”
- “Not that the story need be long, but it will take a long while to make it short.”



Ventricular Interdependence



אנחנו מכירים ?

Secondary Tricuspid Regurgitation

Pathophysiology

Functional TV incompetence
“A normal valve with dilated annulus”



- The mechanism of this regurgitation is complex, and it is unlikely the valve is truly “normal”
- Recent echocardiographic studies have demonstrated abnormal geometry and function of the tricuspid valve in patients with functional regurgitation

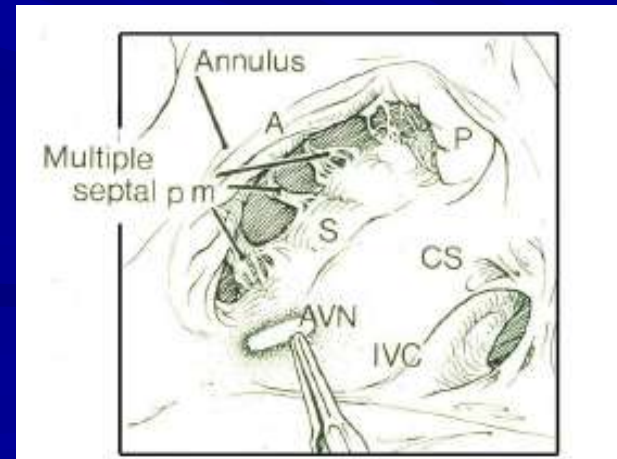
Fukuda S, Gillinov AM, Song JM, et al.: *Am Heart J* 2006, **152**:1208–1214.

Ton-Nu TT, Levine RA, Handschumacher MD, et al.: *Circulation* 2006, **114**:143–149

Secondary Tricuspid Regurgitation

Geometrical alteration

- Geometrical alteration of the tricuspid apparatus are caused by interaction between:
 - *altered tricuspid annulus size and shape,*
 - *right ventricular remodeling, and*
 - *displacement of papillary muscles,*which lead to ***leaflet tethering***



