弁膜症治療のための心臓解剖

新古賀病院　心臓血管外科　　吉戒　勝

Under – 40 Basic Lecture 2019.7.6.

心臓解剖検定問題－１

心臓に Valve はいくつある？

４つ　→　常識レベル

６つ　→　2級レベル

７つ　→　1級合格！

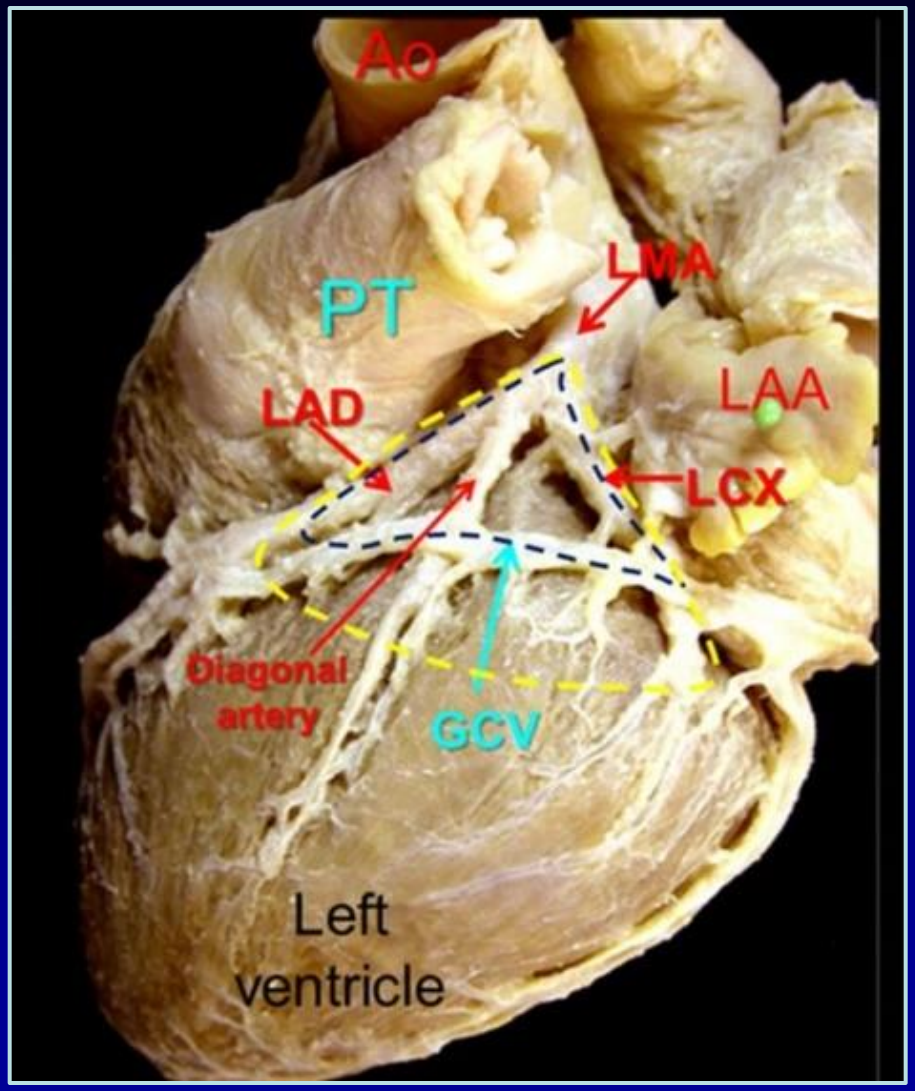
心臓解剖検定問題－２

心嚢内にあるものは？

SVC、IVCのTaping はどこでする？

SVC、IVCのTapingの際には何を何枚切る？

心臓解剖検定問題－3



心臓を左側より見た図

KochのTriangleは知ってる。
では左図黒点線で囲まれたTriangleは？
（LAD, LCX, GCVで囲まれたTriangel）

GCV: great cardiac vein

心臓の構造

心筋：心房筋、心室筋

弁：三尖弁、肺動脈弁、僧帽弁、大動脈弁

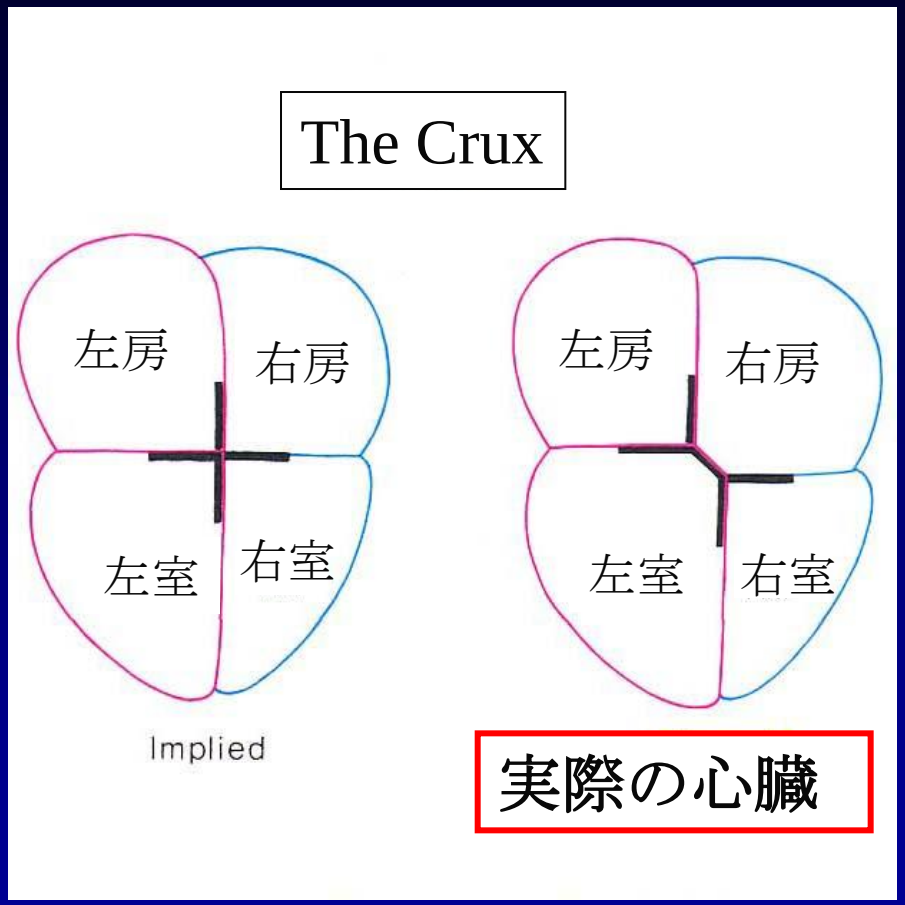
冠状動脈：右冠状動脈、左冠状動脈（左主幹部、
左前下行枝、左回旋枝）

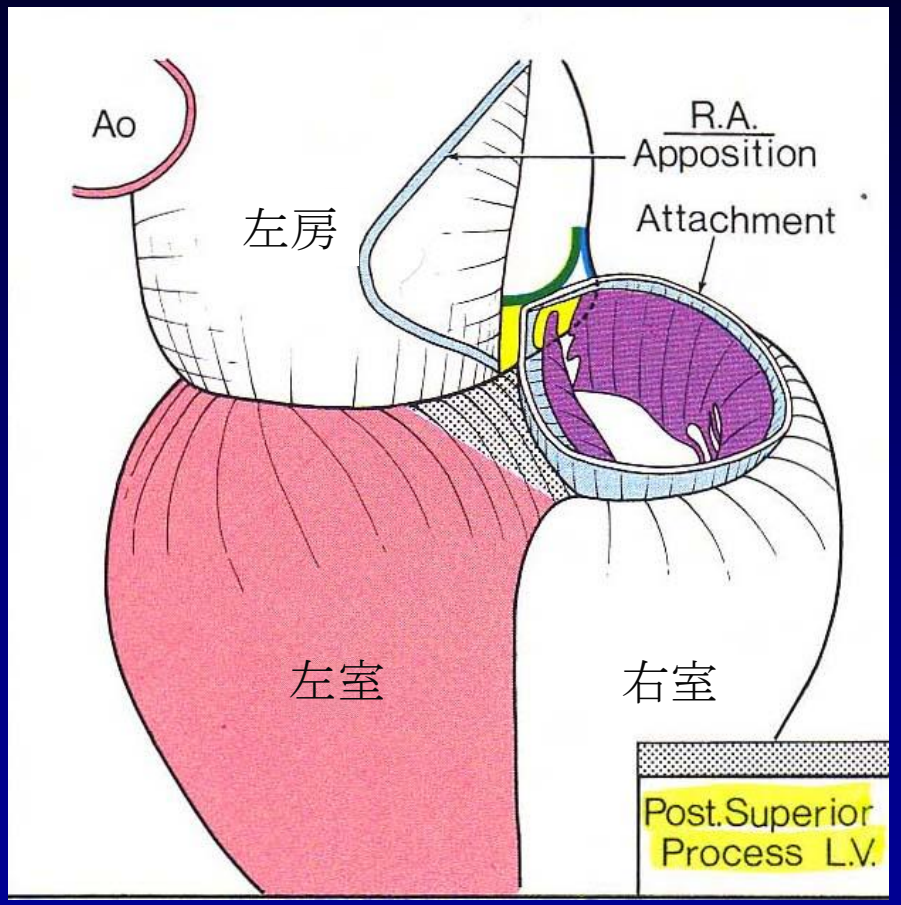
冠状静脈：冠状静脈、冠状静脈洞(coronary sinus)

刺激伝導系：洞房結節、結節間伝導路
房室結節、右脚、左脚

神経系：交感神経、副交感神経

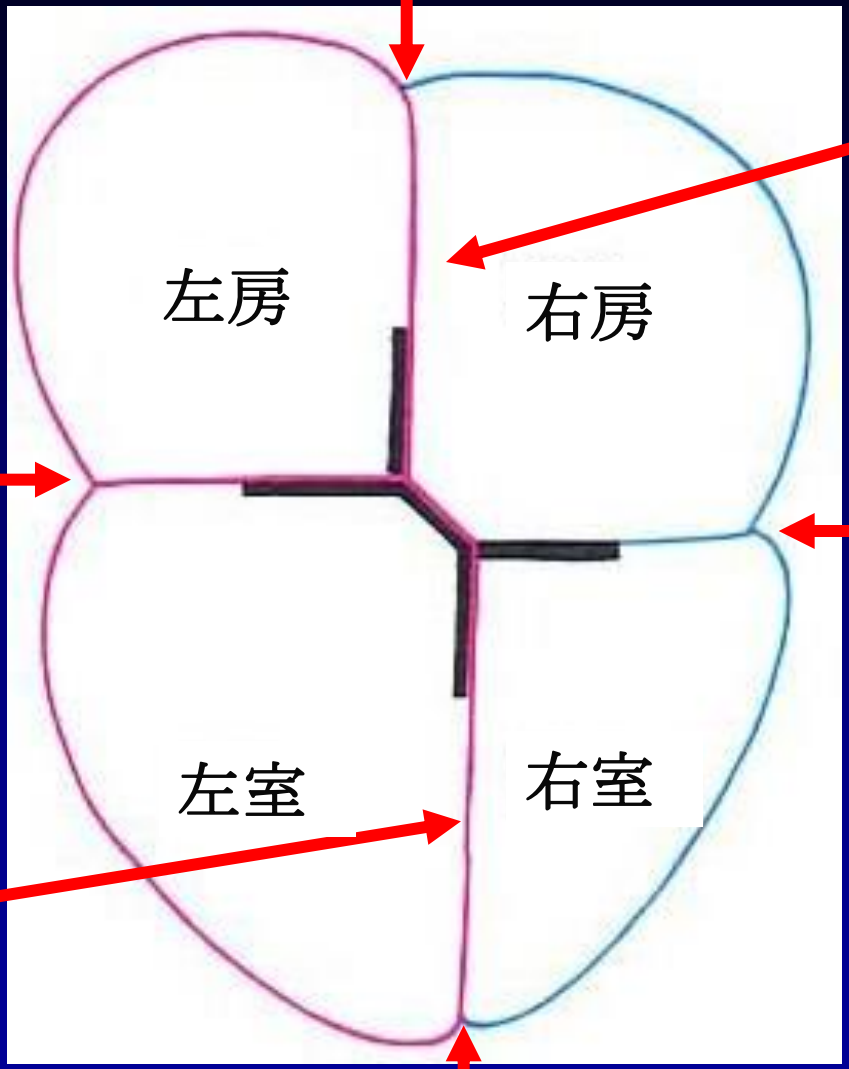
心臓の４つの部屋





心臓を後方より見た図

溝と中隔



心臓を後方より見た図

発生過程におけるConus absorptionの差異

Conus：房室弁と半月弁間に介在する筋組織
(円錐)

Subaortic conus→吸収されて
(大動脈下円錐)　　→ aortic-mitral continuity

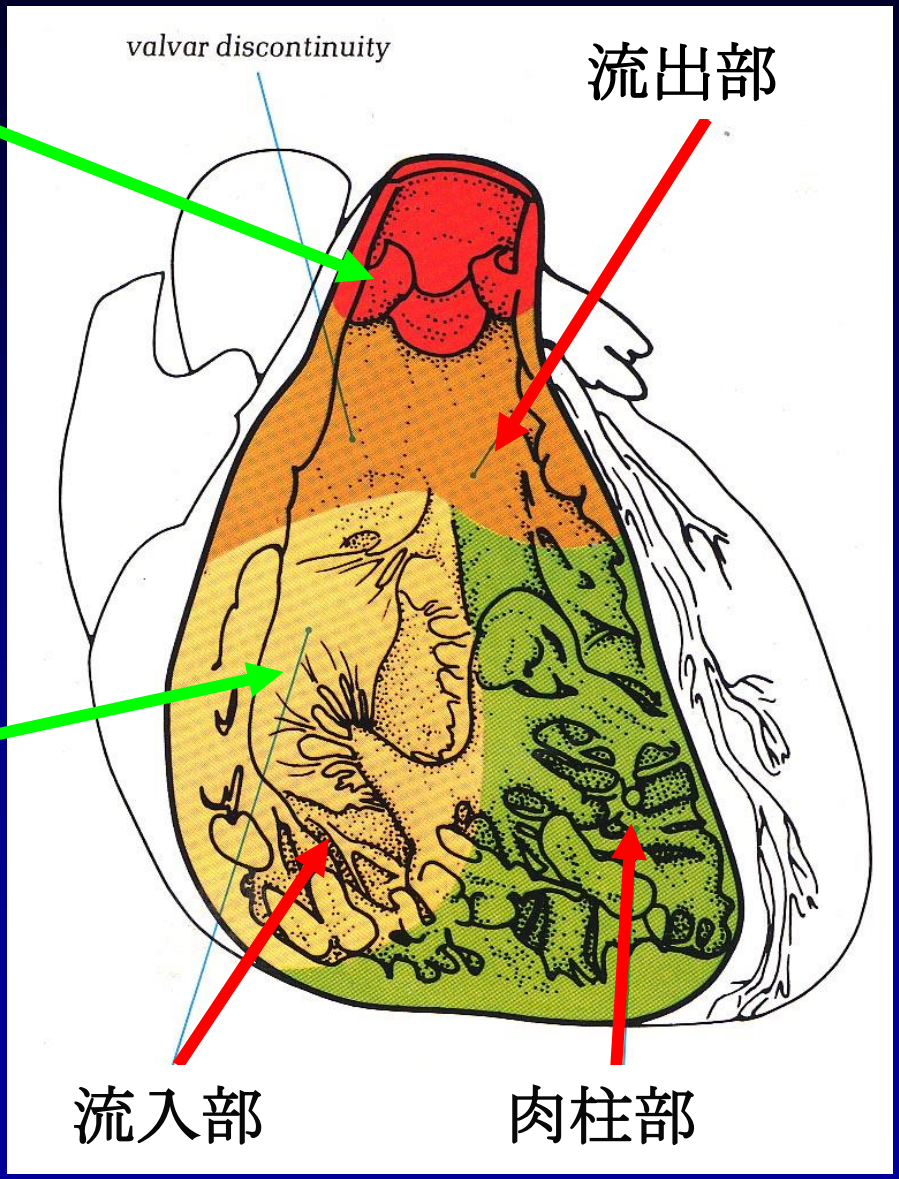
Subpulmonary conus→吸収されず→漏斗部
(肺動脈下円錐)

右心室

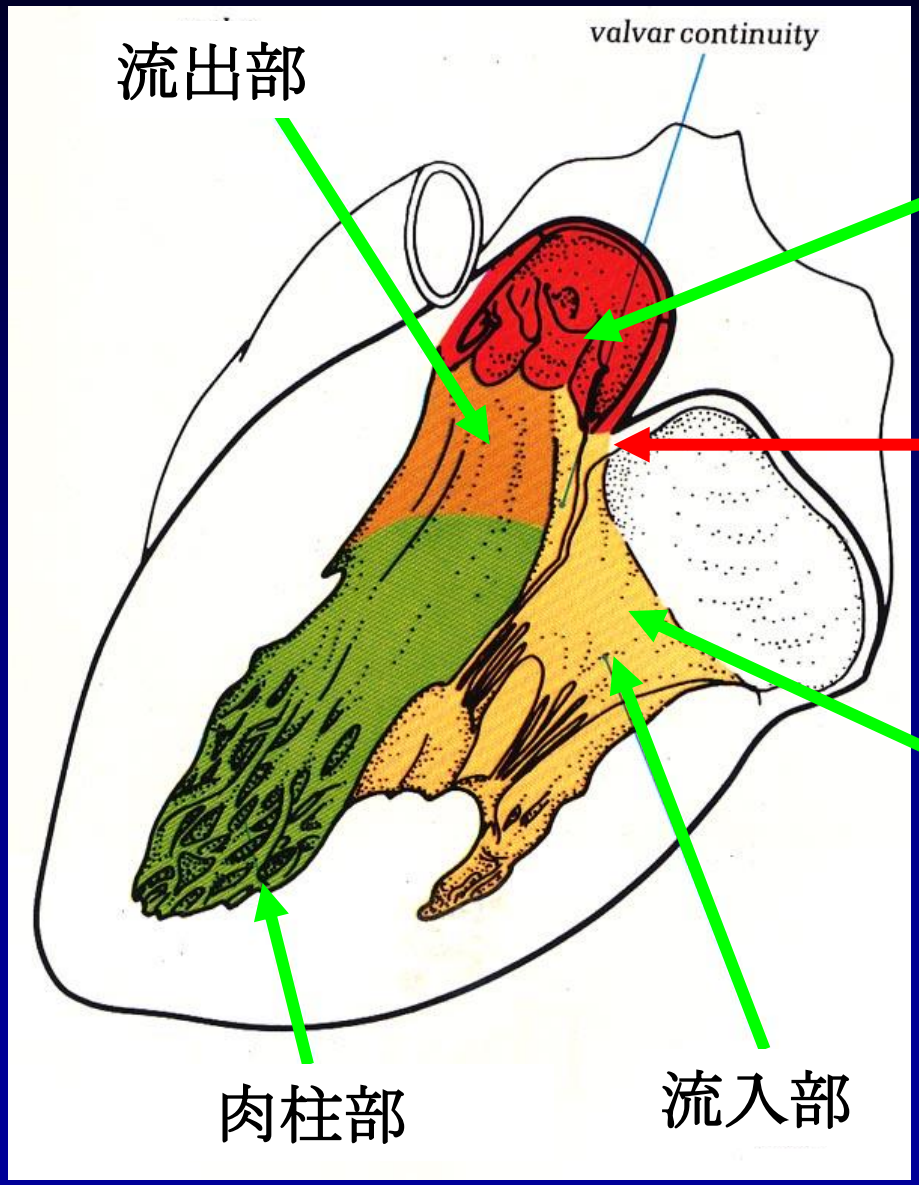
肺動脈弁

連続性なし

三尖弁

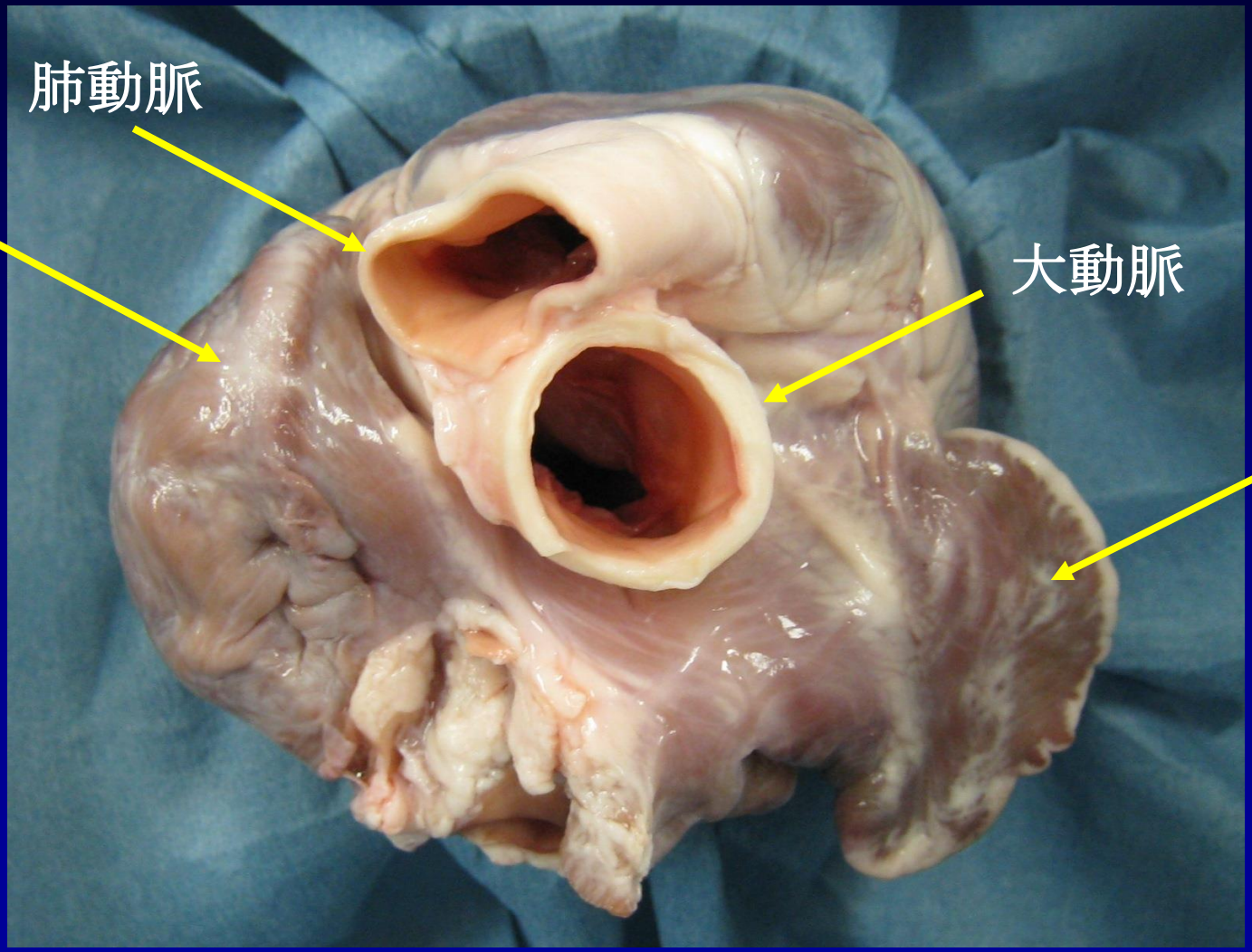


左心室



大血管の位置関係

大動脈ー右後、肺動脈ー左前



胸骨正中切開

↓

Innominate vein を確認

↓

Innominate vein が無い！

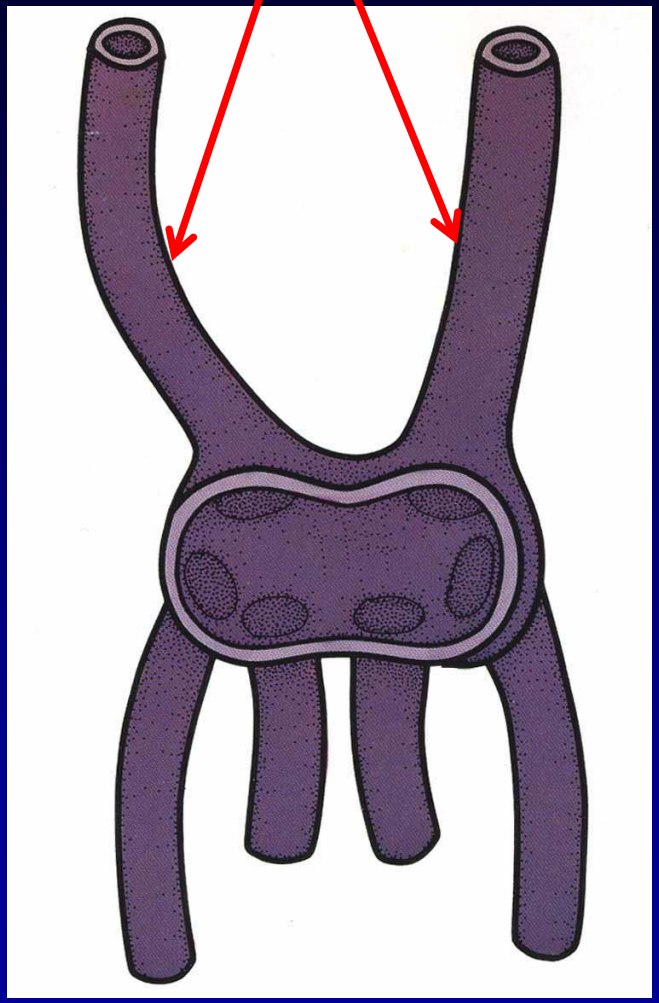
↓

1) Persistent left superior vena cava

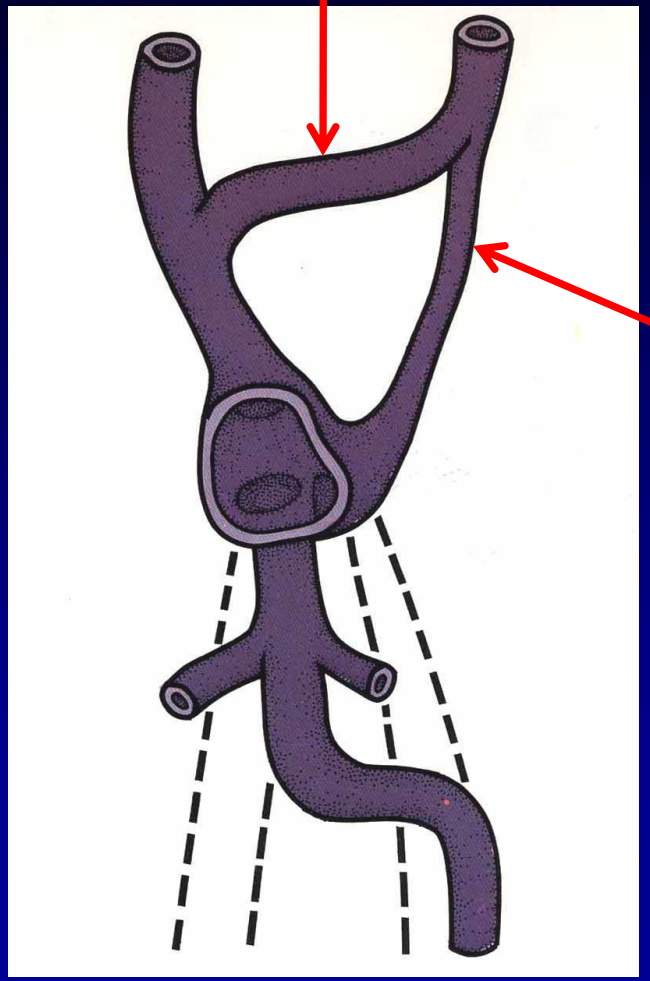
2) Post aortic innominate vein

体静脈系の発生

Cardinal vein



superior anastomosis

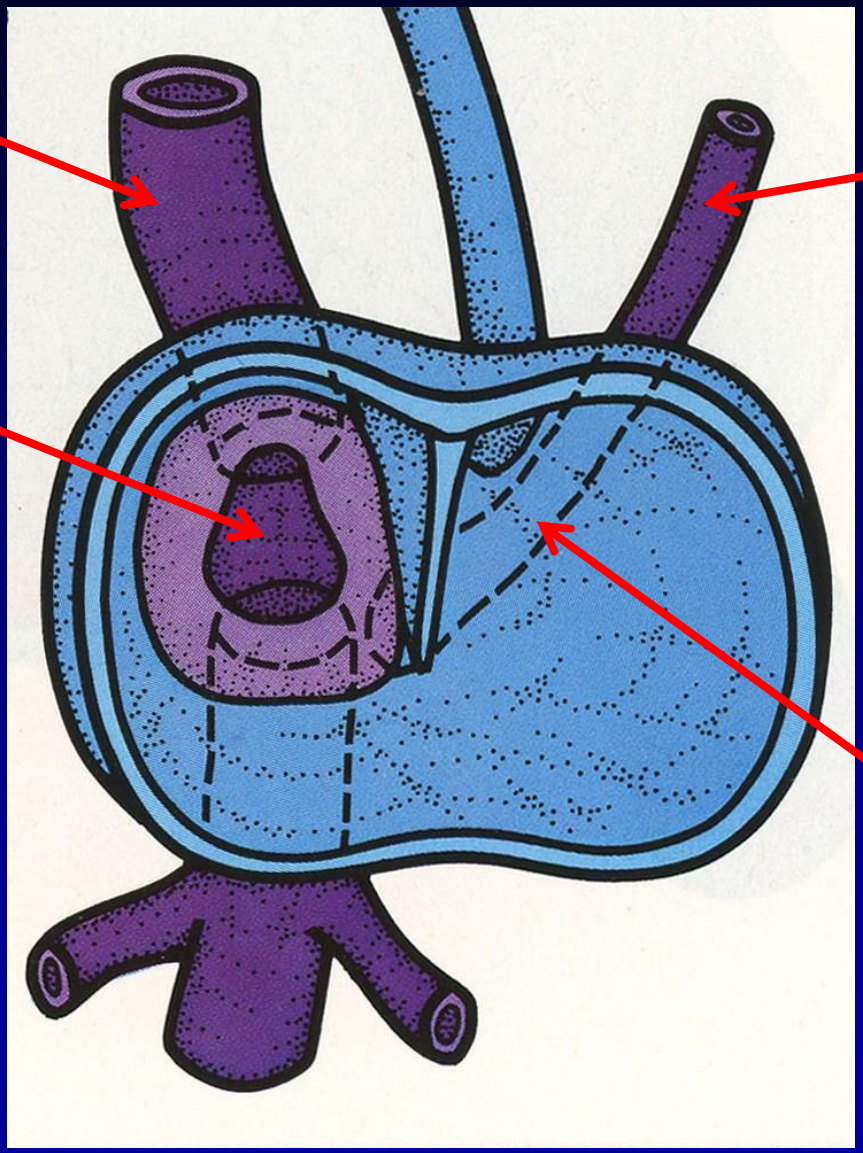


退縮

体静脈系の発生

Rt. SVC

sinus venosus



Lt. SVC

↓

退縮

↓

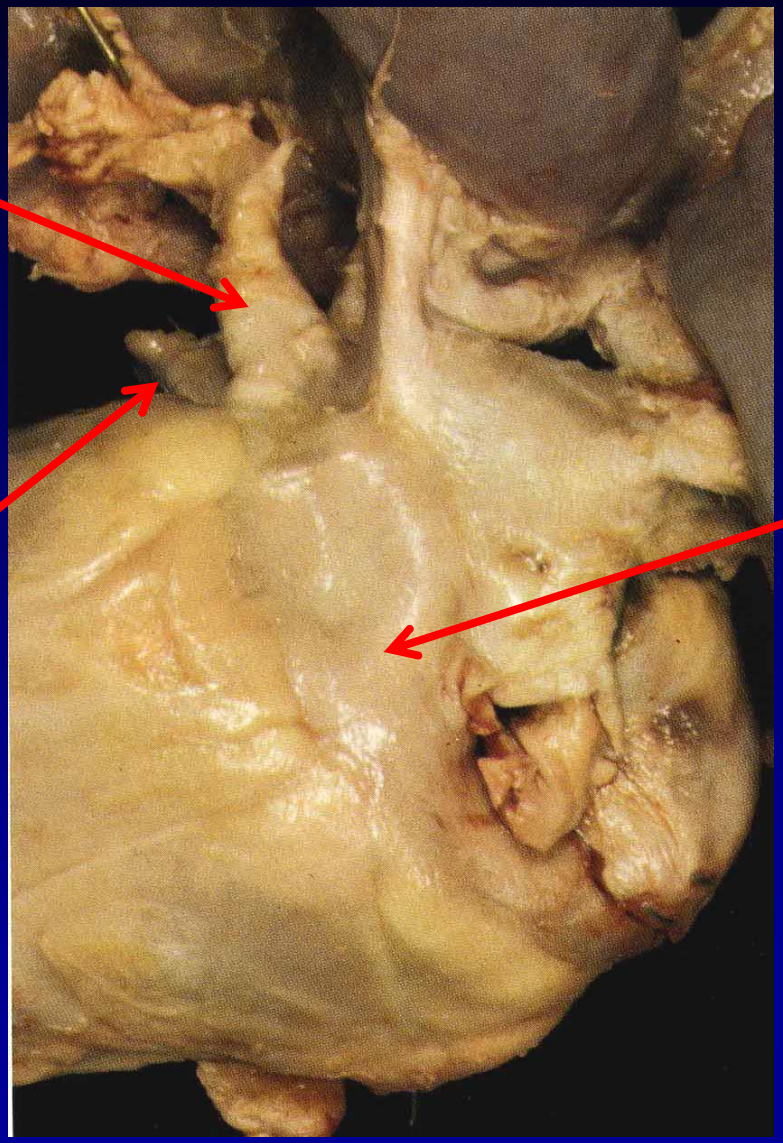
- Vestigial fold
- Marchall靭帯
  または斜静脈

coronary sinus

Persistent left SVC

PLSVC

左心耳



coronary sinus
(拡大している)

術前UCGでチェック

Persistent left SVCがあったら

1) Duplicate SVC　82~90%

Innominate vein (＋)　30 %　しかし細いかも

Innominate vein (－)　70%

右房切開を要する手術時

十分な太さのInnominate vein→遮断

細いInnominate vein,　Innominate vein(－)

