Functional Anatomy of the Tricuspid Valve and Right Ventricle

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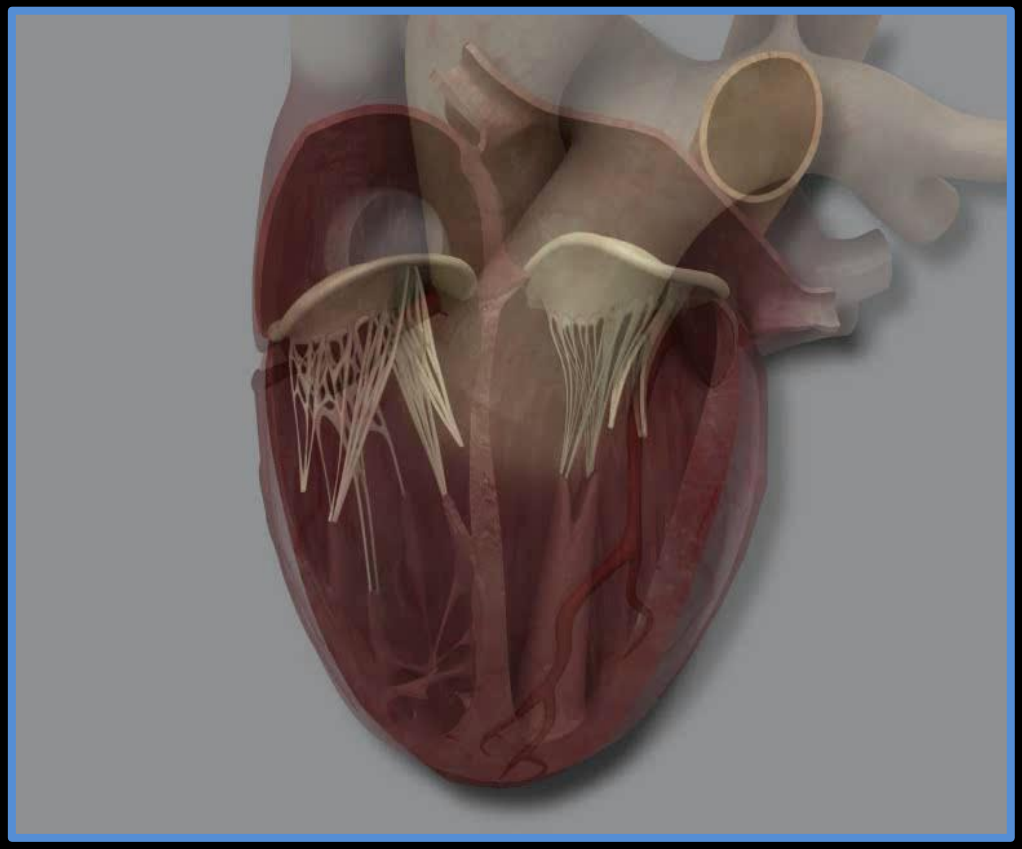
Tricuspid valve

- TV is the inflow valve of the RV

- In contrast with MV, the TV has a direct relationship with the septum, but not in the continuity with the pulmonary valve as the mitral valve is with the aortic valve

Tricuspid valve anatomy

- Annulus
- Leaflets
- Commissures
- Chords
- Papillary muscles
- RV wall



Tricuspid valve anatomy and pathology is much more complex as it appears to be

Tricuspid valve annulus

- The annulus is only partially fibrous at the level of the membranous septum and has a strict realtionship with the aortic annulus.
- The most part of the anulus is muscular.

Tricuspid valve annulus

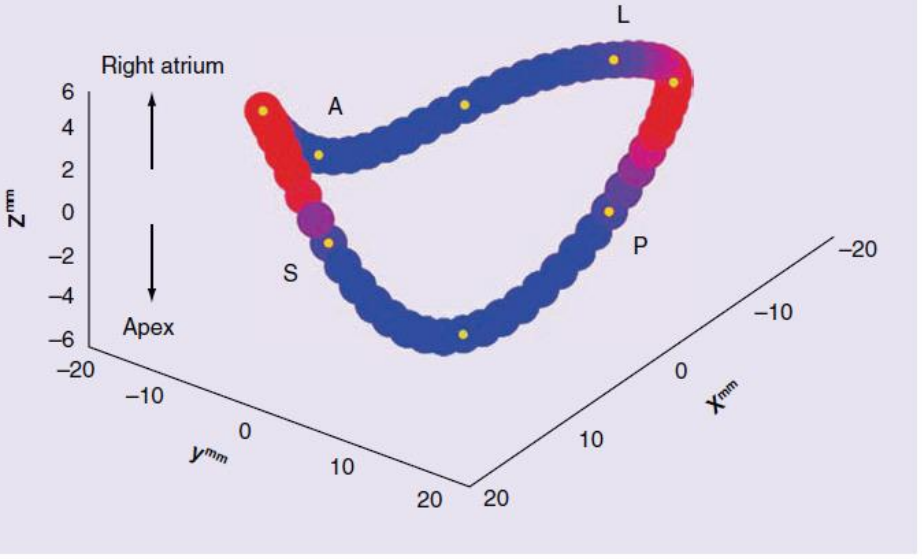
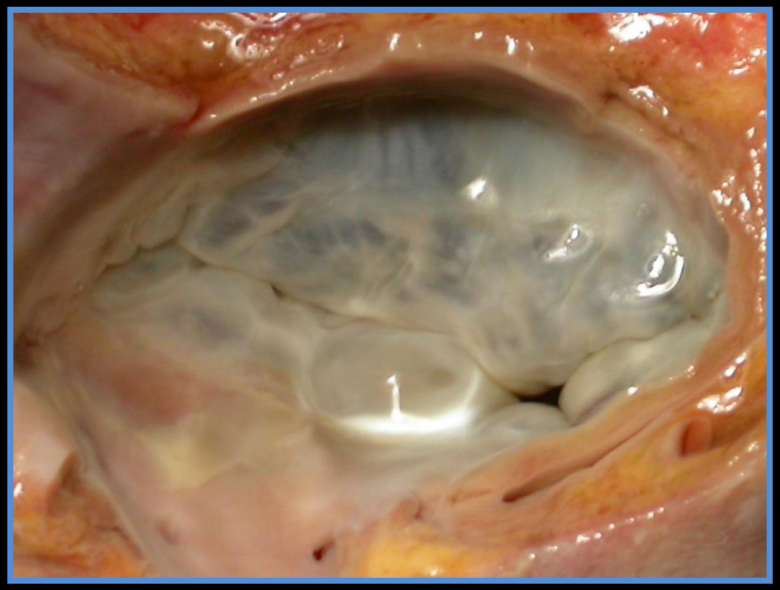
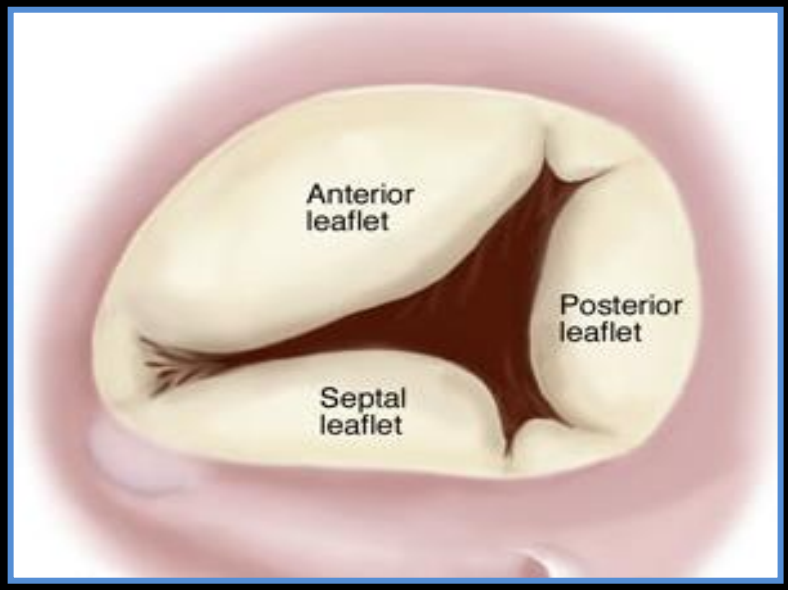