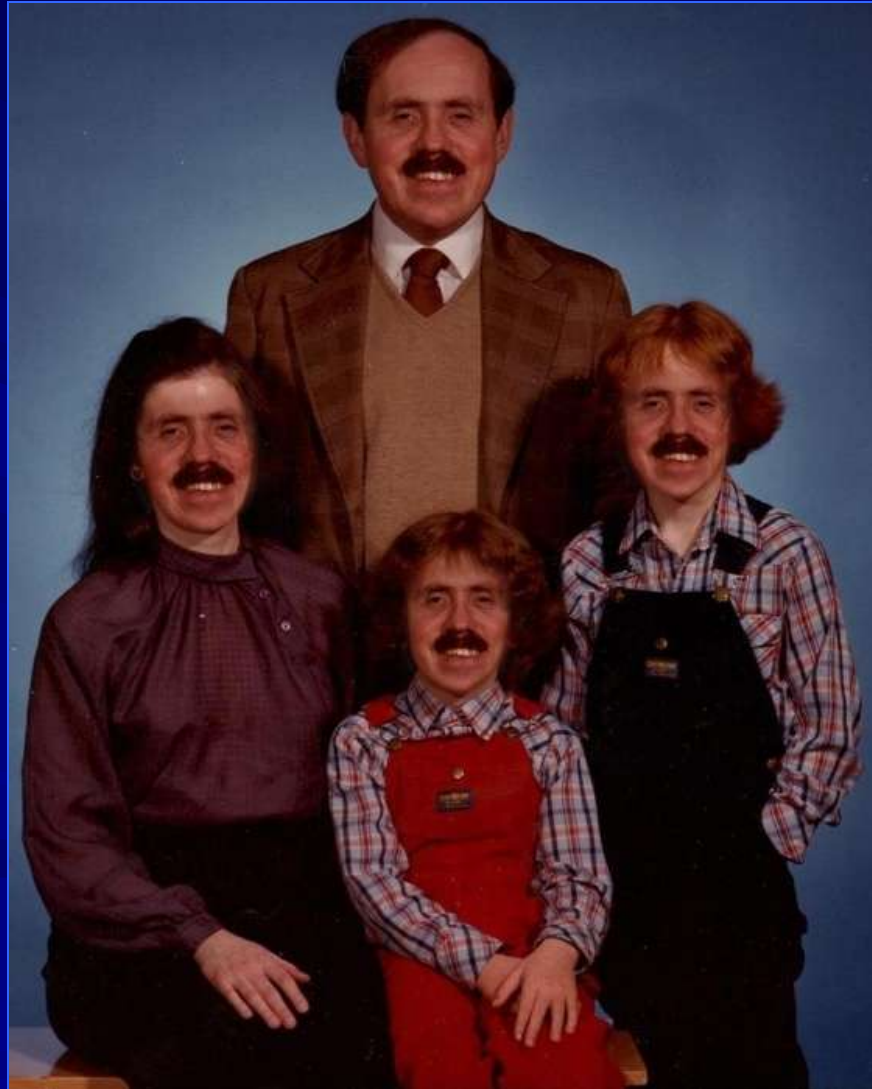
Secondary Tricuspid Regurgitation

Tricuspid Annular Dysfunction

- Kim et al. support this theory in an echocardiographic study of 75 patients with right ventricular dilatation.
- Predictive of the severity of secondary tricuspid regurgitation were:
 - eccentricity of the right ventricle
 - tricuspid valve tethering (tenting) area
 - end-diastolic tricuspid annular diameter
- Non significant predictive factors of the severity of secondary tricuspid regurgitation were:
 - the right ventricular dimensions
 - right ventricular function
 - pulmonary artery pressures
- All these suggesting that change in geometry of the right ventricle and the consequent papillary muscle displacement, is the critical factor in the pathophysiology of tricuspid regurgitation.