→脱血管を追加

Direct cannulation

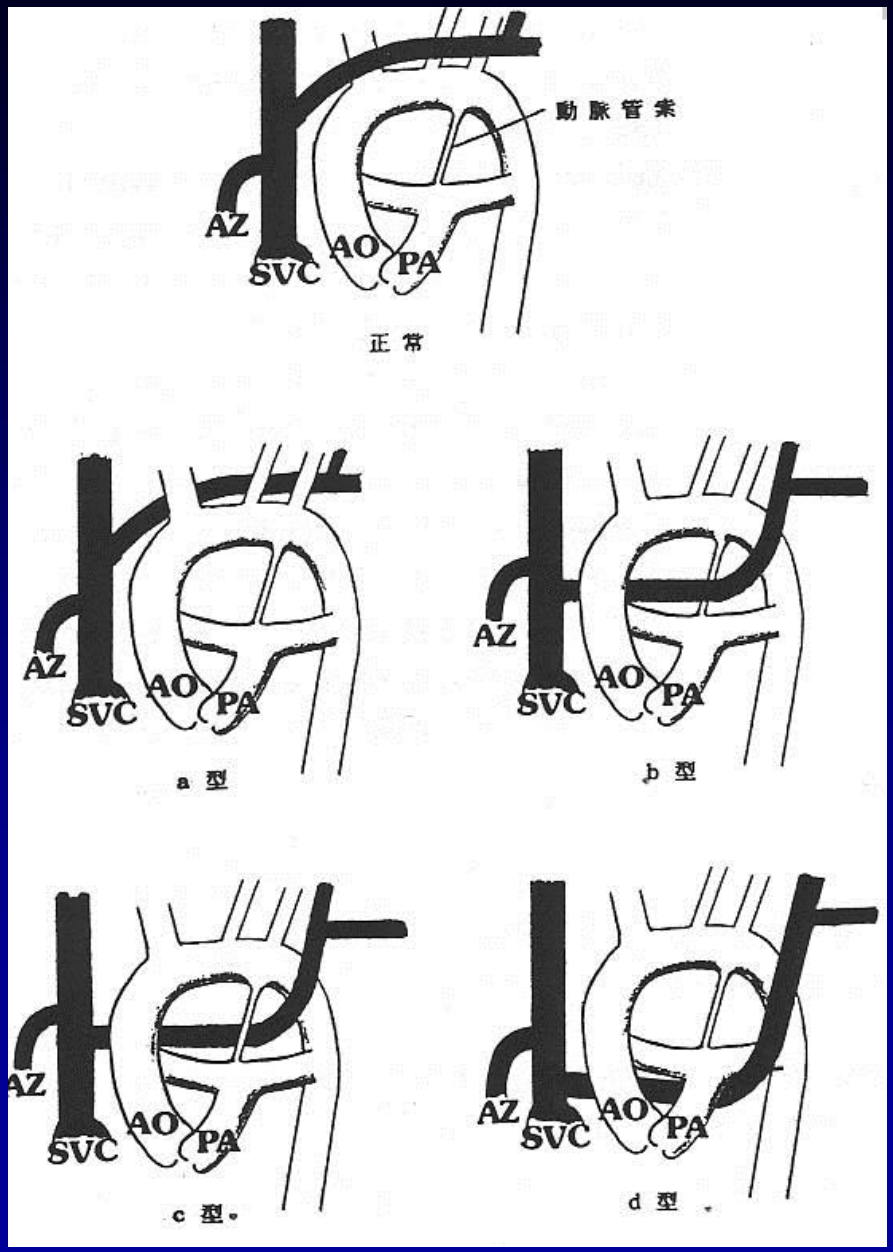
Cannulation via coronary sinus

Retrograde cardioplegia 無効

2) Isolated PLSVC →dextrocardia, situs inversus

R.B. Irwin et al. European Heart Jourrnal 2012. 13. 284-291

Postaortic innominate vein



b 型、c 型、d 型

SVC taping 要注意

SVCとIVCのテーピング

- どこで行うか？
- 何を何枚切るか？

heart tube

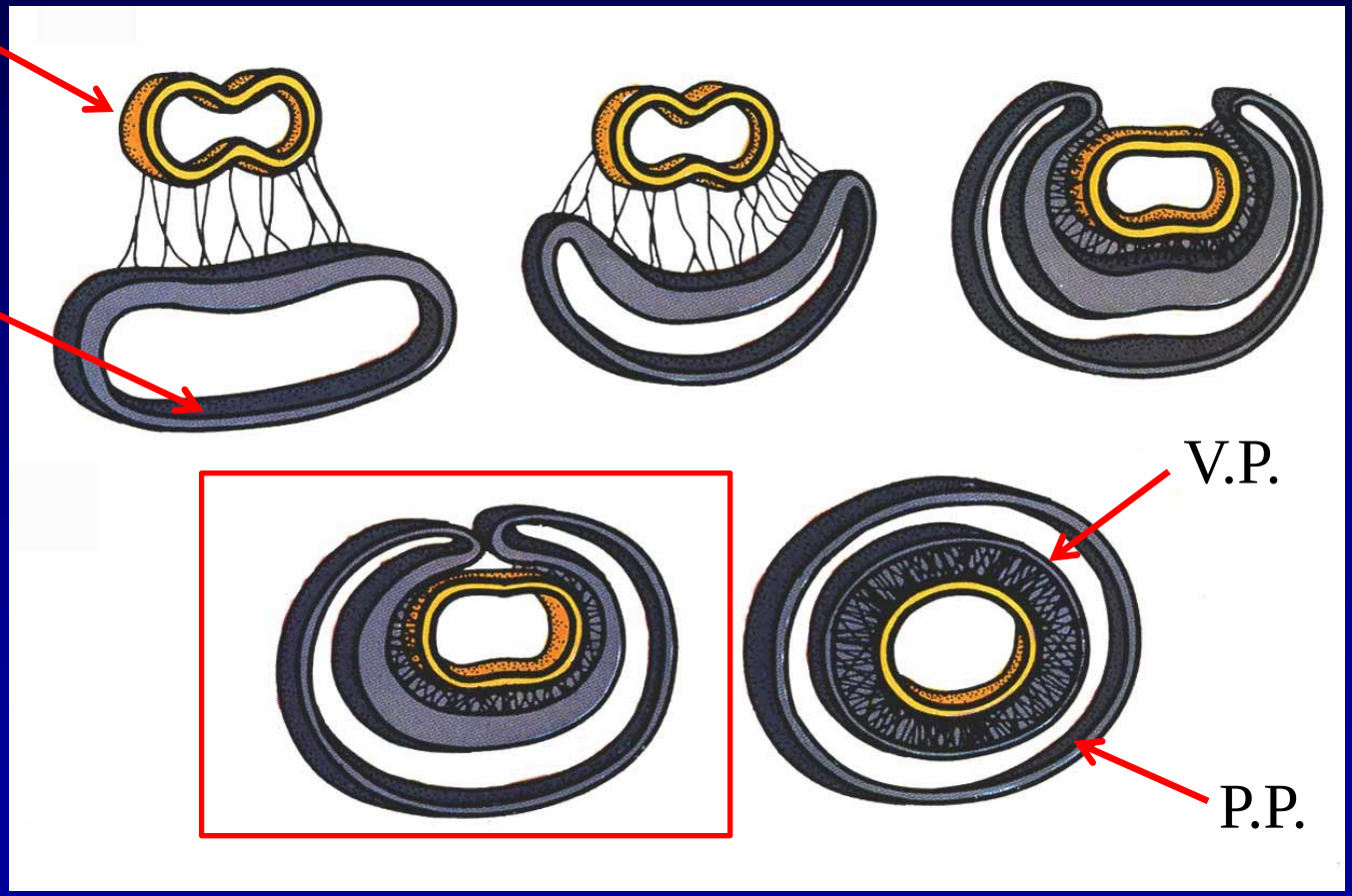
pericardium

V.P. : visceral pericardium

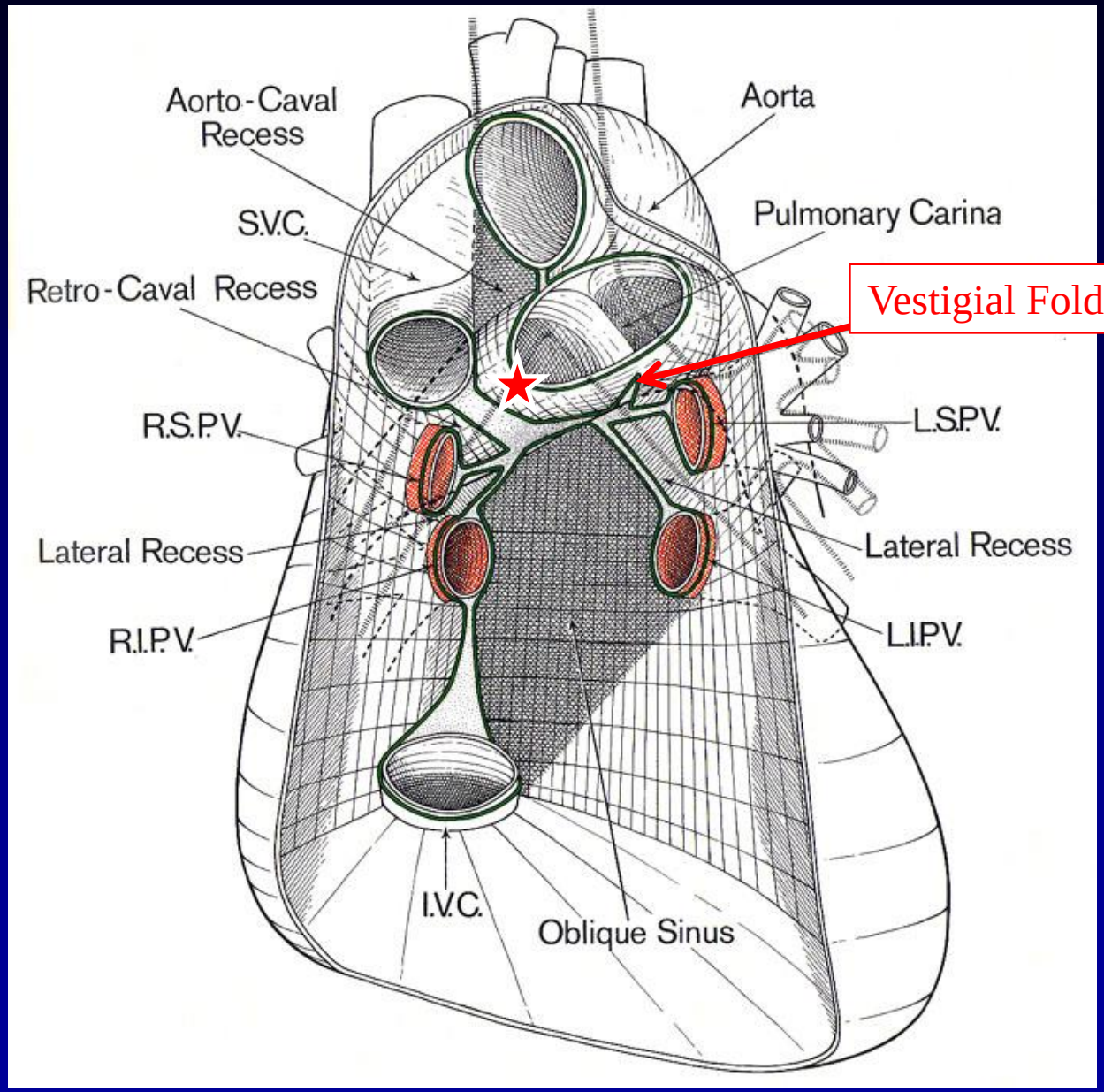
↓

epicardium

P.P.: parietal pericardium



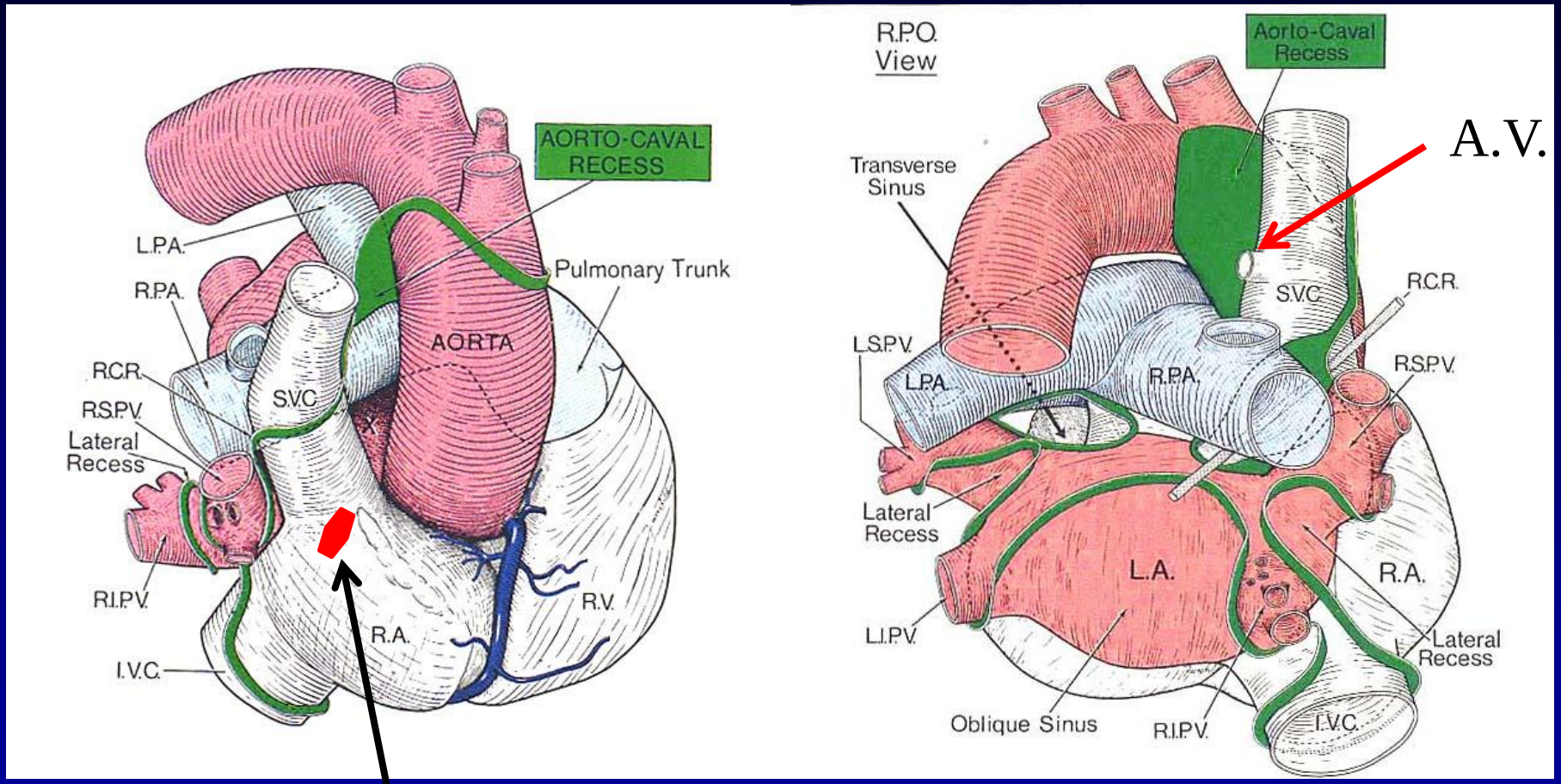
心　膜



Left PV isolation時に切離

☆ 心膜近接

心　膜



Sinus node

A.V. : azygos vein

Taping 時の留意点

SVC Taping　右肺動脈前面で行う

心膜間の距離が狭いのは右PAよりも心臓側

→Sinus Nodeを障害

右肺動脈よりも頭側で行うと

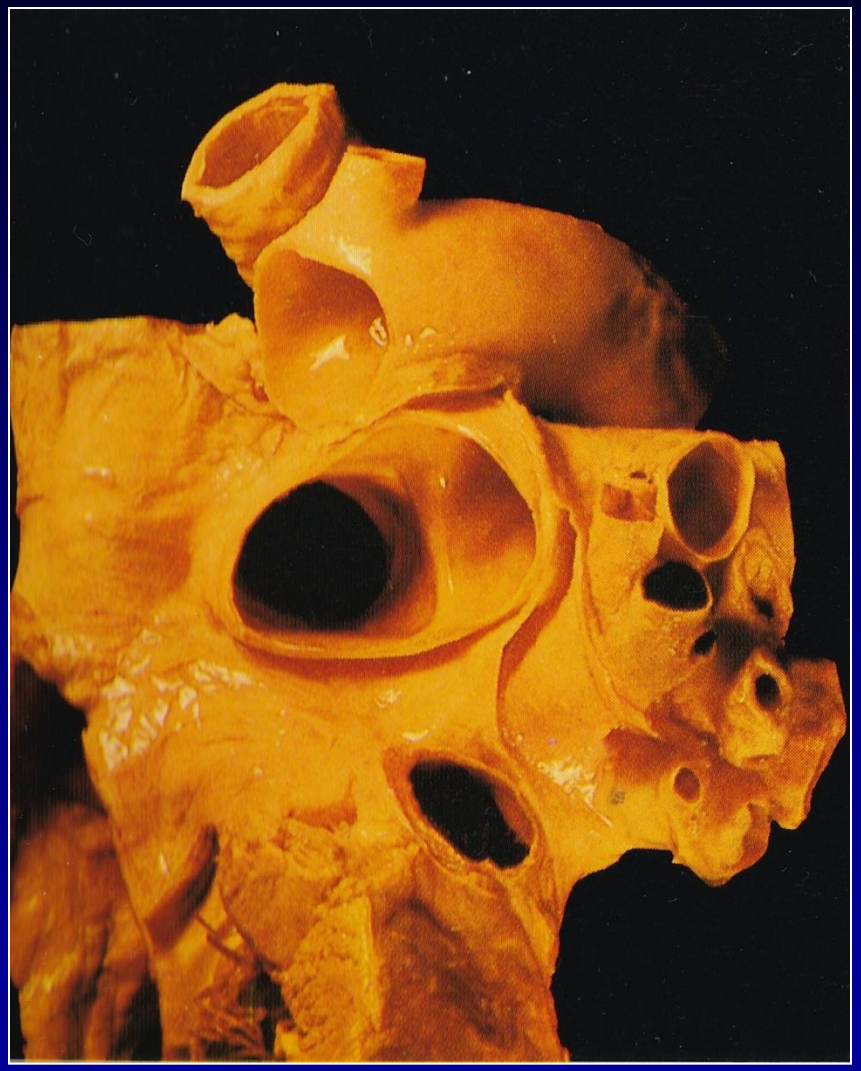
→Azygos veinを損傷

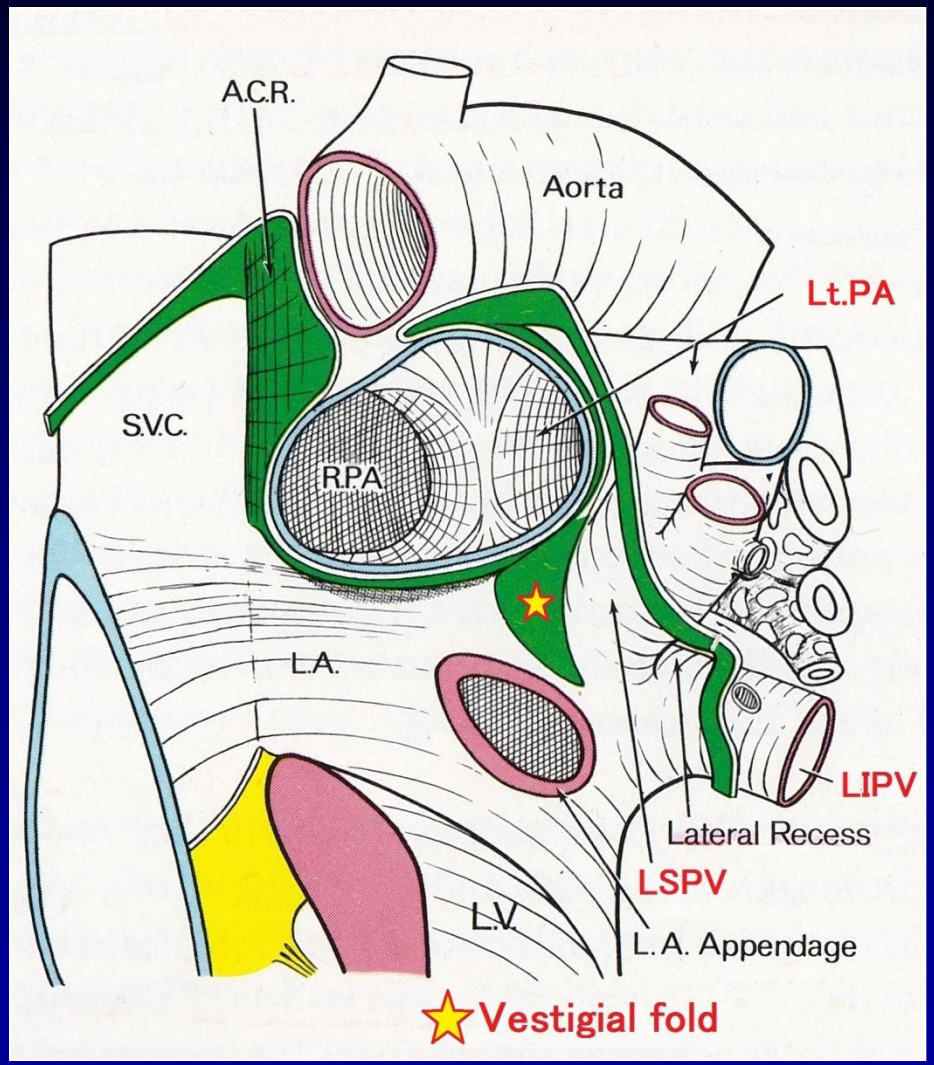
IVC Taping

右下肺静脈下端と下大静脈背面間で行う

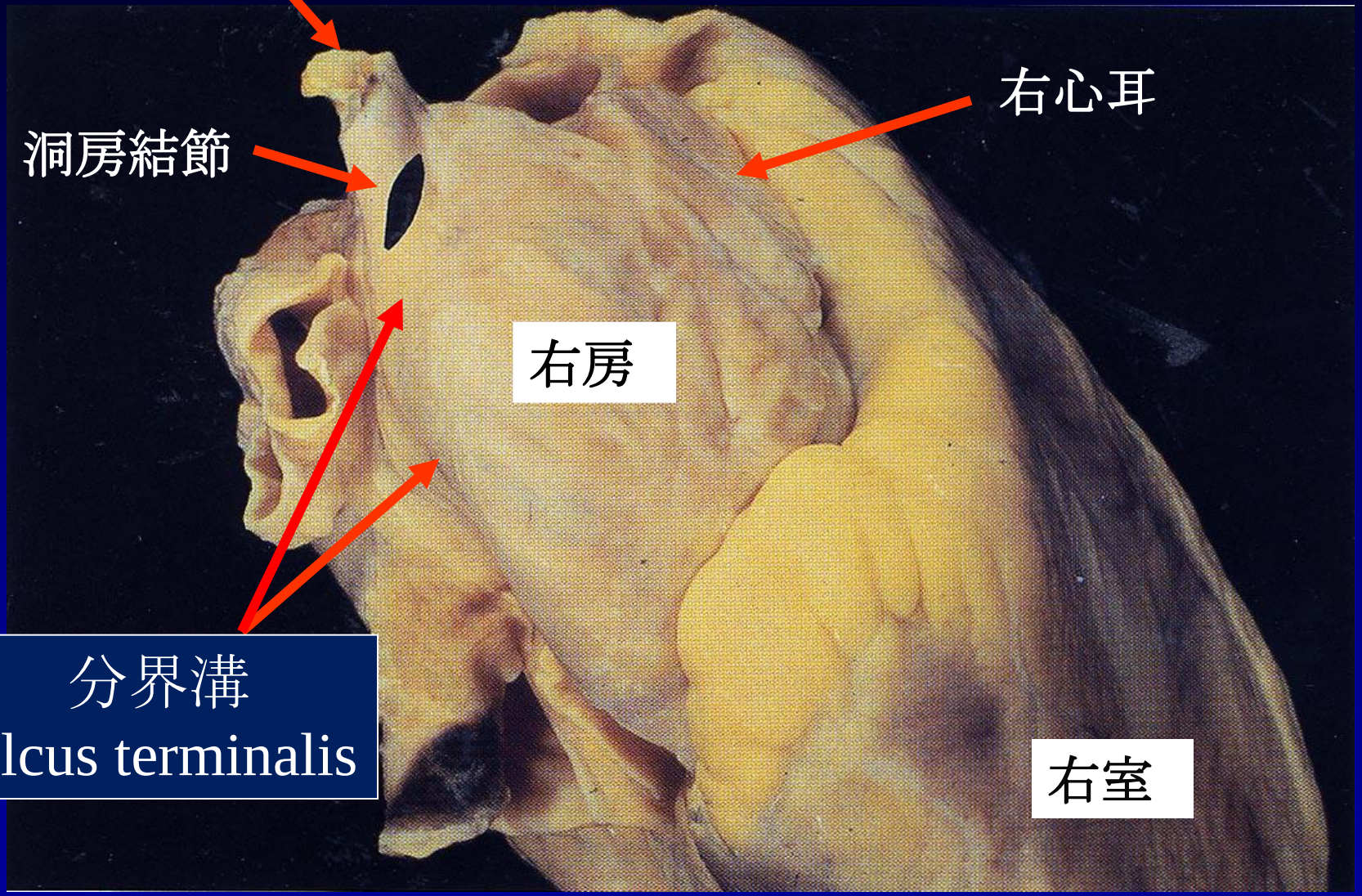
心嚢膜内には・・・心嚢液のみ

Left PV isolation: Vestigial fold



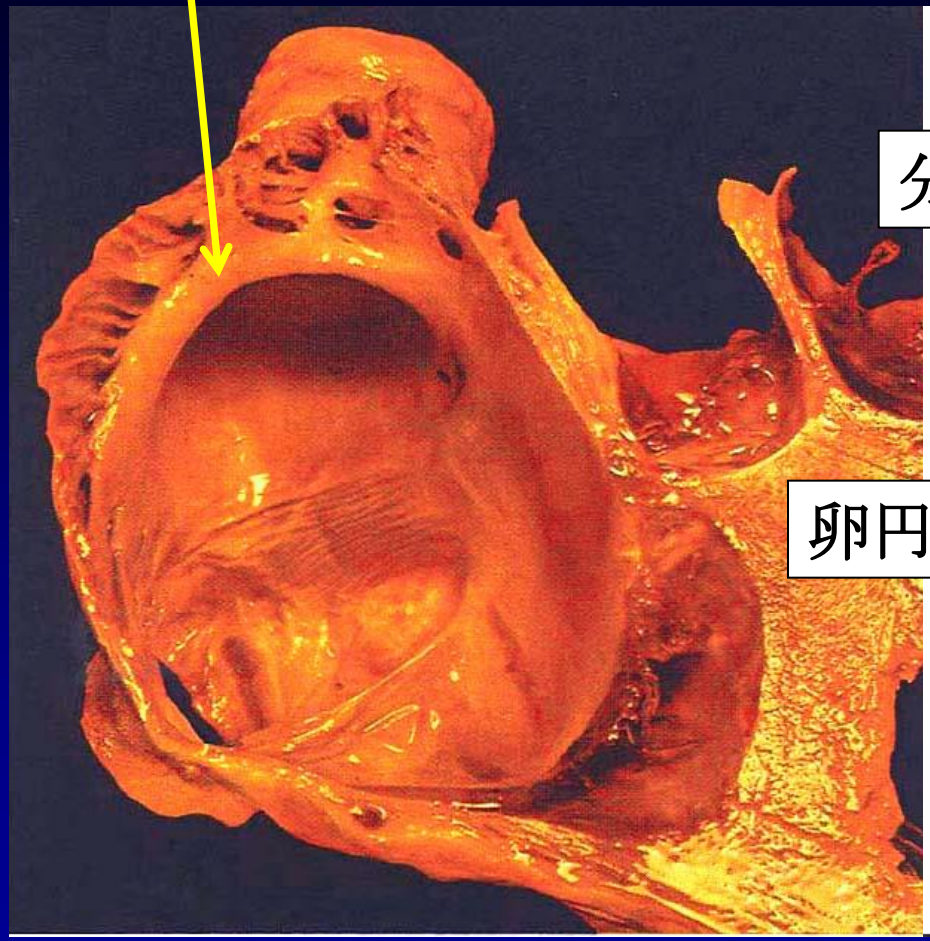


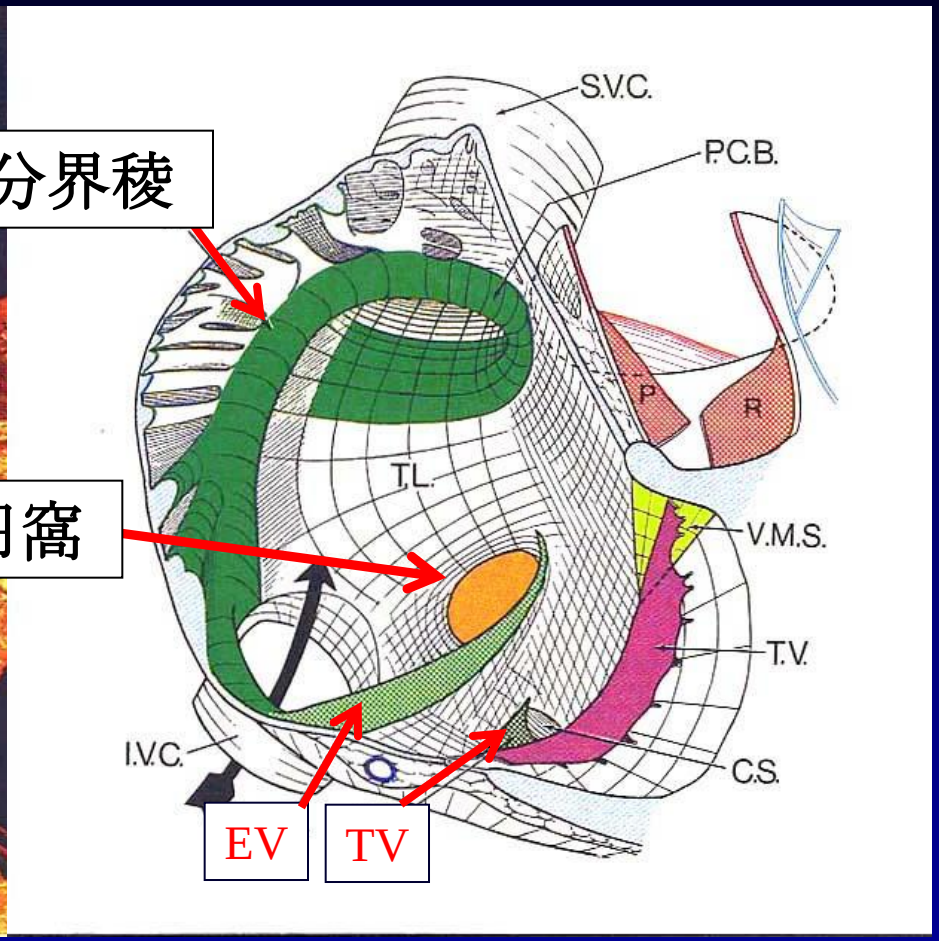
洞房結節：上大静脈ー右房接合部の分界溝上



右心房

Crista terminalis(分界稜)

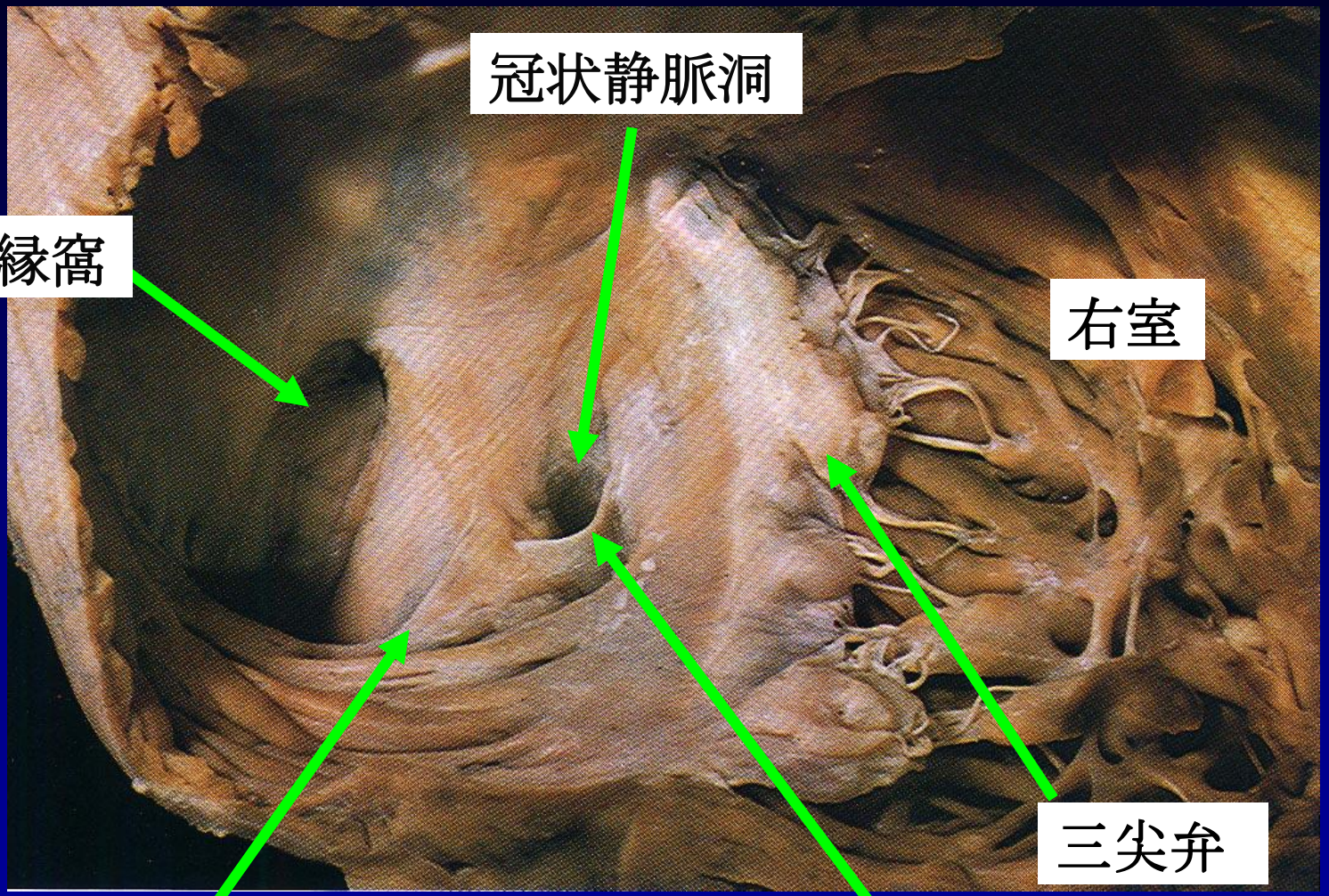




E. V. : Eustachian valve

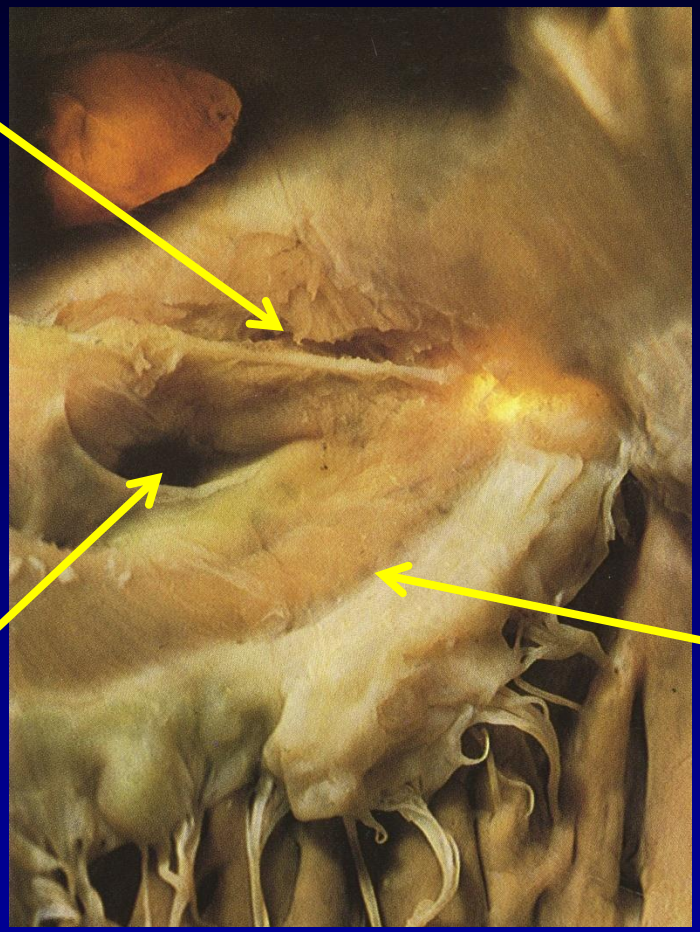
T. V. : Thebesian valve

右心房



Triangle of Koch : 頂上に房室結節

tendon of Todaro



Coronary sinus

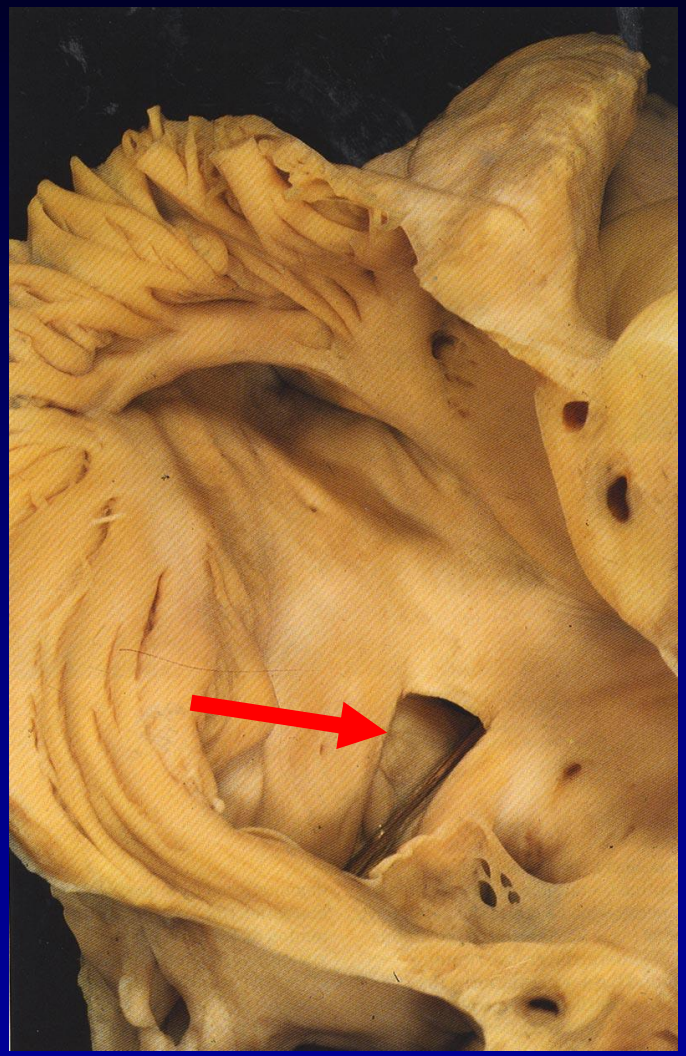
中隔尖弁輪

tendon of Todaro(幼児1/4, 成人 2/3 認めず)

James TN. J Cardiovasc Electrophysiol. 1999;10:1478-96.

Braunwald ’ s Heart Disease に引用

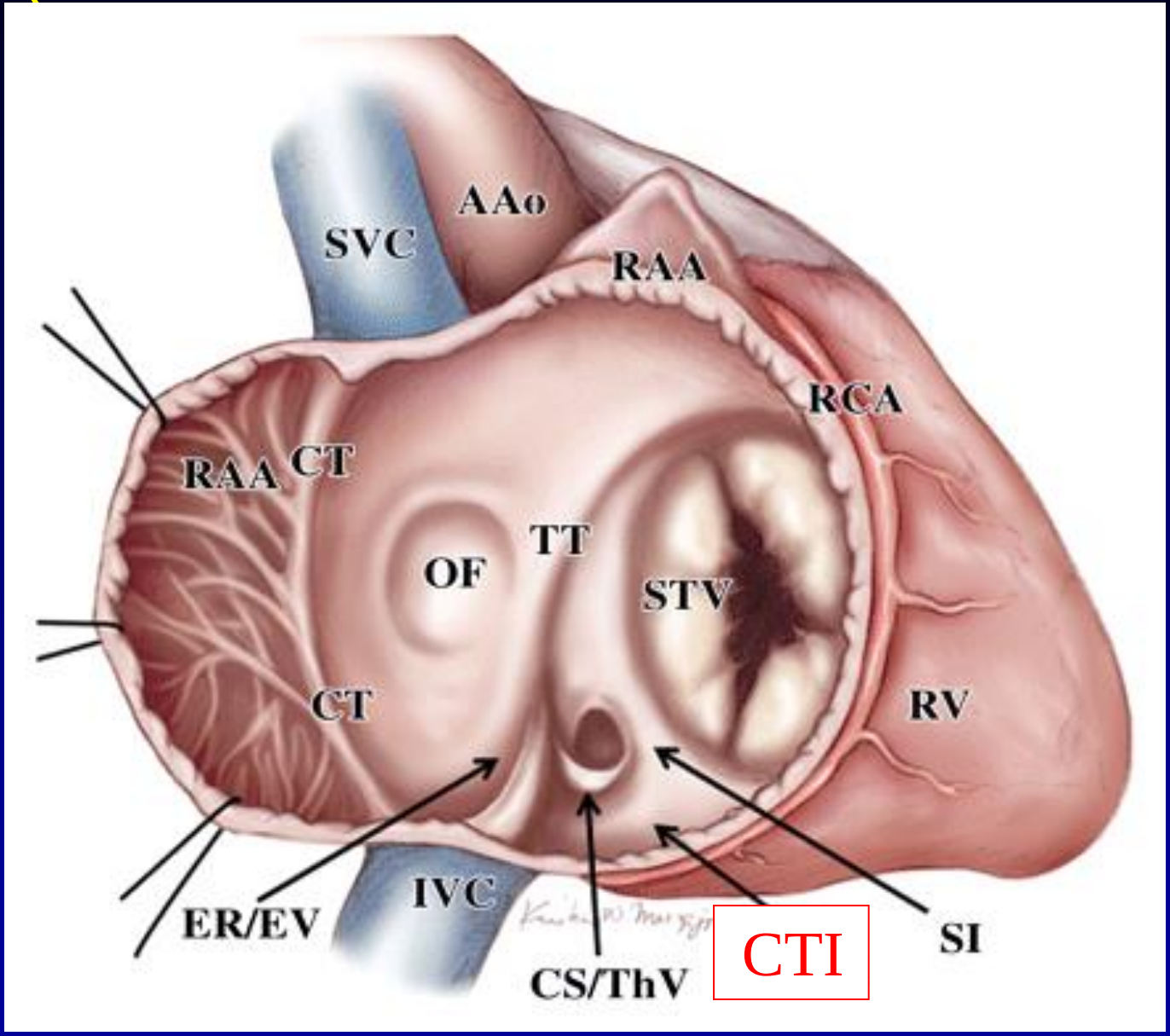
卵円孔開存：patent foramen ovale(PFO)



右房側

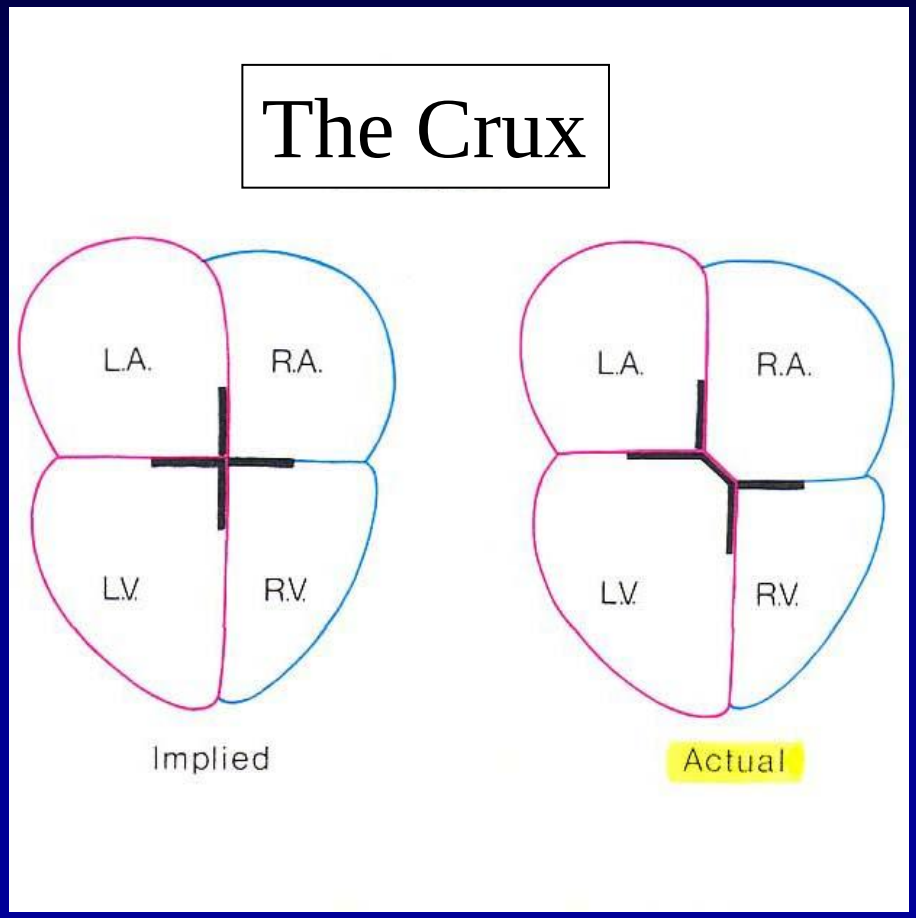
- 成人の25％
- 奇異性塞栓症の原因
- 55歳以下、Strokeの40％
- 片頭痛の原因！？

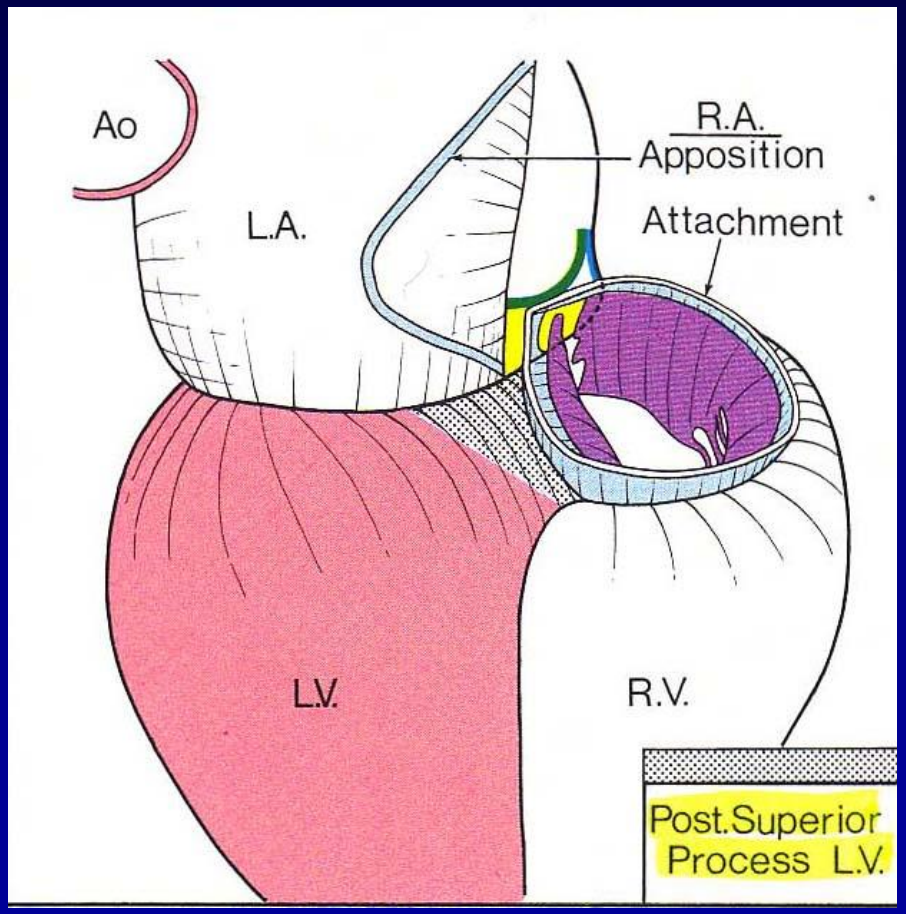
Cavotricuspid isthmus (CTI：峡部)



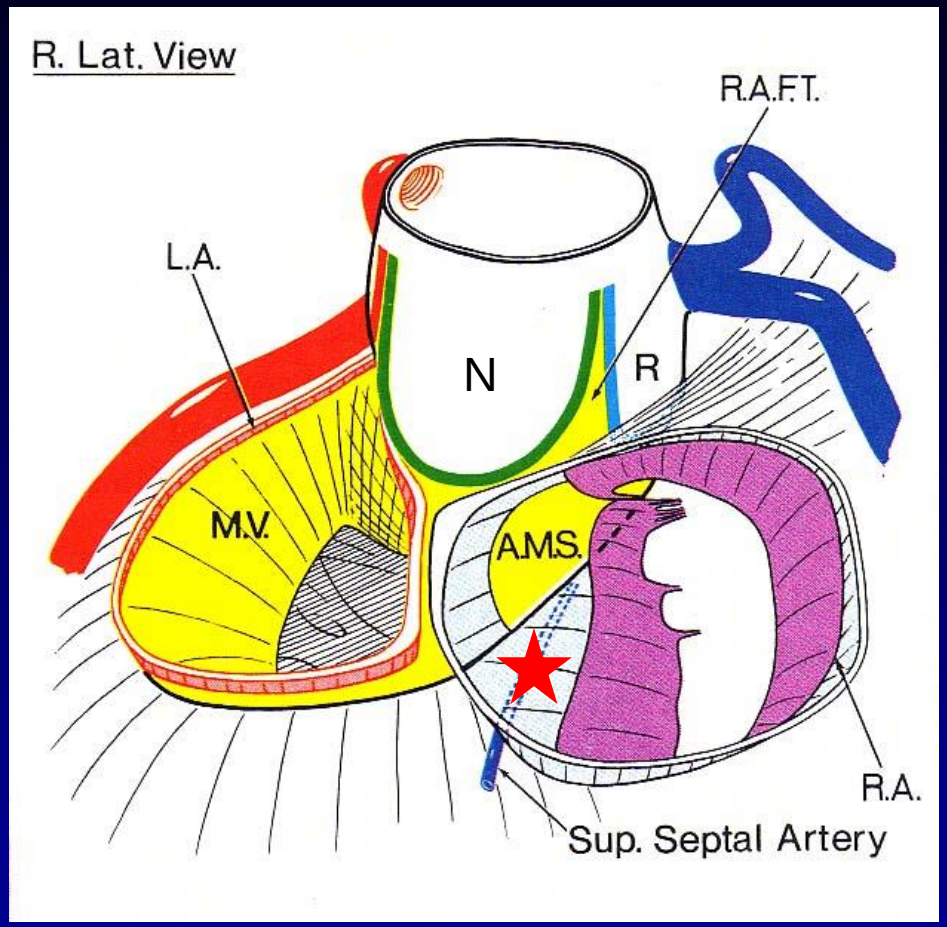
房室中隔：Atrio-ventricular septum

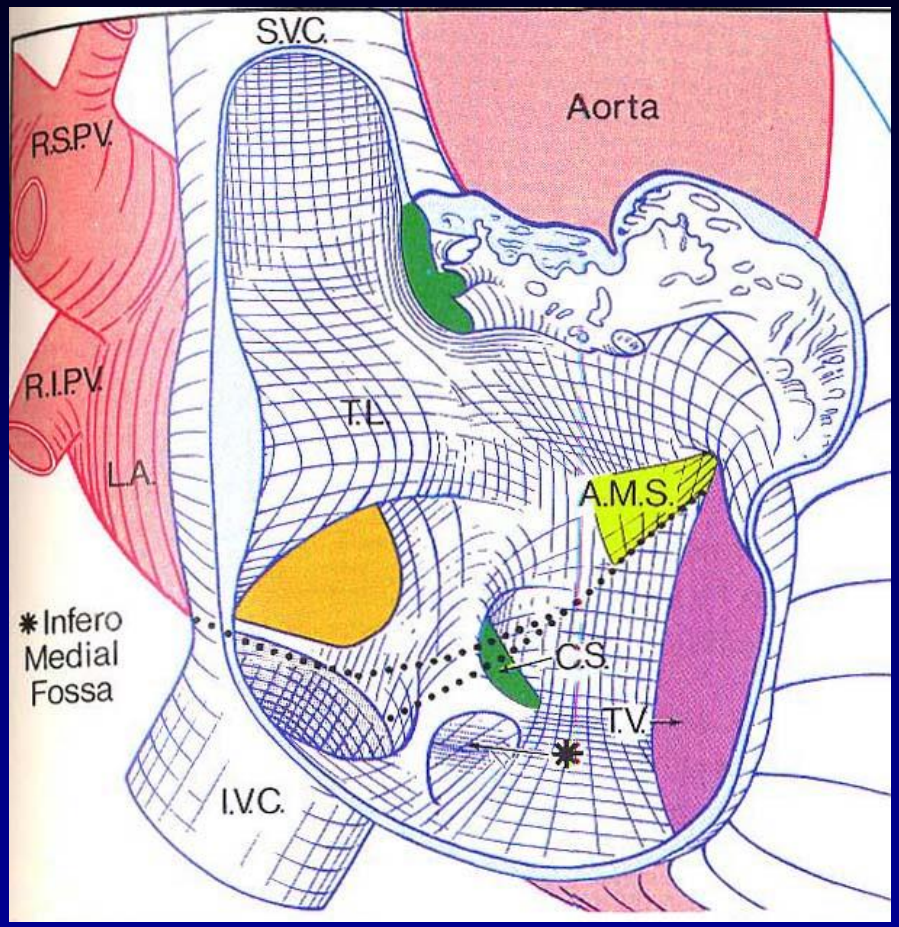
右心房ー左心室を隔てる





房室中隔：Atrio-ventricular septum

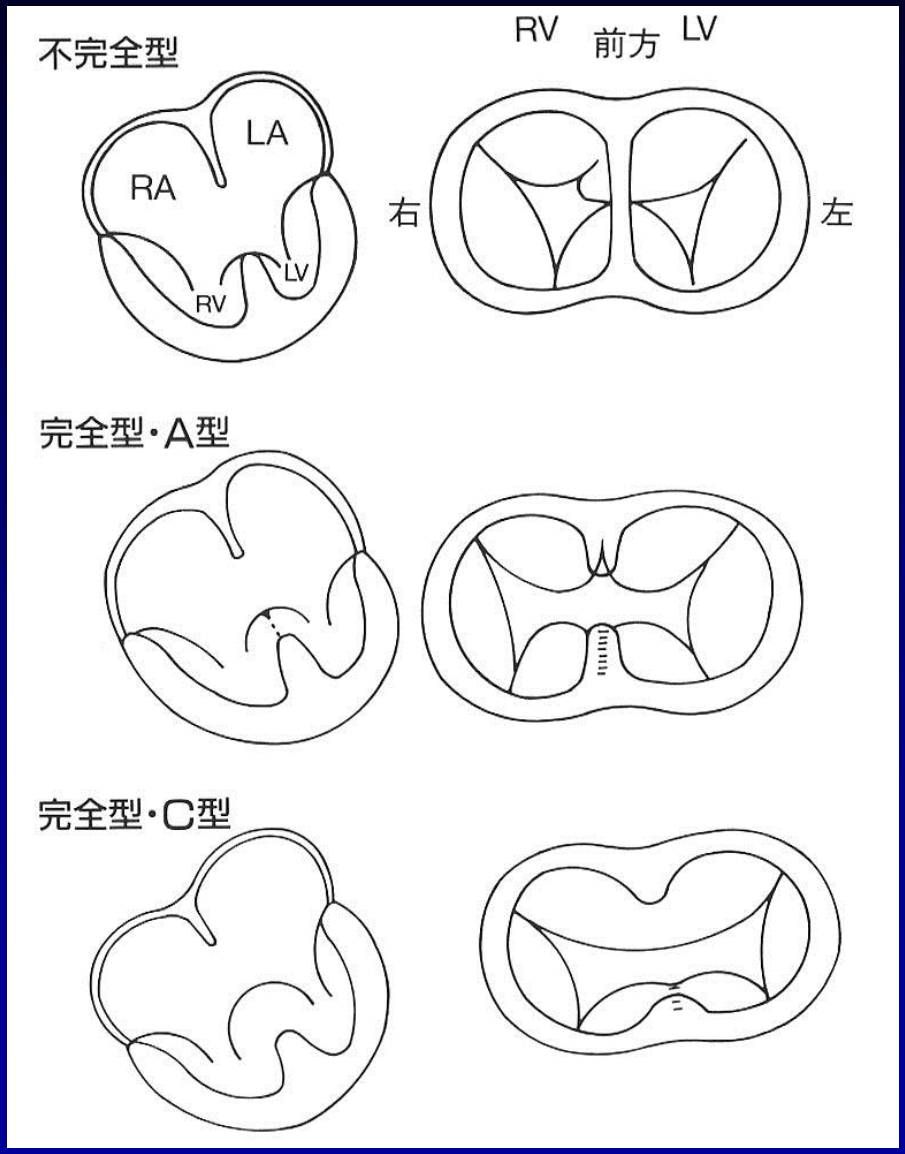




A.M.S.: membranous portion of atrioventricular septum
(atrioventricular portion of membranous septum)