Figure 2. Reconstructed tricuspid annular shape in healthy subjects when tricuspid annular area is the smallest. The part in red indicates the highest portion toward the atrium.
A: Anterior; L: Lateral; P: Posterior; S: Septum.

- The annulus is not planar , but shows a complex 3D shape, with the highest point being located anteroposteriorly and the lowest point mediolaterally.
- The high-low distance is about 7.2

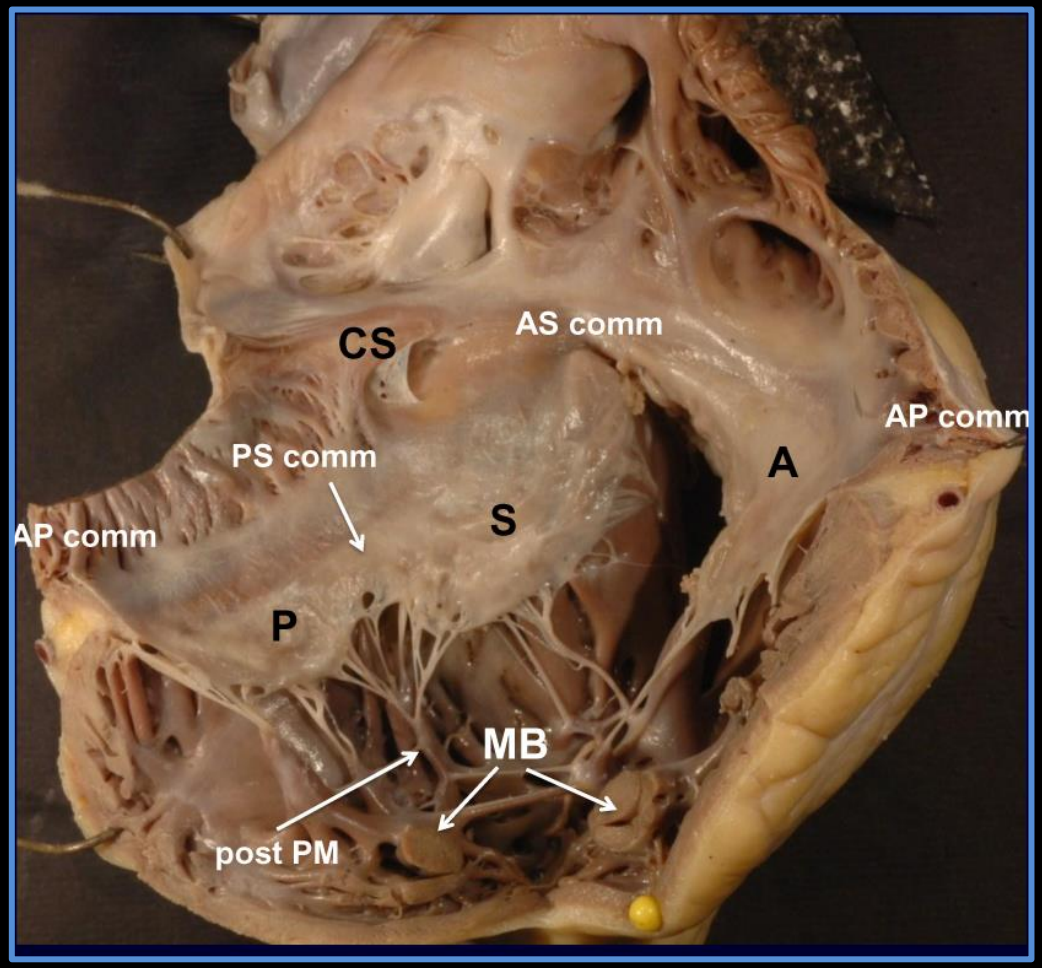
Tricuspid Leaflets





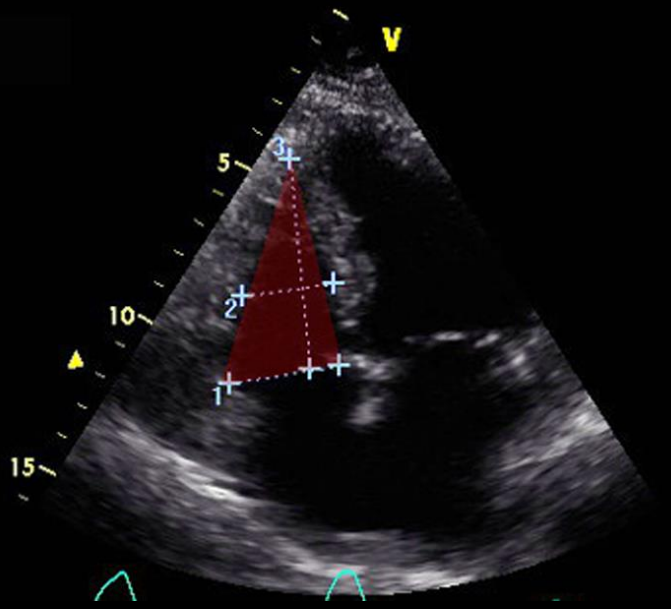
There are 3 leaflets: the septal, anterior and posterior one.