- Whereas such eccentric displacement of the ventricle is more likely to occur in the globally dilated ventricle, it can also occur in normal-sized ventricles

Systematic Tricuspid Valve Repair

Consistency



Heart Team



Severe tricuspid regurgitation

- The American College of Cardiology and American Heart Association guidelines recommend repair of all valves with severe tricuspid regurgitation in patients undergoing mitral valve surgery

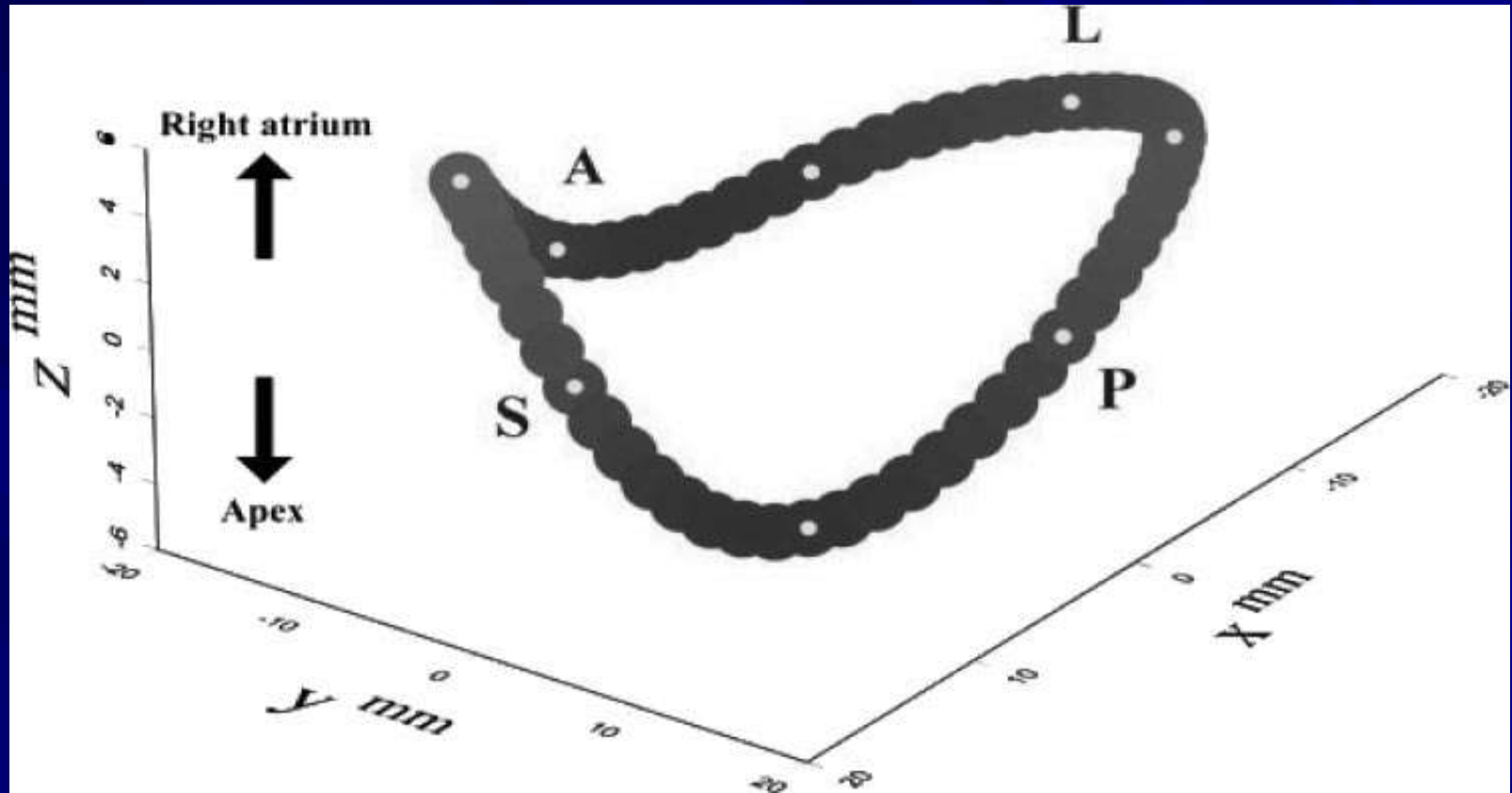
ACC/ AHA 2006 guidelines for the management of patients with valvular heart disease: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (writing committee to revise the 1998 Guidelines for the Management of Patients With Valvular Heart Disease), *Circulation* 2006, 114:E84–E231.