★ : muscular portion of atrioventricular septum

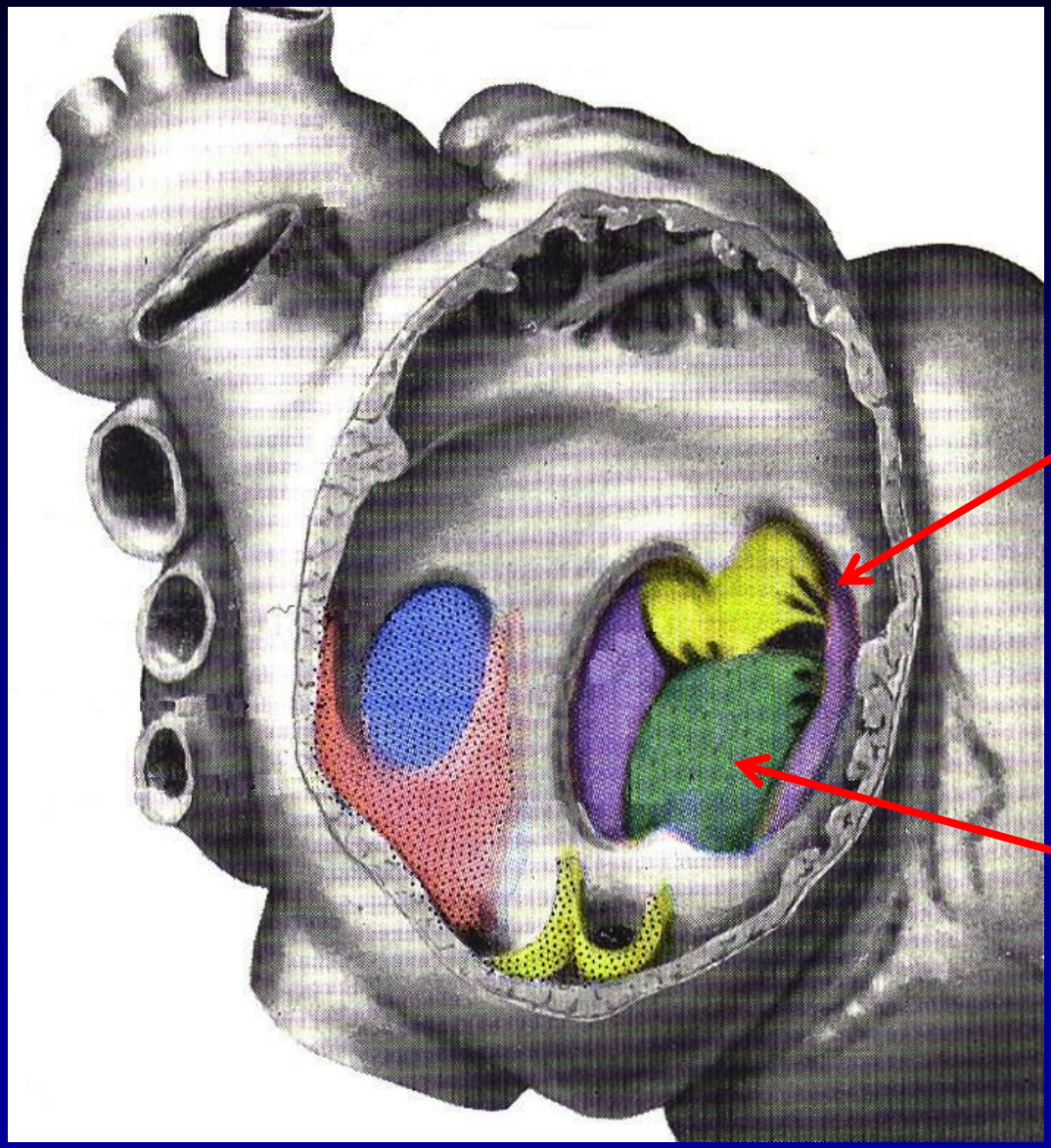
Atrioventricular septal defect



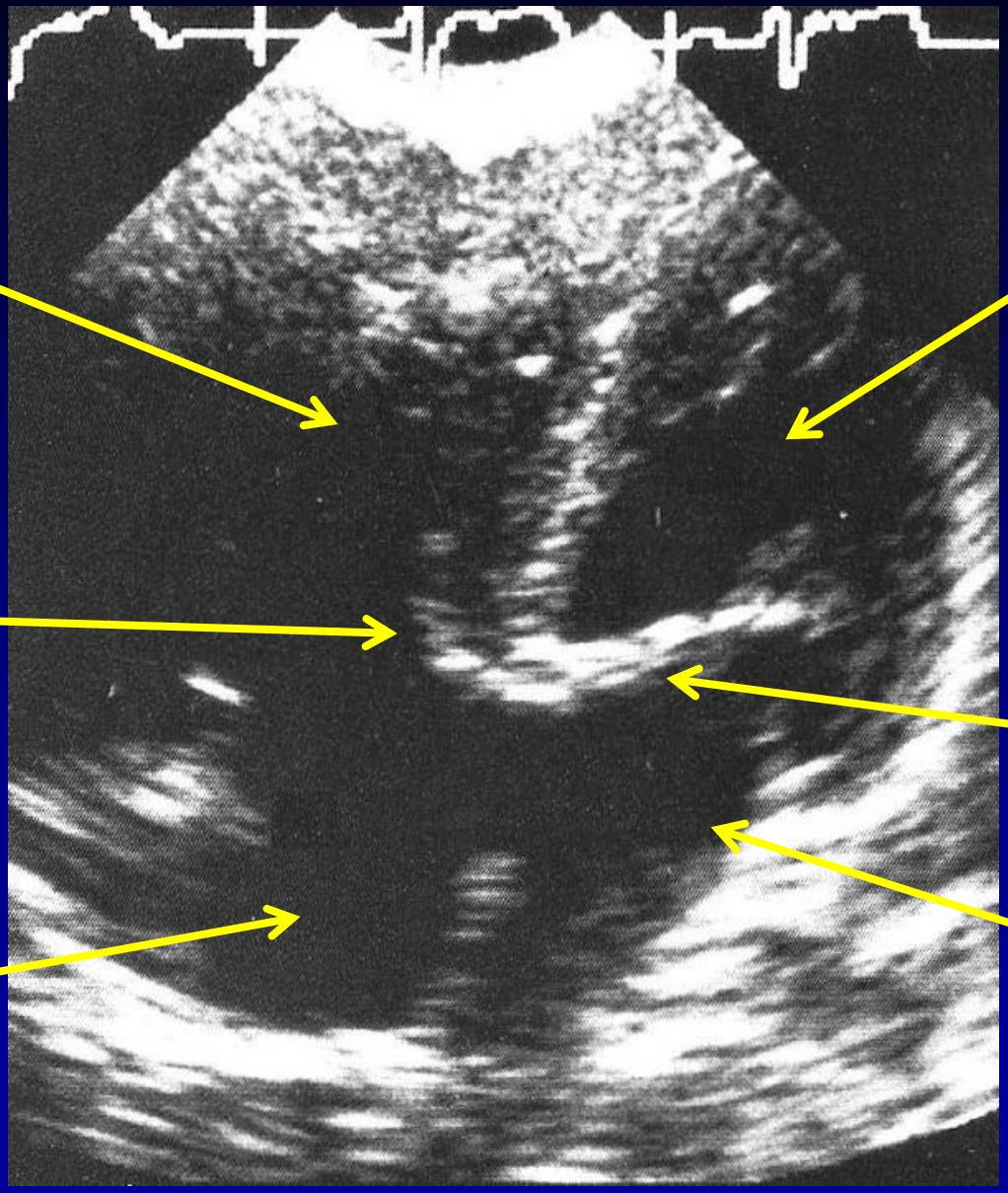
筋性房室中隔の欠損

不完全型か完全型かは
心室間交通があるか
ないかの違いのみ

Atrioventricular septal defect

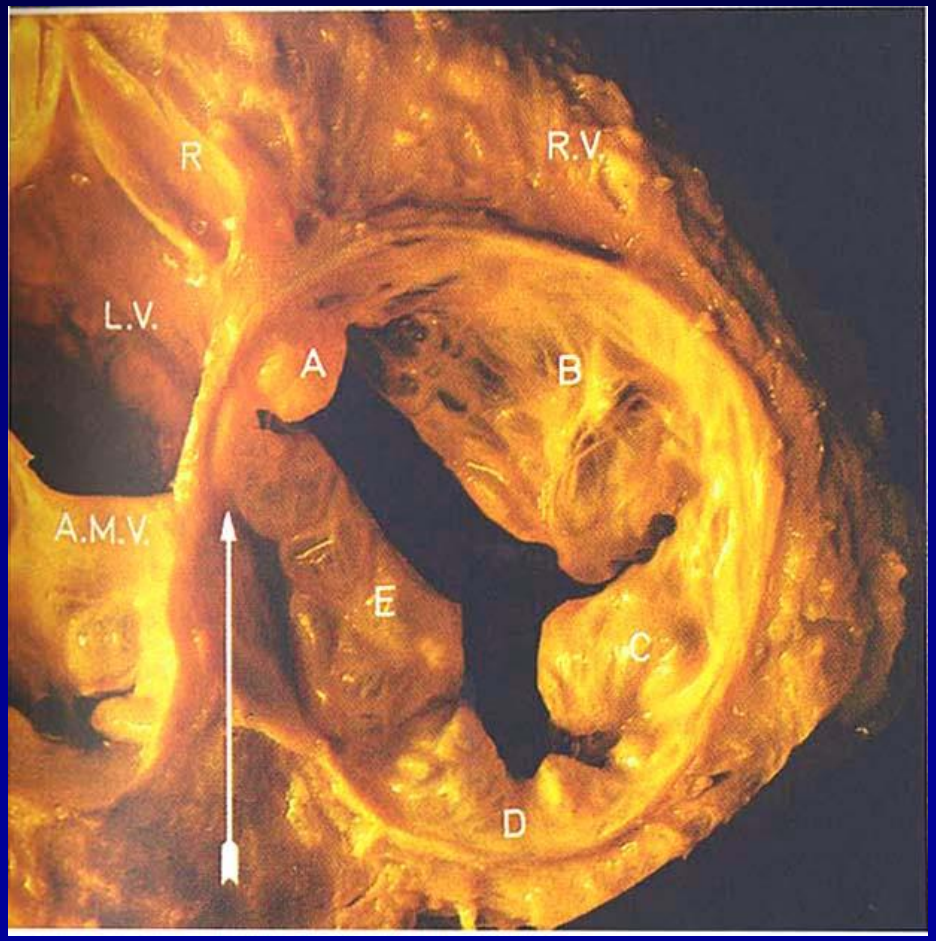


Atrioventricular septal defect



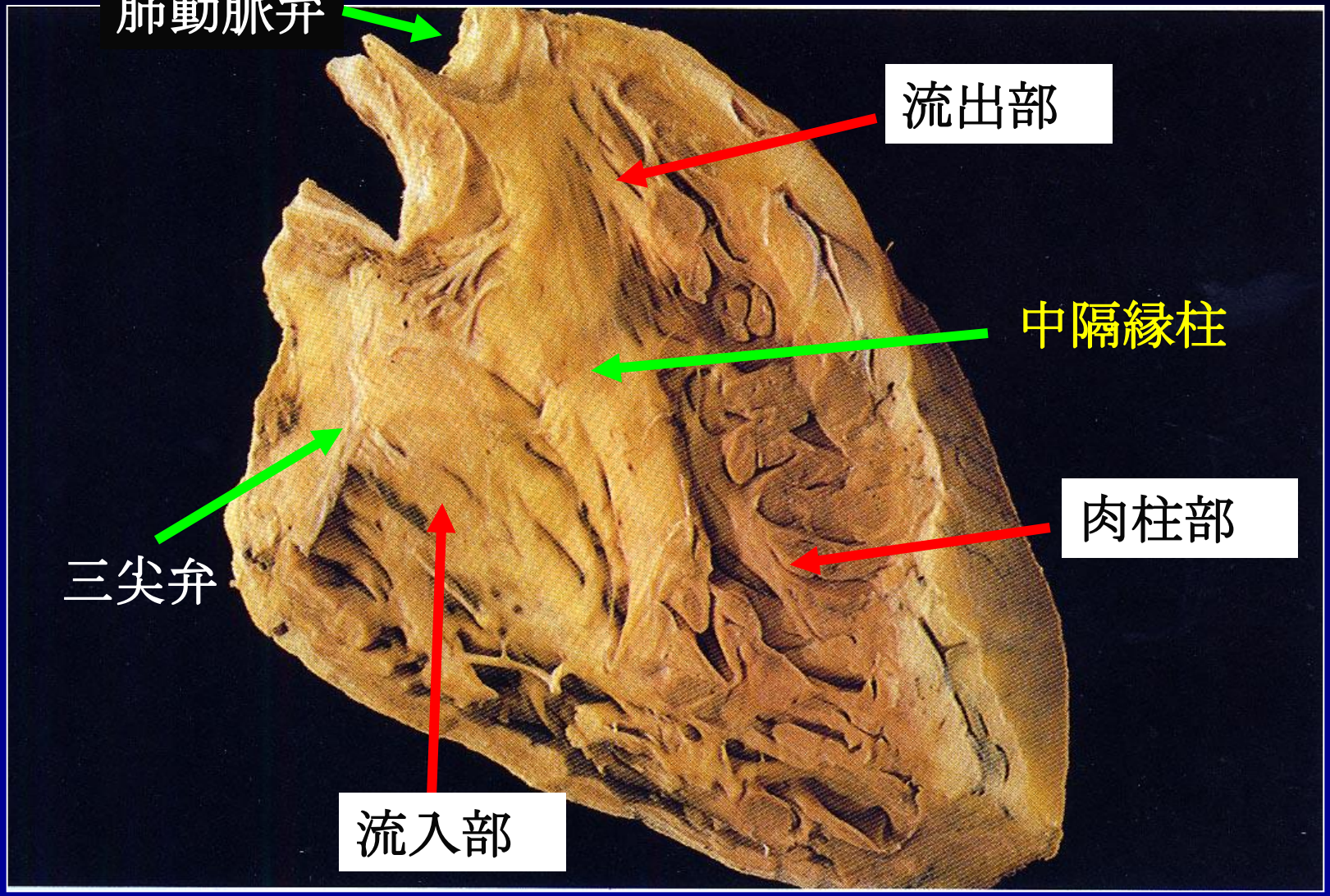
三尖弁：不適切？

弁尖の命名：一般的には anterior, posterior, septal
三次元的にはanterosuperior, inferior, septal
三尖弁：実際は四尖のことも多い



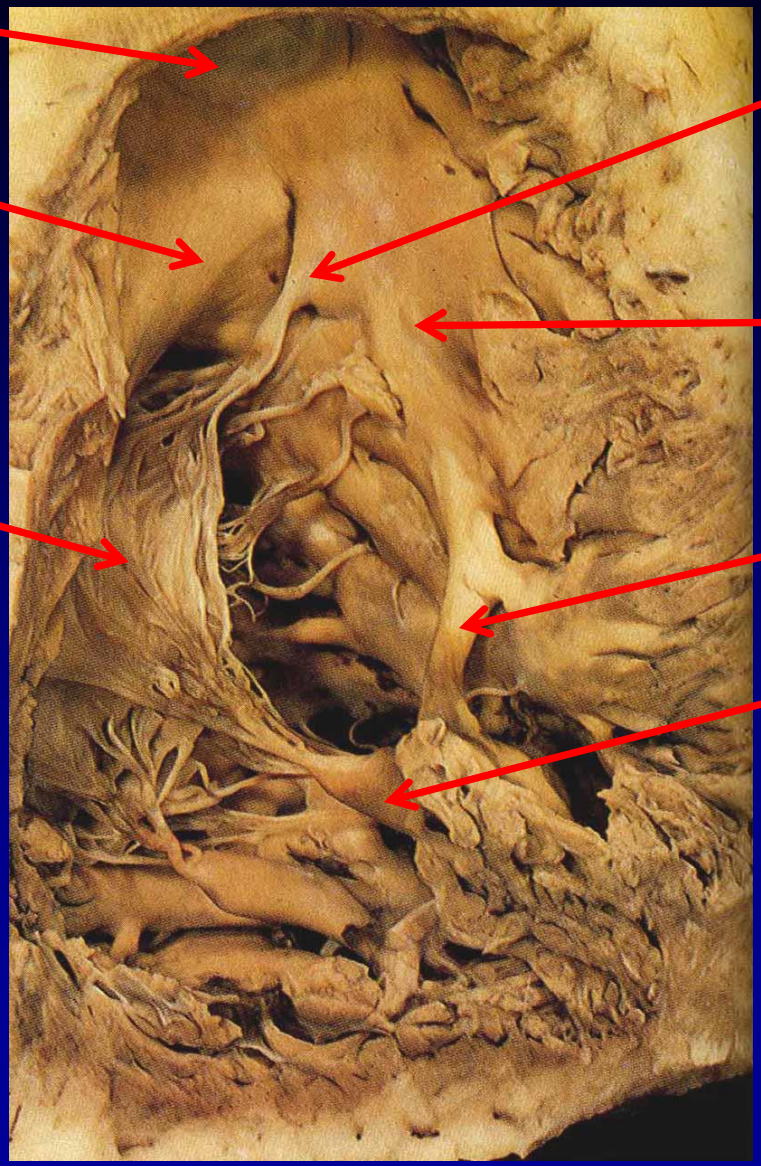
B : anterosuperior leaflet
C : anteroinferior leaflet
D : inferior leaflet
E : septal leaflet

右心室

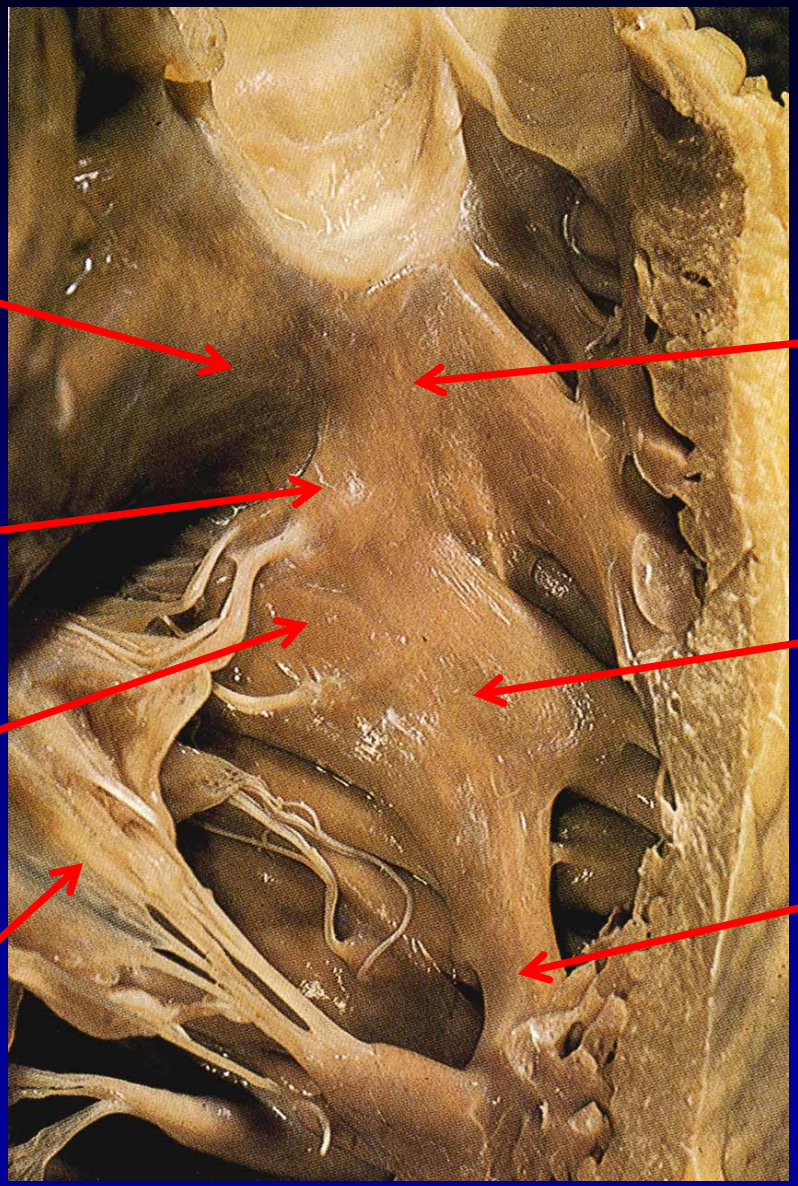


中隔縁柱:trabecula septomarginalis(TSM)

右心室


pulmonary valve
crista supraventricularis
tricuspid valve
medial papillary muscle
trabecula septomarginalis (TSM)
moderator band
anterior papillary muscle