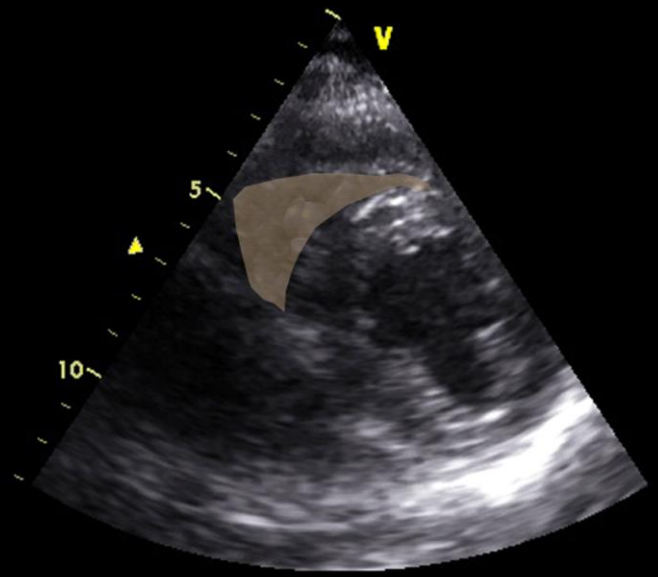
Papillary muscles

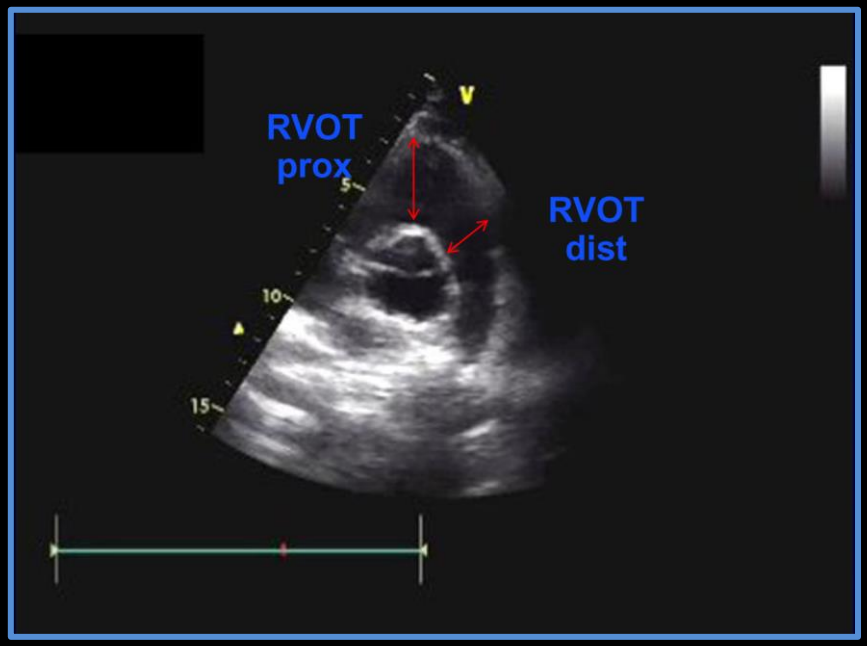


- The septal PM is the furthest from the centroid and the closest to the annular plane.
- The anterior PM was the most apical

The shape of the RV







RV shape is also dependent on the position and function of the interventricular septum.

The RV in normal human heart

- The right ventricle volume is large than the LV, the septum is concave towards the LV in both systole and diastole.

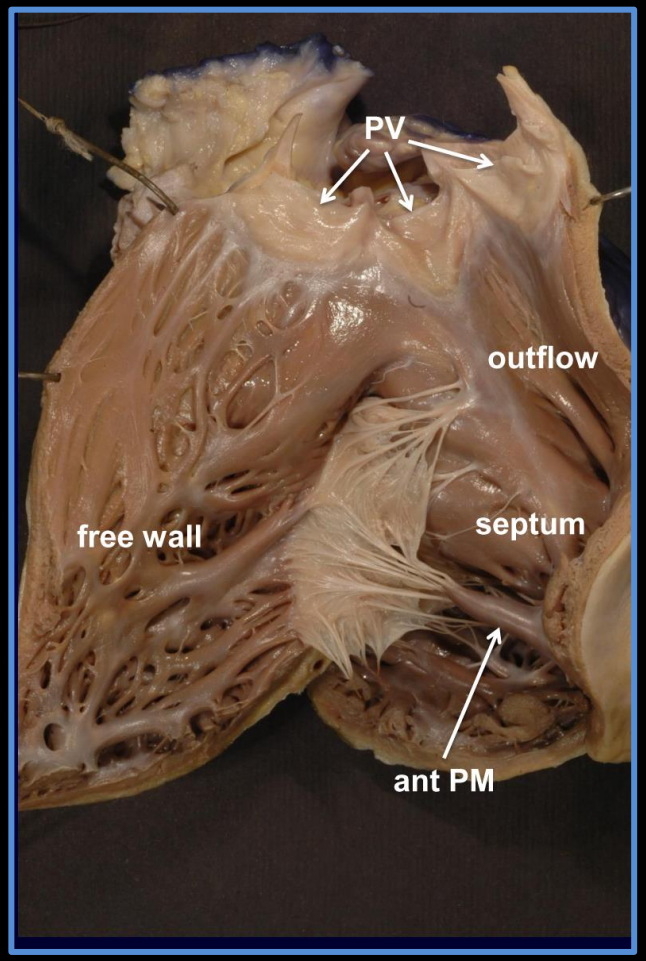
- The normal range of RV end-diastolic volume is 49-101ml/m2, whereas the normal range of LV is 44-89ml/m2

  Kovalova S, et al. Eur J Echocardiogr. 7(4), 293-297. 2006

- The RV mass is approximately a third that of LV mass: 26 g/m2 versus 87 g/m2

  Lorenz CH, et al. J. Cardiovasc. Magn. Reson. 1(1), 7-21. 1999

Right ventricle walls



- The RV has 3 walls: anterior, inferior and septal, with the last in common with the LV
- There are 3 RV components: the inlet portion (between the TV and the base of PPMs), the apical trabecular portion shows coarser trabeculations than the LV, and the outlet corresponds to the outflow tract.

Muscle layers

- Superficial muscle layer:

fibers are arranged more or less circumferentially in a direction that is parallel to the atriovantricular groove. These fibers turn obliquely toward the cardiac apex and continue into the superficial LV myofibers.

- Deep muscle layer:

fibers are arranged longitudinally from base to apex.

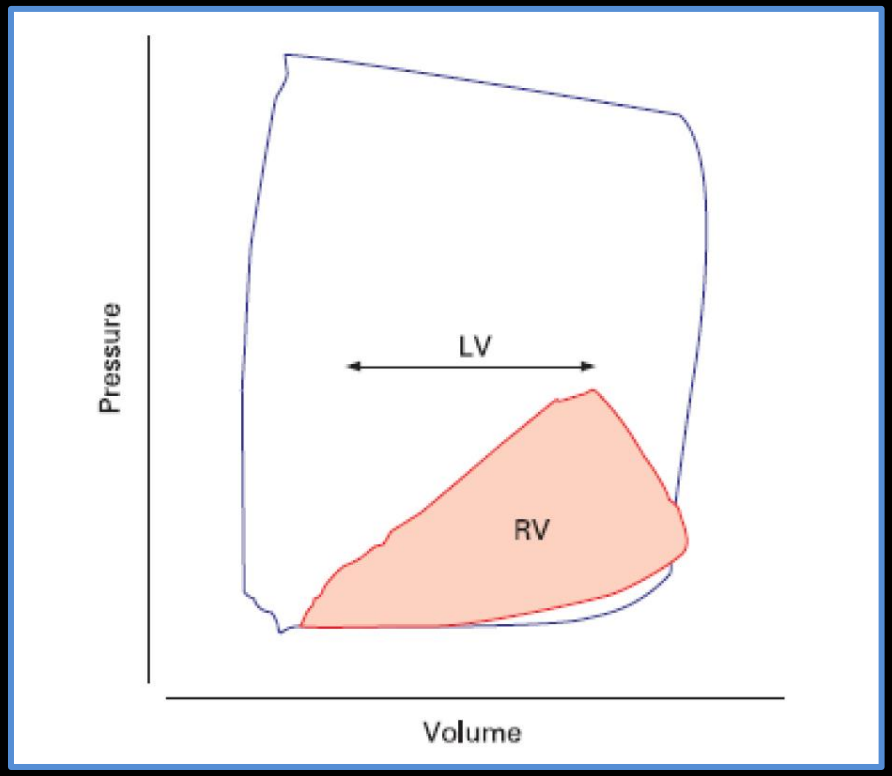
- In contrast to the RV, the LV contains obliquely orients myofibers superficially, longitudinally oriented fibers in subendocardium, and predominantlly circular fibers in between.