Despite this

- Most authorities would now recommend repairing the tricuspid valve in any patient with a less than severe tricuspid regurgitation undergoing any heart operation

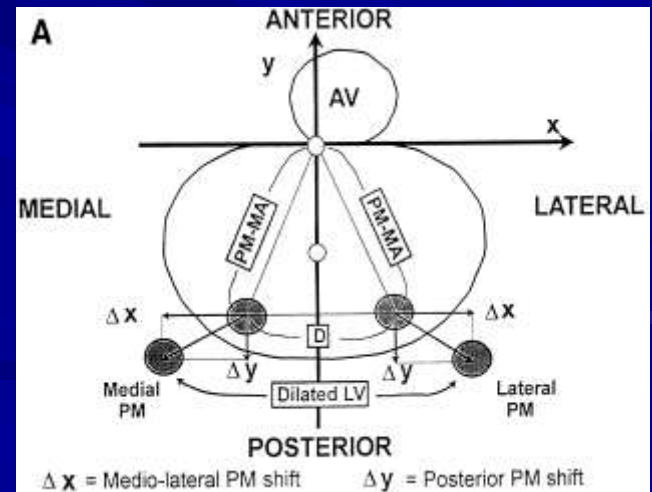
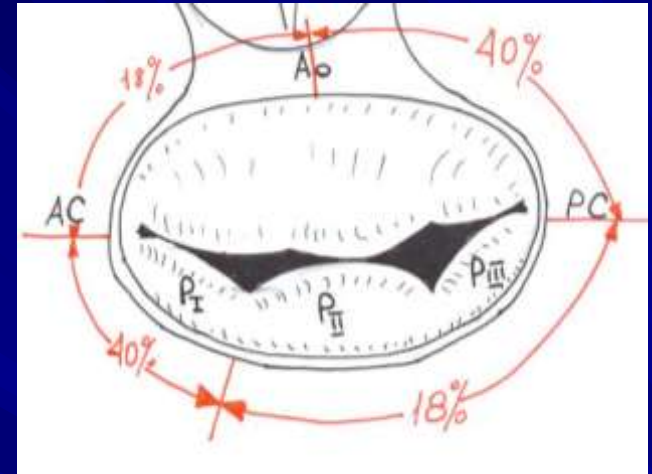
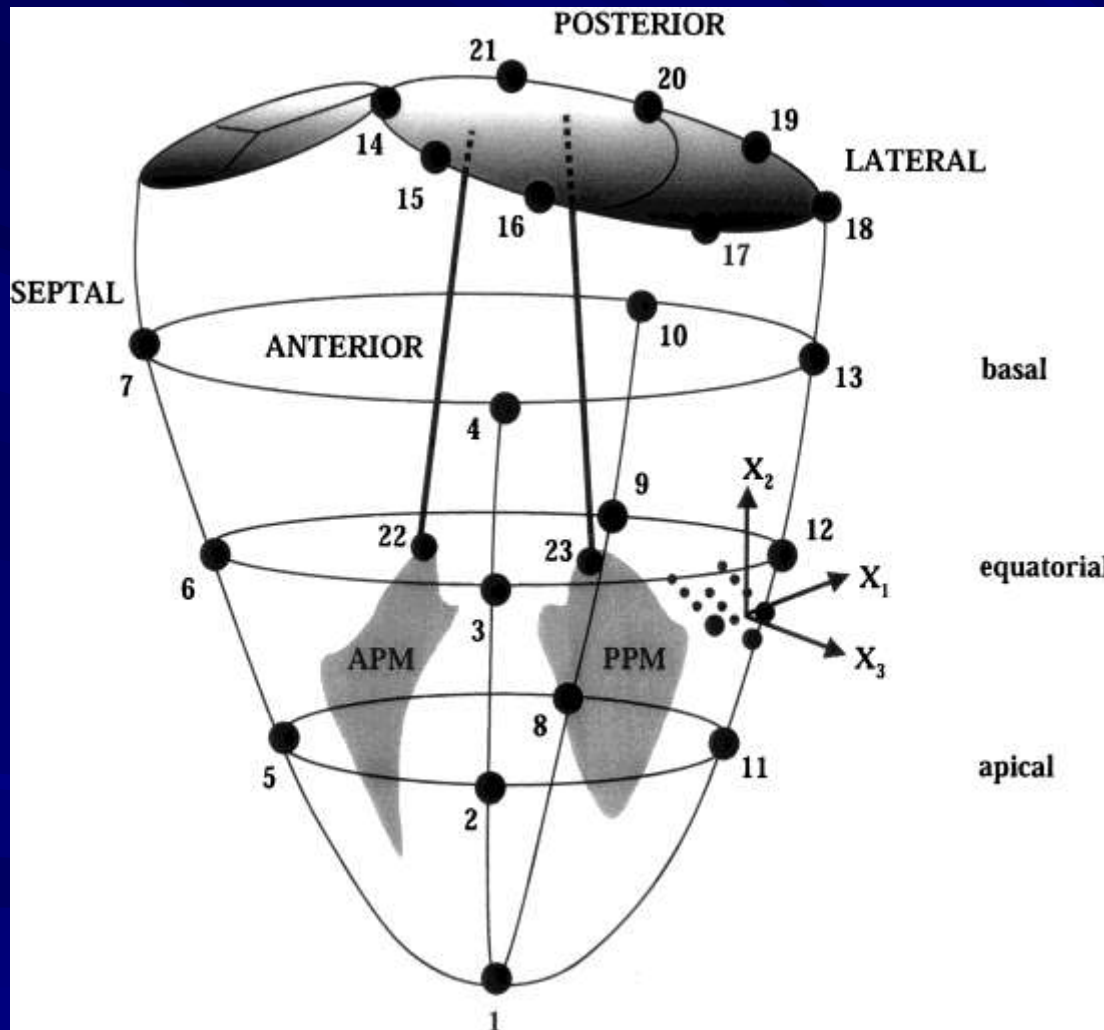
But this postulate is not completely correct too. Why?