右心室



crista supraventricularis

medial papillary muscle

posterior limb of TSM

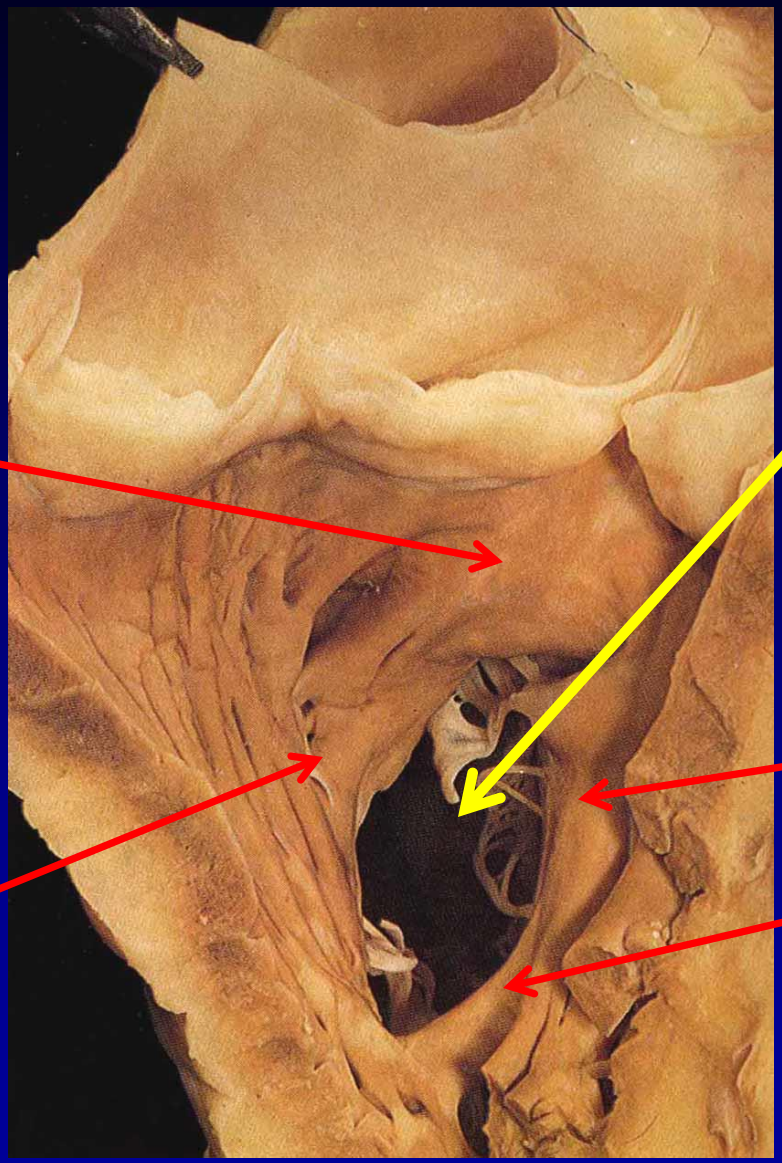
tricuspid valve

anterior limb of TSM

body of TSM

moderator band

右心室



crista
supraventricularis

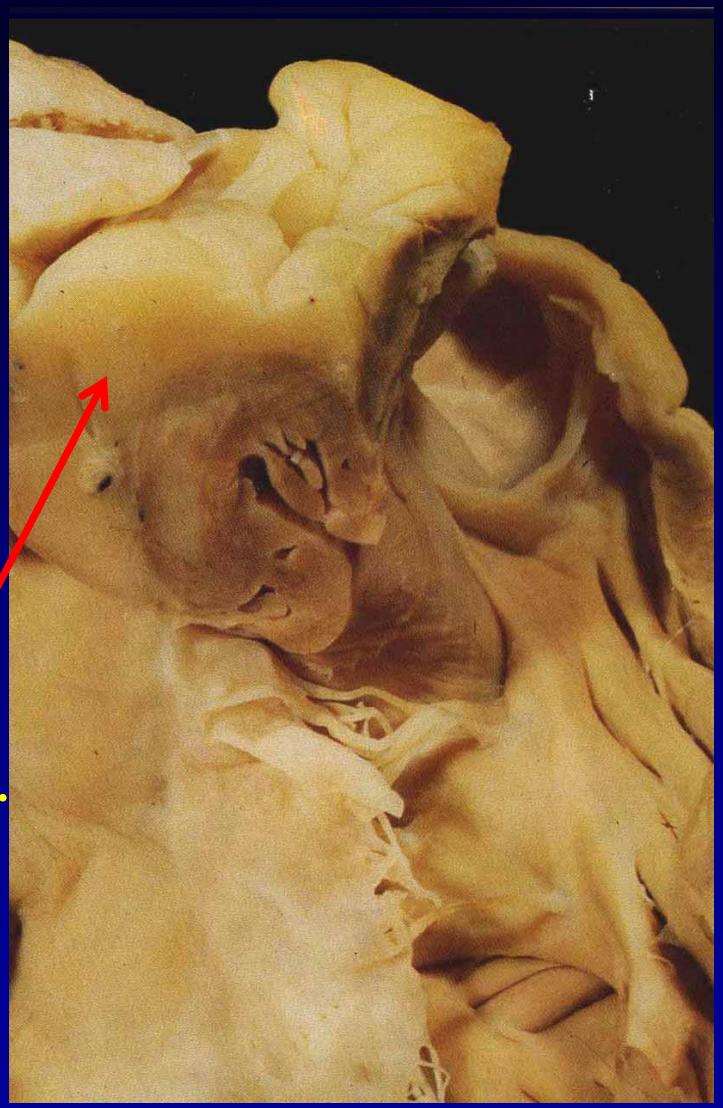
parietal extension
of crista

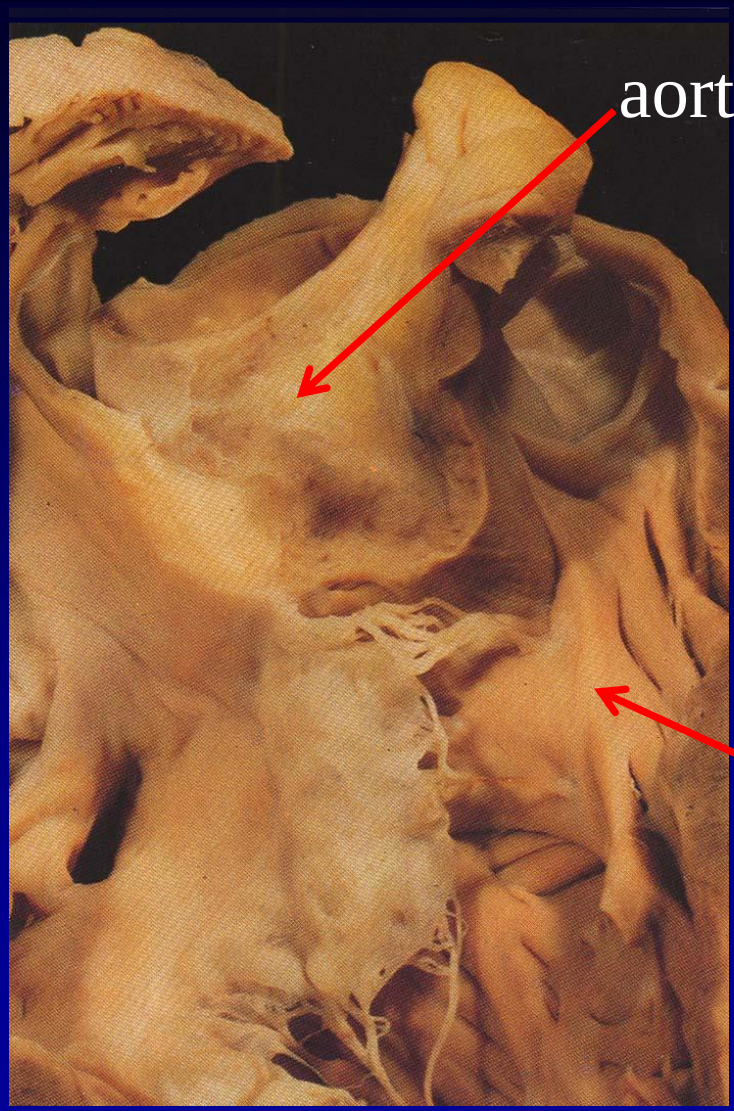
muscular annulus

TSM

moderator band

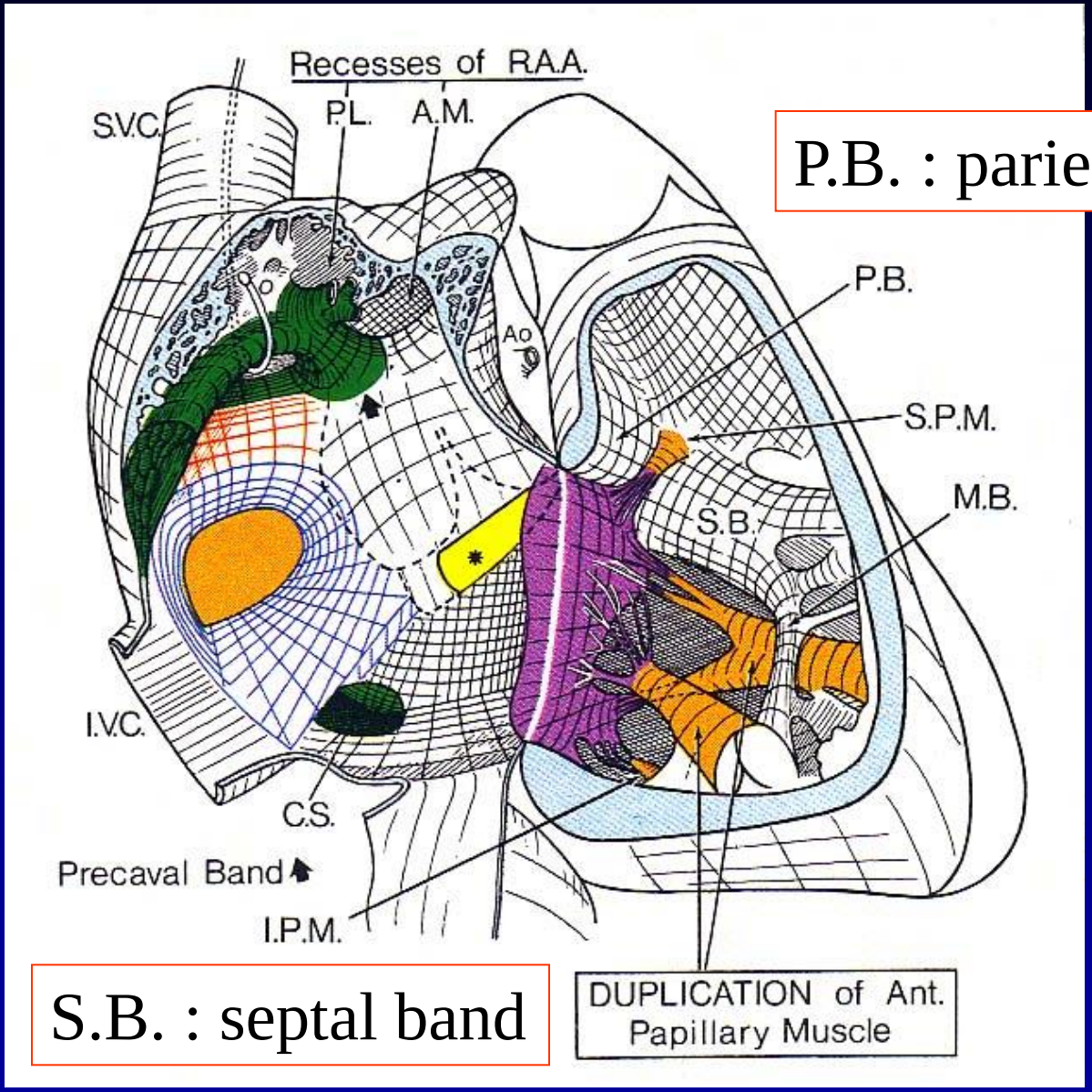
右心室





V. I. F. : Ventriculo-infundibular fold

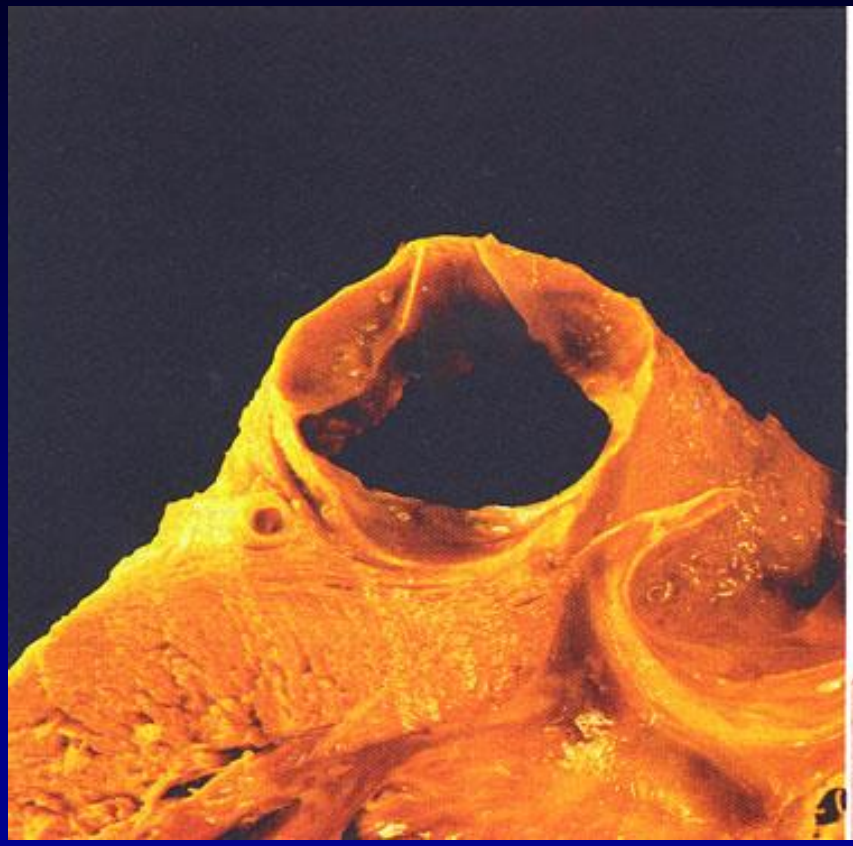
右心室

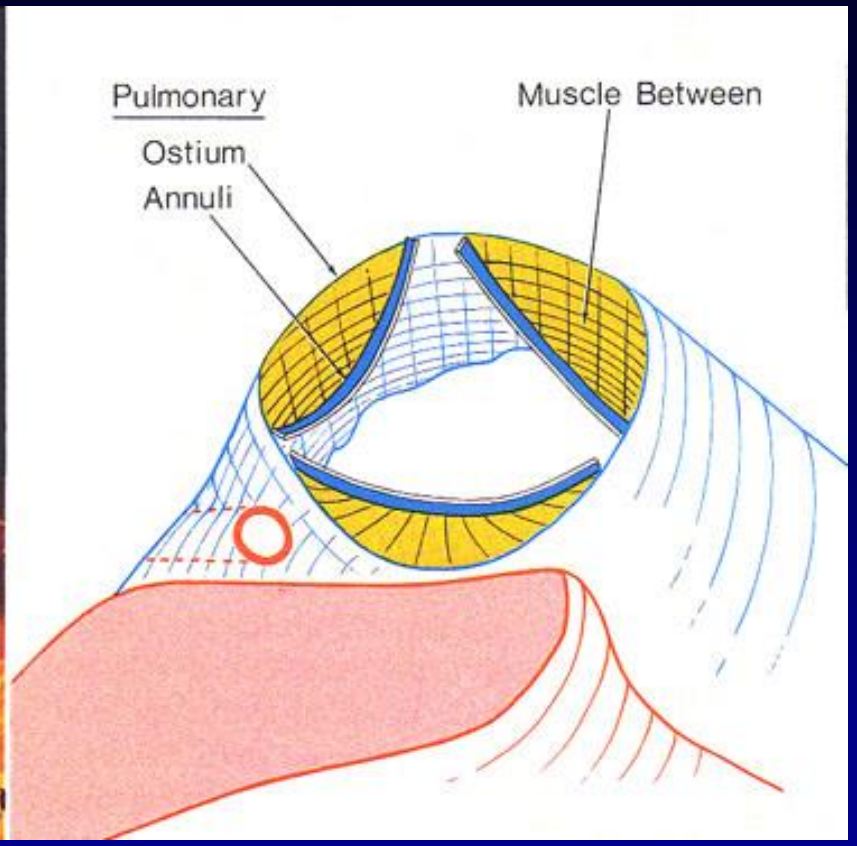


P.B. : parietal band

S.B. : septal band

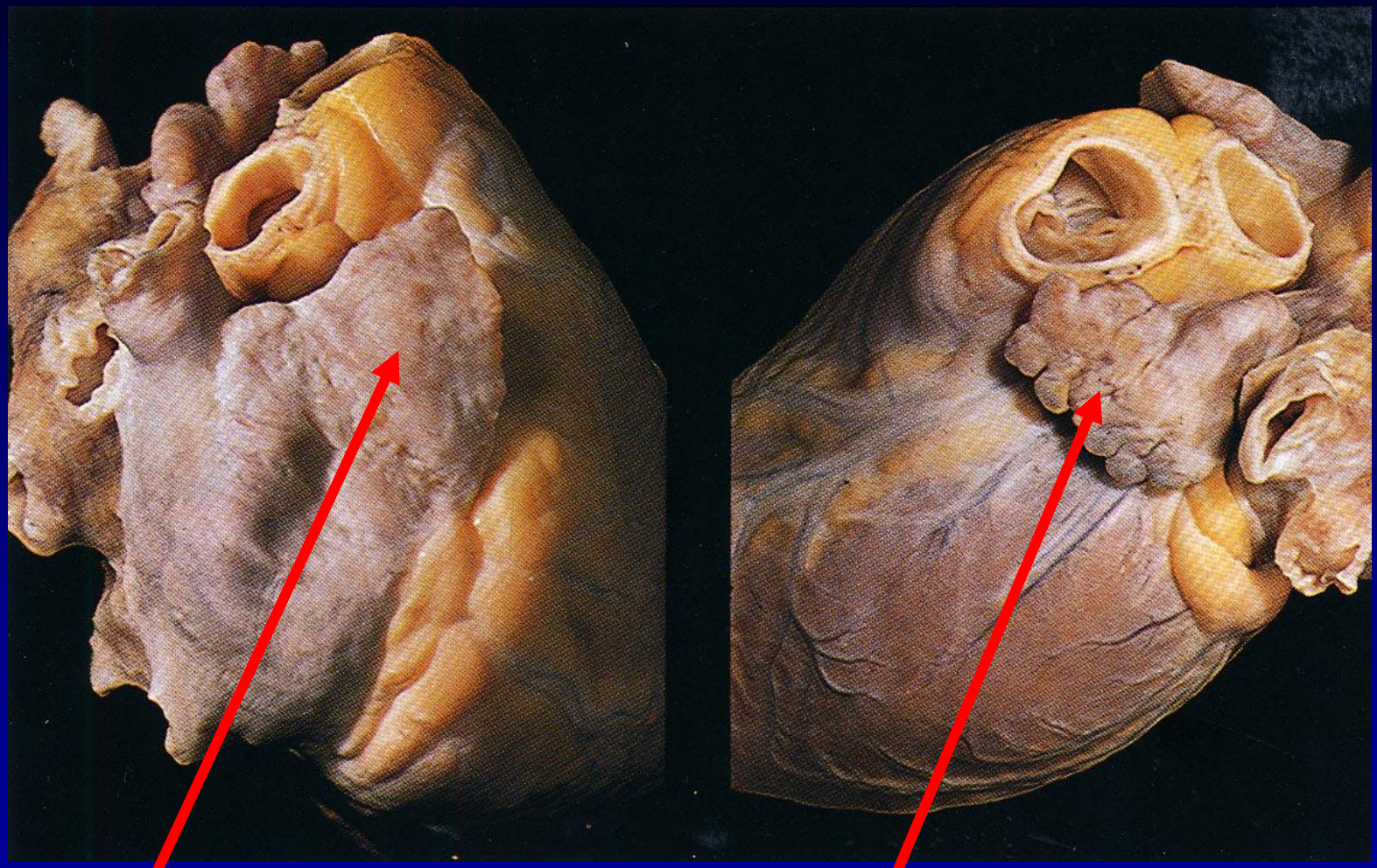
肺動脈弁





解剖学的弁輪と血行動態的（機能的）弁輪は一致しない。

右心耳と左心耳

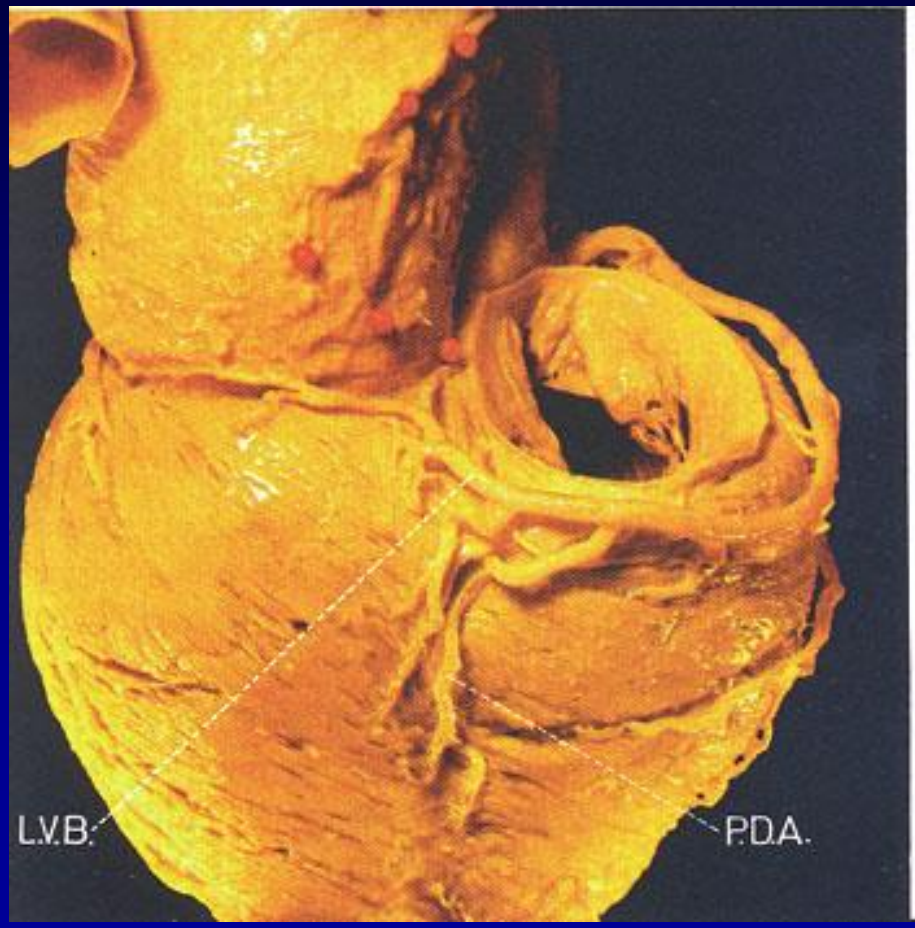


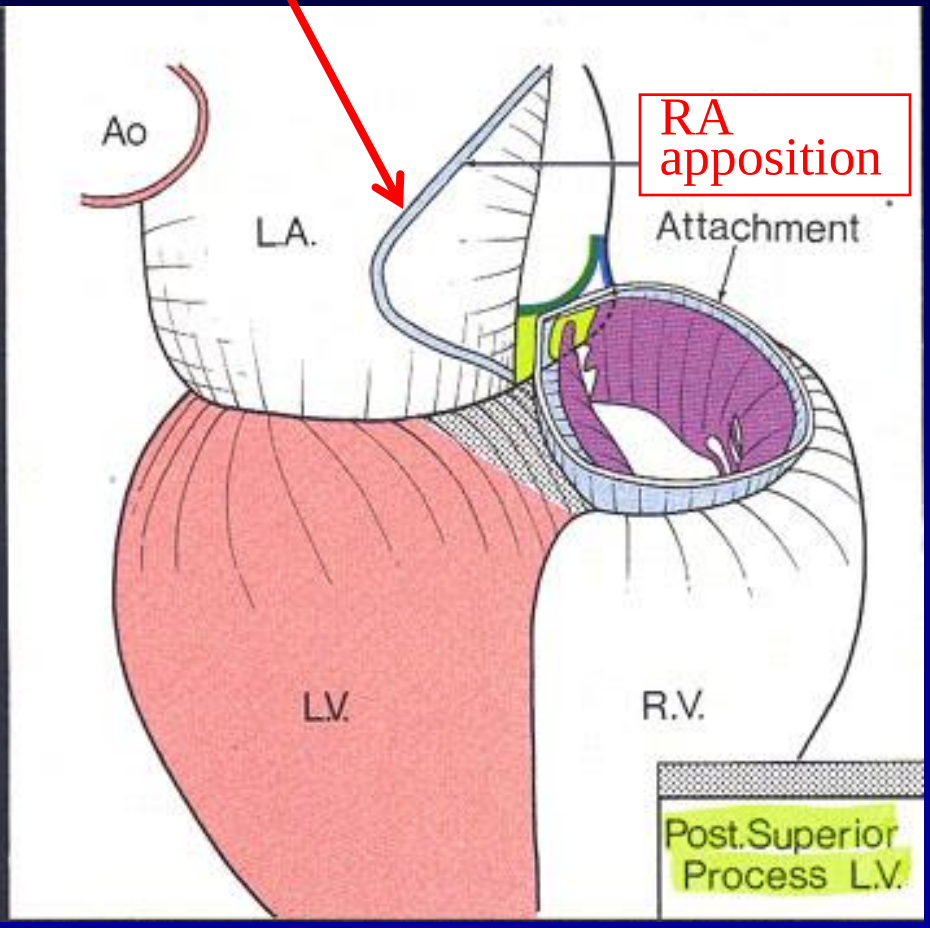
右心耳：基部の幅広く、鈍

左心耳：基部の幅狭、鋭

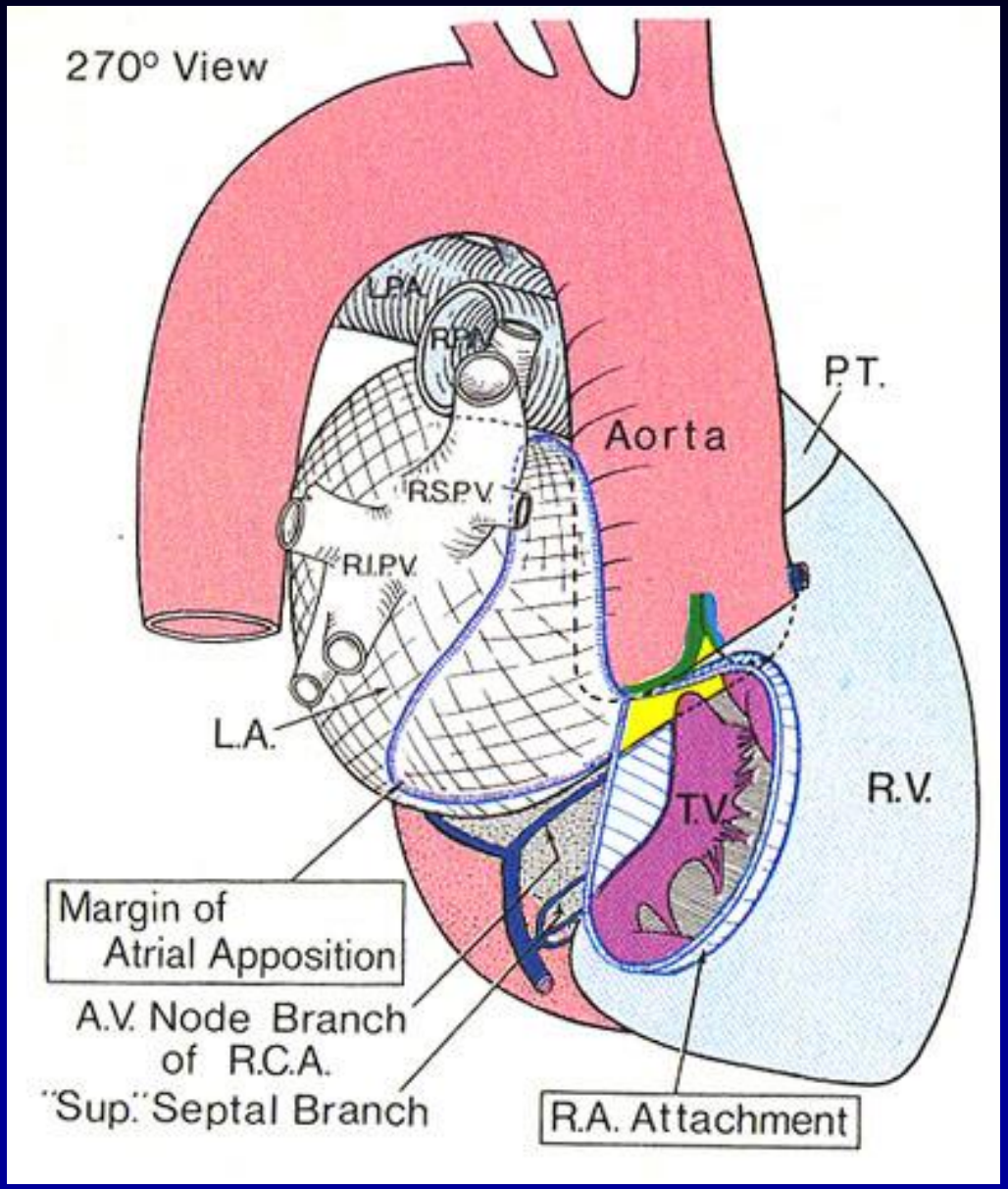
左房と右房の関係

Waterston's groove





Left Atrial Approach for Mitral Valve

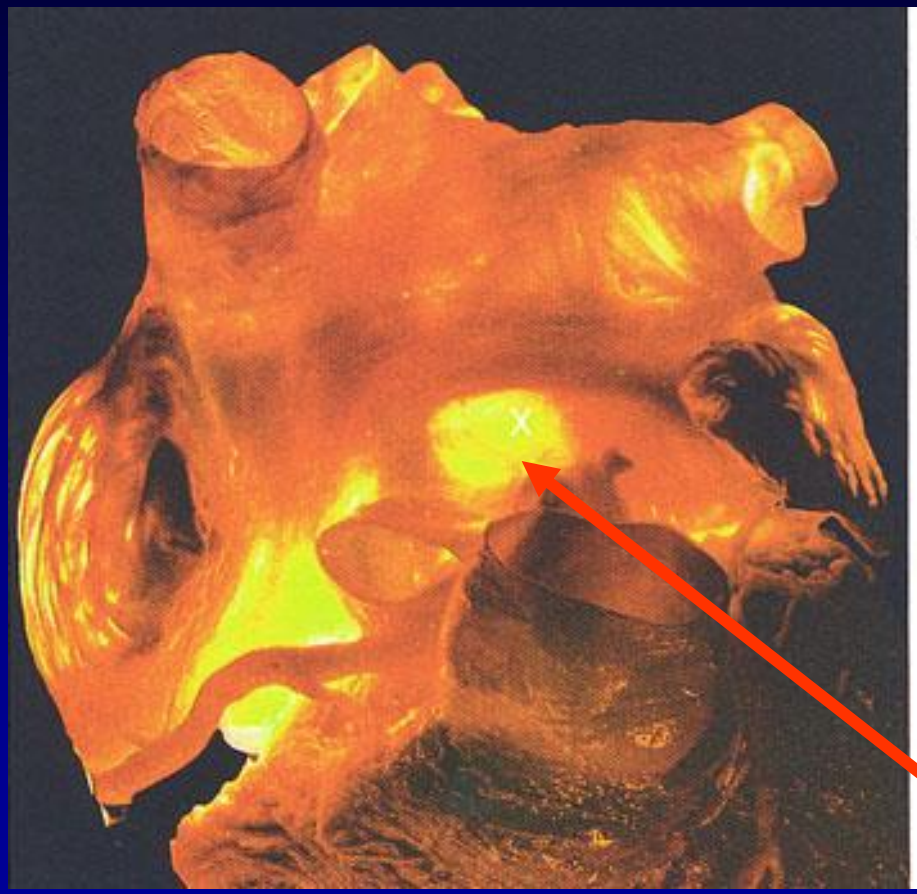


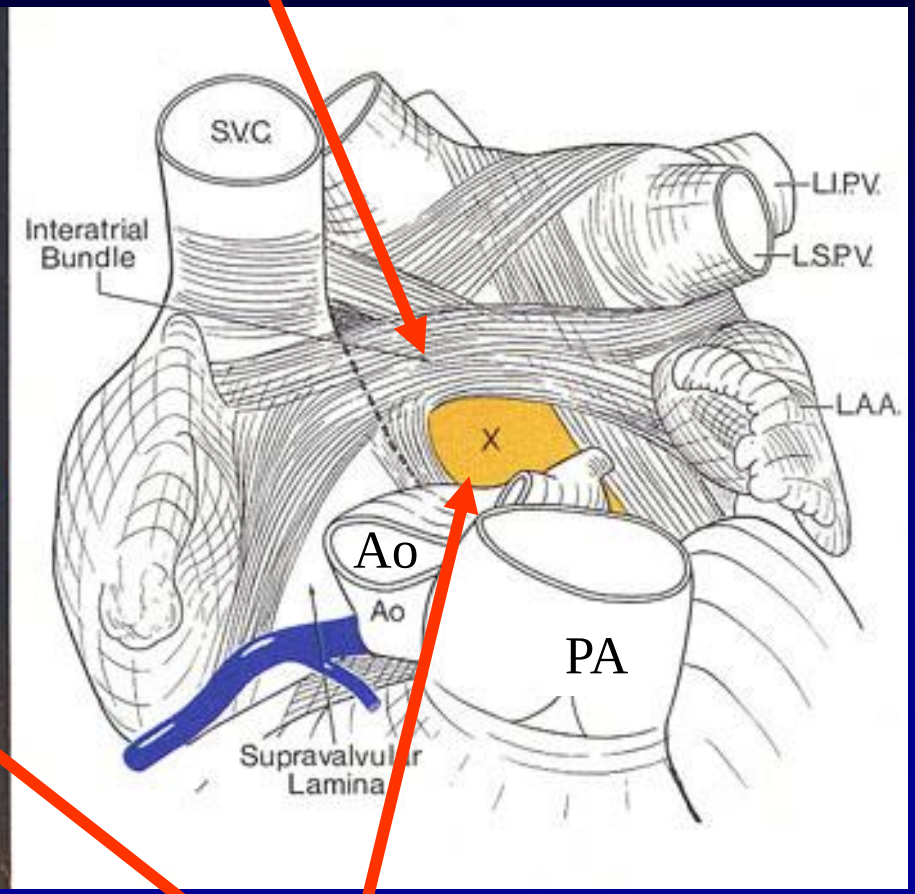
Left Atrial Approach for Mitral Valve

心房間溝の剥離：右上肺静脈流入部から始めて
IVC後方(背側)に向かう！

Inteatrial bundle：その前方は危険地帯！

Interatrial bundle





危険地帯！！

Superior Septal Approach for Mitral Valve

Superior Septal Approach for Mitral Valve

Interatrial bundle前方の部分→非常に脆弱
切開のみならず縫合線がかからないようにする！

Inteatrial bundle 前方の危険地帯！

1) 危険地帯には踏み込まない

Superior septal approachにおける左房天井切開時

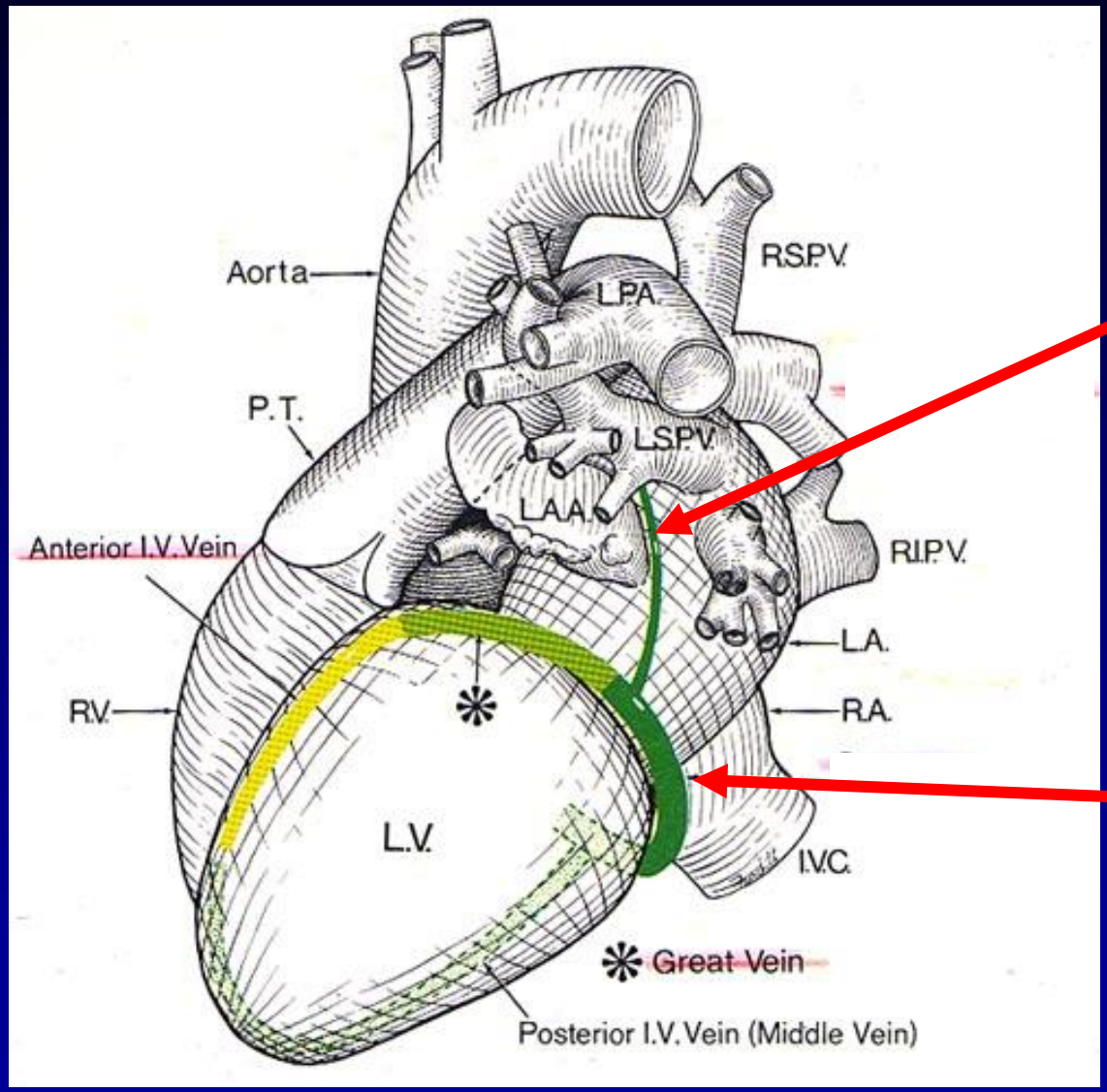
切開線のみならず縫合糸がかからないようにする！

2) 危険地帯に踏み込まざるを得ない時

狭小大動脈弁輪症例やIE症例に対する**Manouguian**法

パッチ縫着は優しく丁寧に！

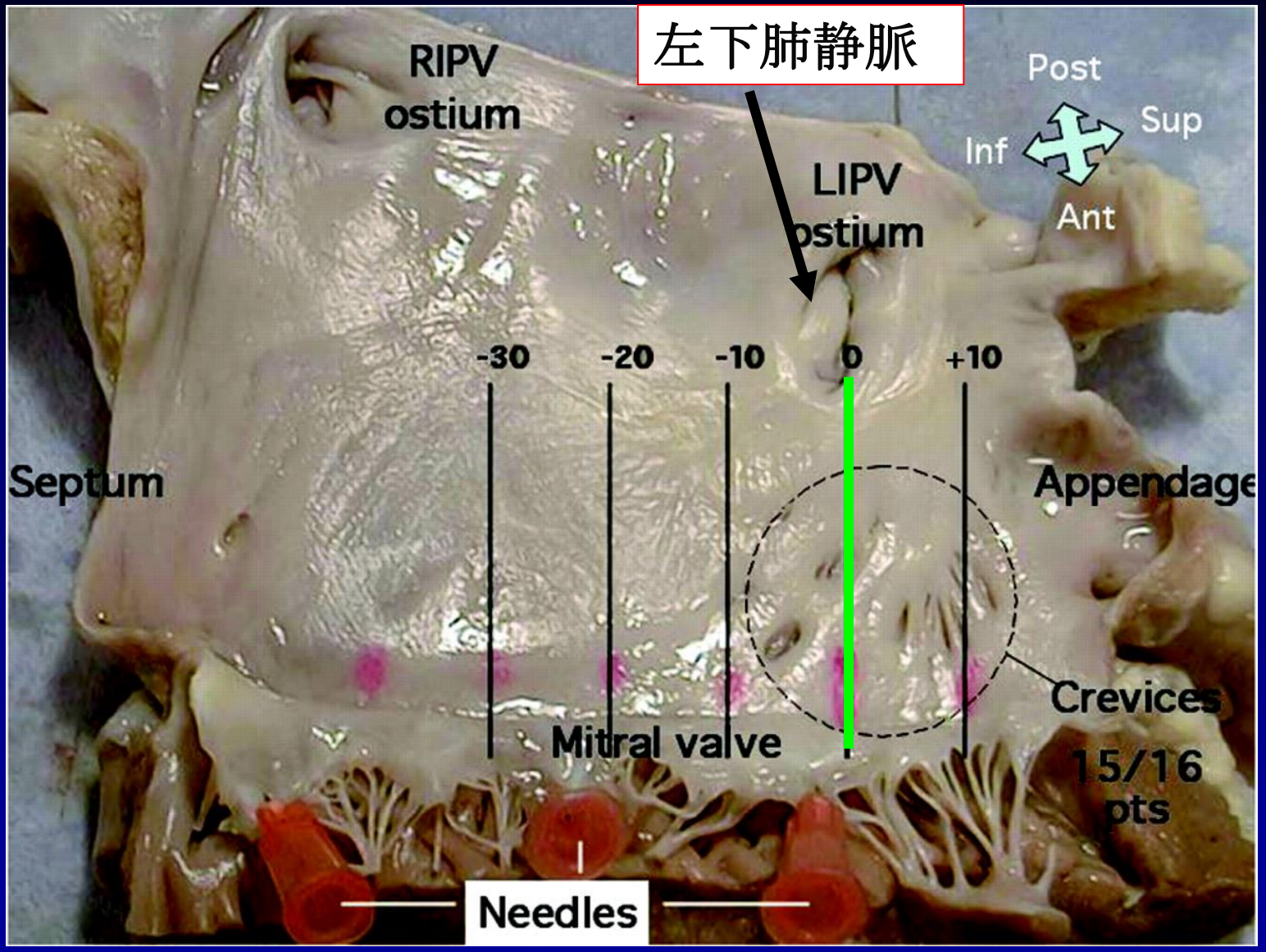
左心房



Marshall靭帯
または
斜静脈
(左上大静脈由来)

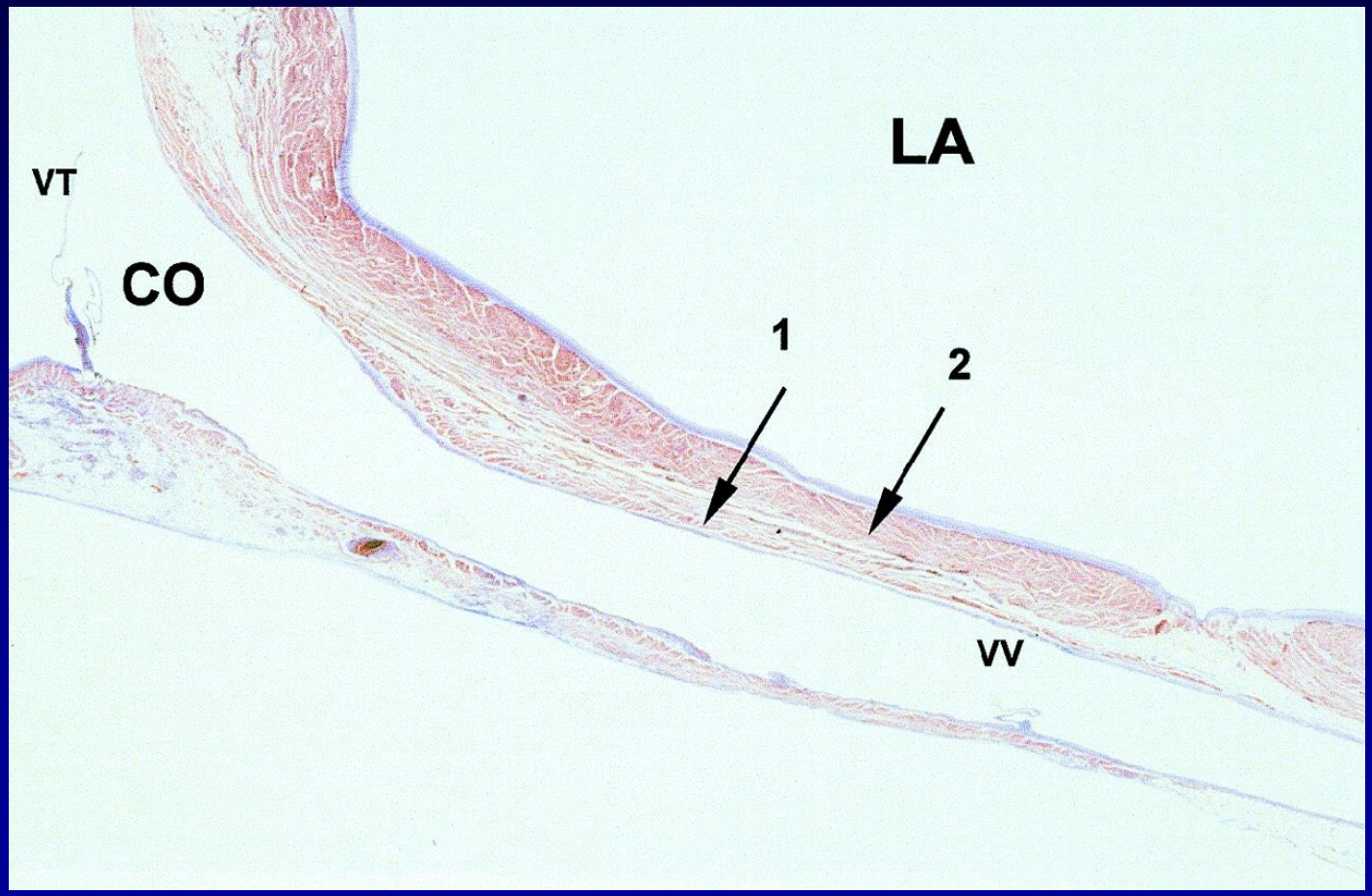
冠状静脈洞

Mitral isthmus

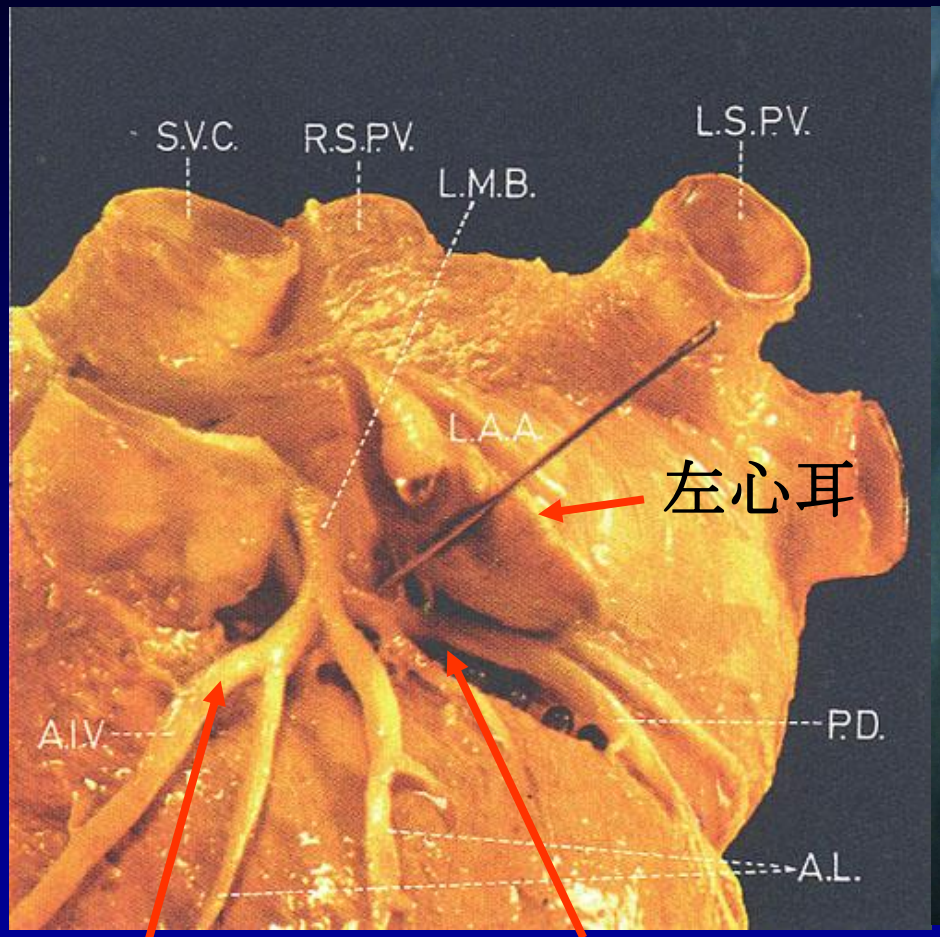


Coronary sinus ー左房間の筋性結合

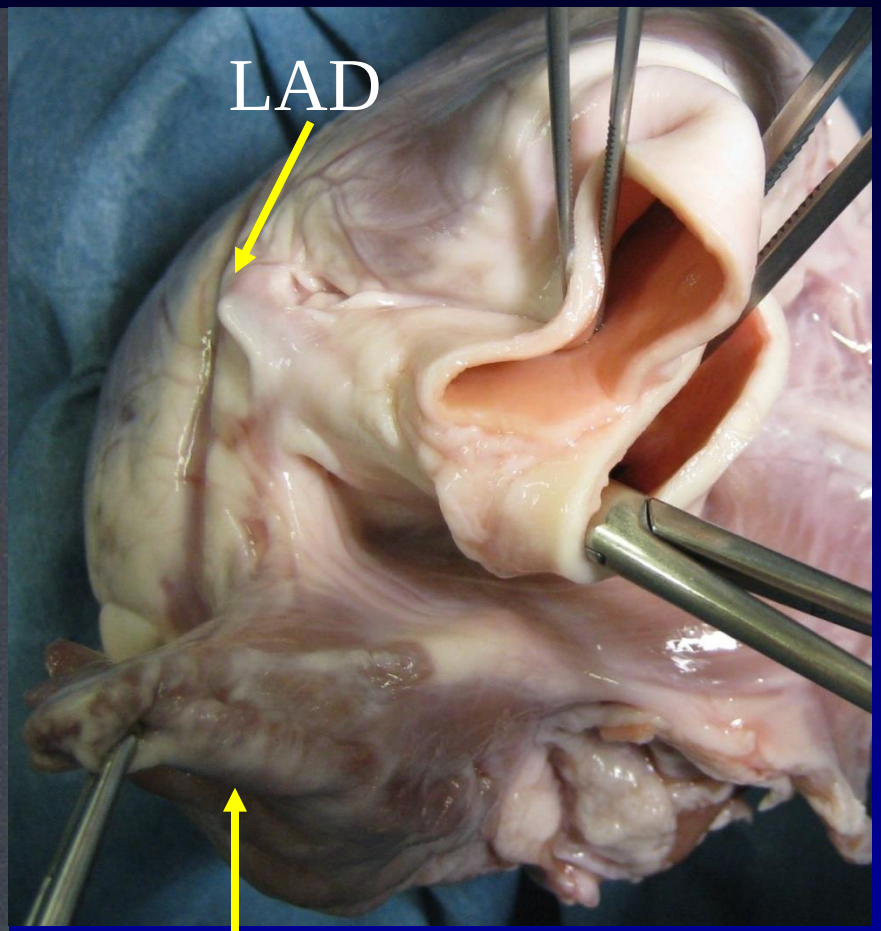
The Anatomic Basis of Connections Between the Coronary Sinus Musculature and the Left Atrium in Humans
Michel Chauvin, ***Circulation. 2000;101:647-652.***



左心耳と左冠動脈との位置関係



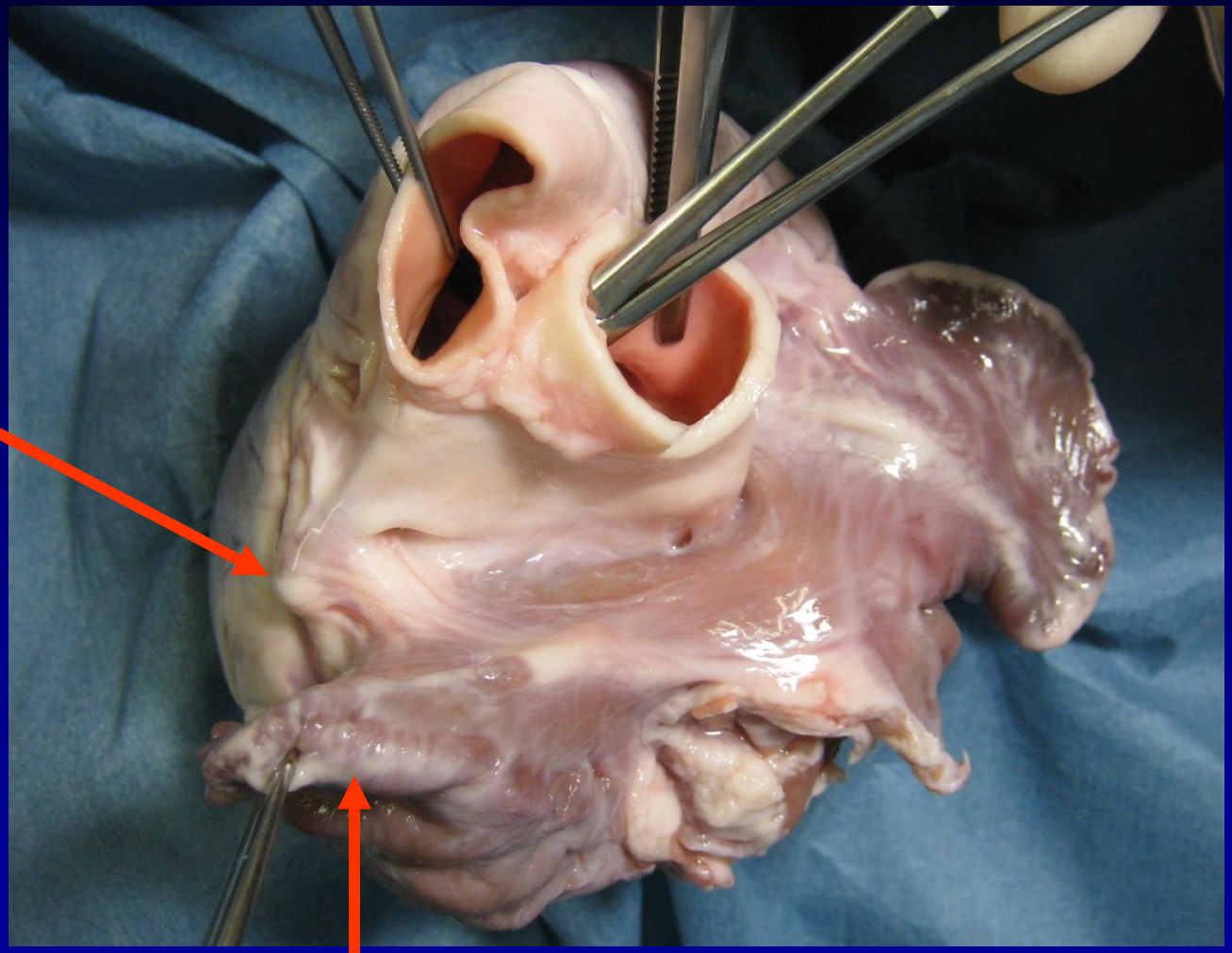
LAD　　LCX



左心耳

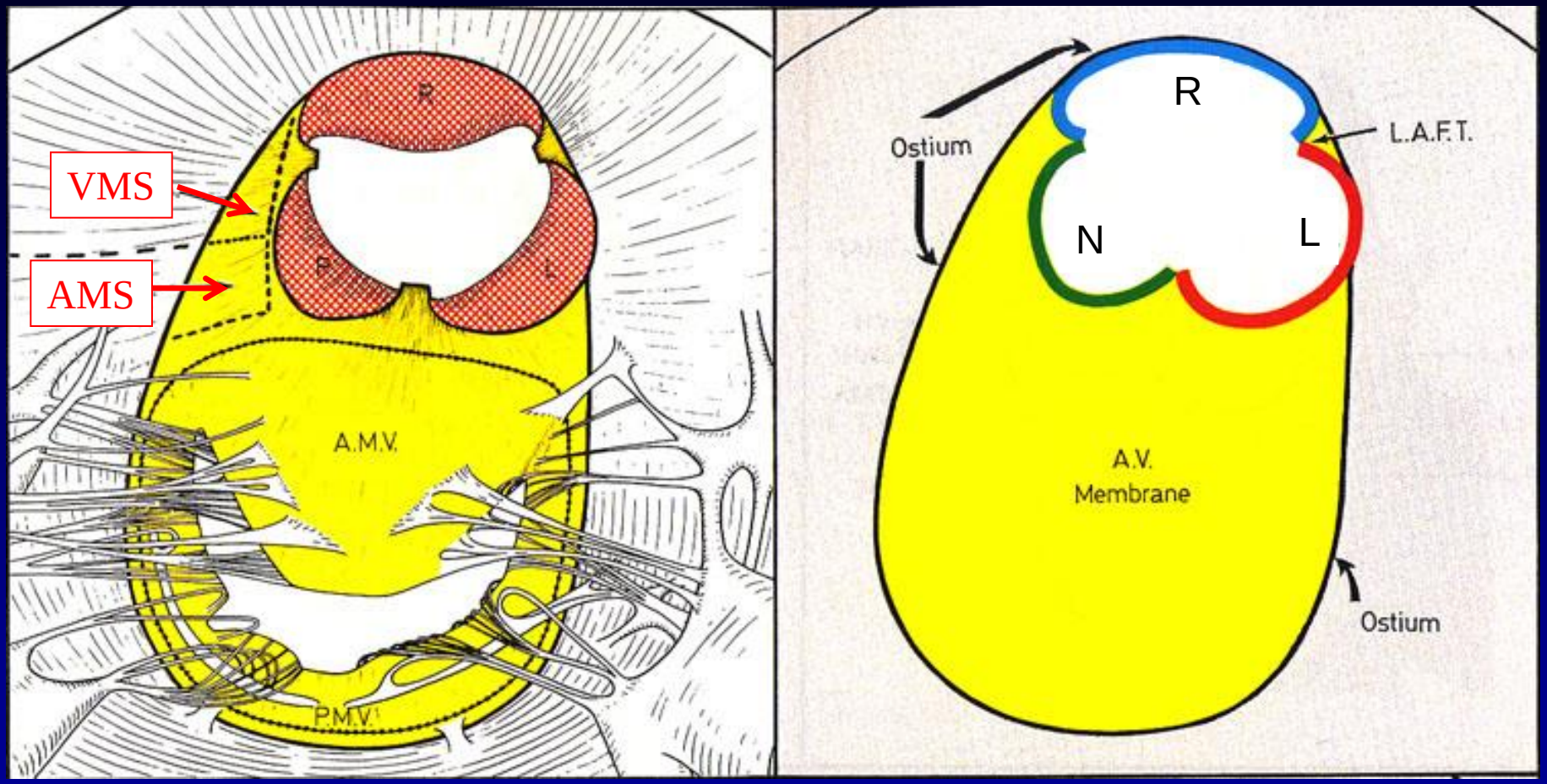
左心耳と左冠動脈との位置関係

左心耳切除、縫合の際、左回旋枝に要注意！



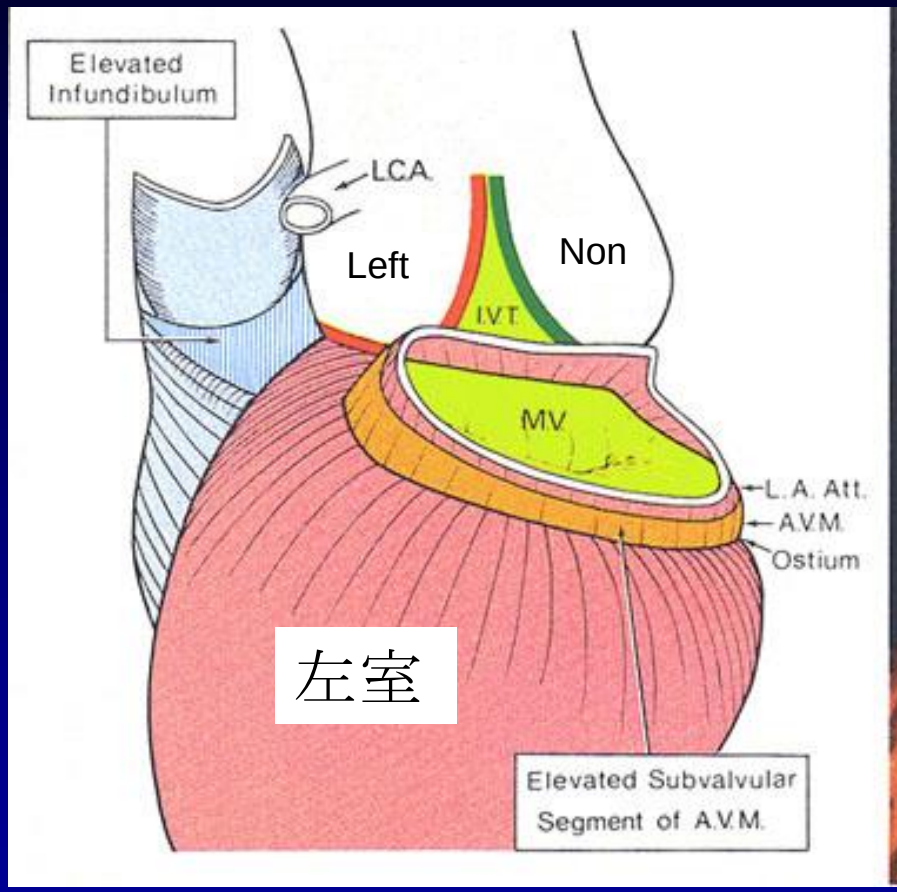
左心耳と左冠動脈との位置関係

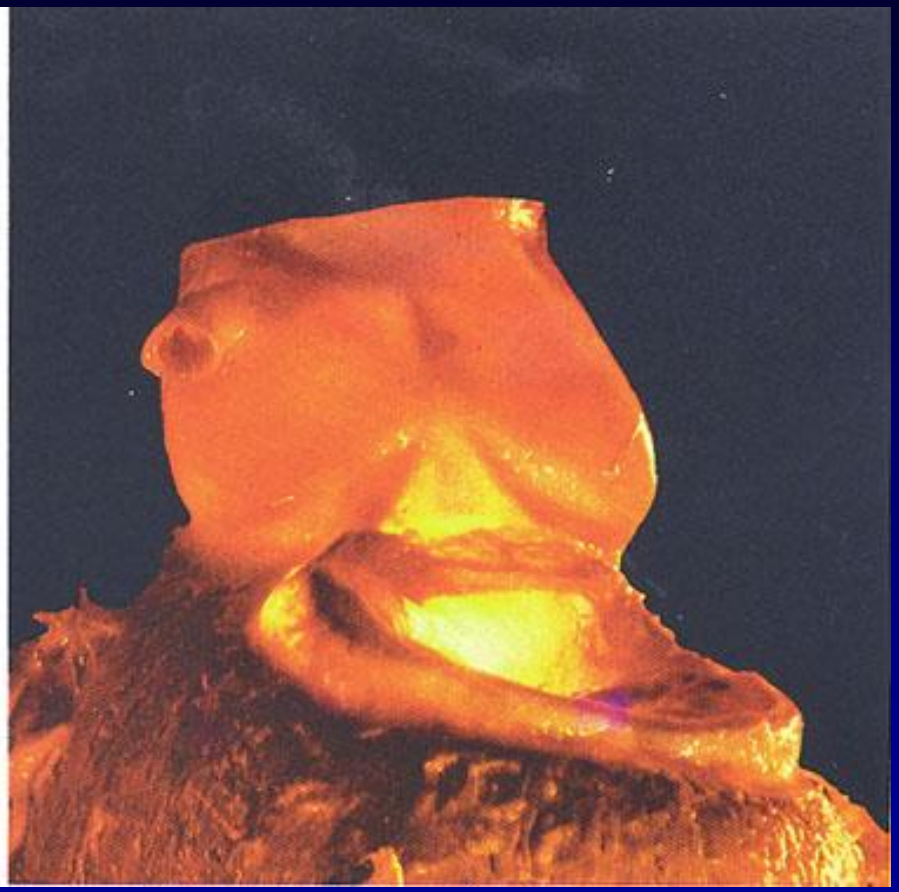
Aorto-Ventricular Membrane



VMS:interventricular portion of membranous septum
AMS:atrioventricular portion of membranous septum