- This arragement contribute to more complex movement of the LV, which includes torsion, translation, rotation and thickening.

The ventricular interdependence

- The continuity between the muscle fibers
- Interventricular septum and pericardium

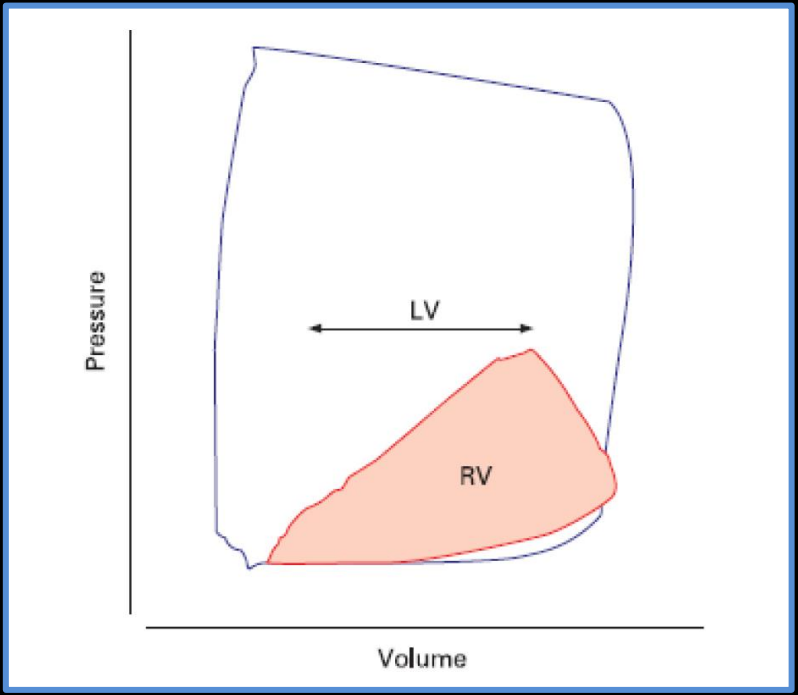
The pressure-volume relationship



- The RV is an energetically efficient pump, almost entirely dependent on the low pulmonary hydraulic impedance.
- This is a dynamic phenomen.

Redington AN, et al. Characterisation of the normal right ventricle presure-volume relation by biplane angiography and simultaneous micromanometre pressure measurements.
Br. Heart J. 59(1) 23-30 (1988)

The Hangout period



- **The RV contraction is dependent on its loading condition.**
- **The RV contract in a peristaltic manner.**

Schaver JA, et al. Sound pressure correlates of the second heart sound. Circulation 49 (2), 316-325 (1974)

RV & LV

The impact of the LV contractility on RV function is well known.

1. Whereas the RV contribution to develop pressure in the LV was minimal, the LV caused pronounced pressure generation in the RV.

2. Approximately 30% of the contractile energy of the RV was generated by the LV.

Damiano Rj. et al. Significant left ventricle contribution to right ventricle systolic function. Am. J. Physiol. 261 (5 Pt 2), H1514-1524 (1991)

RV & LV

Impact of LV unload on RV function

- LV volume reduction
- RV volume expansion
- Load-independent RV dysfunction
- RV heart failure

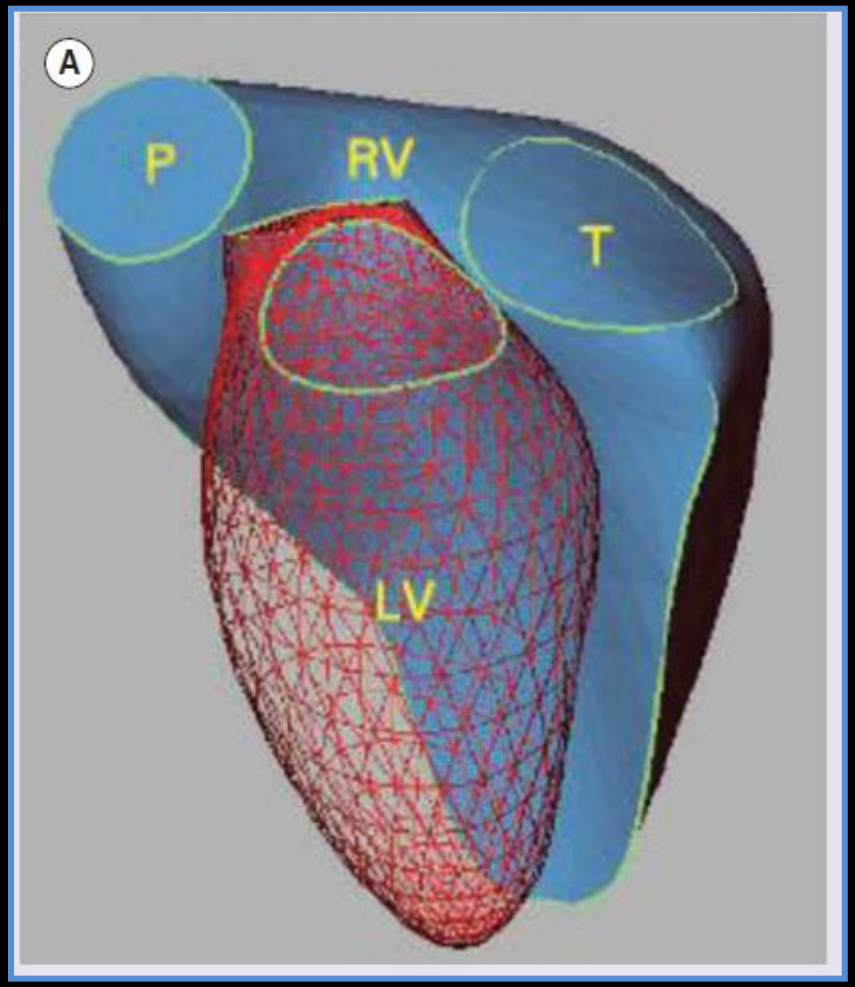
This is caused by chronic septal displacement into the LV that lead to septum fibrosis, reducing thickening and dysfucntion

Moon MR, et al. Septal function during left ventricular unloading. Circulation 95(5), 1320-1327 (1997)