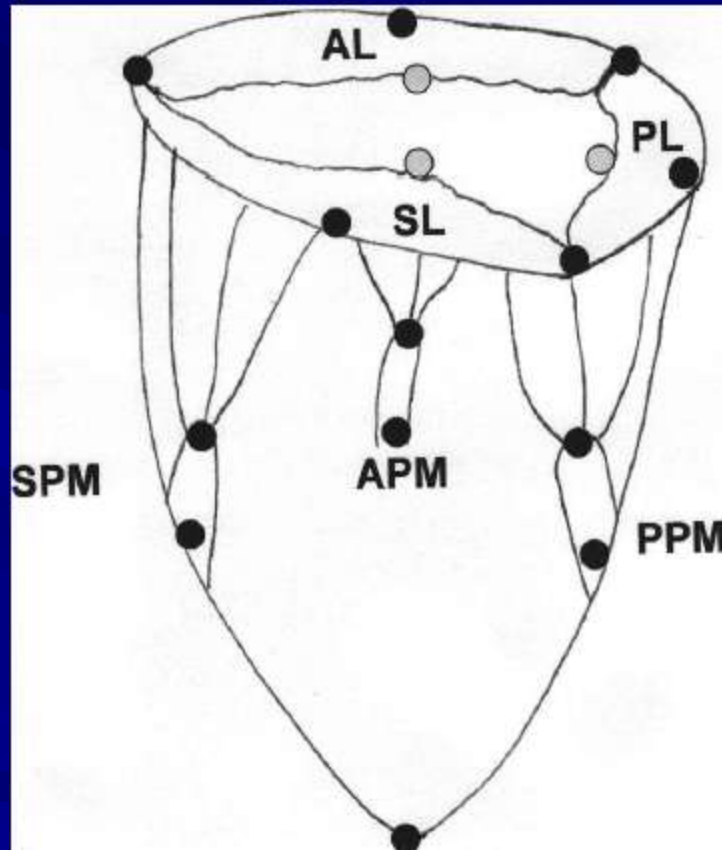
Tricuspid valve complex



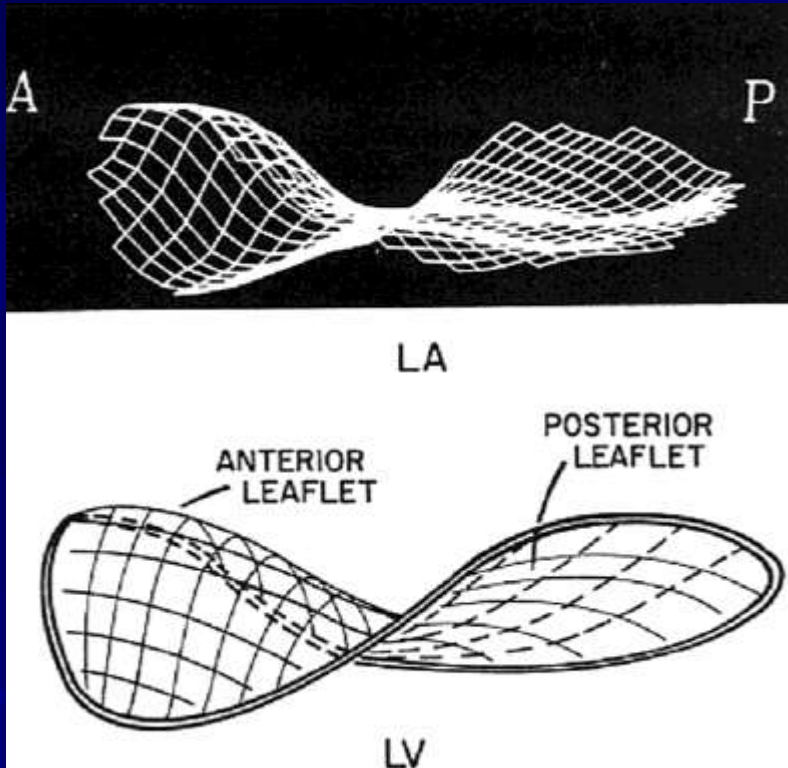
- The tricuspid annulus has a complex 3-dimensional structure, which differs from the more symmetric “saddle-shaped” mitral annulus.
- This distinct shape has implications for the design and application of currently available annuloplasty rings in the tricuspid position (most currently available rings are essentially planar). The novel approaches or rings tailored to the unique tricuspid annular shape might improve ventricular function and reduce leaflet stress.