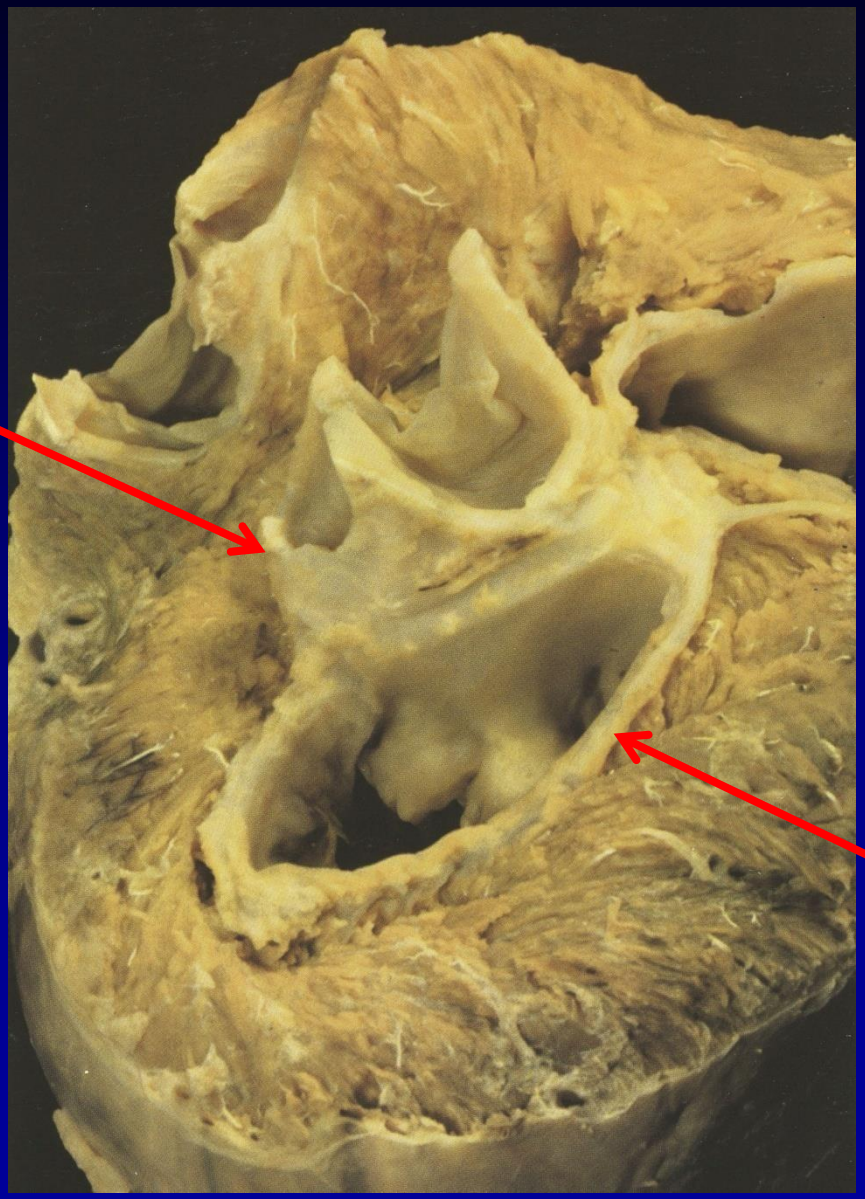
Aorto-Ventricular Membrane



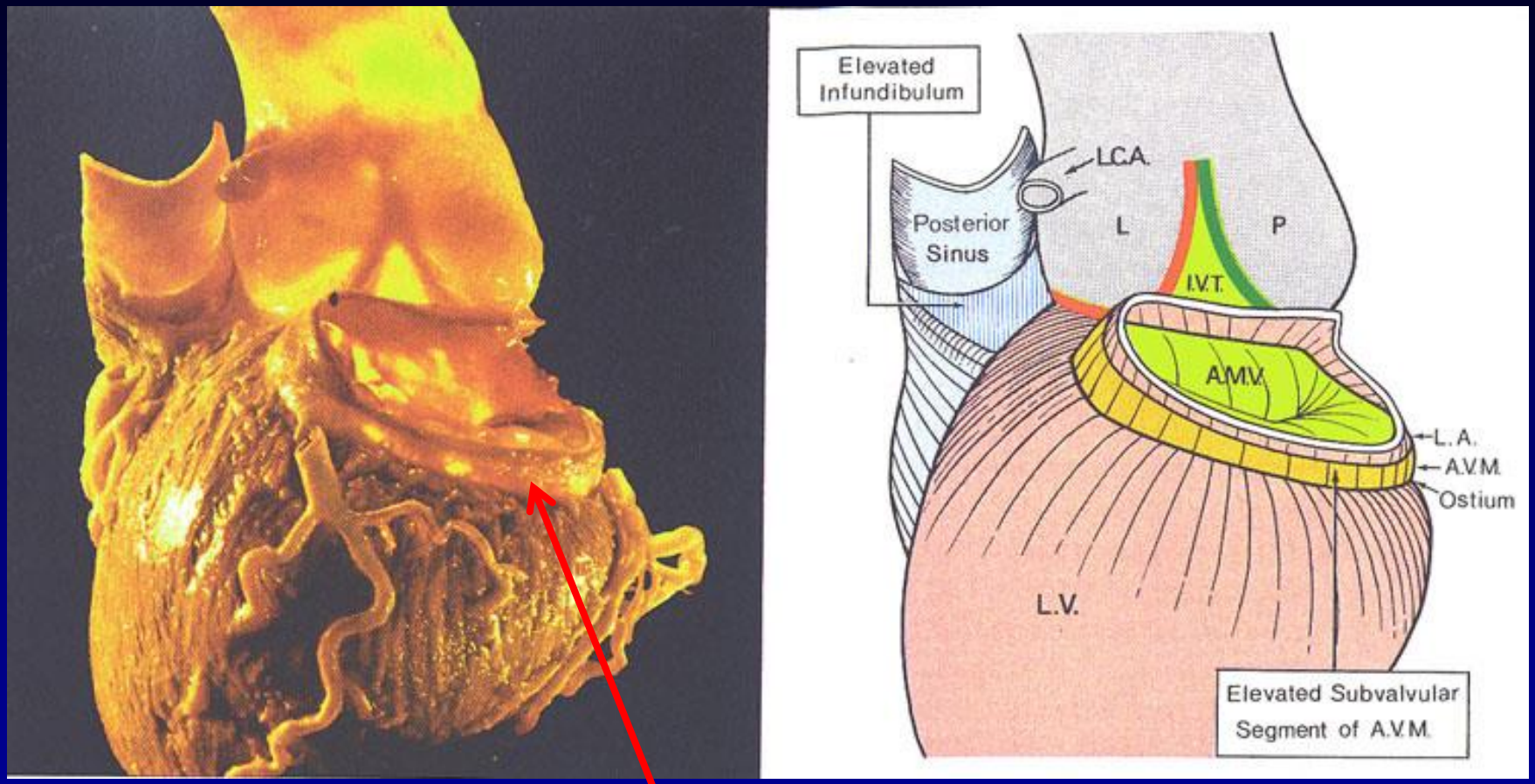


左心室では一つの口に僧帽弁と大動脈弁が連結している

左心系の線維骨格



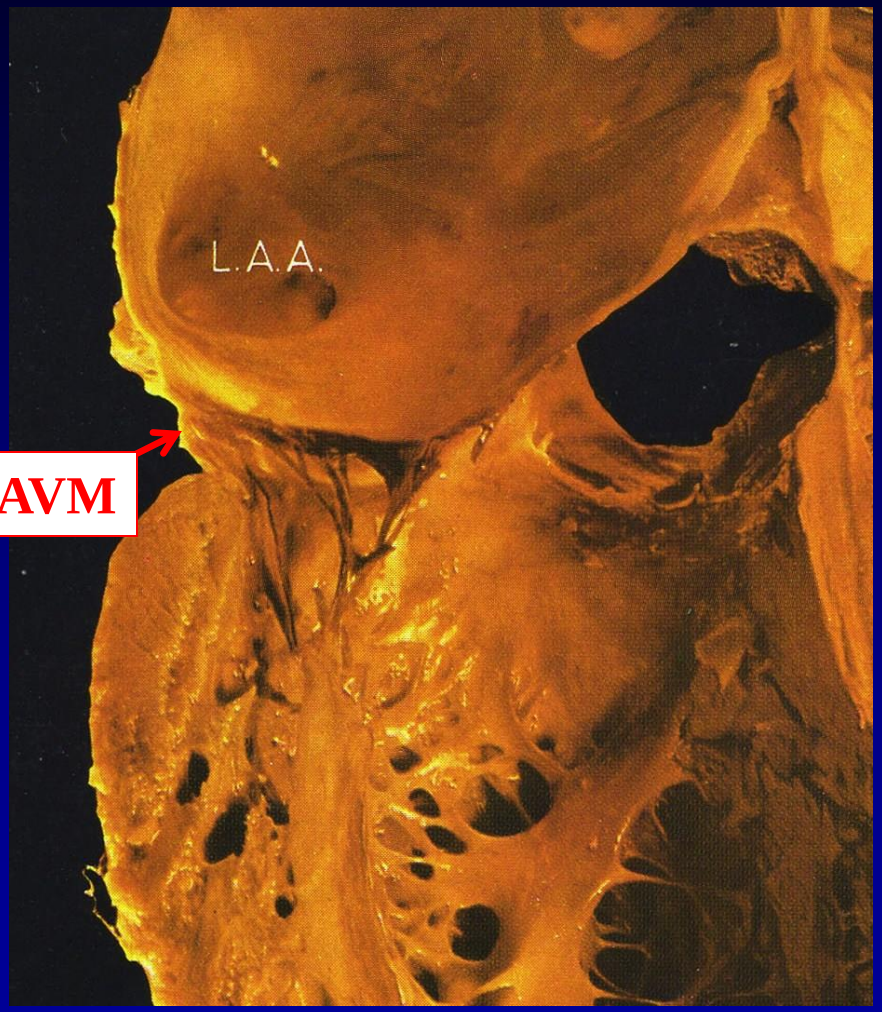
僧帽弁輪の解剖

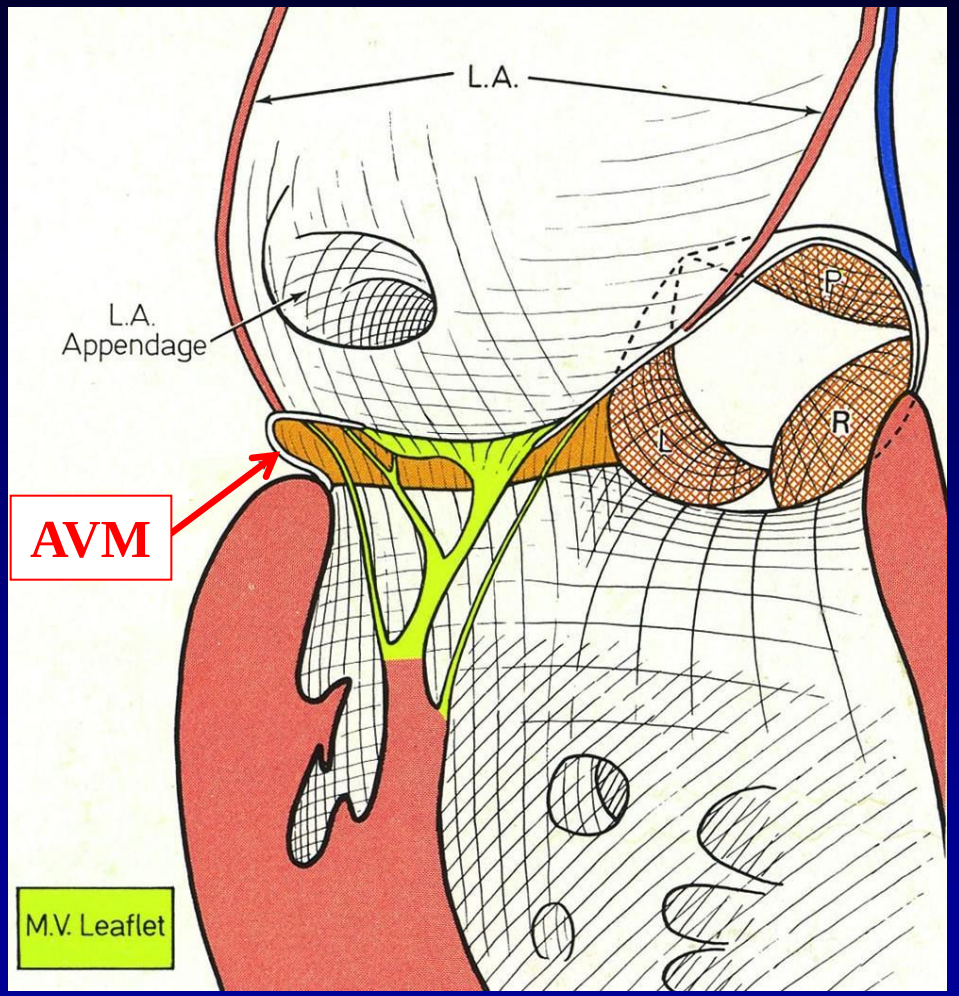


Subvalvular membrane

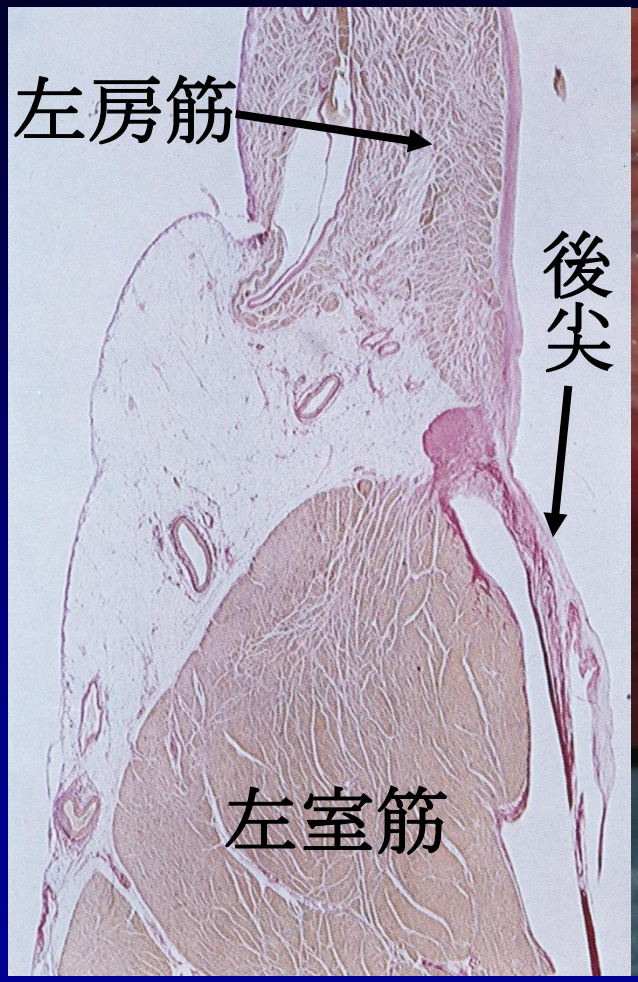
Annular subvalvular aneurysm：感染，手術(僧帽弁置換術)

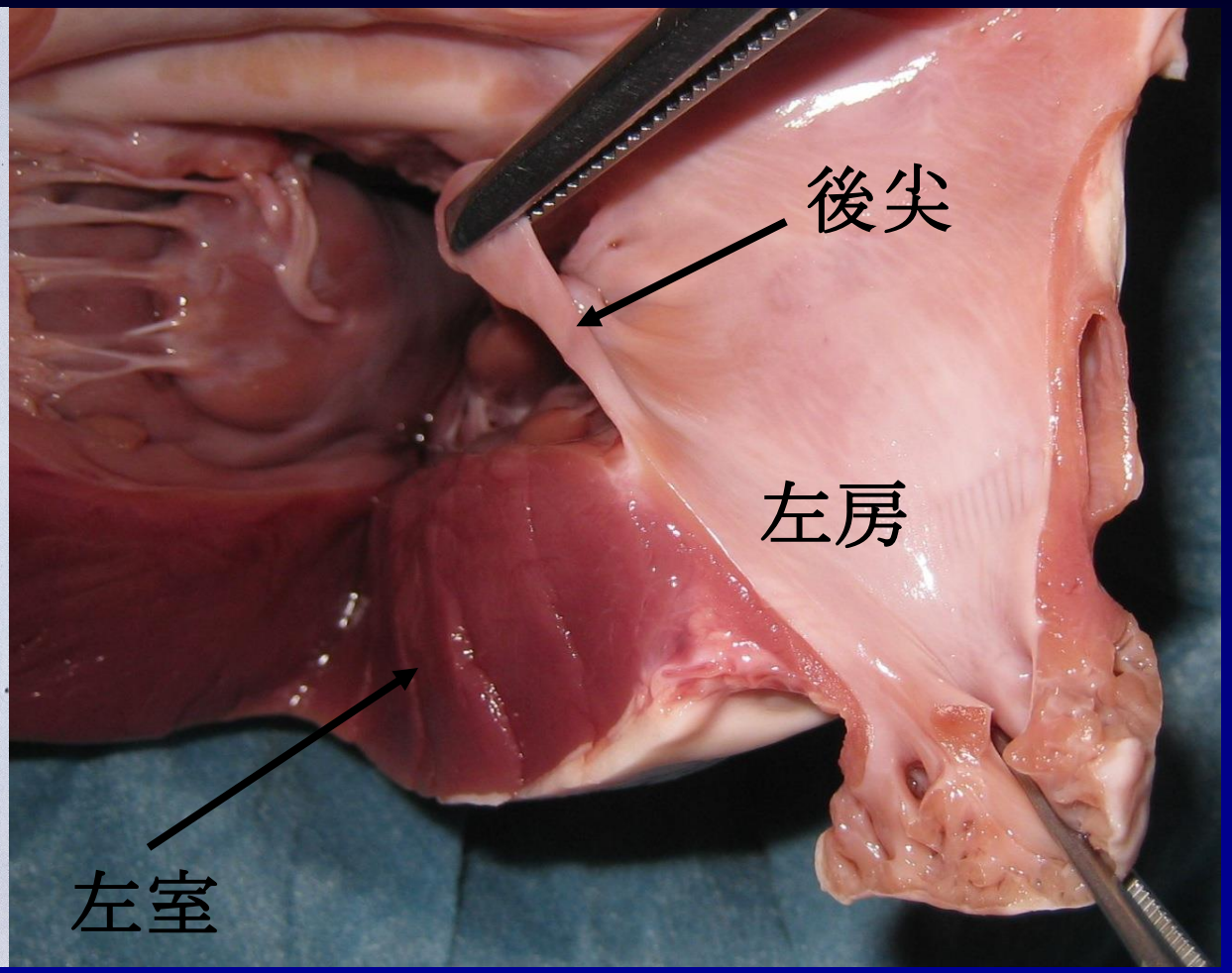
僧帽弁輪の解剖





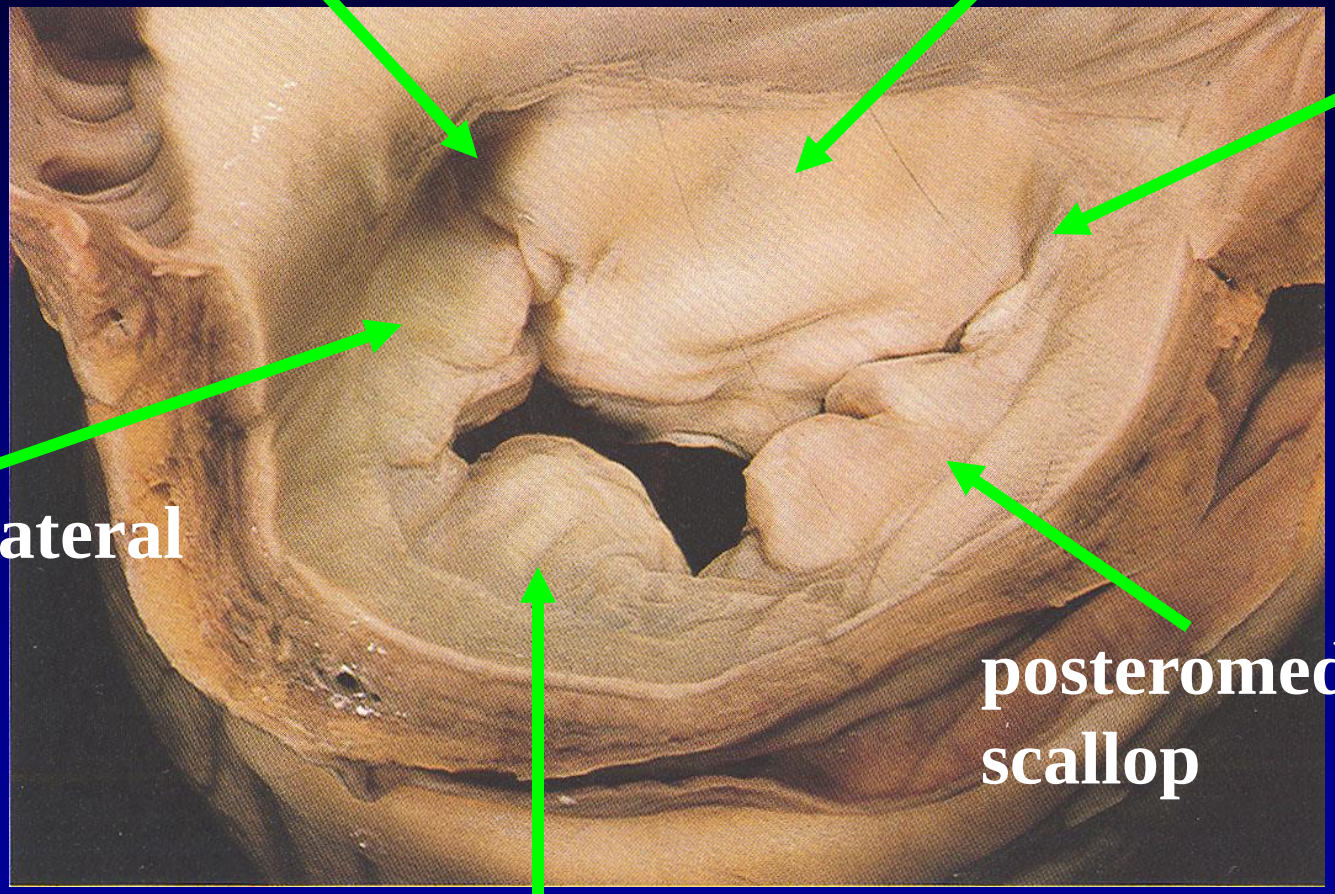
僧帽弁輪の解剖



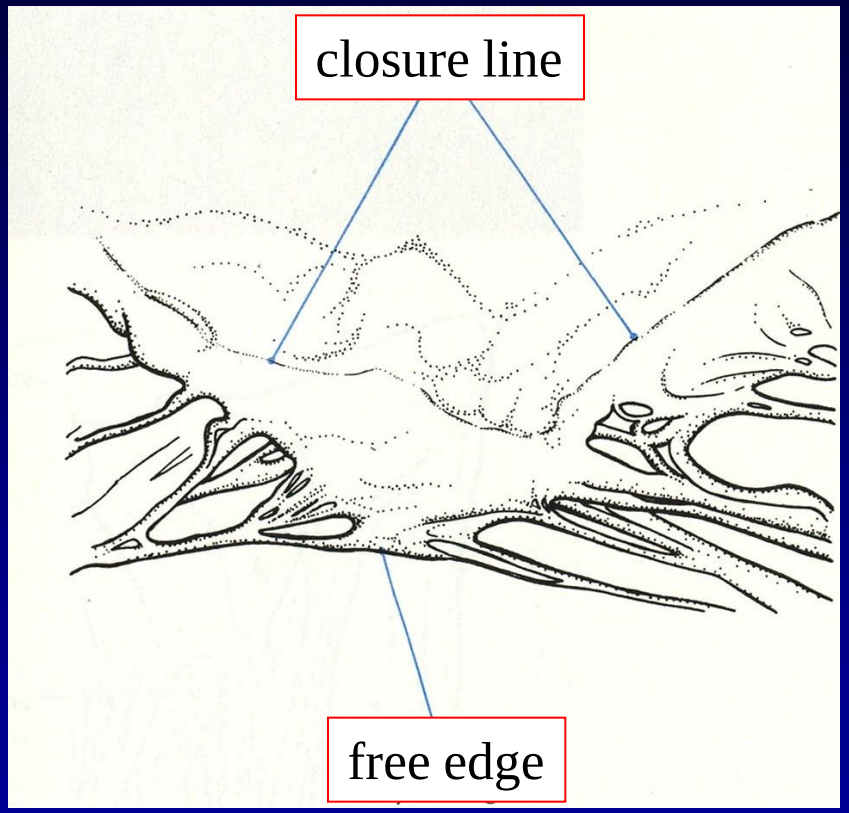


弁置換の糸が左室筋にかかると左室破裂！

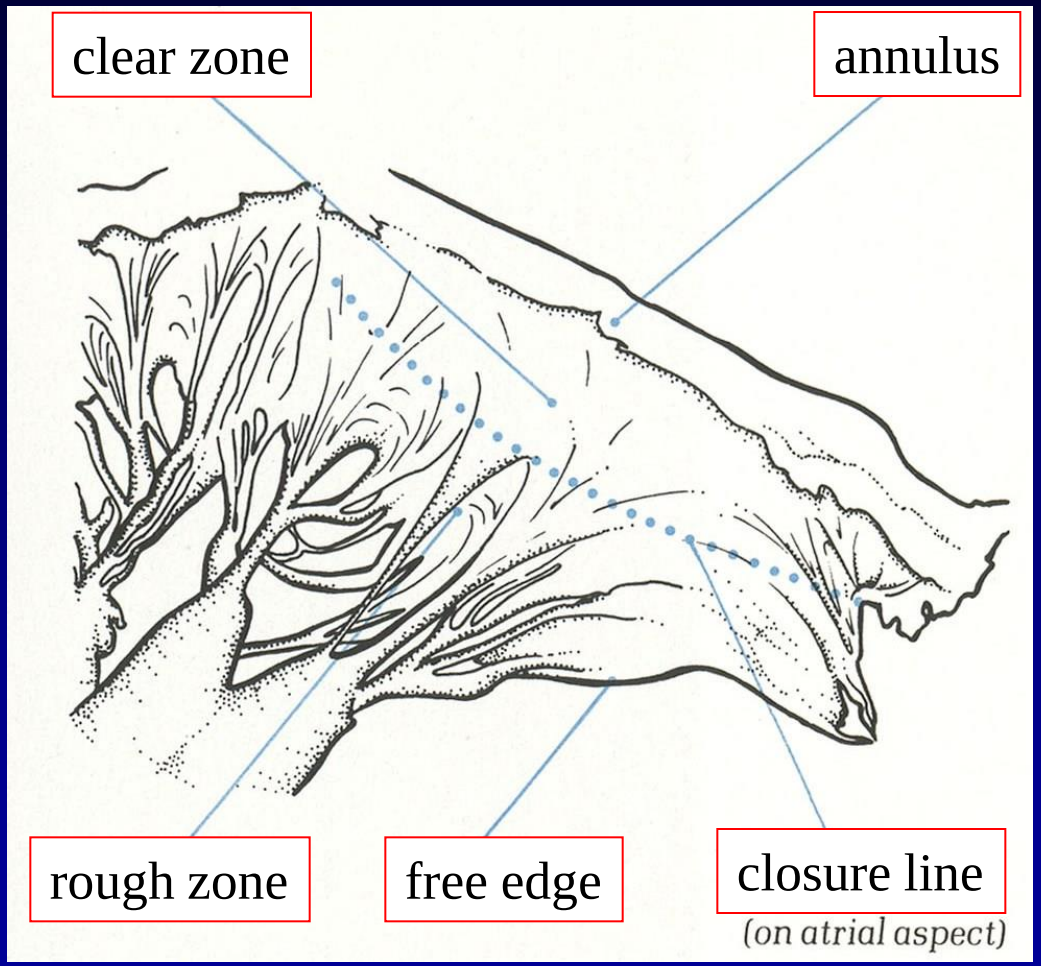
僧帽弁：後方より


前交連
前尖
後交連
anterolateral scallop
posteromedial scallop
middle scallop

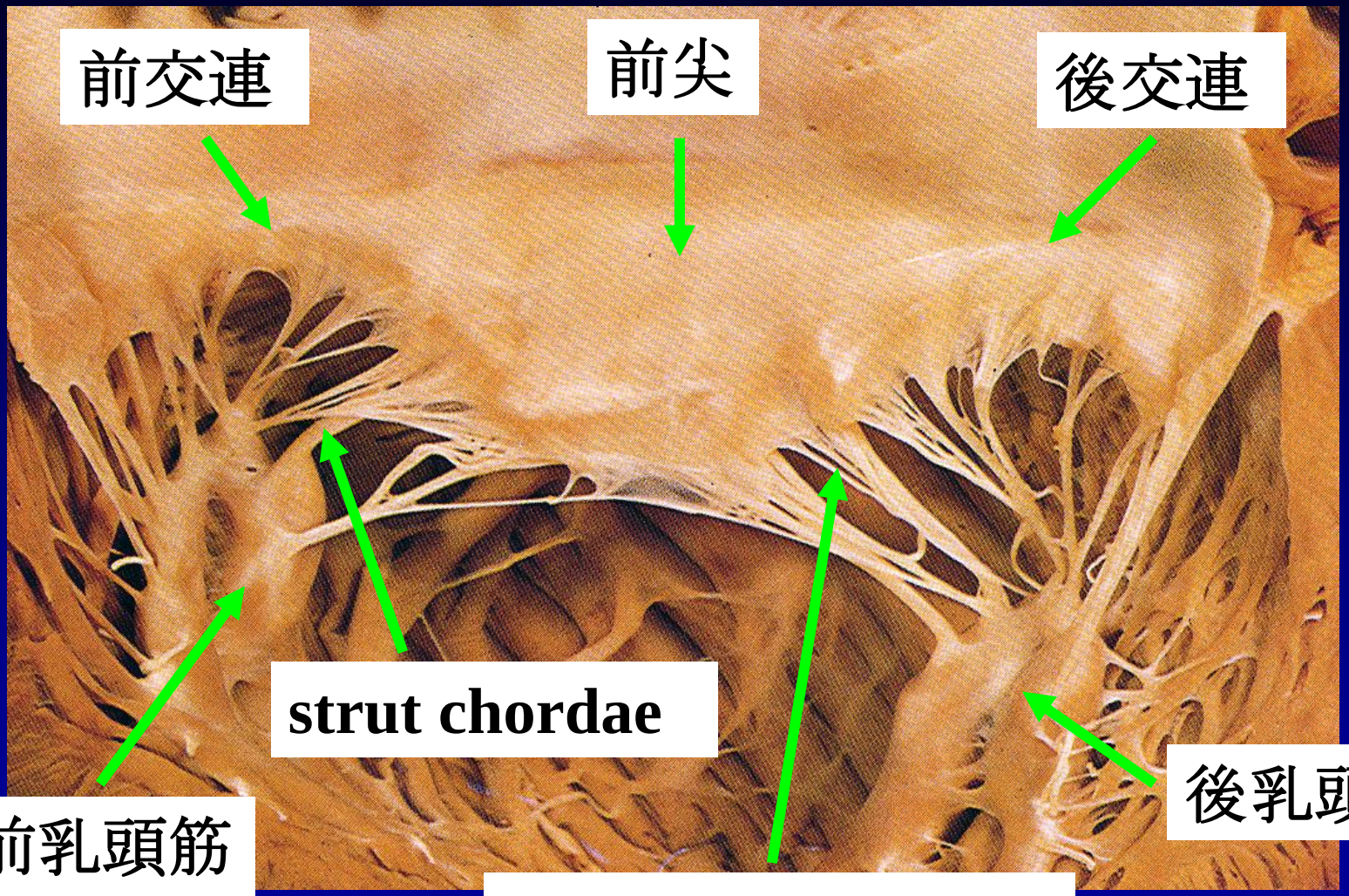
僧帽弁前尖



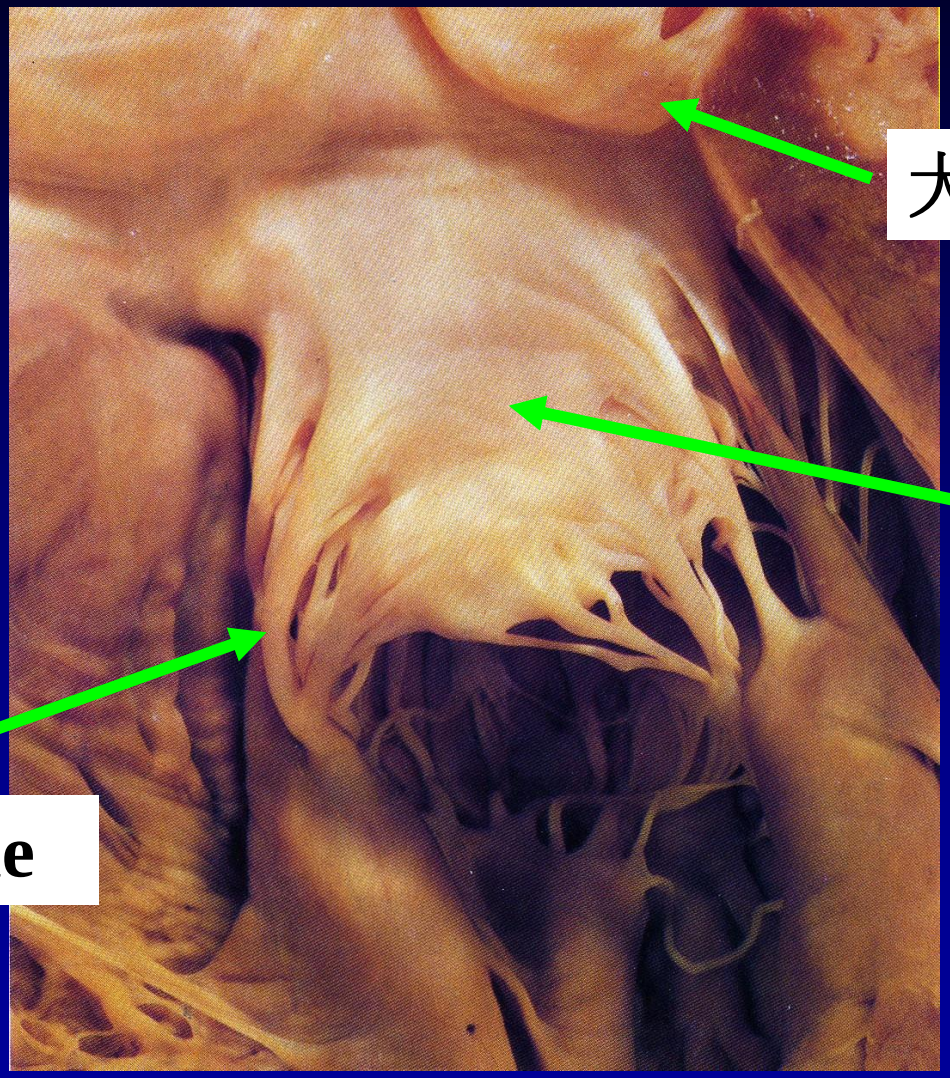
mitral valve : clear zone / rough zone



乳頭筋と腱索:後尖中央で切開



乳頭筋と腱索:左室側より

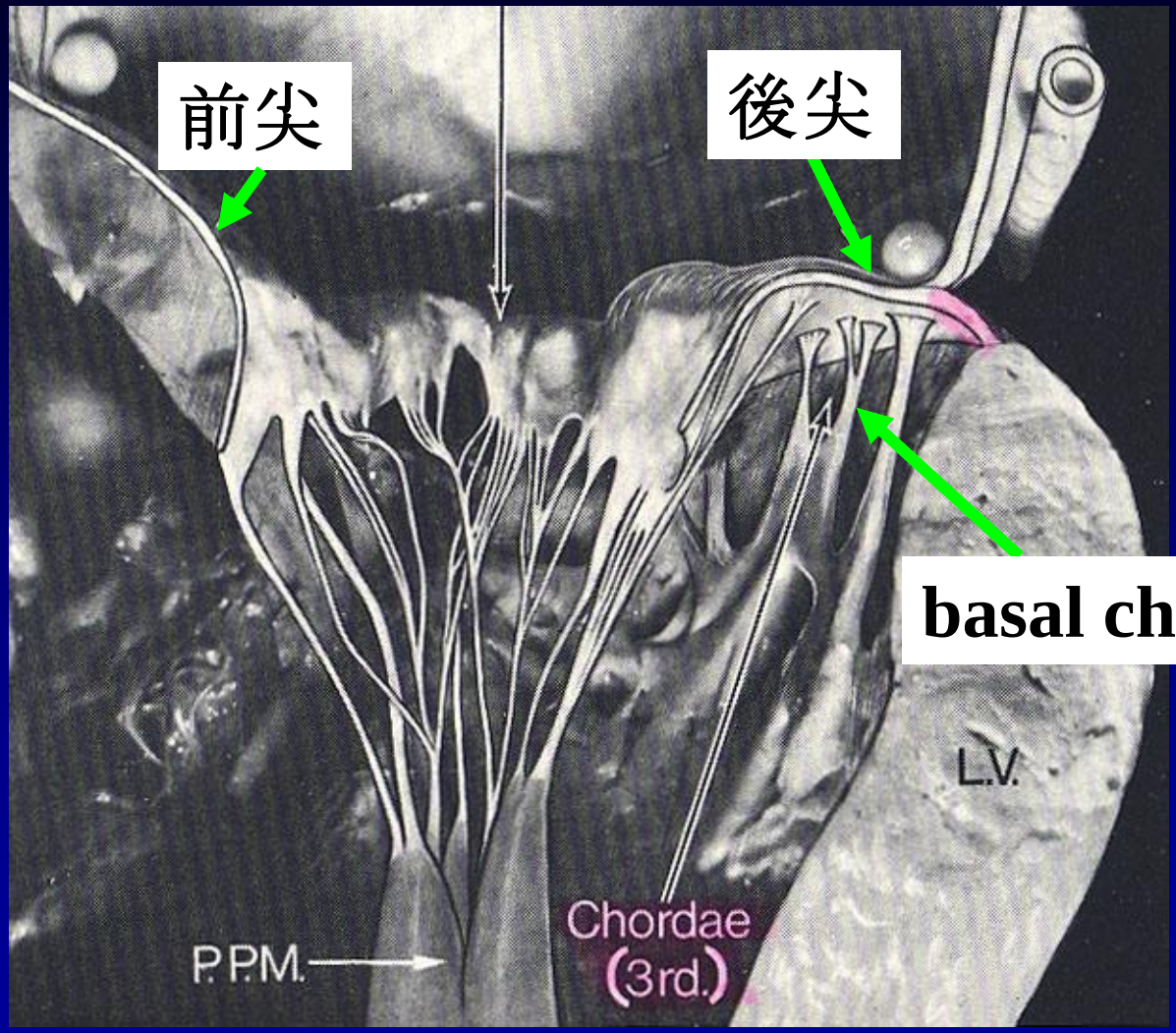


大動脈弁

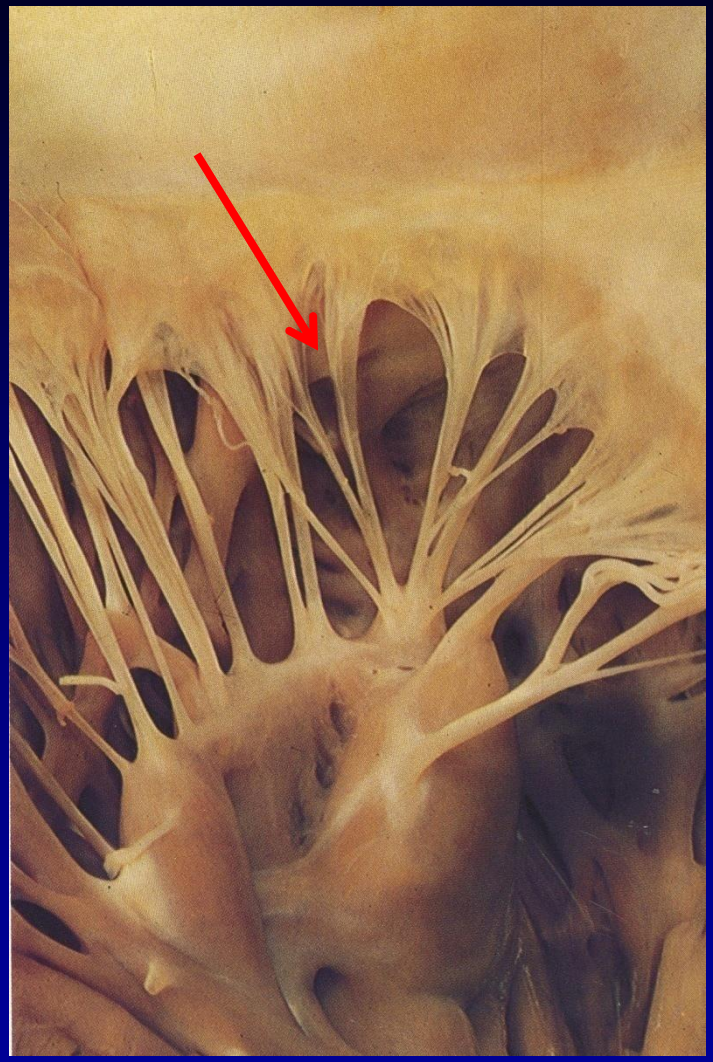
前尖

strut chordae

乳頭筋と腱索



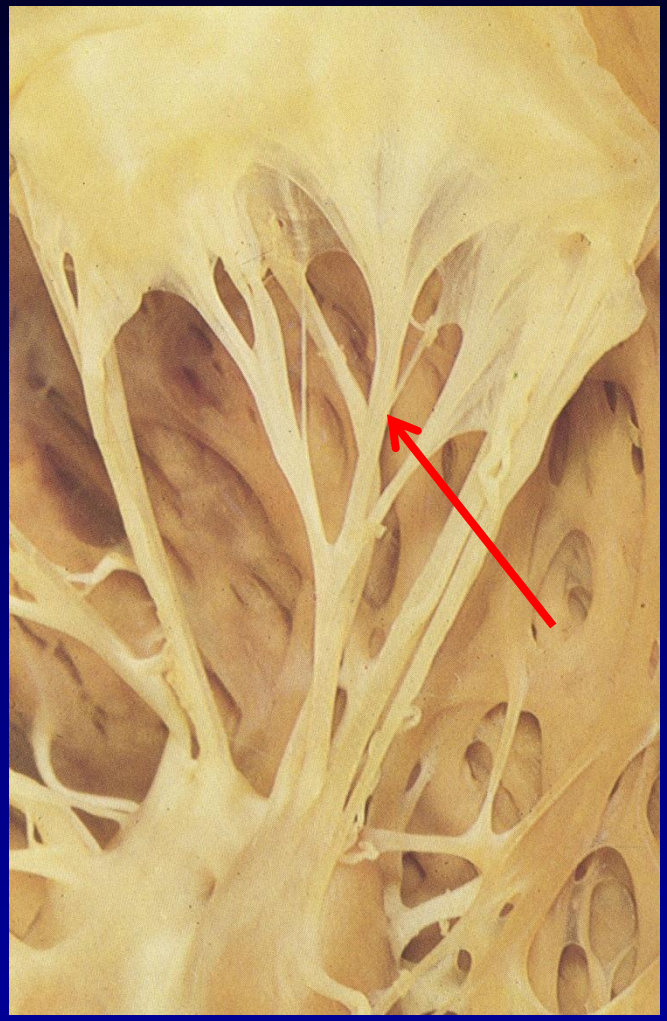
commissural chordae



anterolateral commissural chord

posteromedial commissural chord

腱　索



cleft chordae

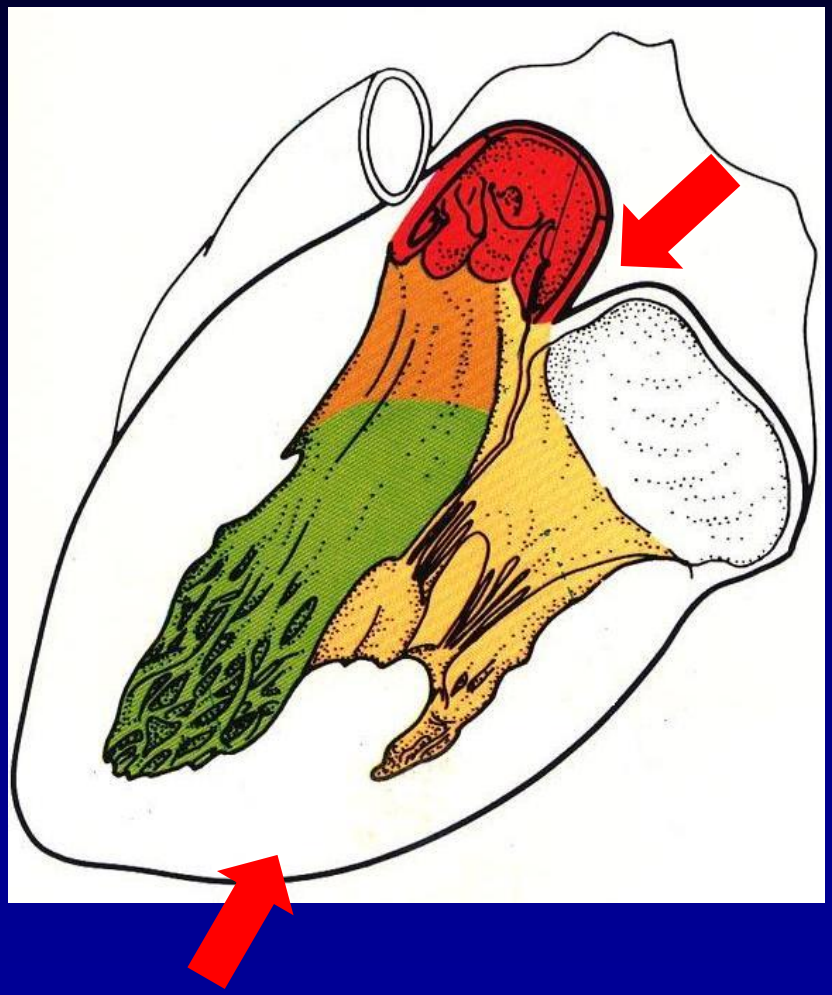
Lam,J.H.C. Circulation 41. 449. 1970

origin : 24

insertion : 72

腱索が支持していない部位は無い！

AM continuity～AML~chordae～PM～LV



前尖への腱索を切断

↓

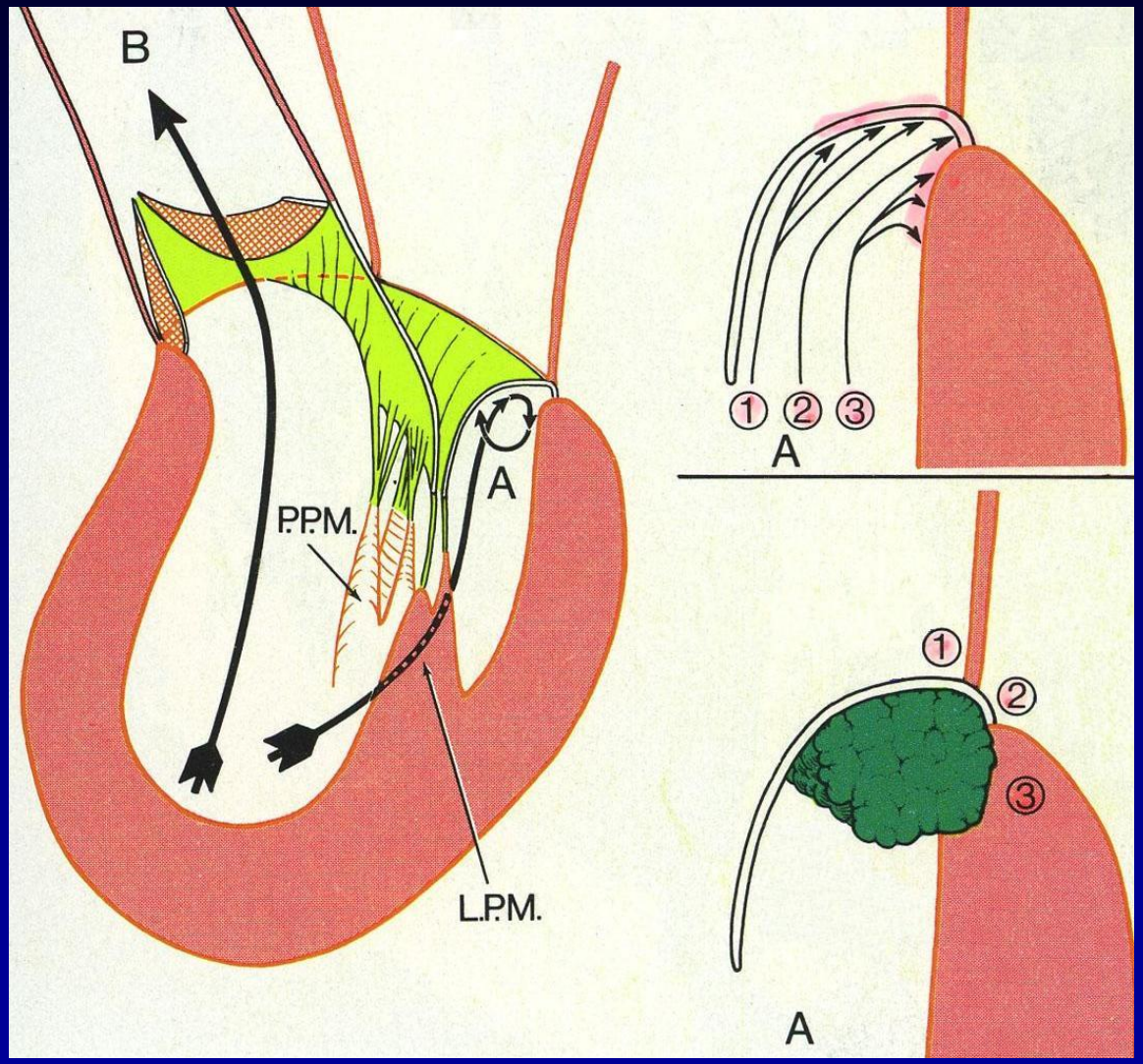
左室：短軸方向に伸展
（球形になる）

↓

Wall stress 増加

$$T = \frac{P\ r}{2h}$$

僧帽弁輪石灰化：MAC



turbulance

stress

↓ !?