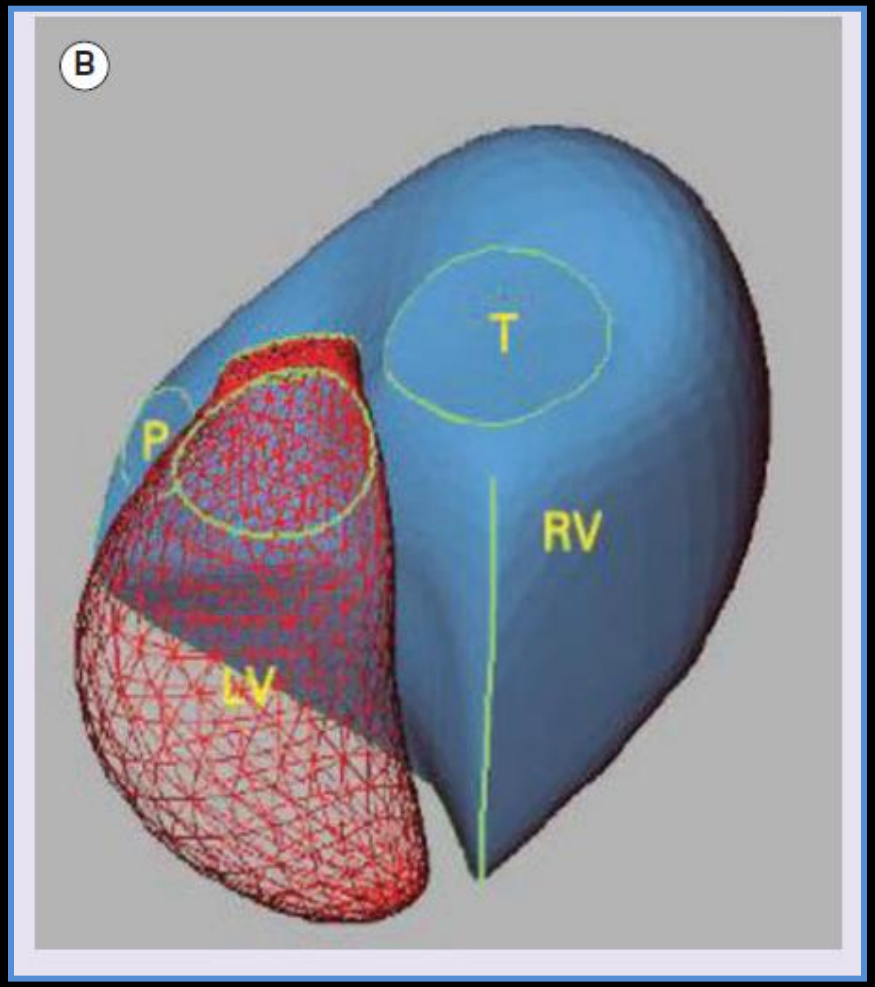
Effects of the LV contraction on the RV Role of interventricular septum

- Septum twists and shortens
- Reduction in ventricular volume
- Forceful ejection of blood out of both ventricle
- When the septum is damaged, the contraction of the RV depend only by the circumferential constriction caused by the basal wall that contains transverse fibers.
- Such construction does not ensure adequate cardiac output specifically when PAP is increased.

RV & LV



Normal heart



Dilated RV

RV & the lungs

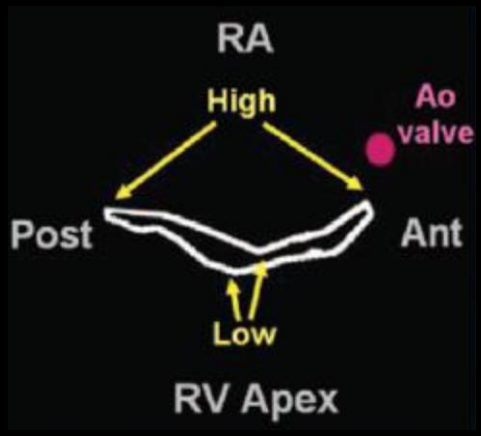
RV is not capable of sustaining long-term pressure overload:

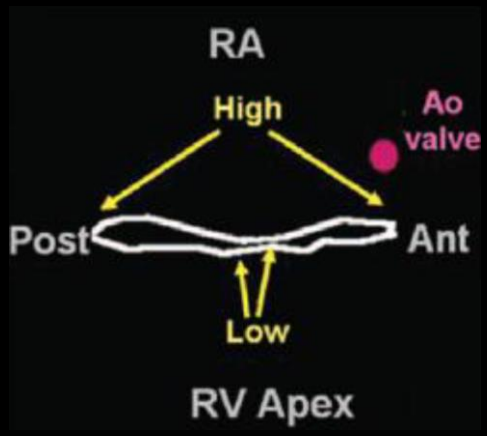
- Cardiac contractile decrease, due to functional or structural (apoptosis) changes in cardiomyocytes
- RV dilate, due to increased wall tension
- Myocardial oxygen demand increase
- RV perfusion decrease

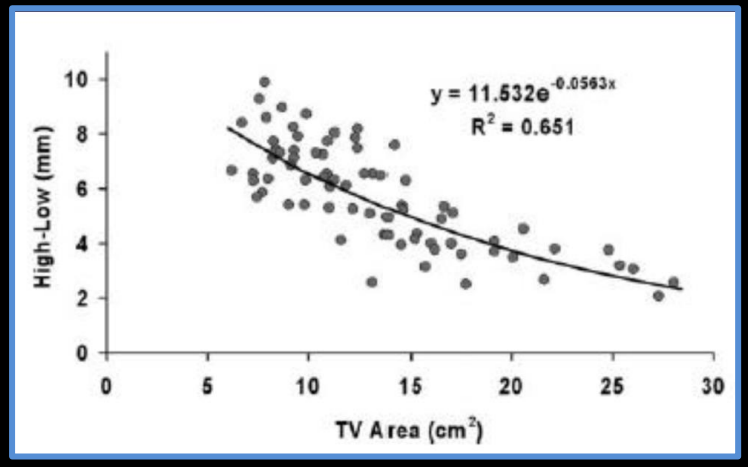
Pathophysiology of functional TR

- Annular dilatation
- RV enlargement
- Papillary muscle displacement
- Leaflets thetering