Pathophysiology of Ischemic MR

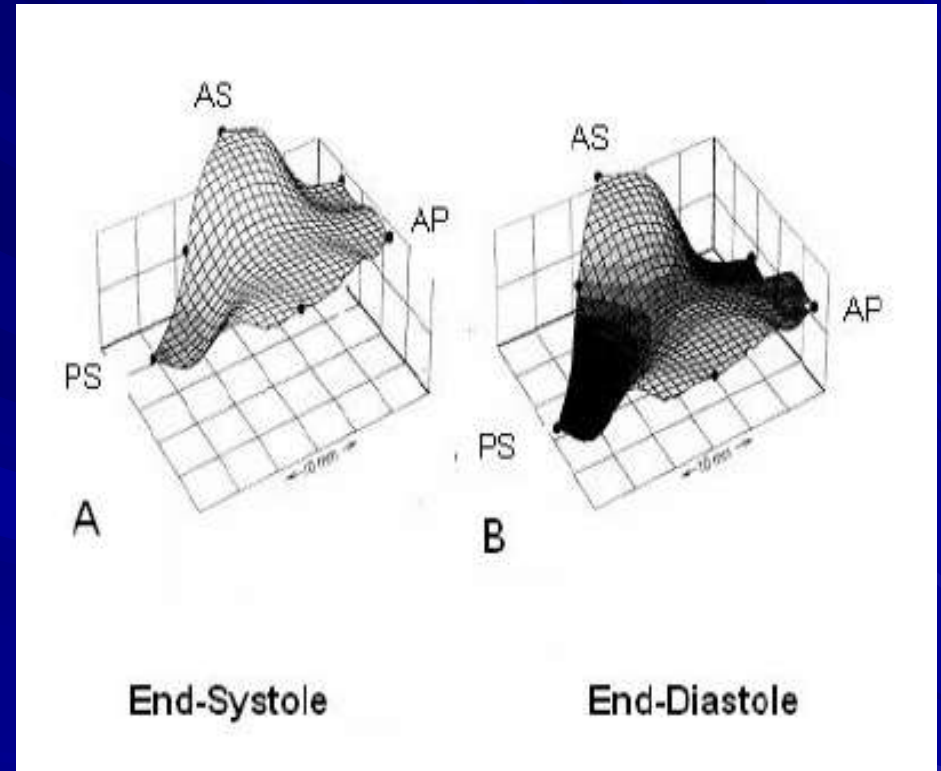




3-D Shape



MV



TV