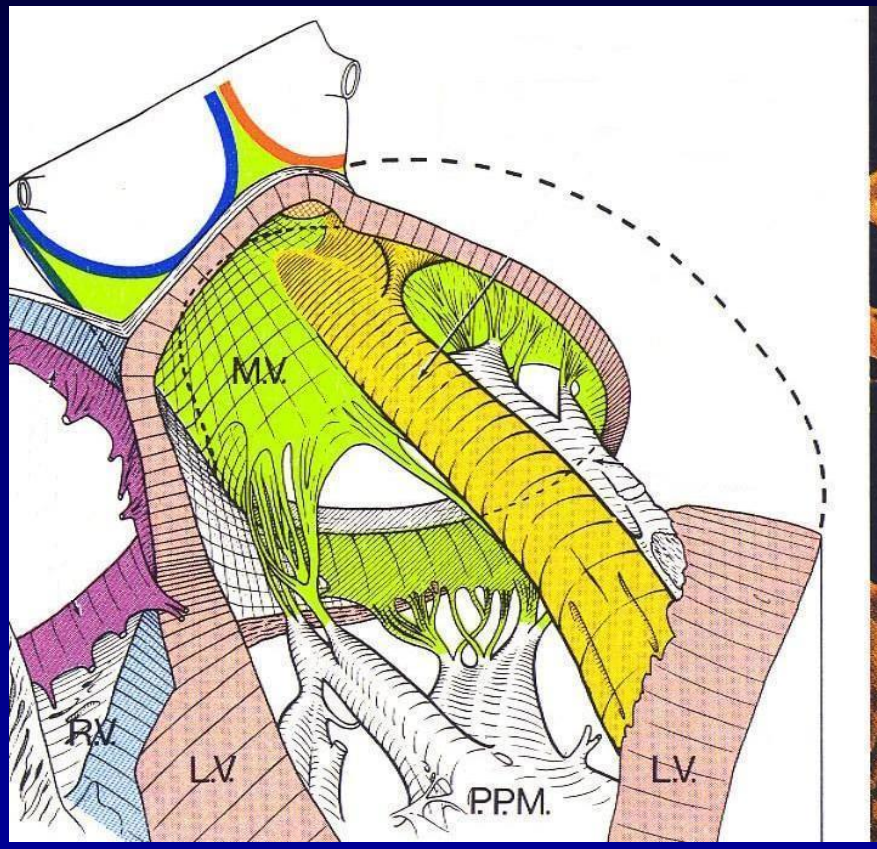
isovolumic stress area

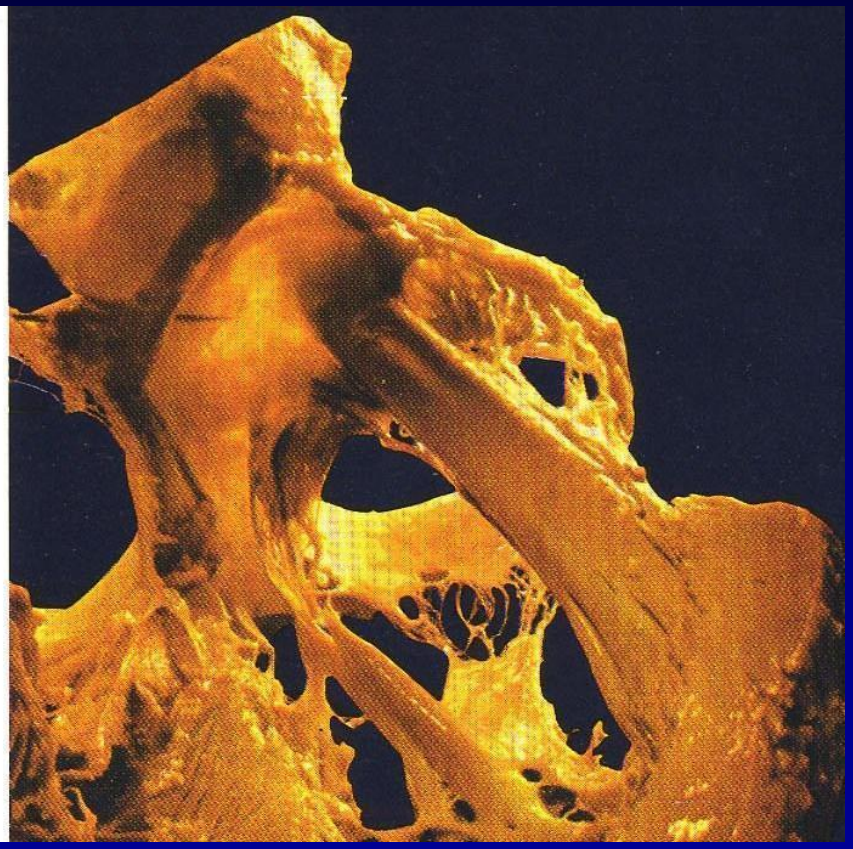
(① ② ③)

↓

MAC

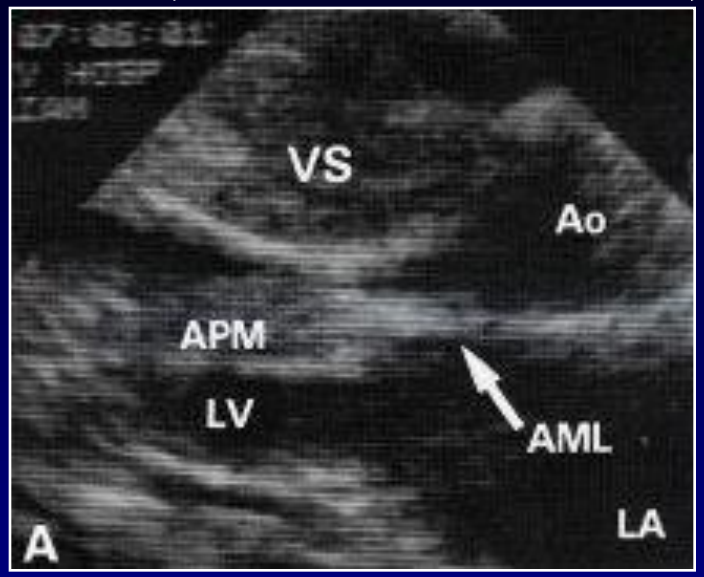
Muscularization of chordae (direct insertion of papillary muscle)

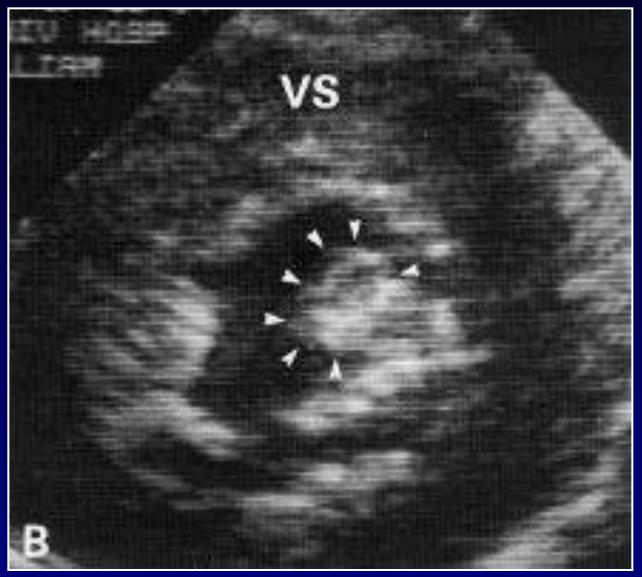


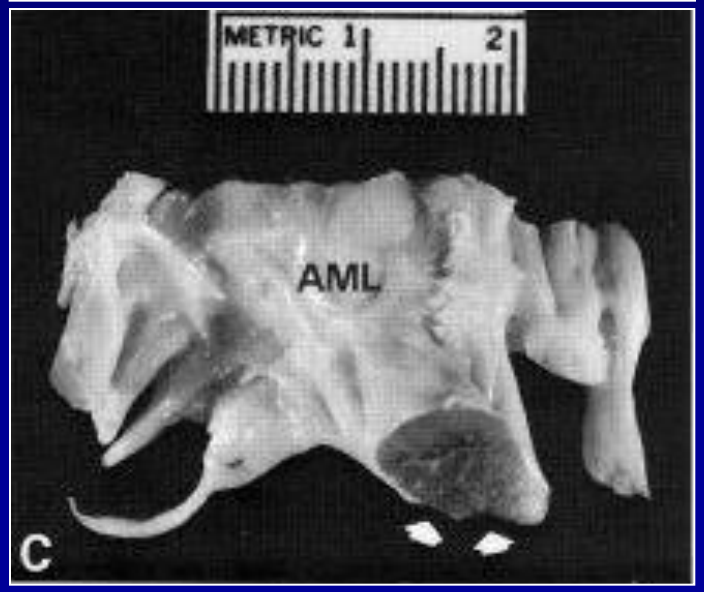


Anomalous insertion of PM directly into AML in HCM. Significance in producing LVOTO.

Klues HG, et al. Circulation. 1991;84:1188-97.

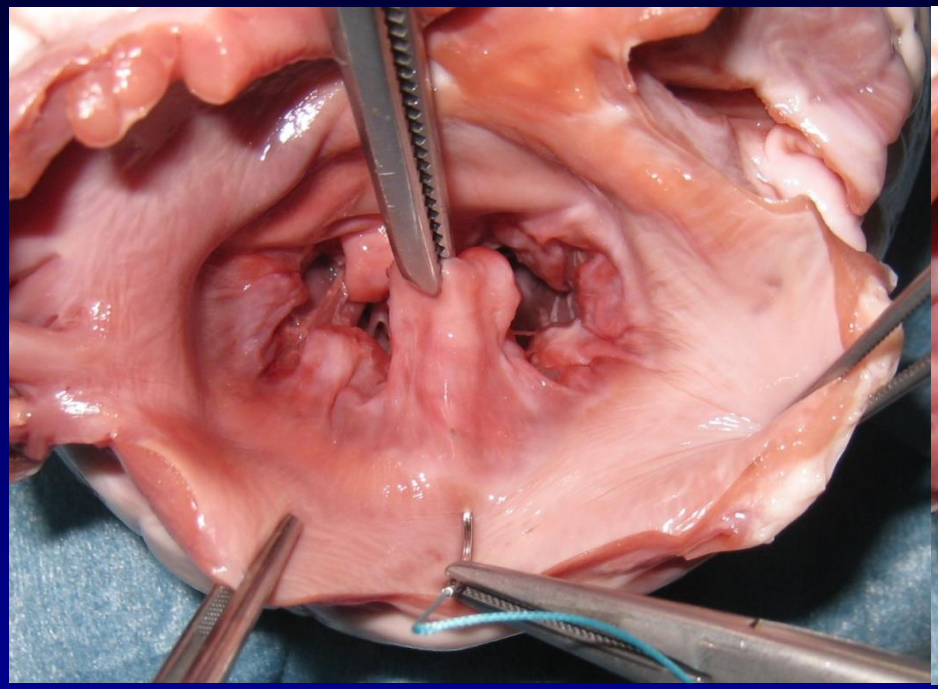


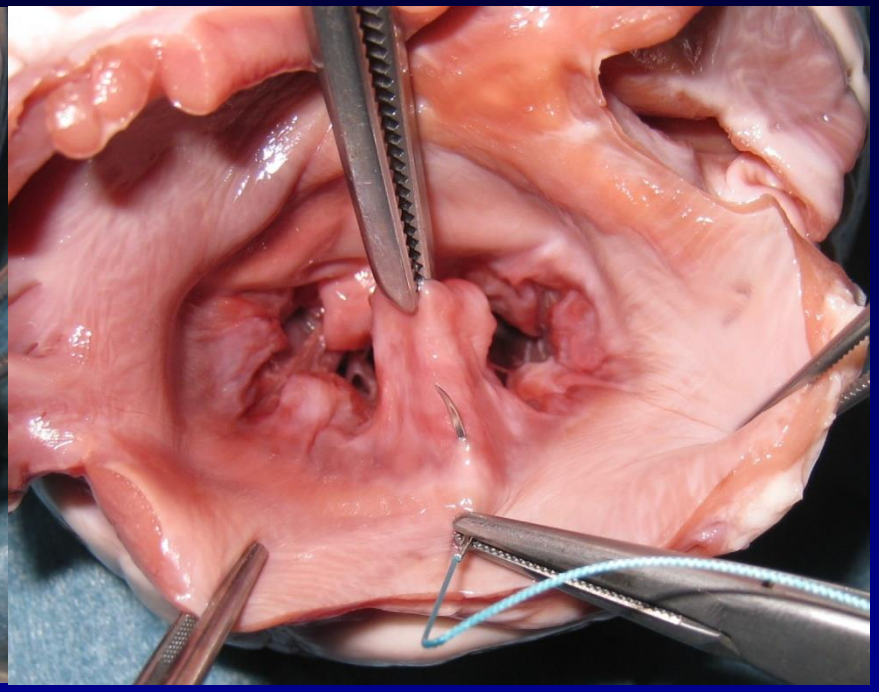




- HOCM 10/78=13%
- Myotomy / Myectomyでは LVOTO 解除不可能
- MVR 必要

僧帽弁輪(後尖部)での運針：MVR

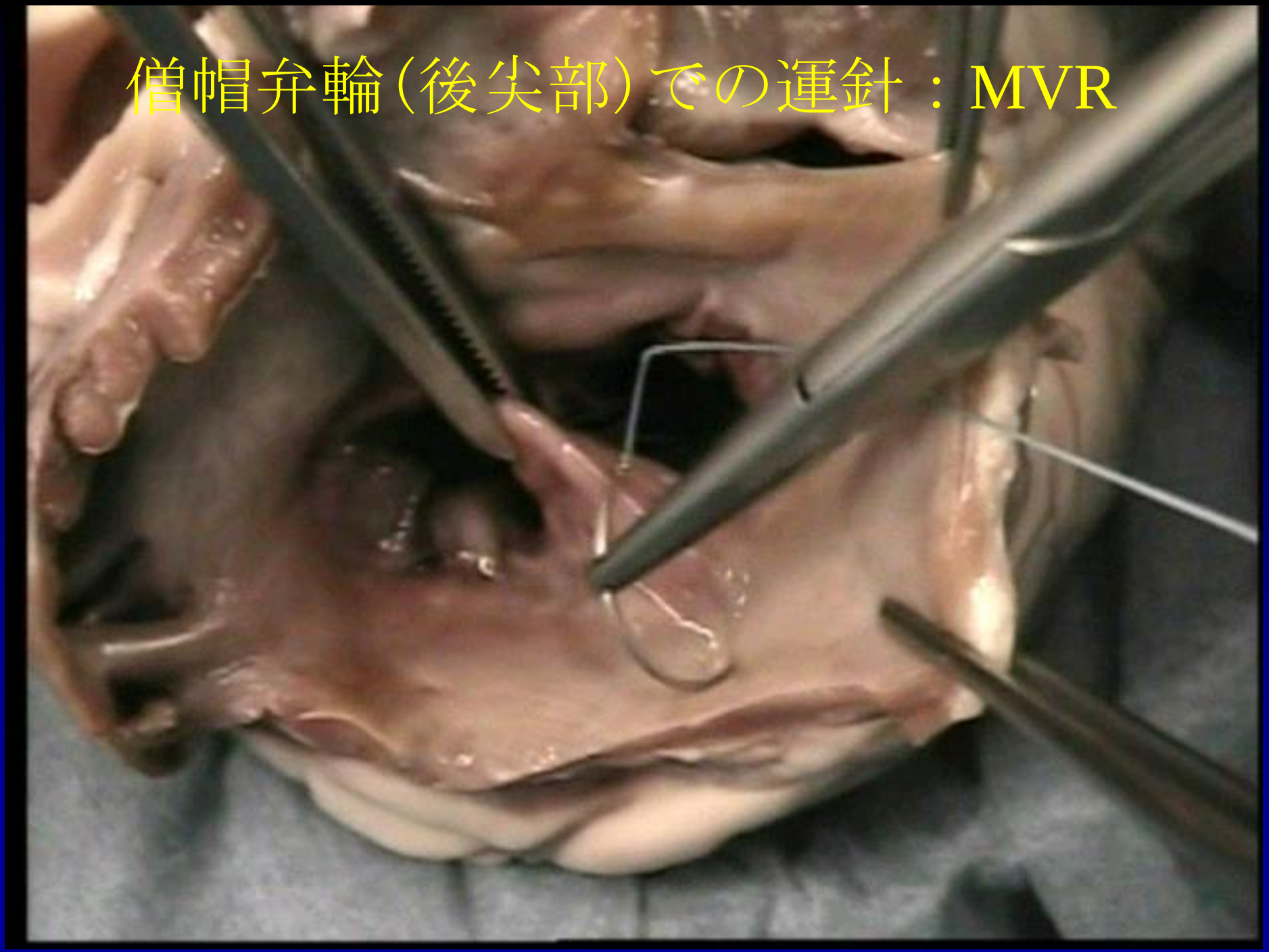




弁輪より数㎜左房側から刺入、左房壁と平行に運針
　→深く運針しない！　裏には何がある？
弁輪を貫き、左室側に刺出
　→左室心筋にはかけない(左室破裂予防)！

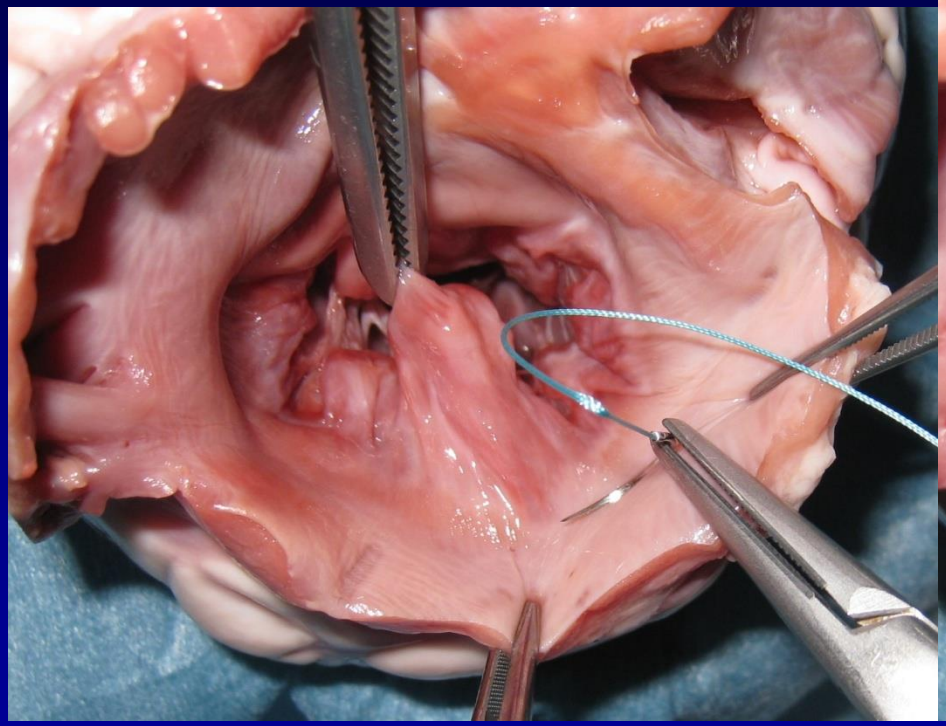

僧帽弁輪(後尖部)での運針：MVR

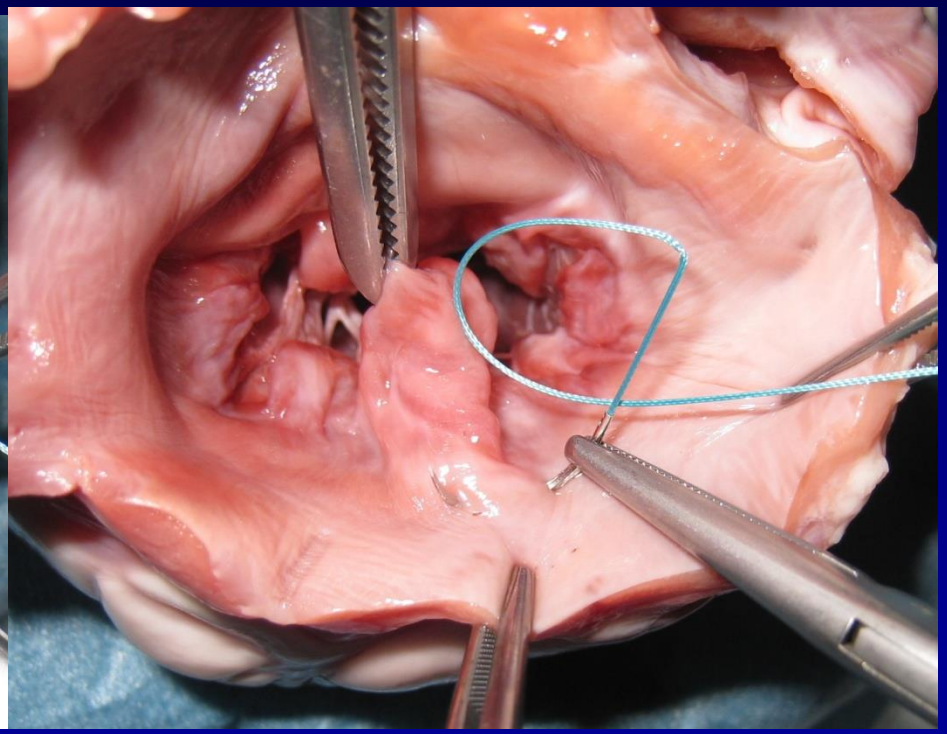
僧帽弁輪(後尖部)での運針：MVR



僧帽弁輪(後尖部)での運針：Ring縫着

縫合針をfore handで保持：左心房筋にしかかからない





僧帽弁輪(後尖部)での運針：Ring縫着

縫合針をfore handで保持：左心房筋にのみかかる！

僧帽弁輪(後尖部)での運針：Ring縫着

縫合針をfore handで保持：弁輪にはかからない

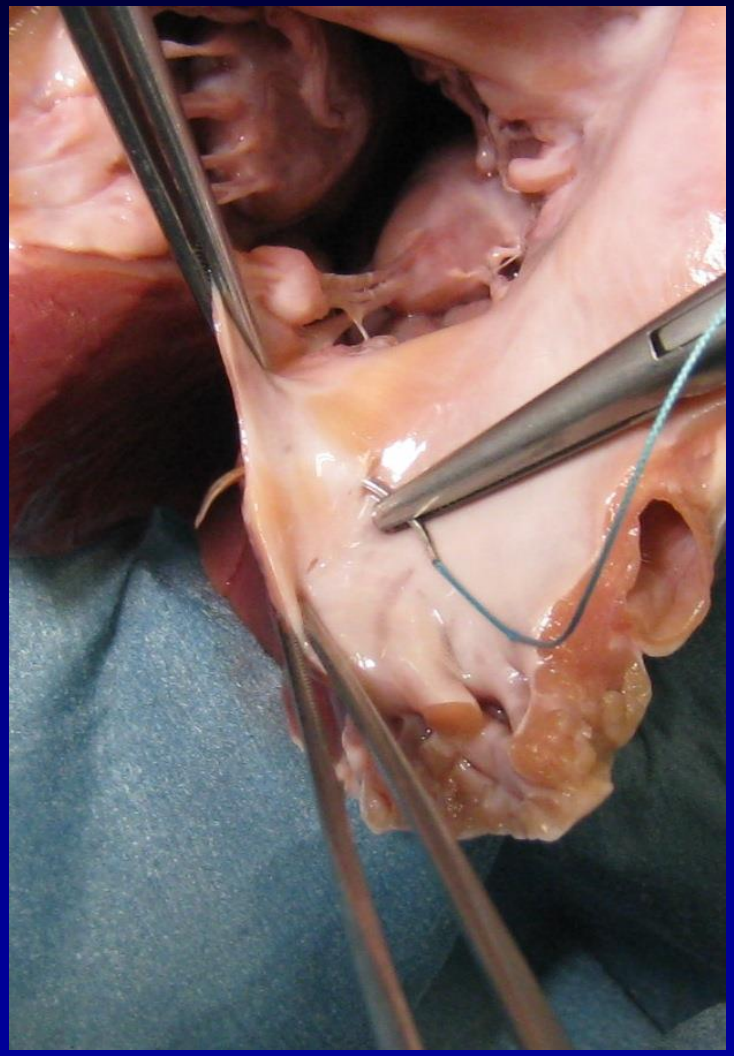
僧帽弁輪(後尖部)での運針：Ring縫着

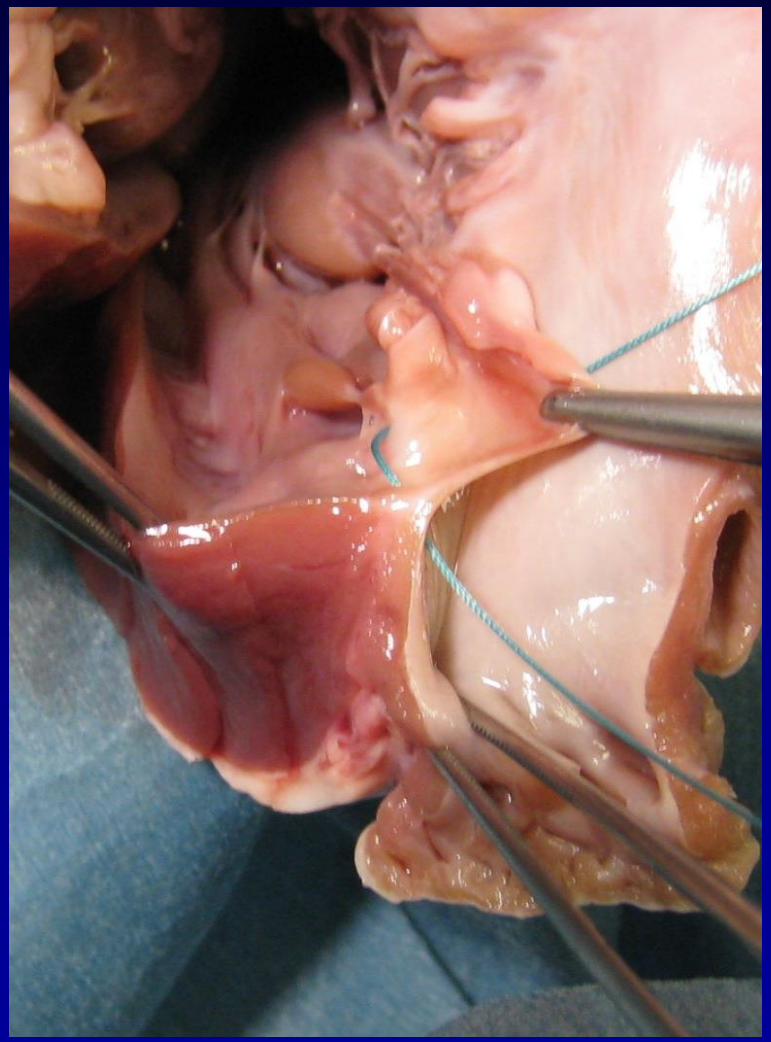
僧帽弁輪(後尖部)での運針：Ring縫着

縫合針をback handで保持！

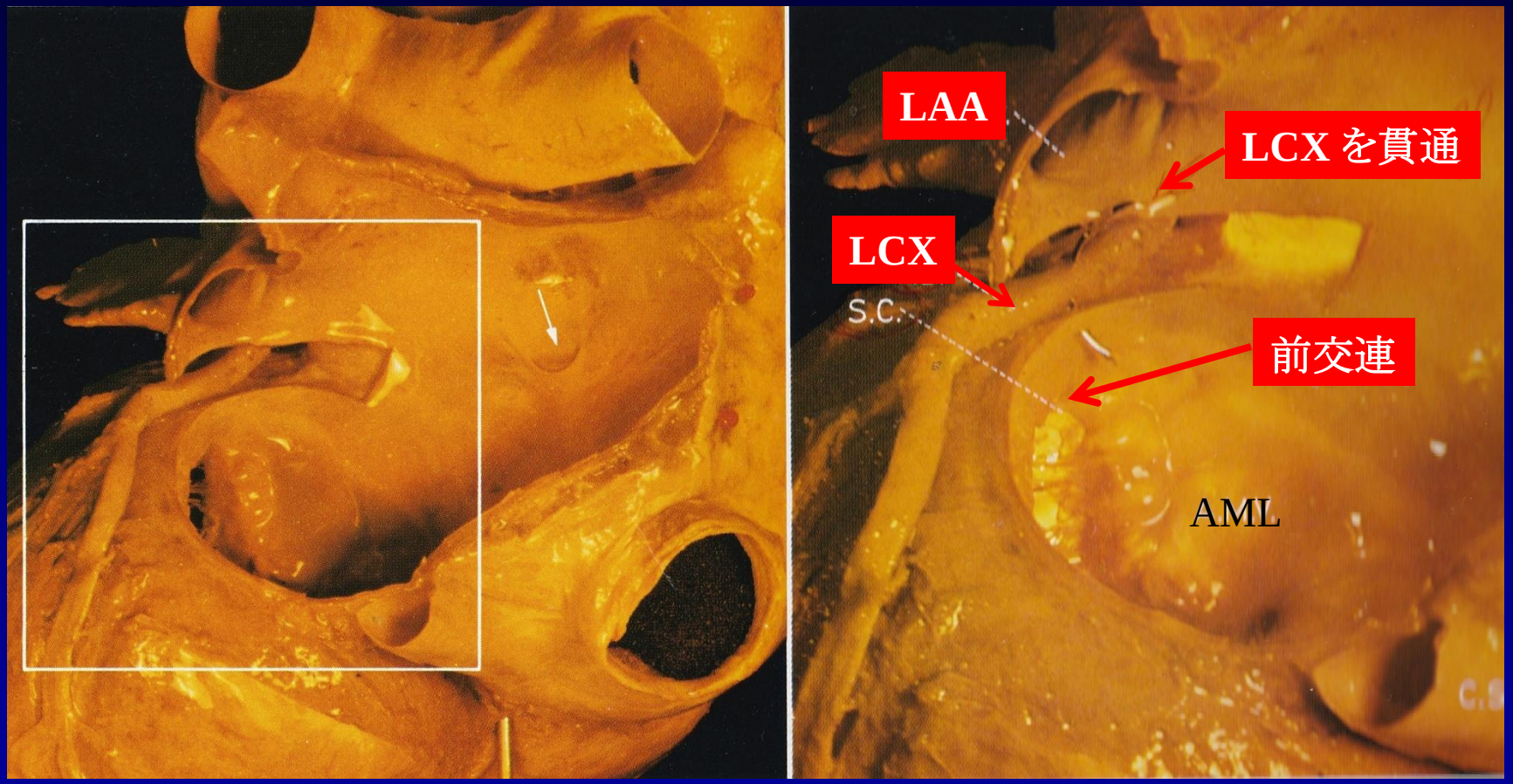
僧帽弁輪(後尖部)での運針：Ring縫着

縫合針をback handで保持→弁輪への確実な運針

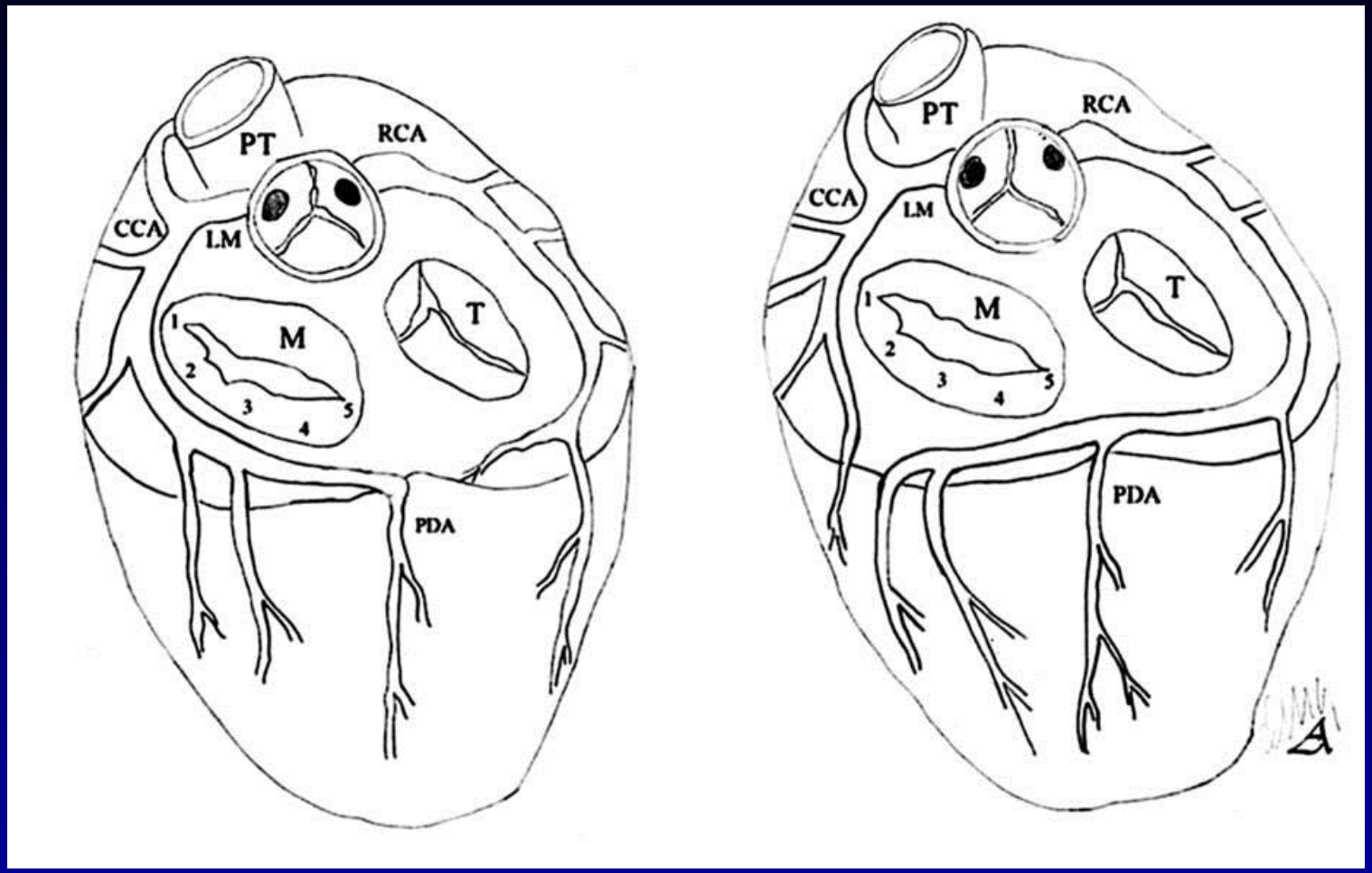




僧帽弁輪と左回旋枝の位置関係



Coronary artery dominance : 後室間枝で決定



Left dominance: 8%[a], 12%[b]　Right dominance: 77%[a],71%[b]

Balanced: 15%[a],17%[b]

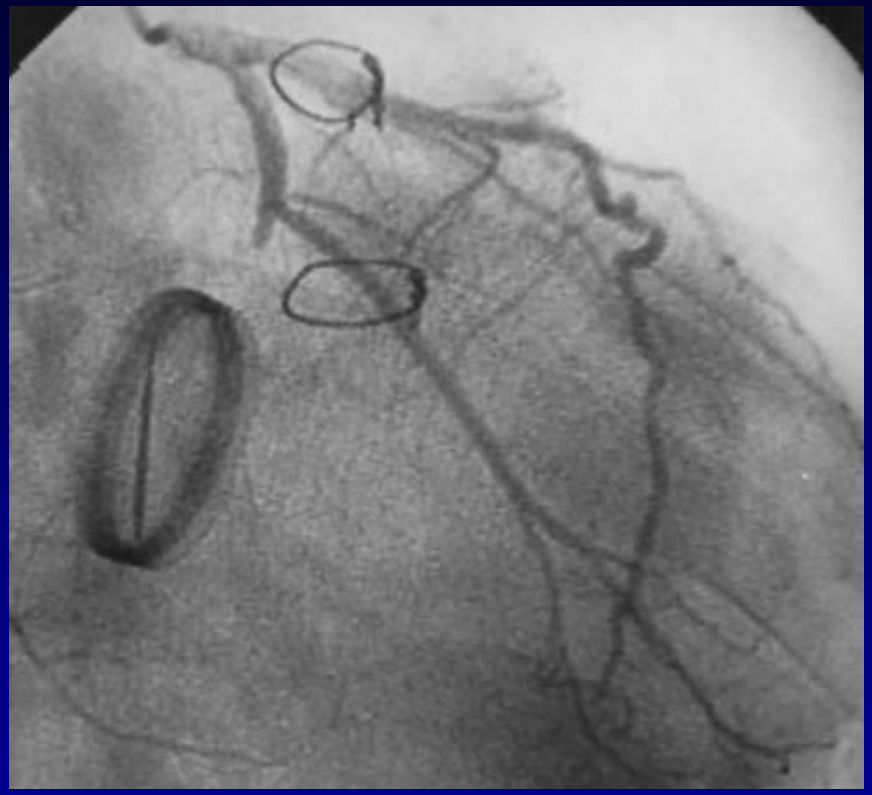
a: Virmani R et al. J Thorac Cardiovasc Surg 1982;84:773-778

b: McAlpine. Heart and Coronary Arteries P163

LCX injury during mitral valve repair

P2 quadrangular resection, sliding technique, ring 34mm

Left dominant coronary artery



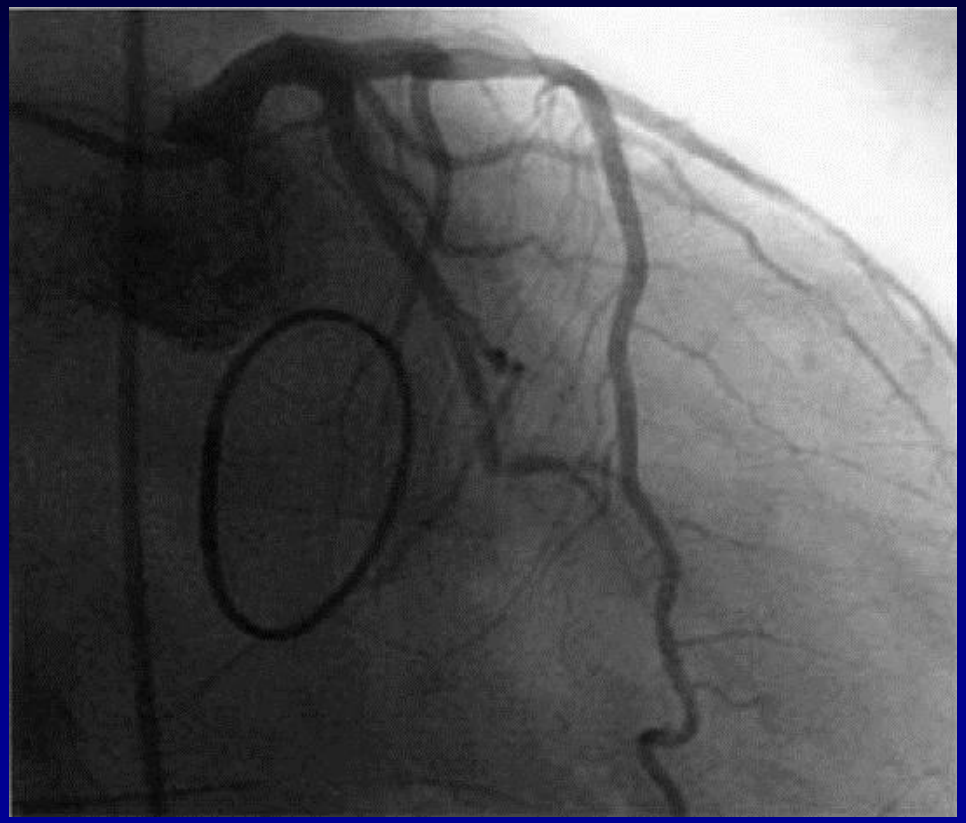
Ring とplication sutureを切除、機械弁で弁置換、SVGでバイパス

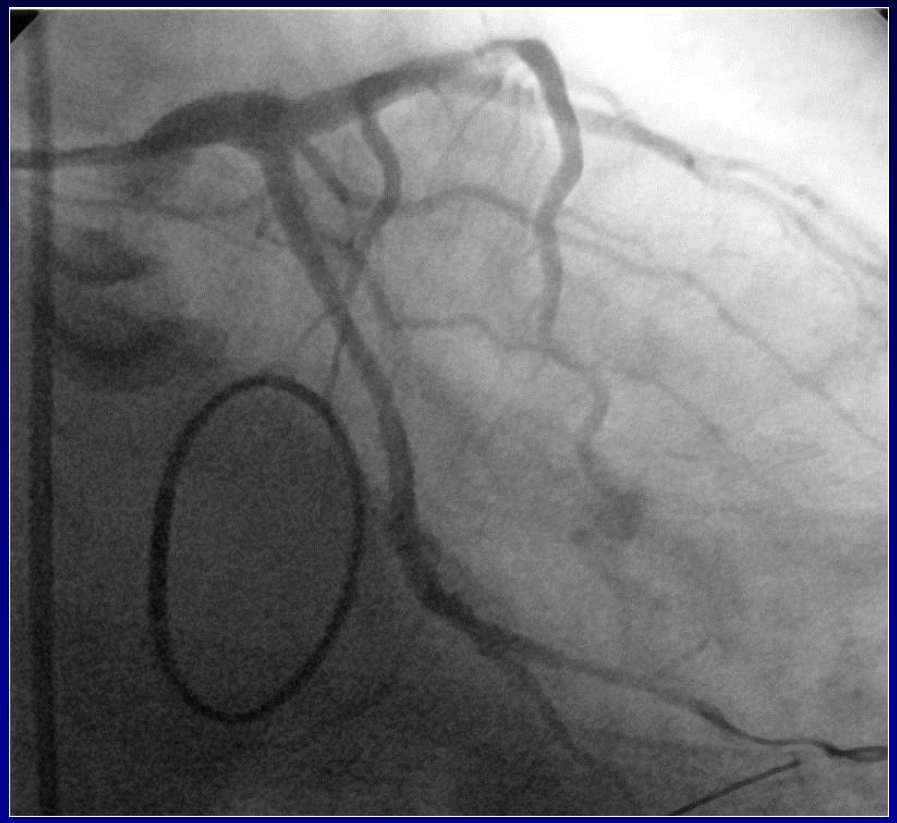
Tavilla G et al. Ann Thorac Surg 1998;66:2091-2093