Annular Enlargement

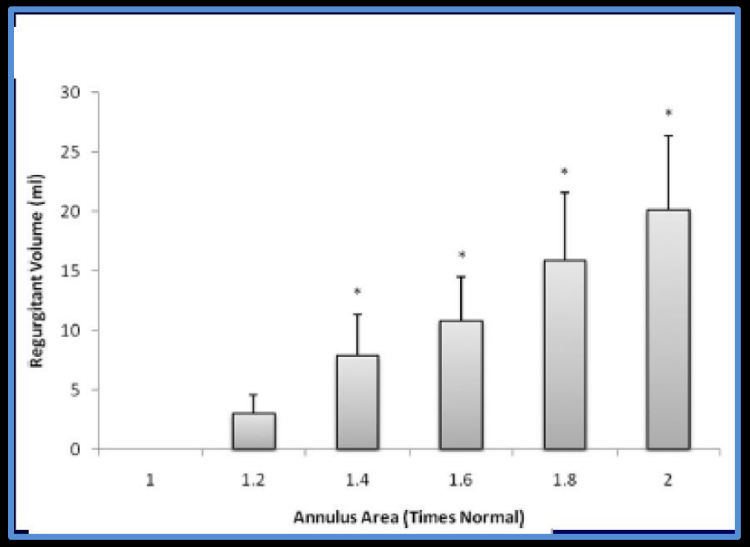


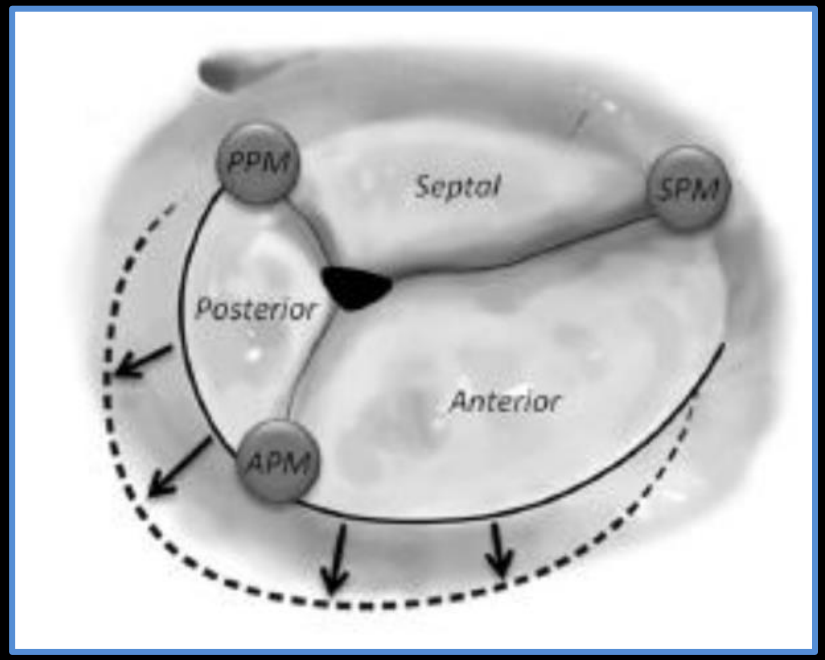


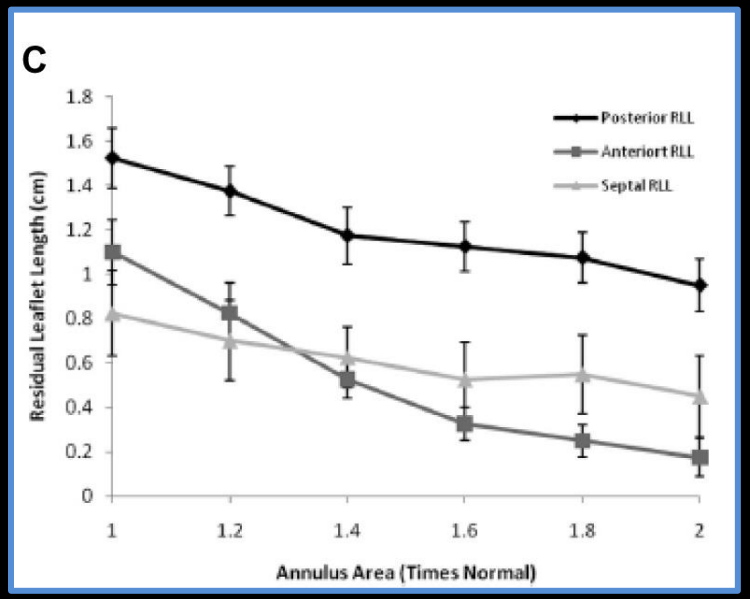


Ton-Nu TT, et al. Geometric determinants of functional tricuspid regurgitation: insights from 3-dimensional echocardiography.

Circulation 114 (2), 143-149 (2006)