Secondary Tricuspid Regurgitation

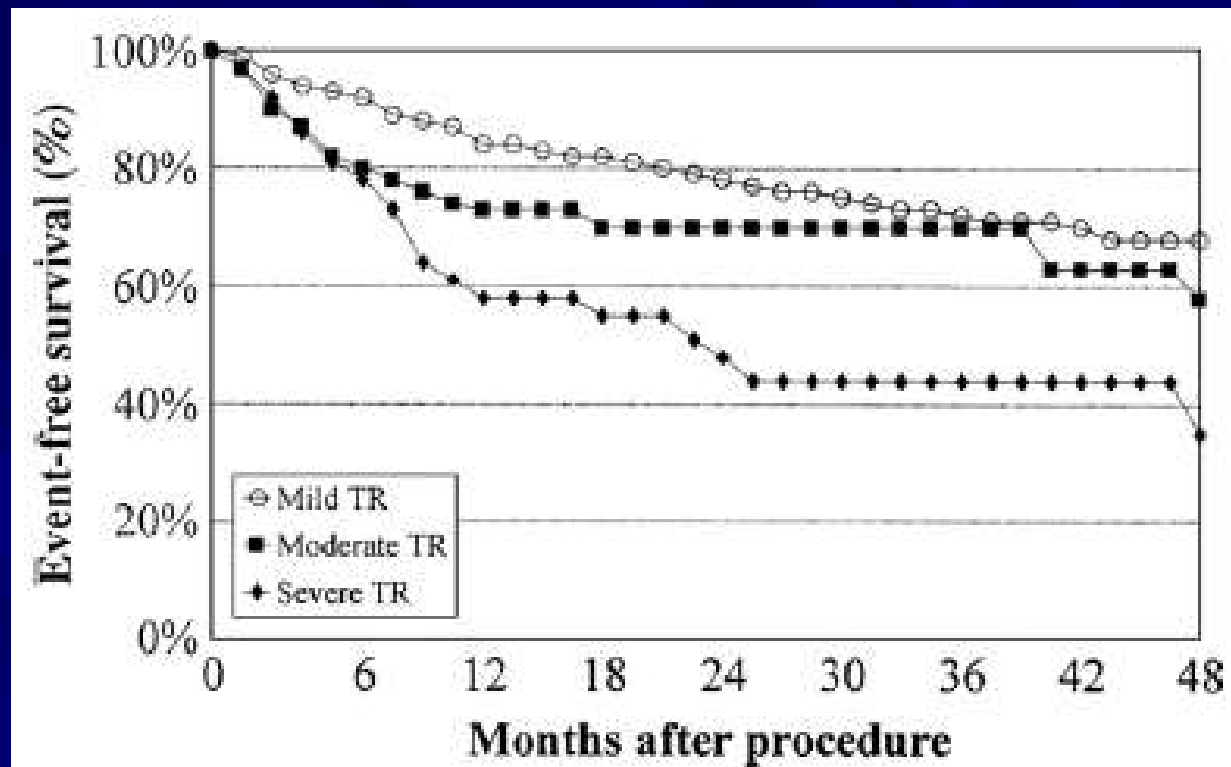
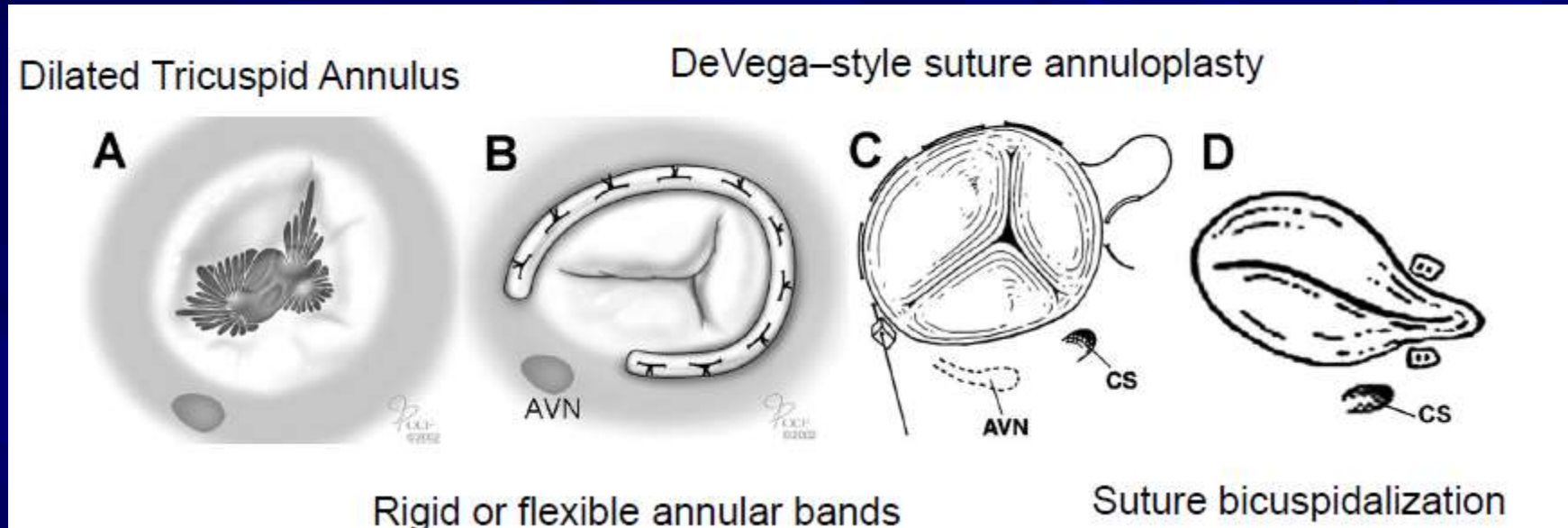