LCX injury during mitral valve repair

PML quadrangular resection, annular plication, ring 32mm

Right dominant coronary artery





PCI 後

Grande AM et al. Texas Heart Institute J. 2008;35:179-183

LCX injury during mitral valve surgery

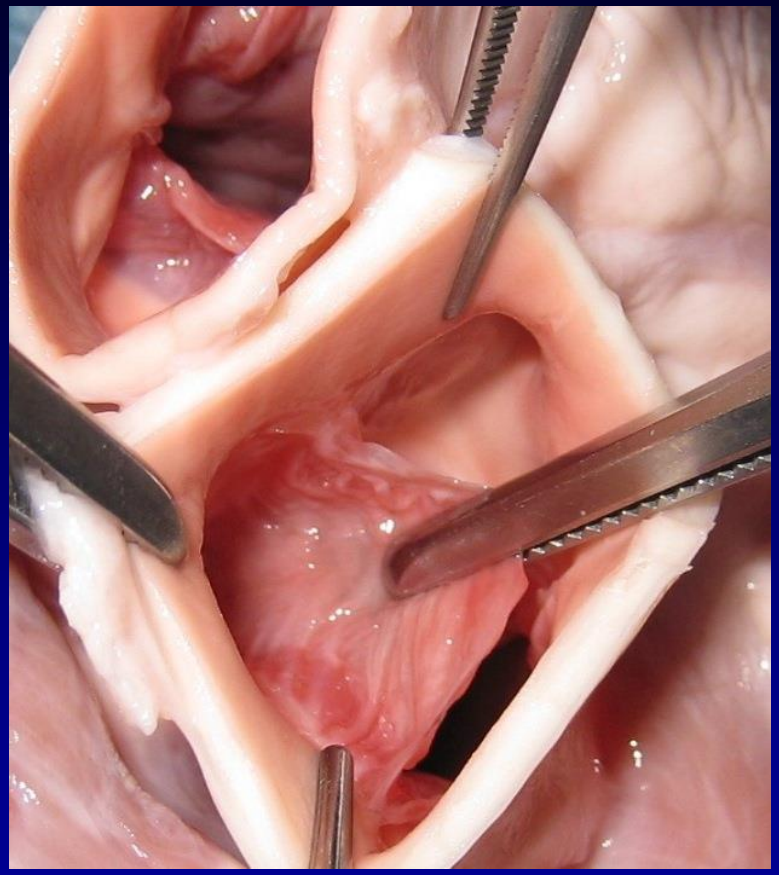
・僧帽弁置換術、僧帽弁形成術ともに報告あり。
・**Right dominance**、**Left dominance**、**Balanced** いずれでも報告あるが、**Left dominance** で多い。

僧帽弁輪と左回旋枝との距離

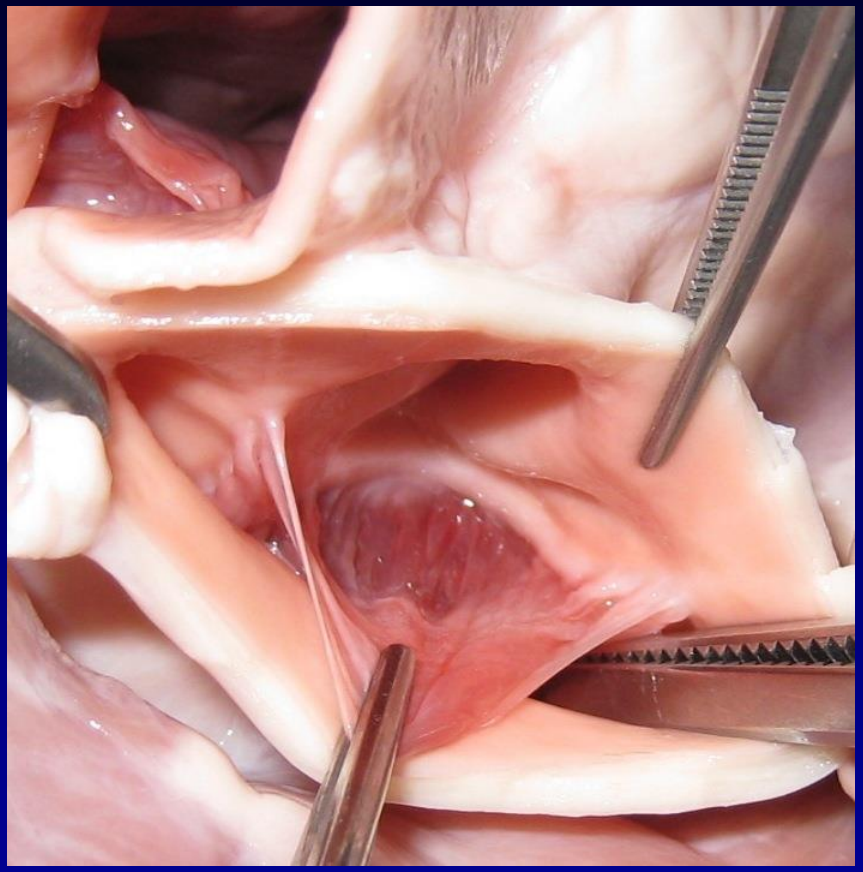
Left dominance	**3.0～6.5mm,**	**mean 4.1mm**
Balanced	**4.5～7.5mm,**	**mean 5.5mm**
Right dominance	**6.0～11mm,**	**mean 8.4mm**

Virmani R et al. J Thoracic Cardiovasc Surg 1982;84:773-778

大動脈弁（豚）

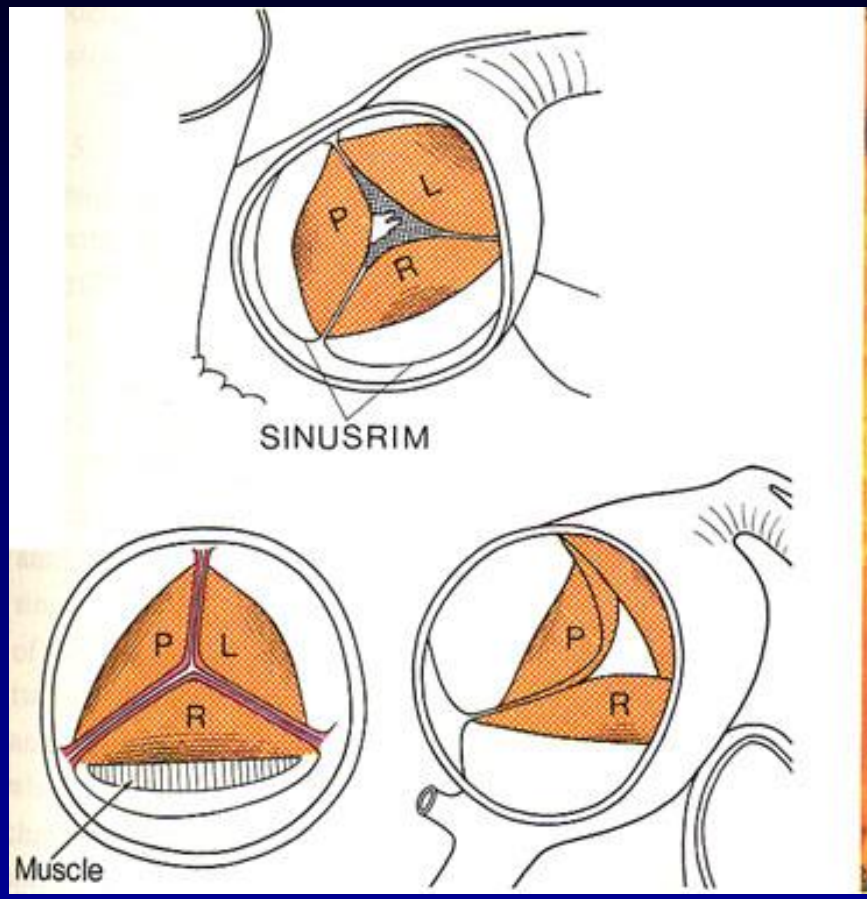


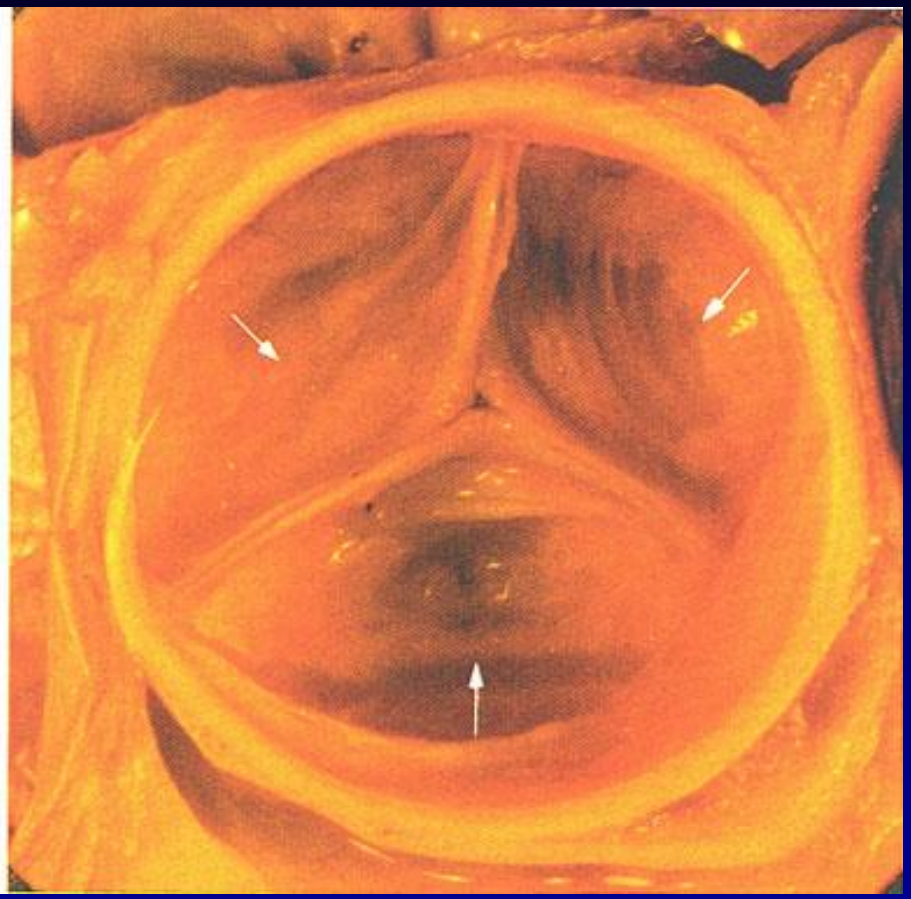
左冠尖



右冠尖

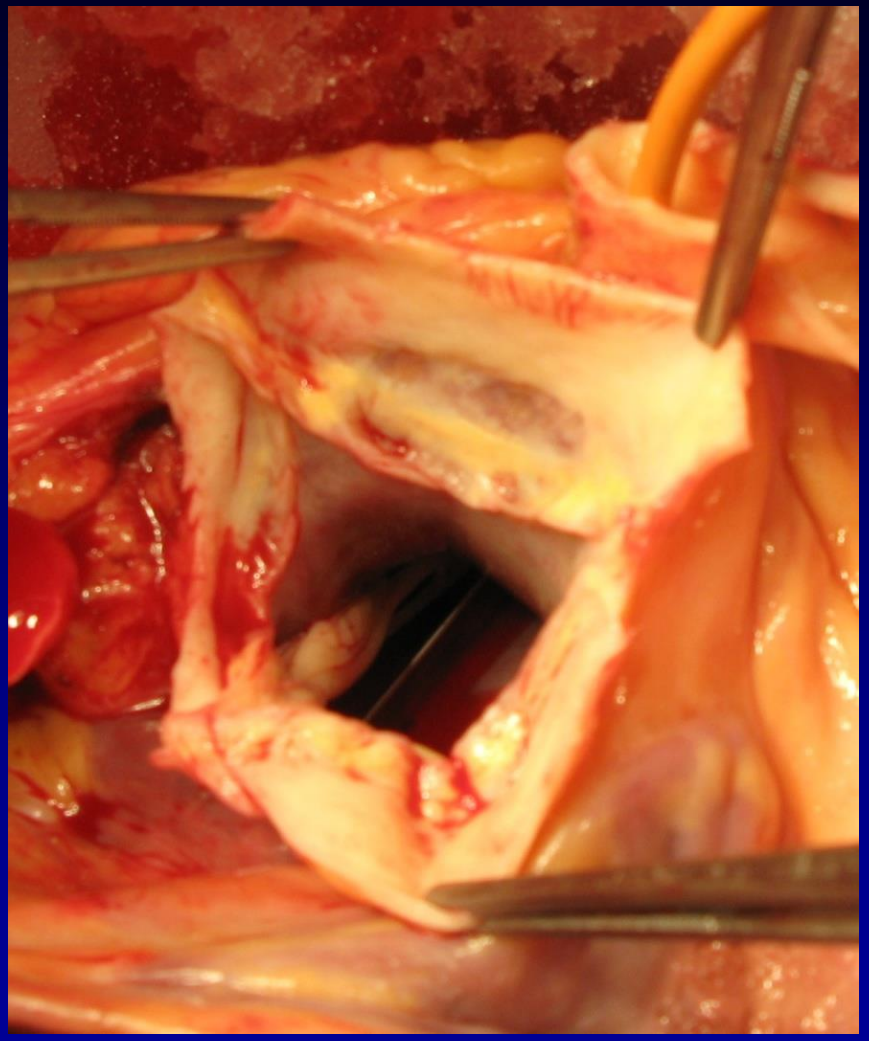
大動脈弁





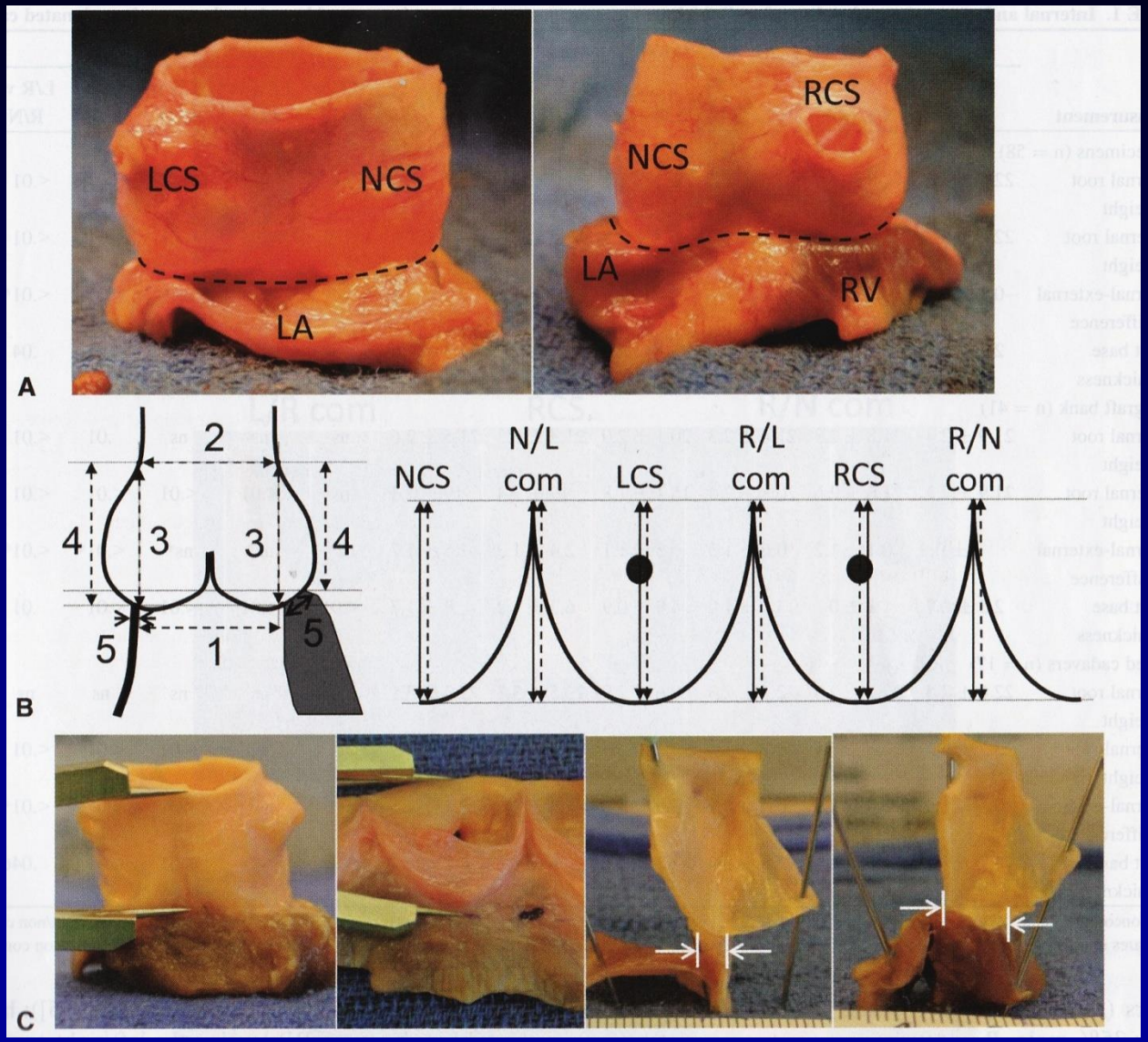
解剖学的弁輪と血行動態的（機能的）弁輪は一致する。
右冠尖では豚の心臓と同様の事あり。

大動脈弁



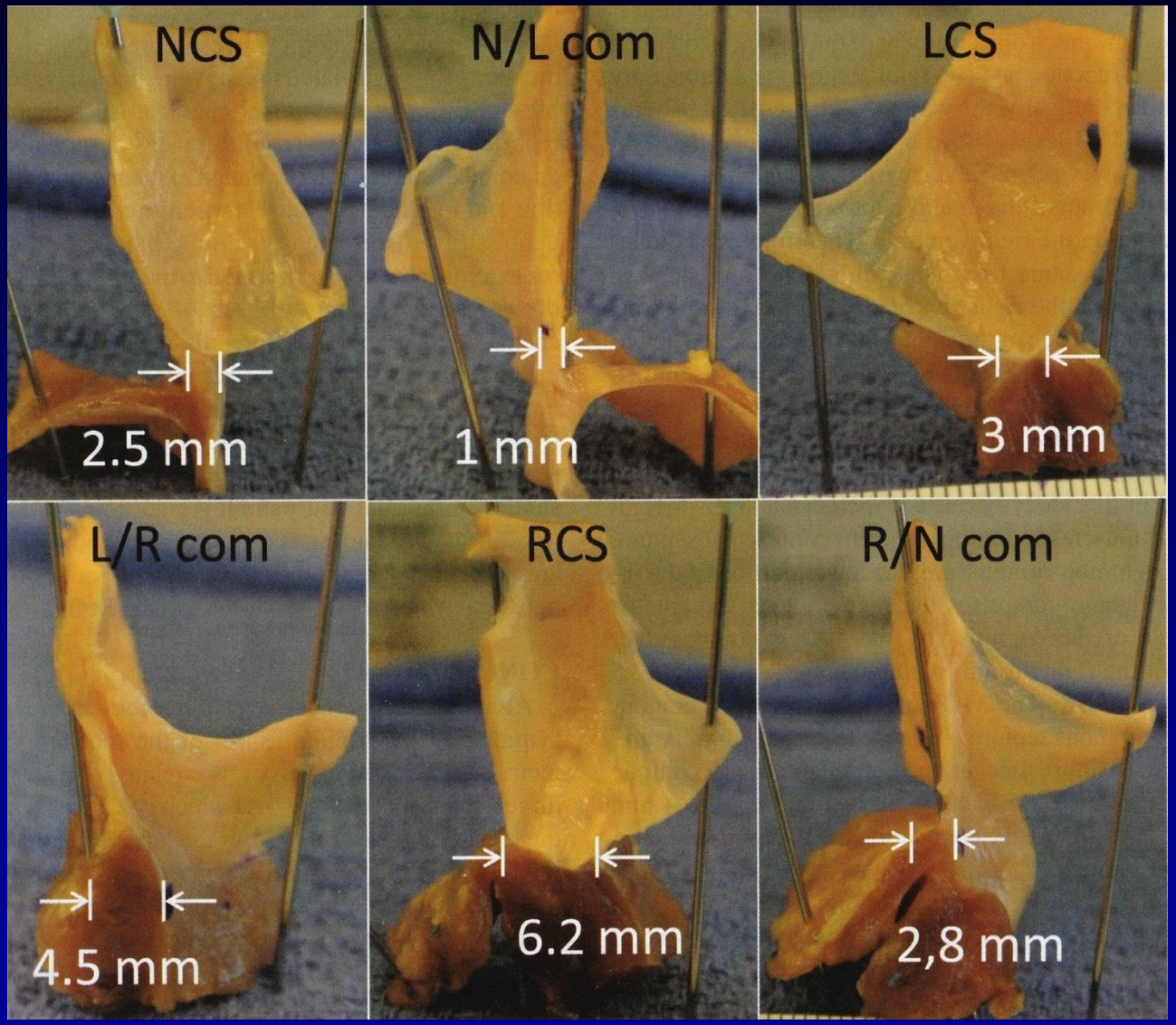
心室頻拍にて右冠尖上より ablation に成功した症例報告あり

大動脈弁基部



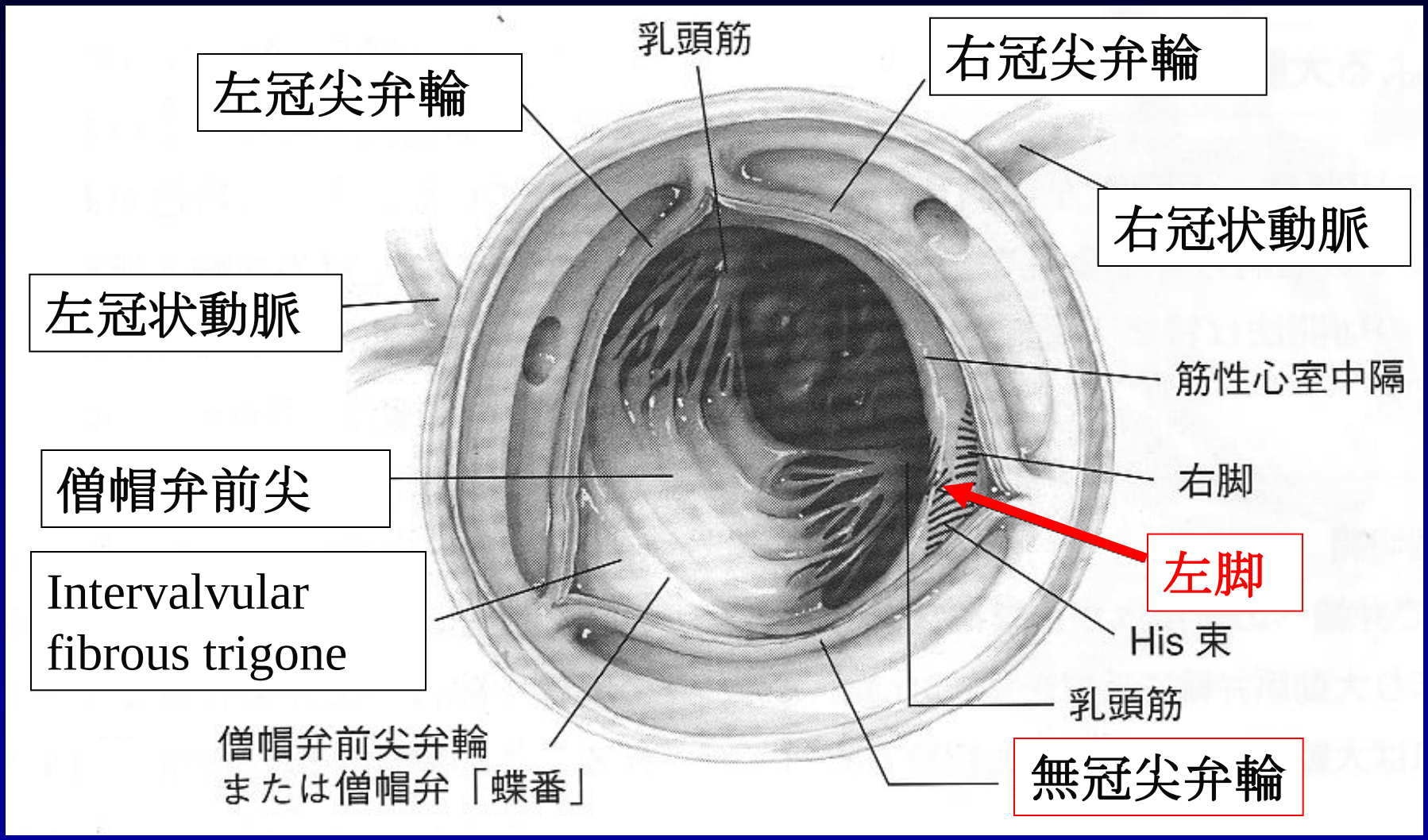
de Kerchove L et al. J Thoracic Cardiovasc Surg 2015; 149: 425-433

大動脈弁基部

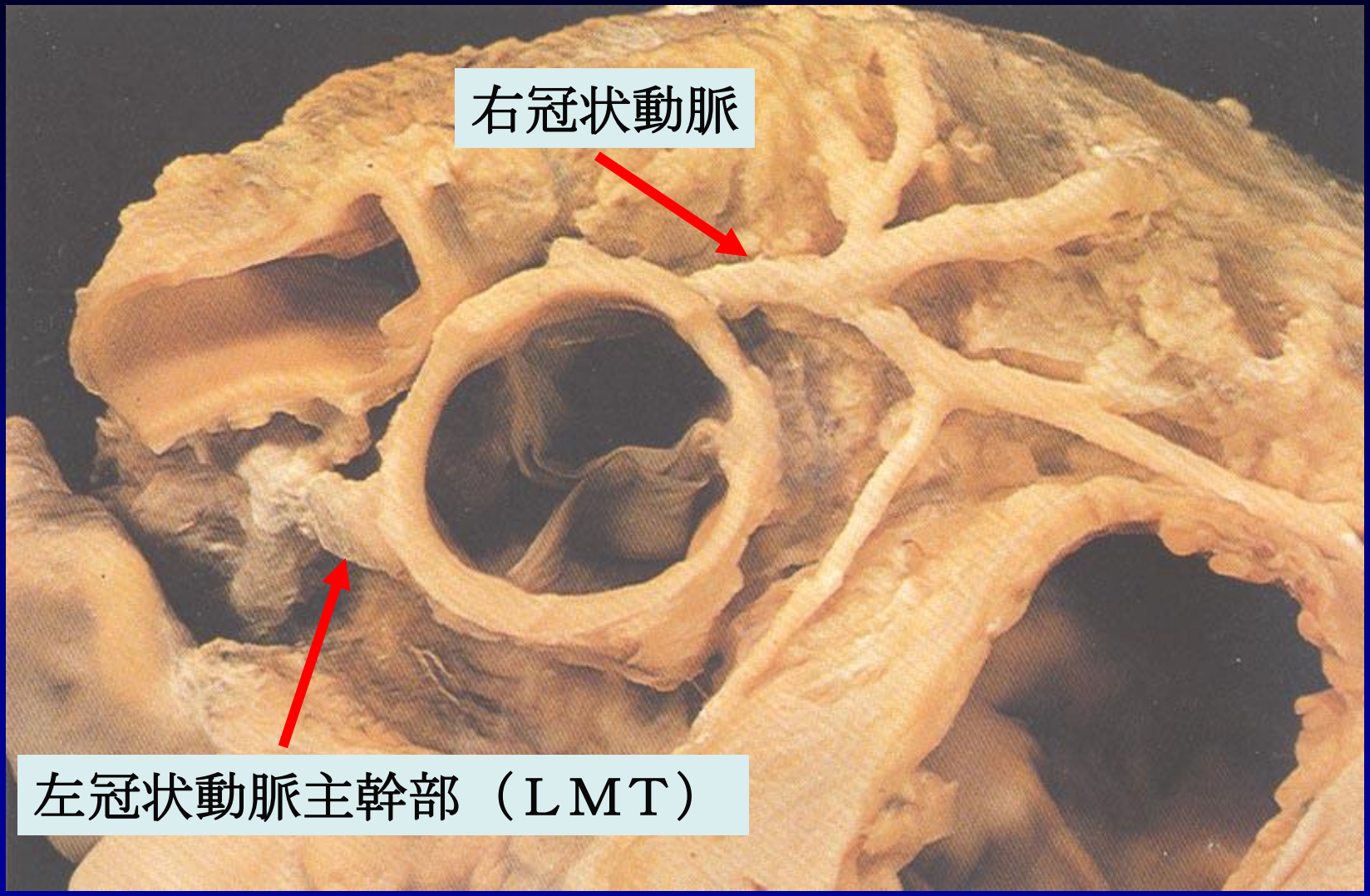


de Kerchove L et al. J Thoracic Cardiovasc Surg 2015; 149: 425-433

大動脈弁の解剖：上方より



冠状動脈

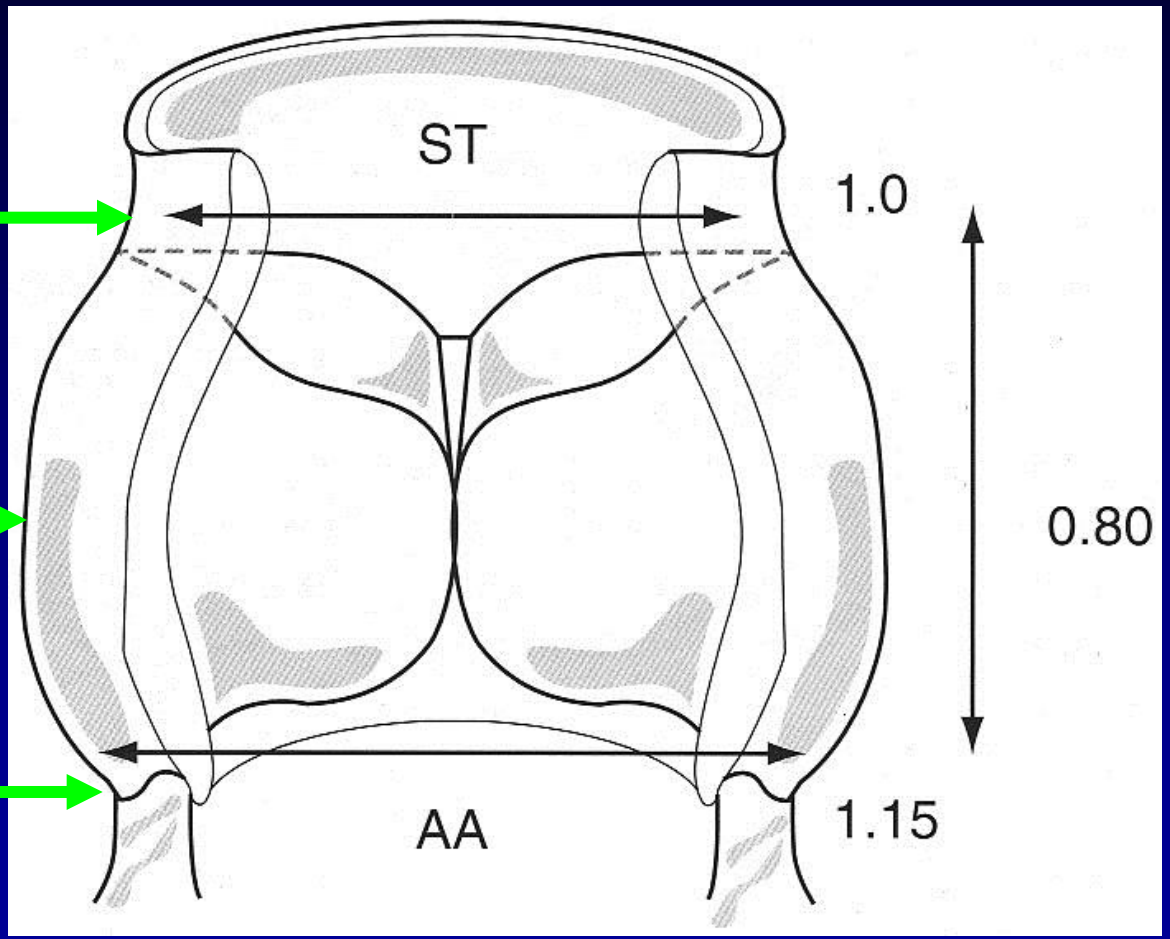


弁輪、Valsalva洞、Sino-tubular junction

Sino-tubular junction

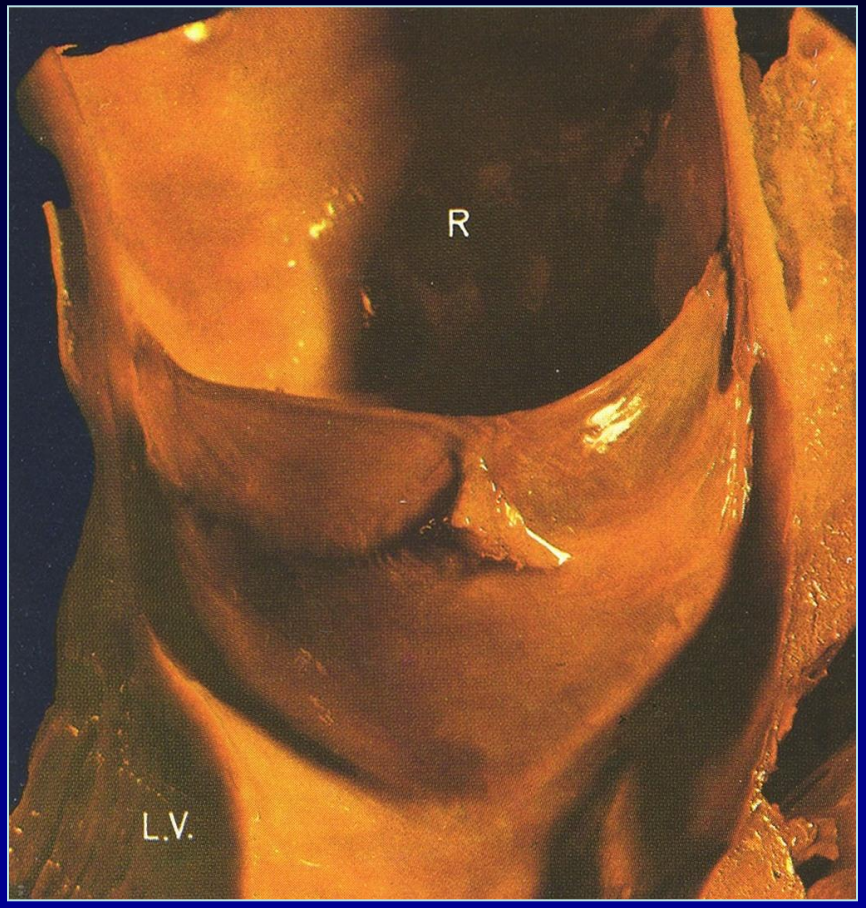
Valsalva 洞

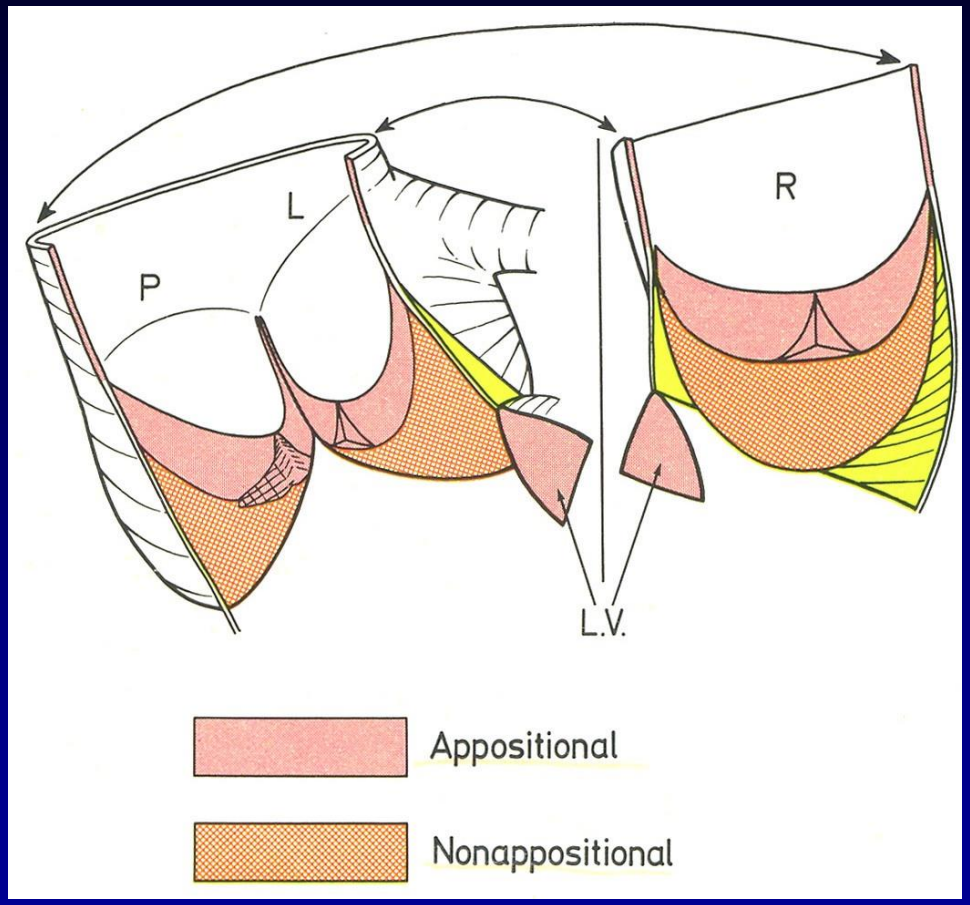
弁輪



Leonardo da Vinci

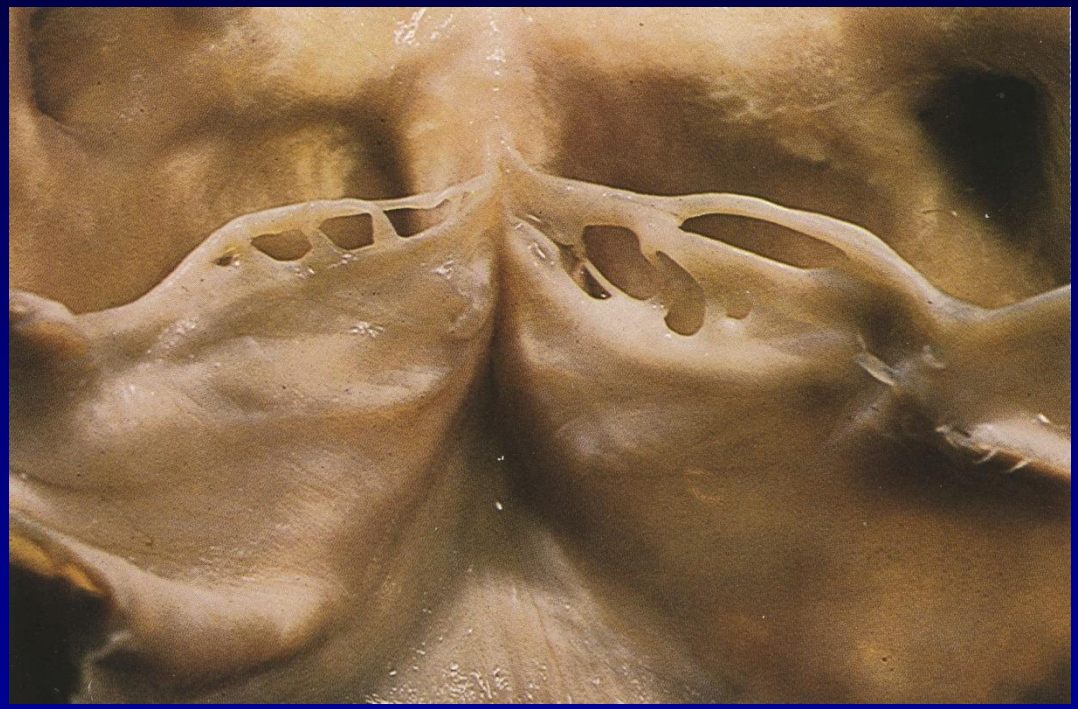
Arantius body

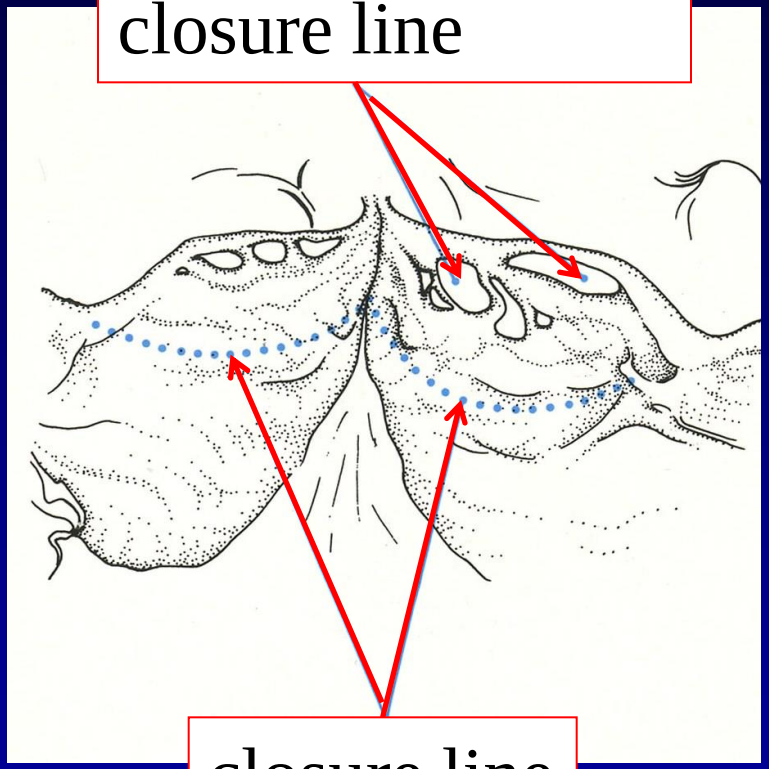




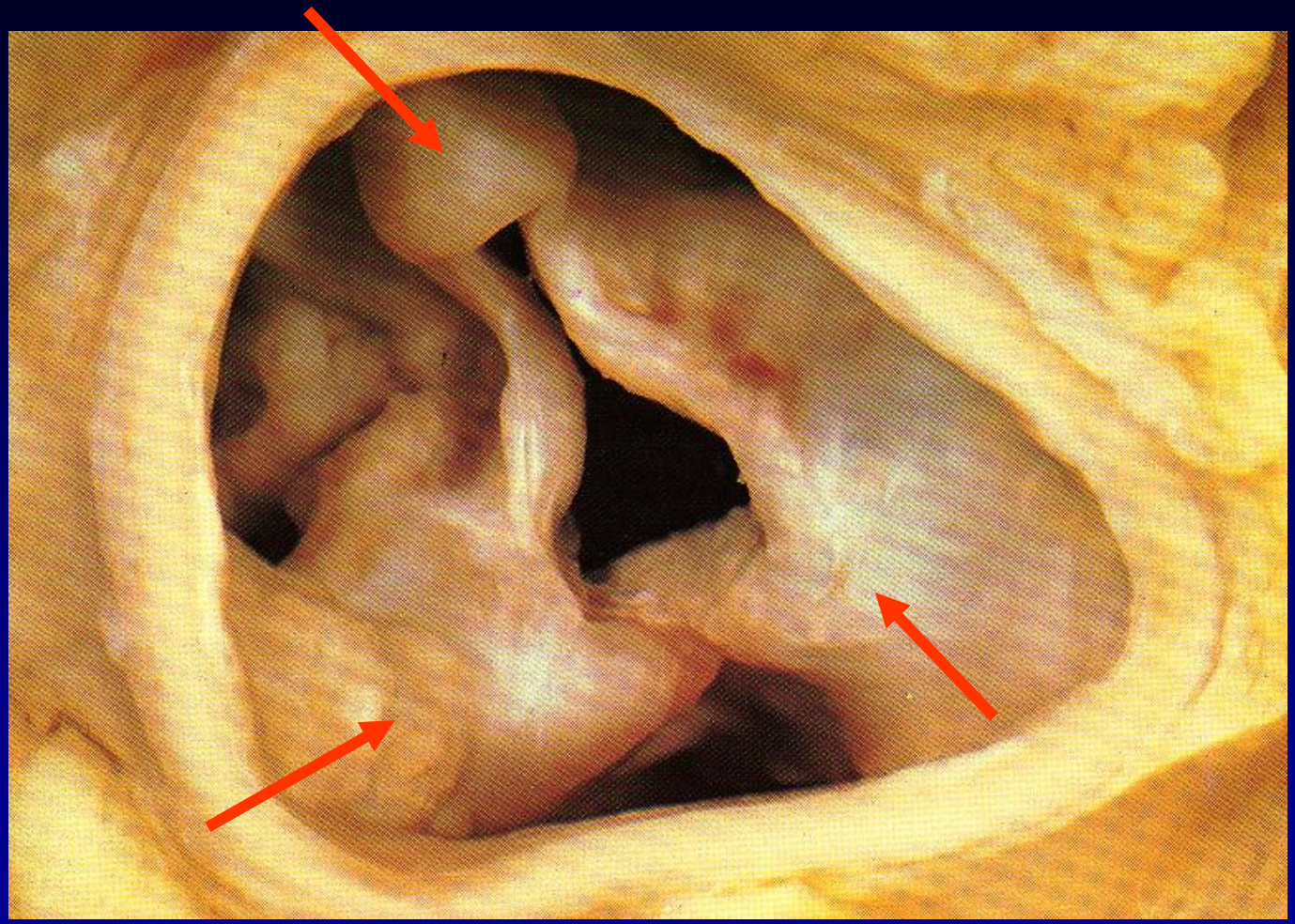
Arantius boy : appositional area を補強
appositional area : leaflet height の約1/3