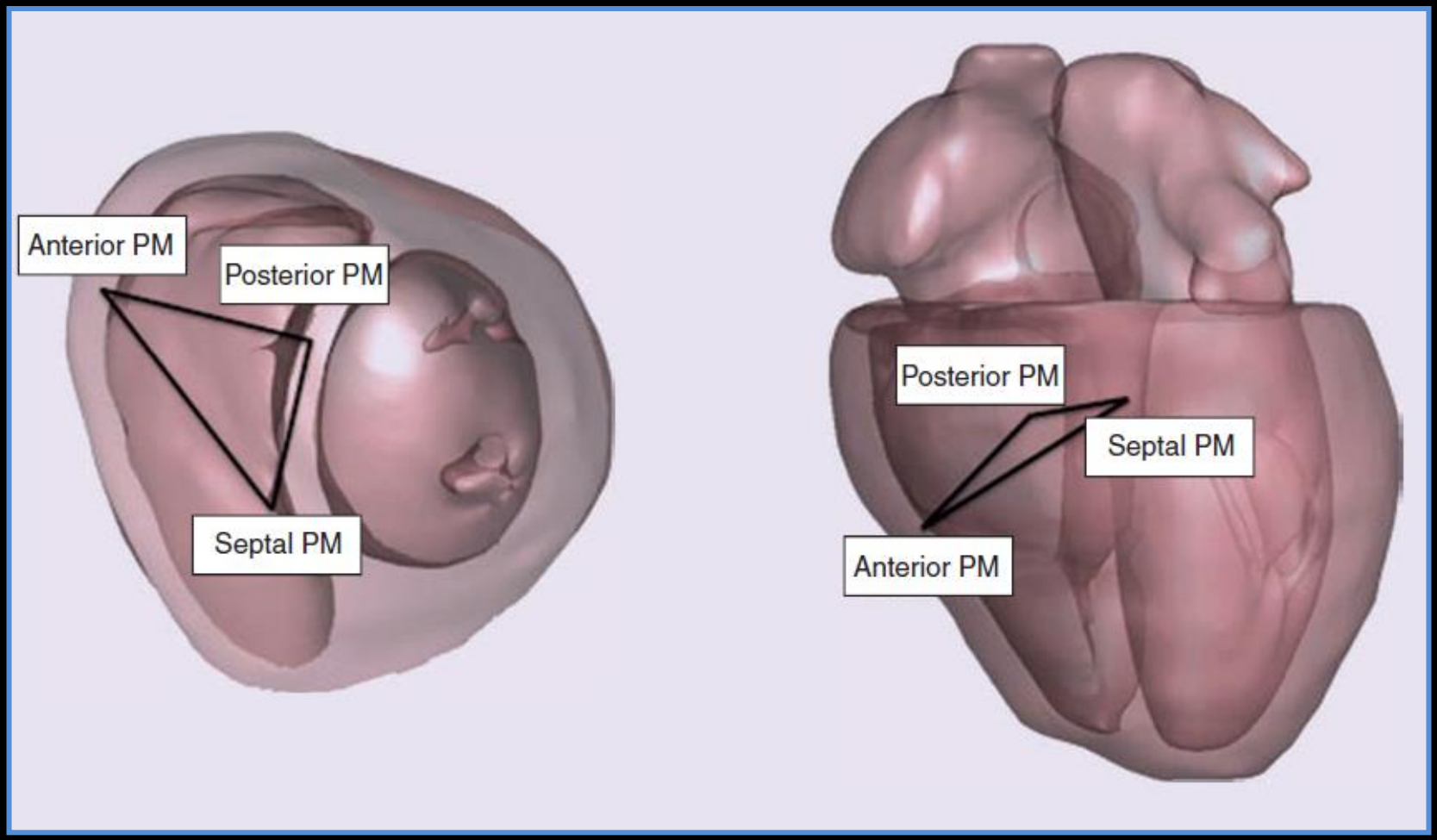




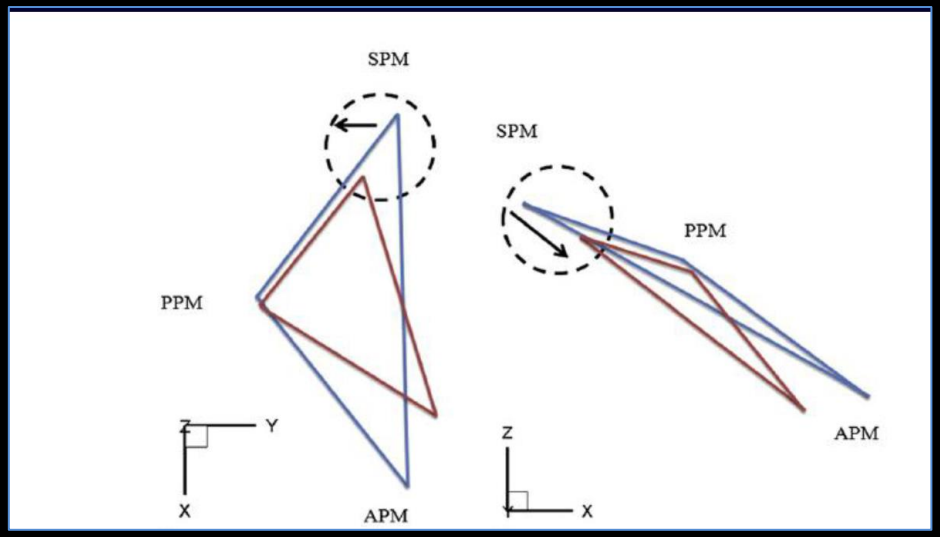


Spinner EM et al. In vitro characterization of the mechanisms responsible for functional tricuspid regurgitation. Circulation 124 (8), 920-929 (2011)

Papillary muscle displacement



Papillary muscle displacement in dilated RV



Surgical Consideration

The TV is not only annulus, but also leaflets, chords and PMs, the position of which depends on the RV size and function.

Conclusions

- TV function is strictly correlated to the RV geometry, which depends on preload, afterload, and LV geometry.
- The RV reverse remodelling is unpredictable
- As the mechanism of functional TR does not found only in annular dilatation, the surgical technique applied mainly to annular reduction, have fluctating results.
- In selected patients leaflets techniques will be used to improve results

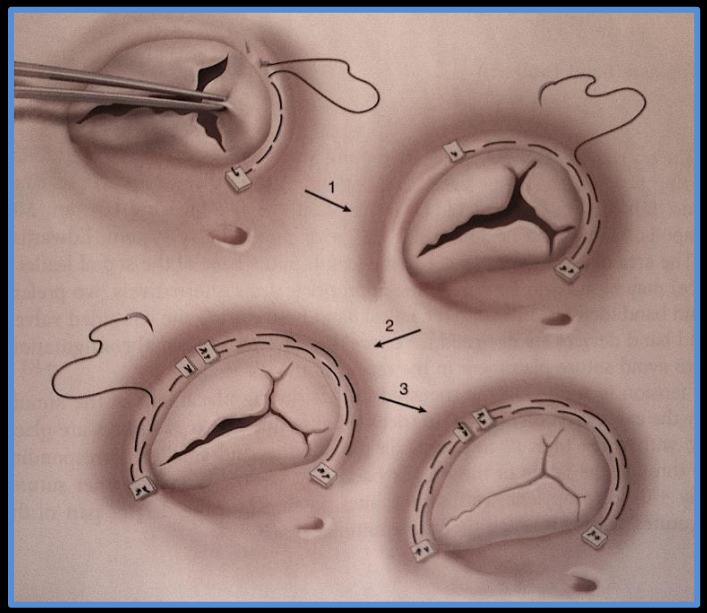
Conclusions

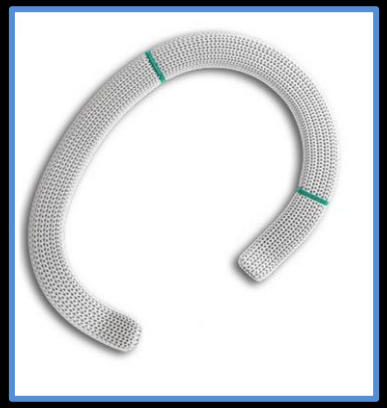
The increasing attention toward the right side of the heart will lead to the diffusion of more standarized diagnostic and surgical techniques, to clarify better the anatomical changes and the reversibility of the RV dysfunction, and to improve surgical repair outcomes.