Figure 2

Event-Free Survival After Balloon Mitral Valvotomy by TR Severity

Events were defined as death, New York Heart Association functional class III or IV, MV surgery, or repeat mitral valve balloon valvotomy (n = 318). Patients with severe tricuspid regurgitation (TR) had significantly worse event-free survival compared with patients with mild TR.

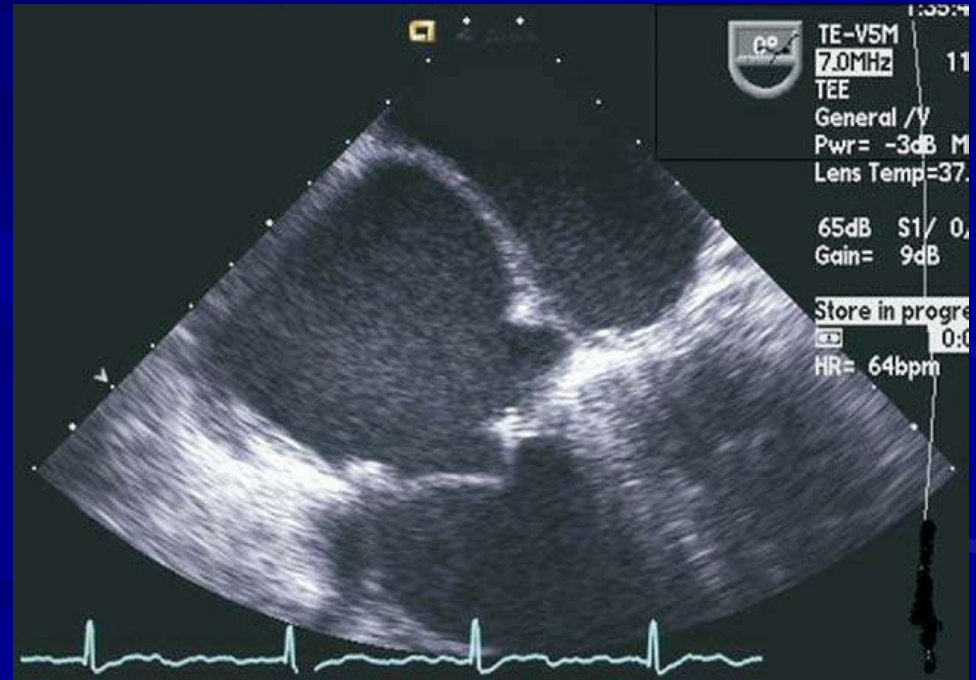
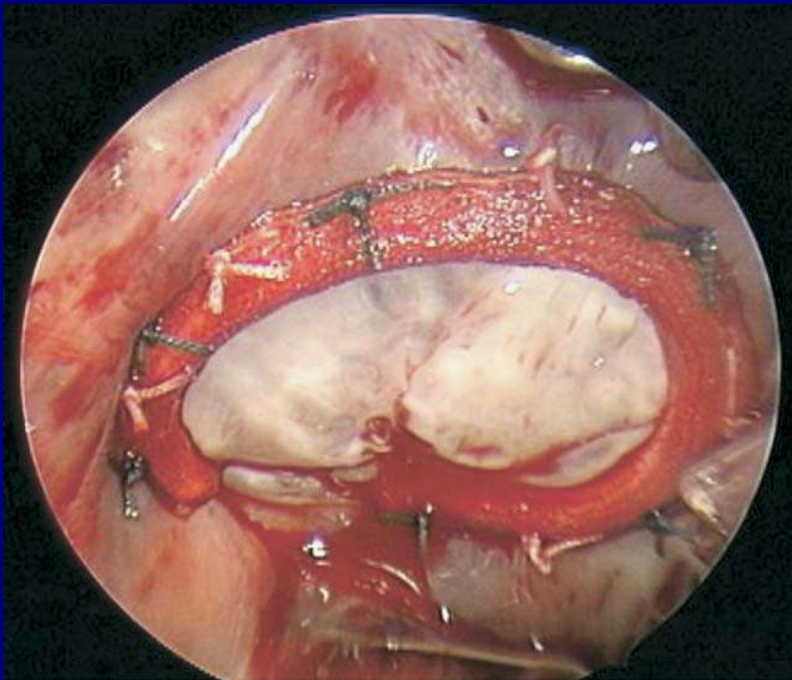
Surgical Techniques for Secondary TR



- (A) Dilated tricuspid annulus with abnormal circular shape, failure of leaflet coaptation, and resultant TR. Dilation occurs primarily along the mural portion of the tricuspid annulus, above the right ventricular free wall
- (B) Rigid or flexible annular bands are used to restore a more normal annular size and shape (ovoid), thereby reducing or eliminating TR
- (C) DeVega-style suture annuloplasty in which a purse-string suture technique is used to partially plicate the annulus and reduce annular circumference and diameter
- (D) Suture bicuspidalization is performed by placement of a mattress suture from the anteroposterior to the posteroseptal commissures along the posterior annulus

Surgical Techniques for Tricuspid Valve Repair

Edwards MC3 annuloplasty system



Intraoperative and two-chamber TEE views of the Edwards MC3 annuloplasty system (Edwards LifeSciences, Irvine, CA).

Systematic Tricuspid Valve Repair

Rationale for Surgical Correction

- Lower long-term incidence of significant tricuspid regurgitation and better symptom status in patients having concomitant tricuspid valve repair at the time of mitral valve repair, and also the late occurrence of significant regurgitation in some patients who had a nondilated annulus at initial surgery, raises the question as to whether all patients should have a tricuspid repair at the time of mitral surgery

Dreyfus GD, Corbi PJ, Chan KM, Bahrami T: *Ann Thorac Surg* 2005, **79**:127–132.

Systematic Tricuspid Valve Repair

Rationale for Surgical Correction

- The low risk of tricuspid repair, high prevalence of late secondary tricuspid regurgitation, the inability to reliably predict which patients will develop secondary regurgitation, and the high mortality and morbidity associated with severe tricuspid regurgitation, it may ultimately prove beneficial to perform prophylactic tricuspid repair in most patients having mitral valve surgery regardless of the presence of annular dilatation or regurgitation