Thanks

Surgical Techniques

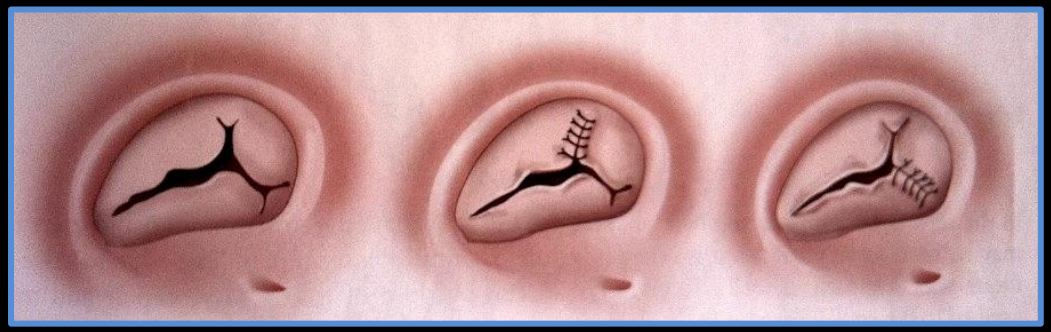
De Vega's technique





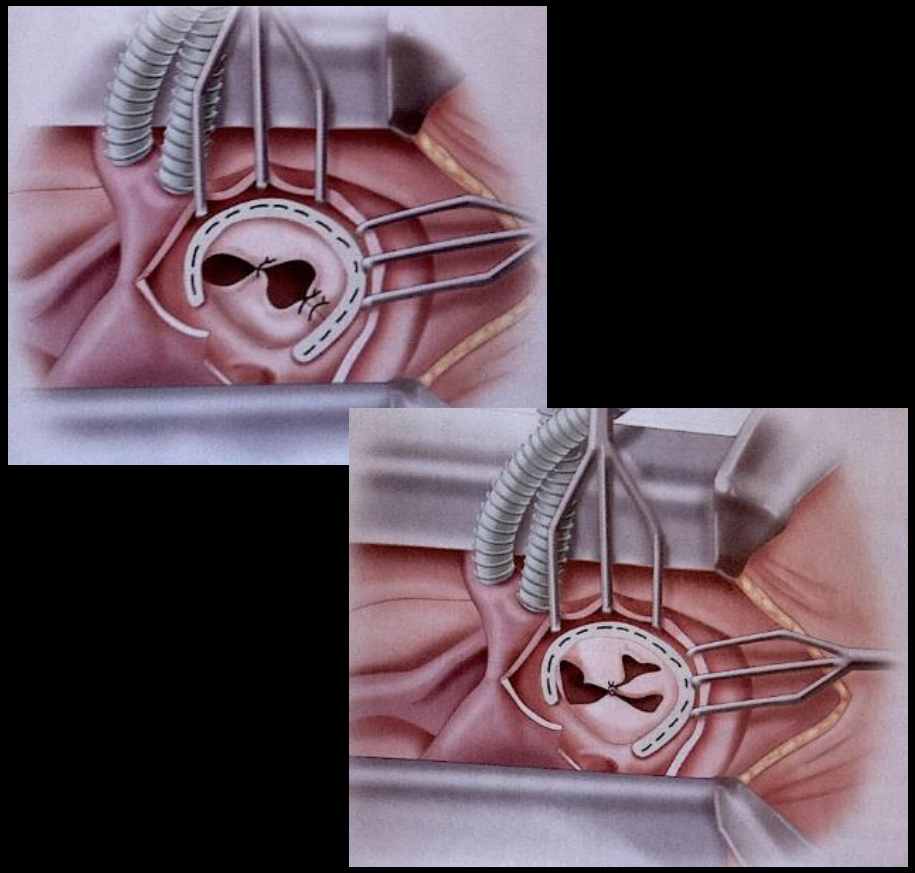
Annuloplastic ring

Kay's technique

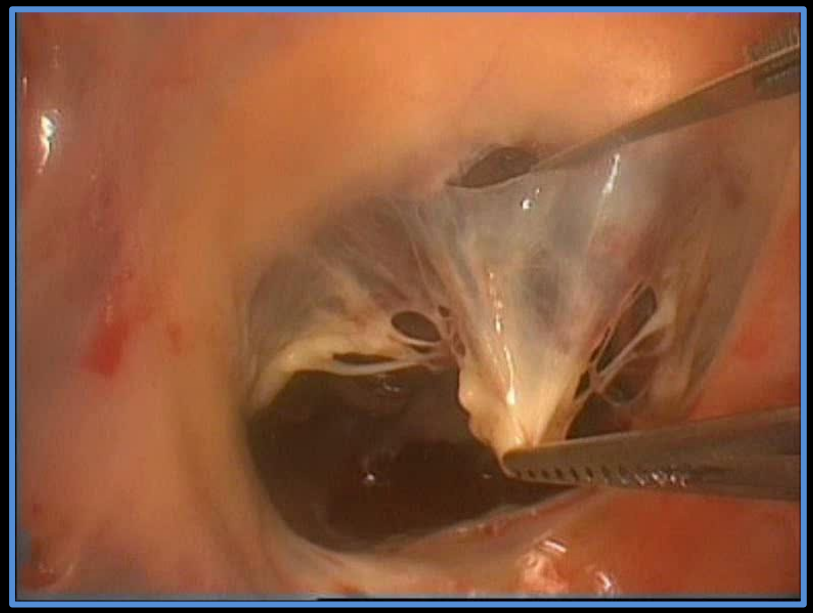


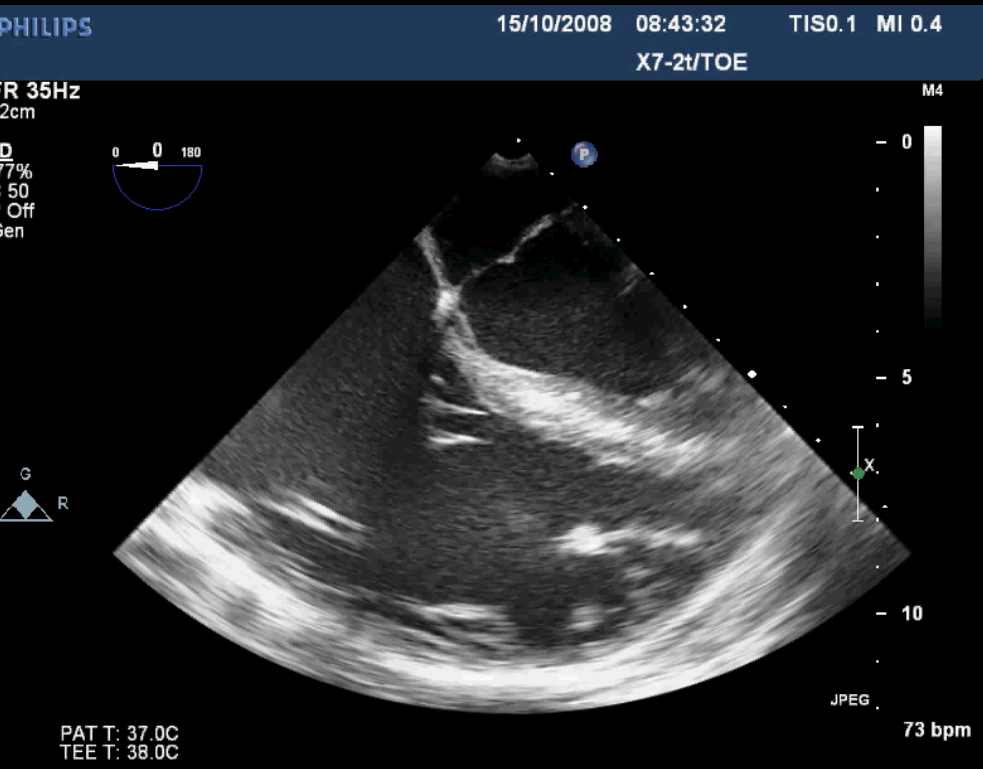
Surgical Techniques adressed to the leaflets

Edge-to-edge



Leaflet augmentation

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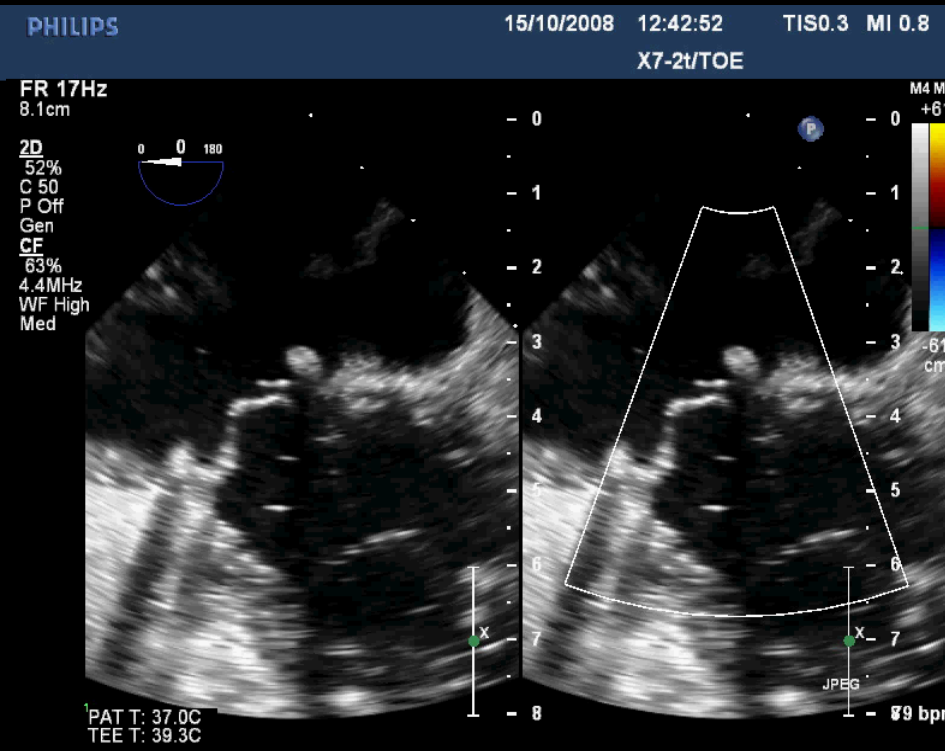
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