Fenestration



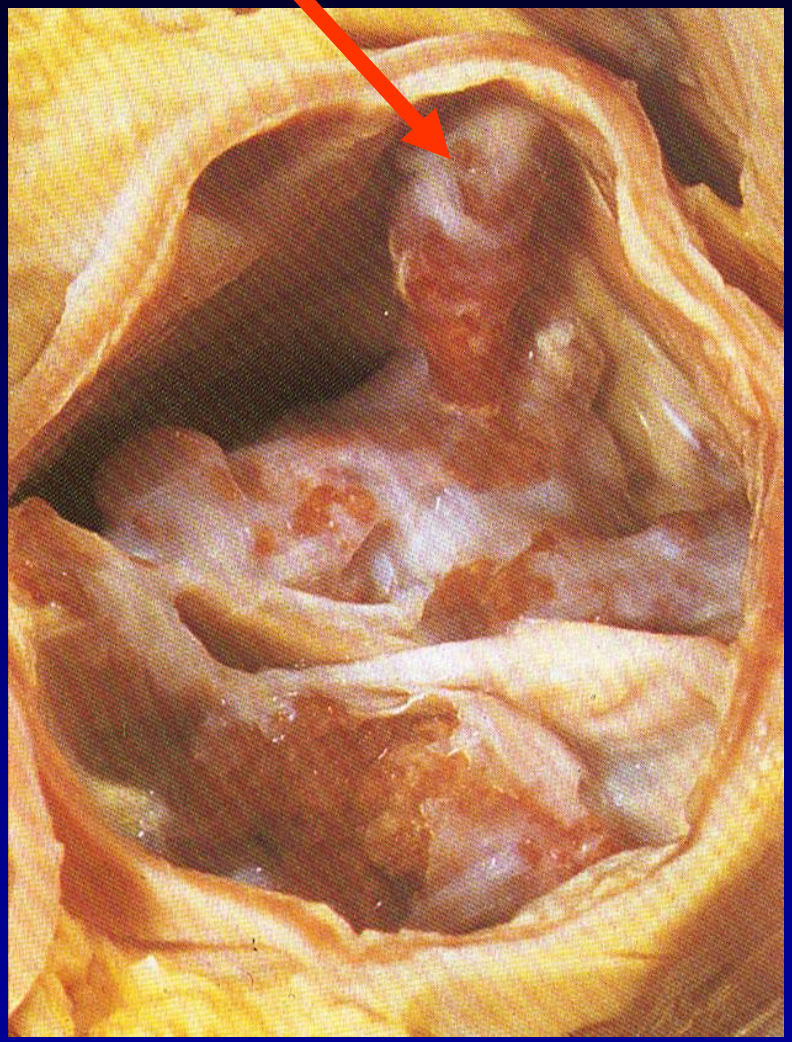


リウマチ性



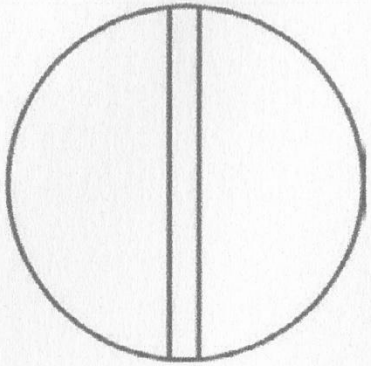
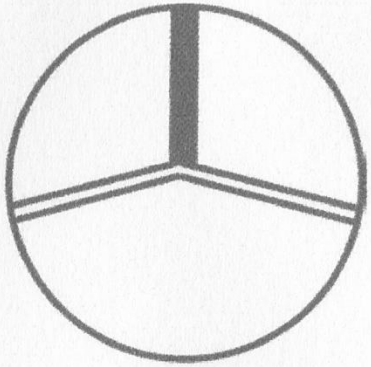
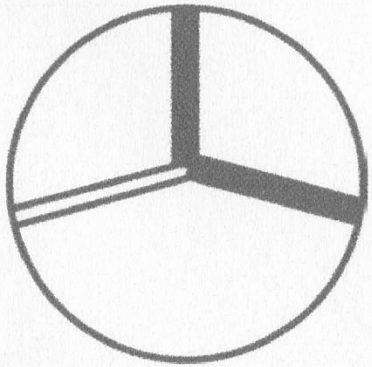
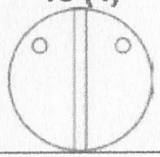
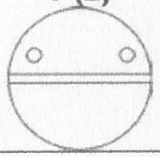
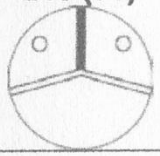
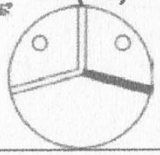
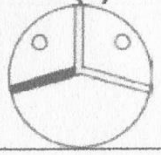
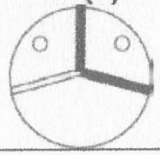
弁尖の肥厚、硬化
交連部癒合（ ⟶ ）

bicuspid valve（二尖弁）



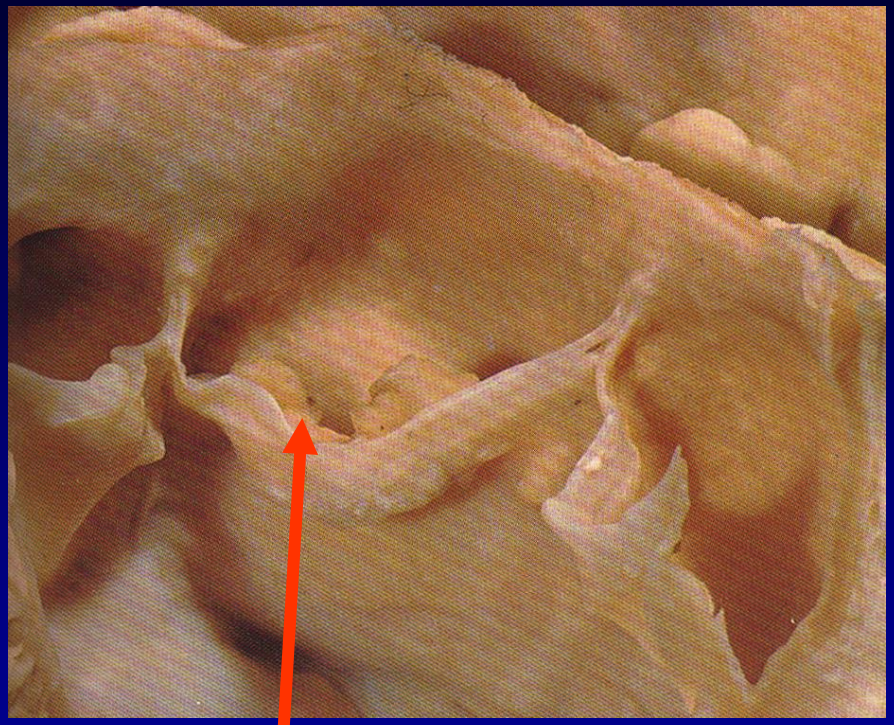
→ raphe

bicuspid valve（二尖弁）

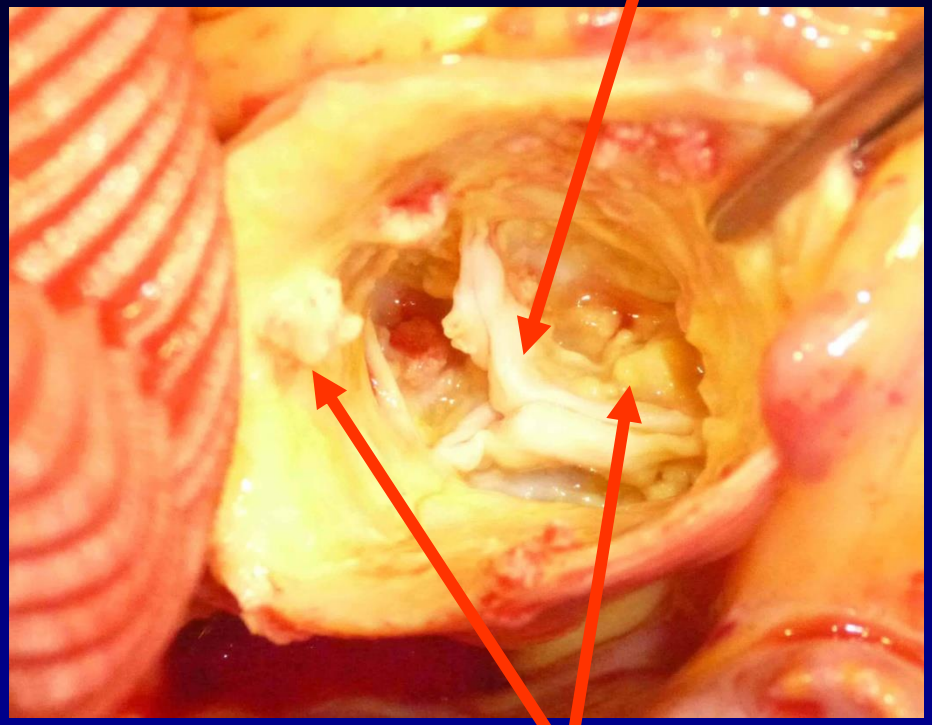
main category: number of raphes	0 raphe - Type 0		1 raphe - Type 1			2 raphes - Type 2
	 21 (7)		 269 (88)			 14 (5)
1. subcategory: spatial position of cusps in Type 0 and raphes in Types 1 and 2	lat 13 (4) 	ap 7 (2) 	L – R 216 (71) 	R – N 45 (15) 	N – L 8 (3) 	L – R / R – N 14 (5) 
2. subcategory: VALVULAR FUNCTION I	6 (2)	1 (0.3)	79 (26)	22 (7)	3 (1)	6 (2)
S	7 (2)	5 (2)	119 (39)	15 (5)	3 (1)	6 (2)
B (I + S)		1 (0.3)	15 (5)	7 (2)	2 (1)	2 (1)
No			3 (1)	1 (0.3)		

Sievers HH et al. A classification system for the bicuspid aortic valve from 304 surgical specimens. J Thorac Cardiovasc Surg. 2007;133:1226-33

硬化性（degenerative calcific）



Spotty calcification



石灰化は原則として大動脈側、交連部癒合はない
石灰化に関する例外：維持透析、Homozygous FH

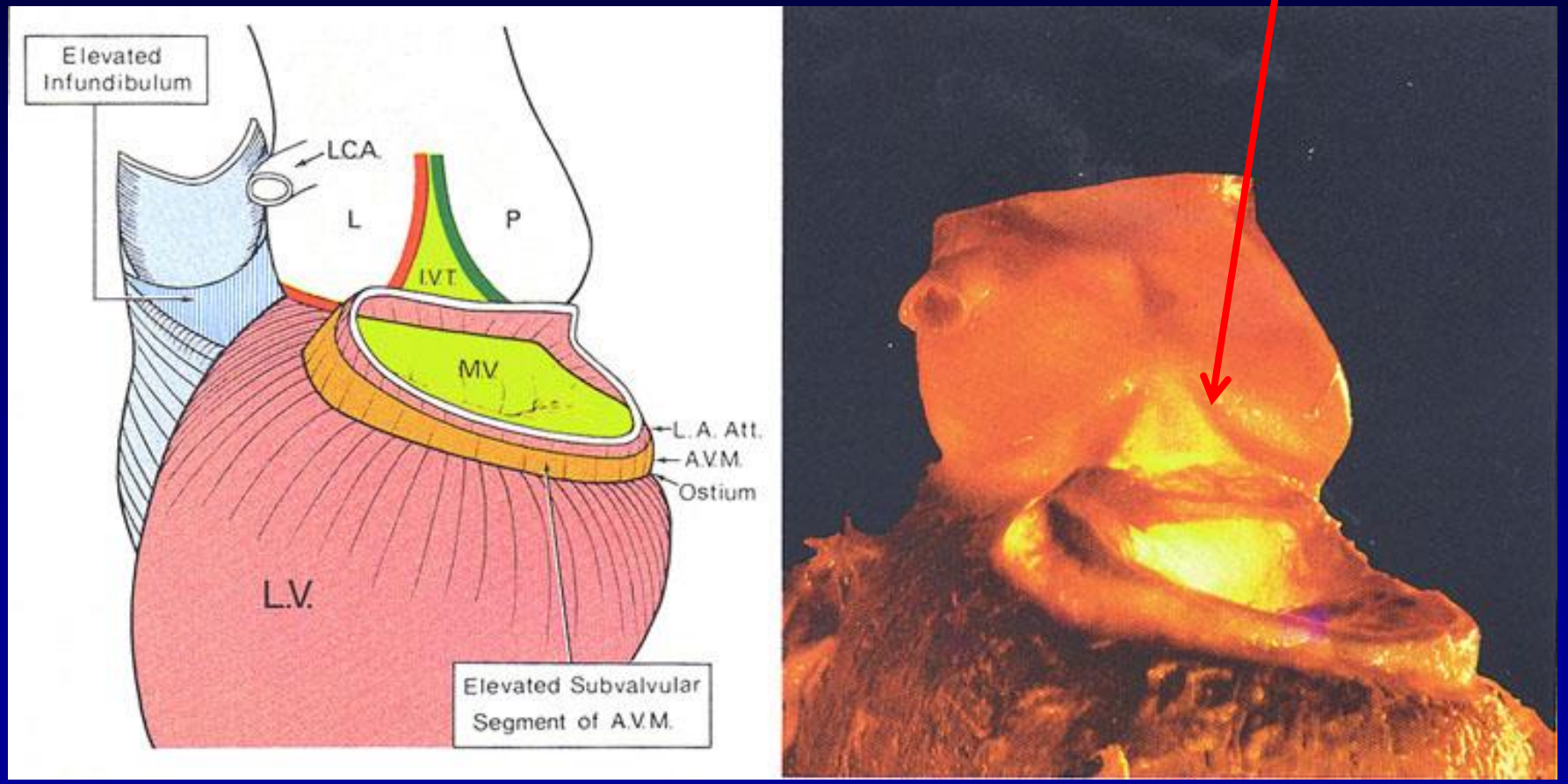
Aortic Valve Replacement : non-everting suture

左冠尖切除ー要注意！
大動脈壁外に出ない様、両方向から切除する。

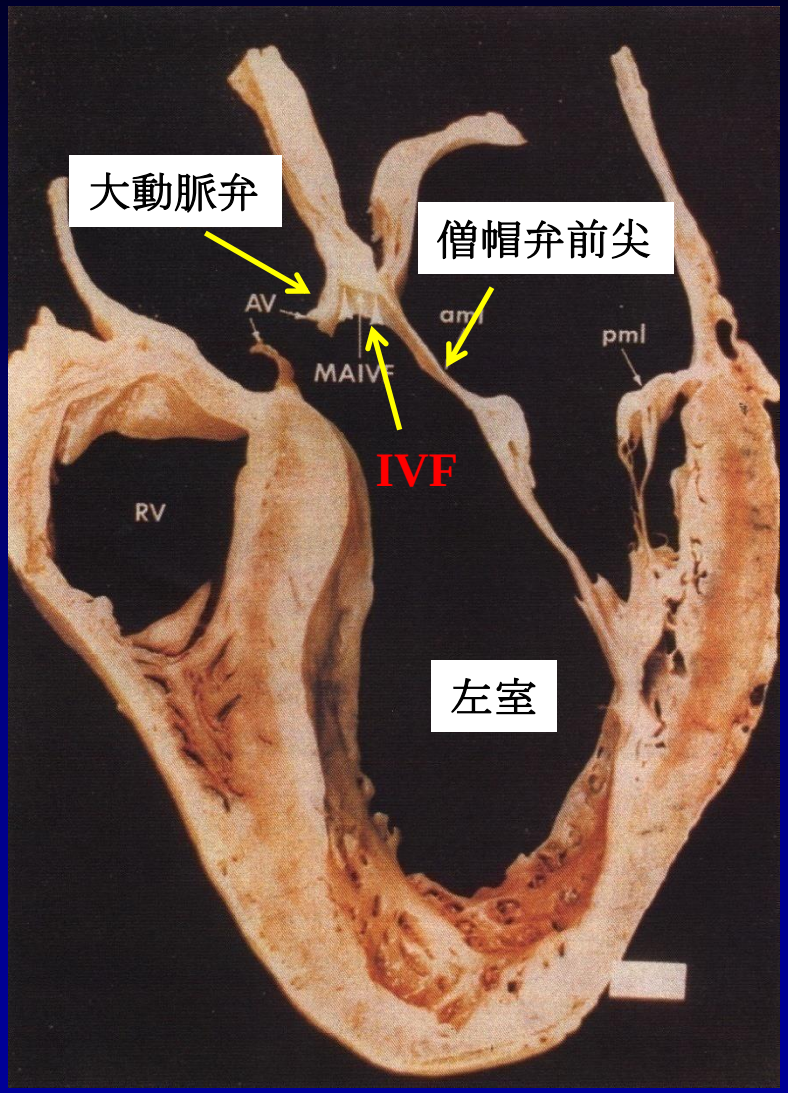
左冠尖左側ではback hand closeに針を保持する。

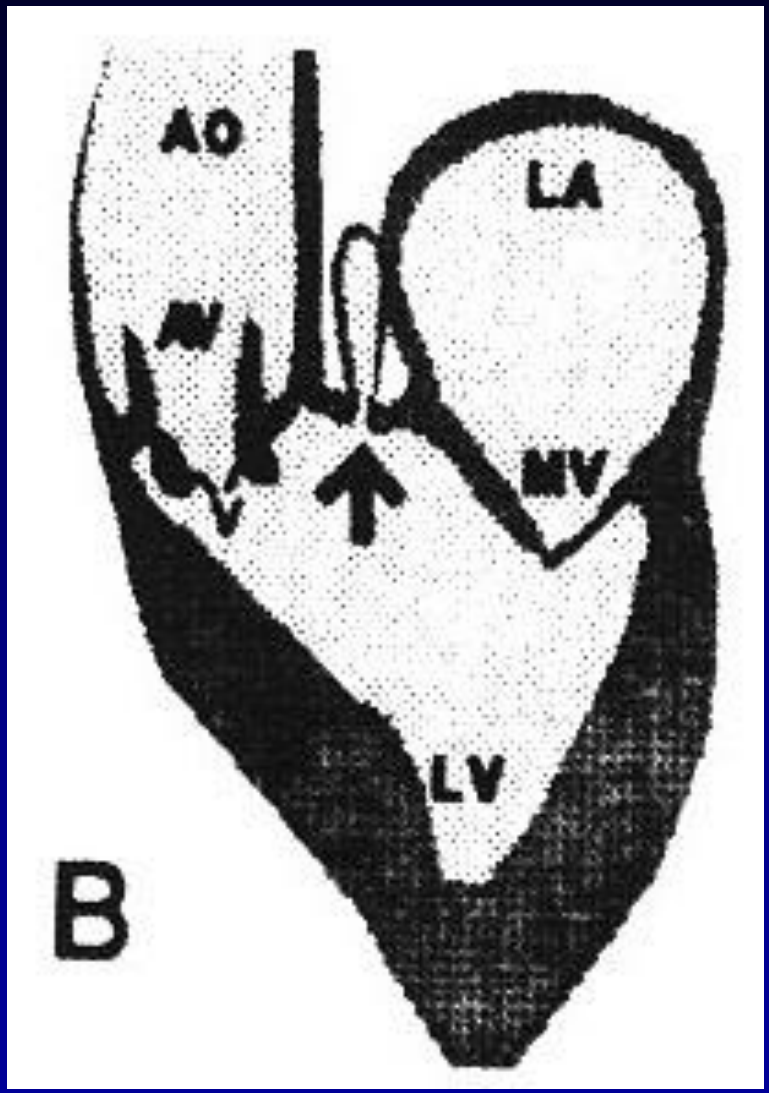
右冠尖では極端な closeに針を保持する。

Intervalvular trigone



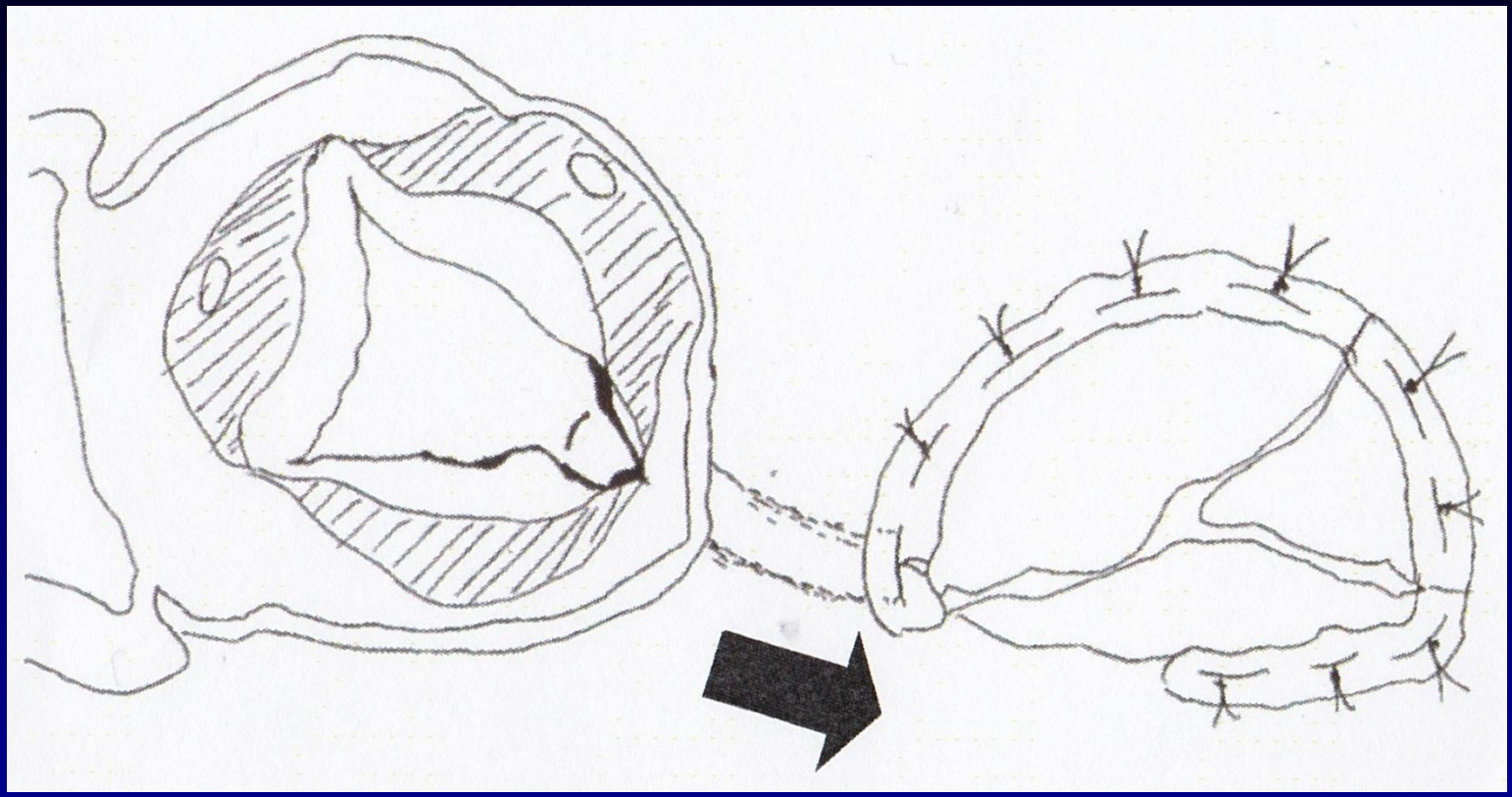
IVFに発生したmycotic aneurysm





IVF : Intervalvular fibrous trigone

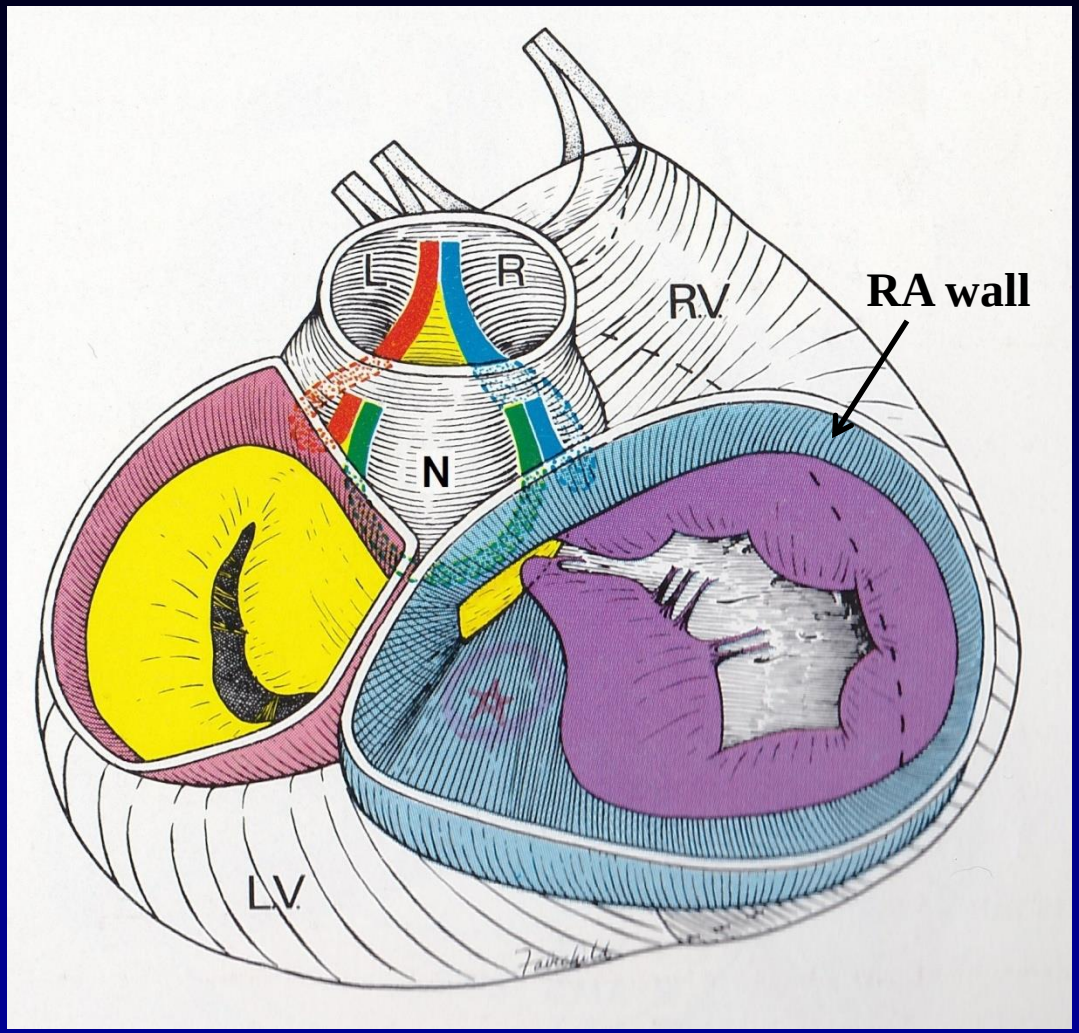
三尖弁輪形成術後に生じた大動脈弁閉鎖不全症



MR、TR→MVR(生体弁 29mm)、TAP（rigid ring 30mm)
1週後、AR(IV)、完全房室ブロック→AVR
TAP の糸が膜性中隔から右冠尖ー無冠尖交連部直下に貫通

日本心臓血管外科学会誌 2015;44:170-172

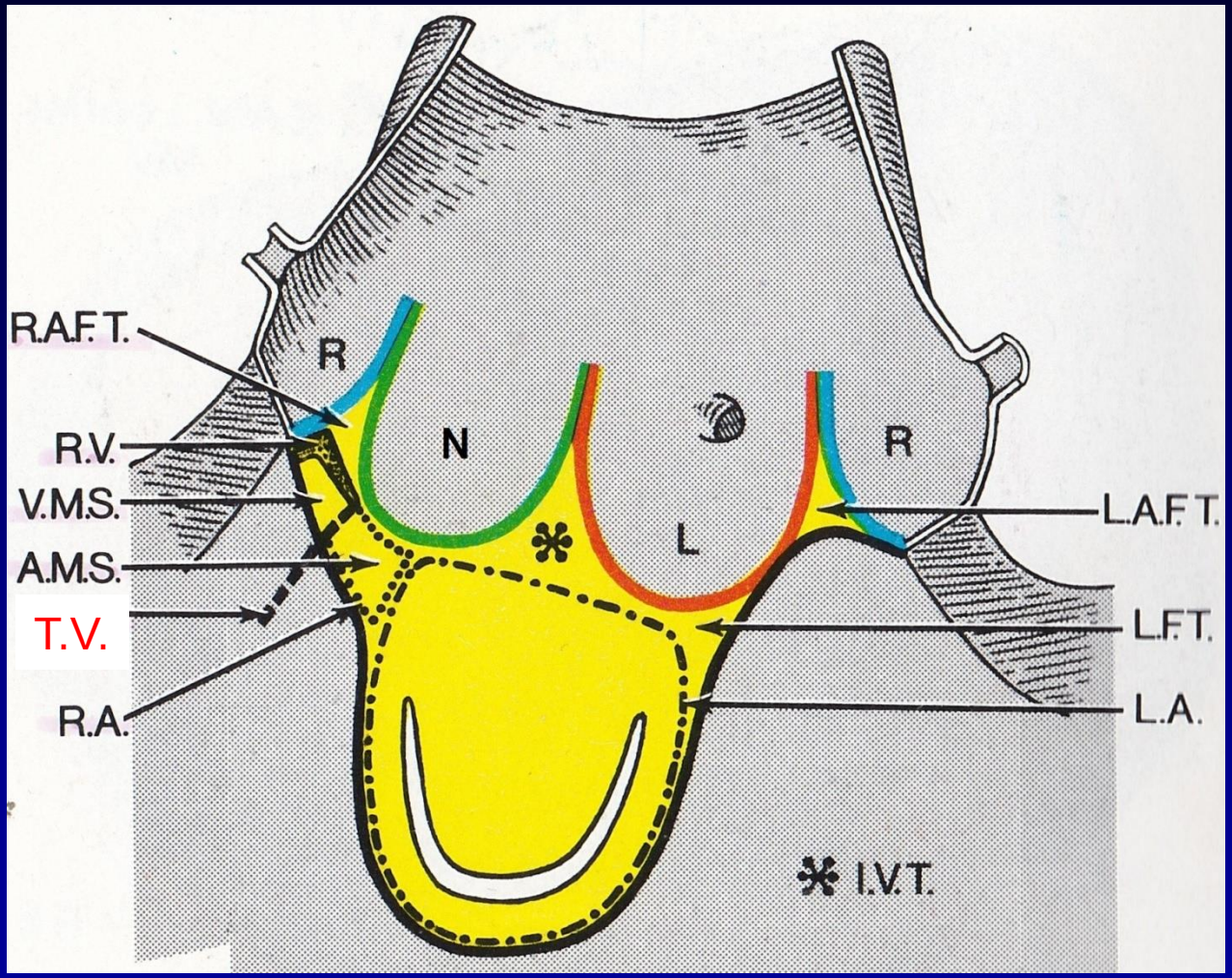
三尖弁輪の向こうには何がある？



三尖弁輪への運針：右房→弁輪→右室→弁輪→右房 を原則とすると
前尖の前尖ー中隔尖交連部付近では腱索にかかりそう・・・
右房壁に深く運針すると右房外もしくは大動脈！！

三尖弁輪の向こうには何がある？

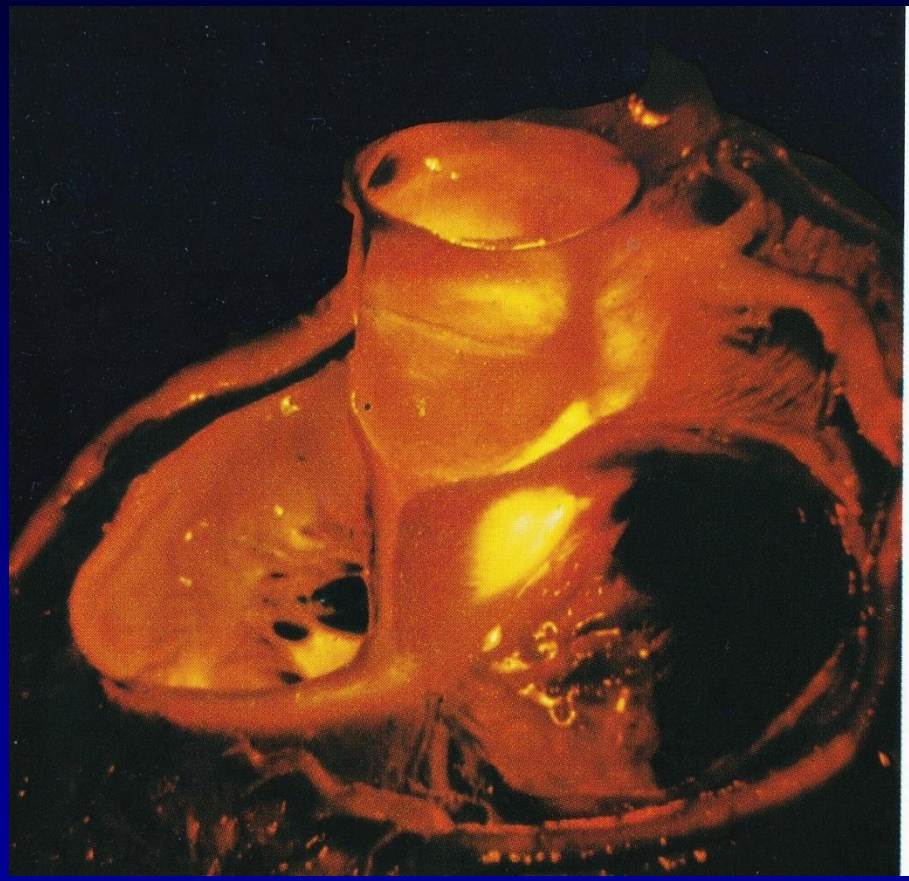
左室心尖部から大動脈弁、僧帽弁を見上げた図

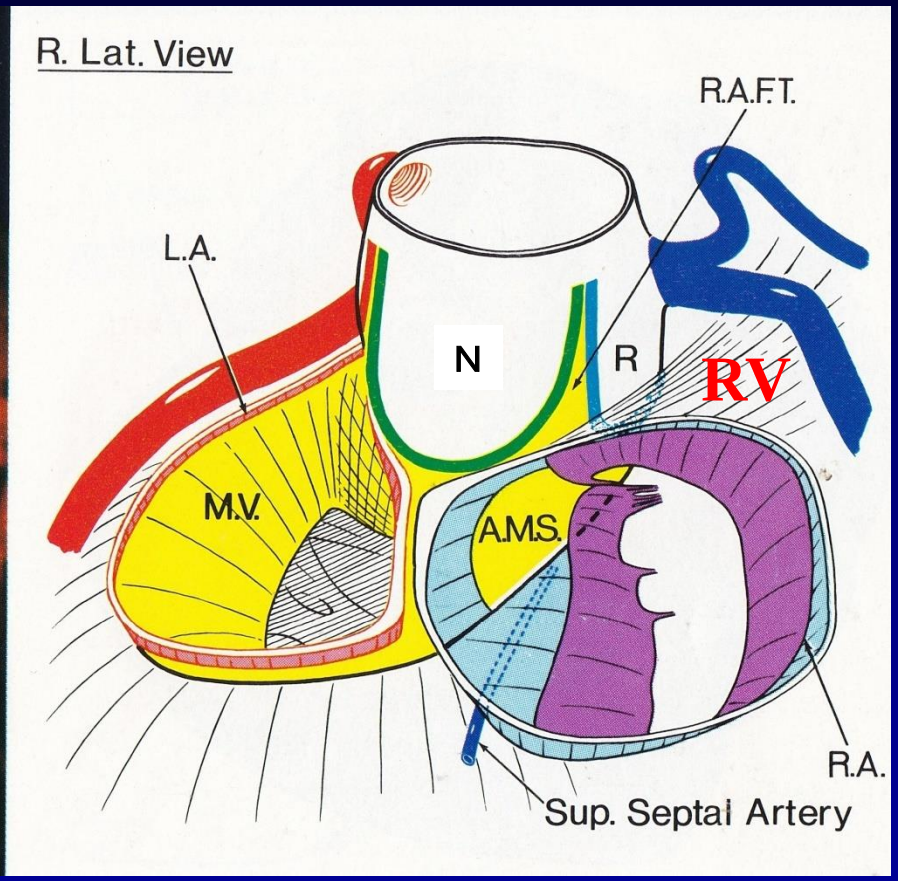


V.M.S.: interventricular portion of membranous septum
A.M.S.: atrioventricular portion of membranous septum

三尖弁輪の向こうには何がある？

大動脈基部置換術で右冠尖ー無冠尖交連部を剝離する時には右室付着部にも注意





A.M.S.: atrioventricular portion of membranous septum

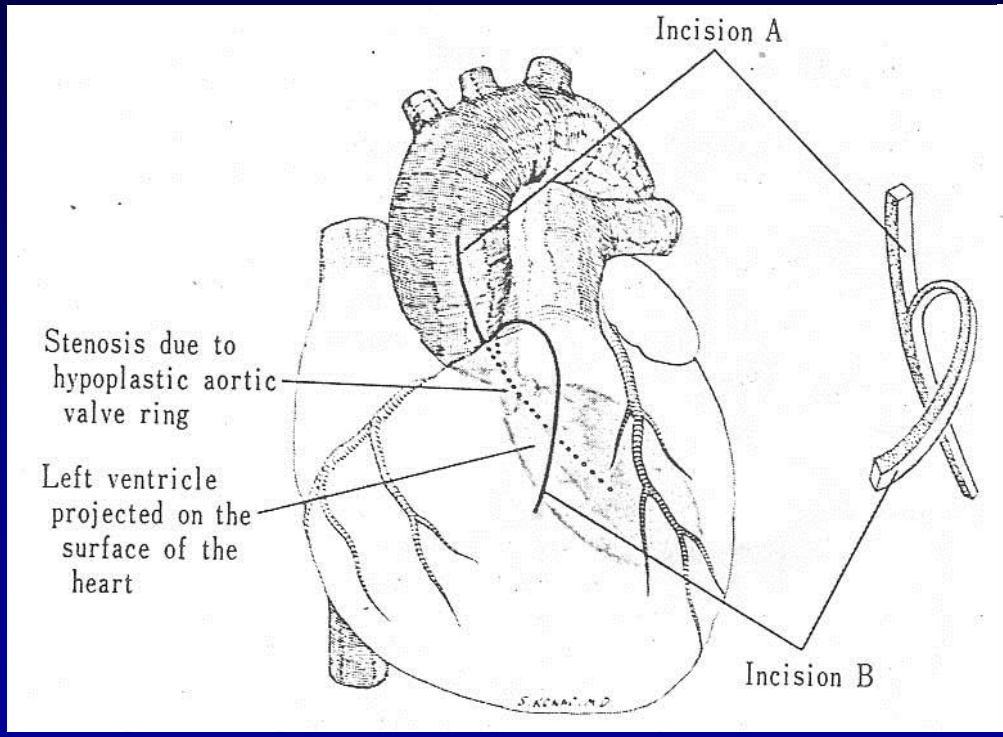
狭小弁輪に対する弁輪拡大

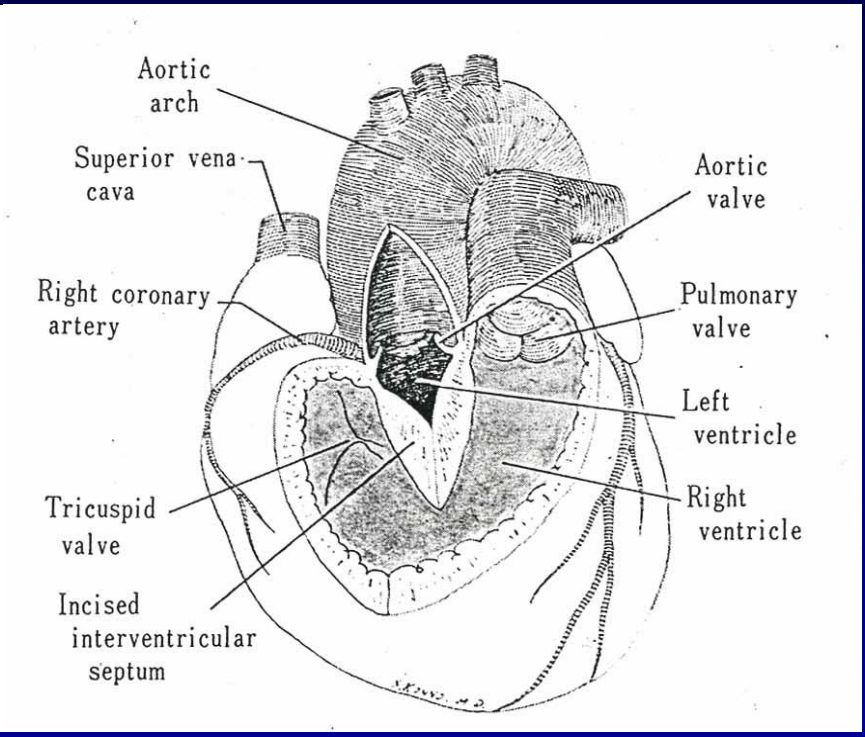
1) Anterior approach
Konno (-Rastan) 法

2) Posterior approach
Nicks 法
Mori, Luis Nunez
Manouguian 法

狭小弁輪に対する弁輪拡大

Konno (-Rastan) 法

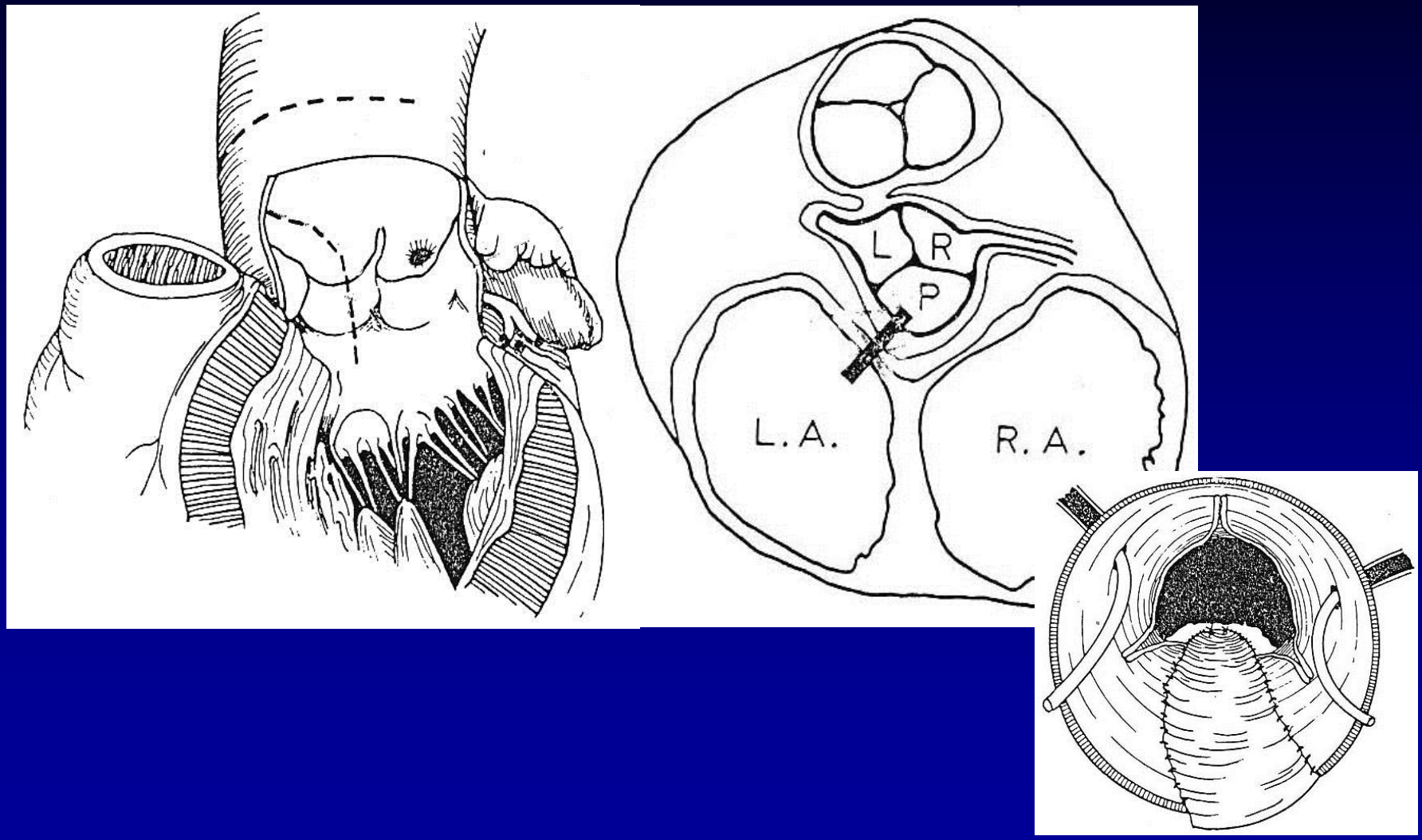




Konno S, et al. JTCS. 1975;70:909-17.

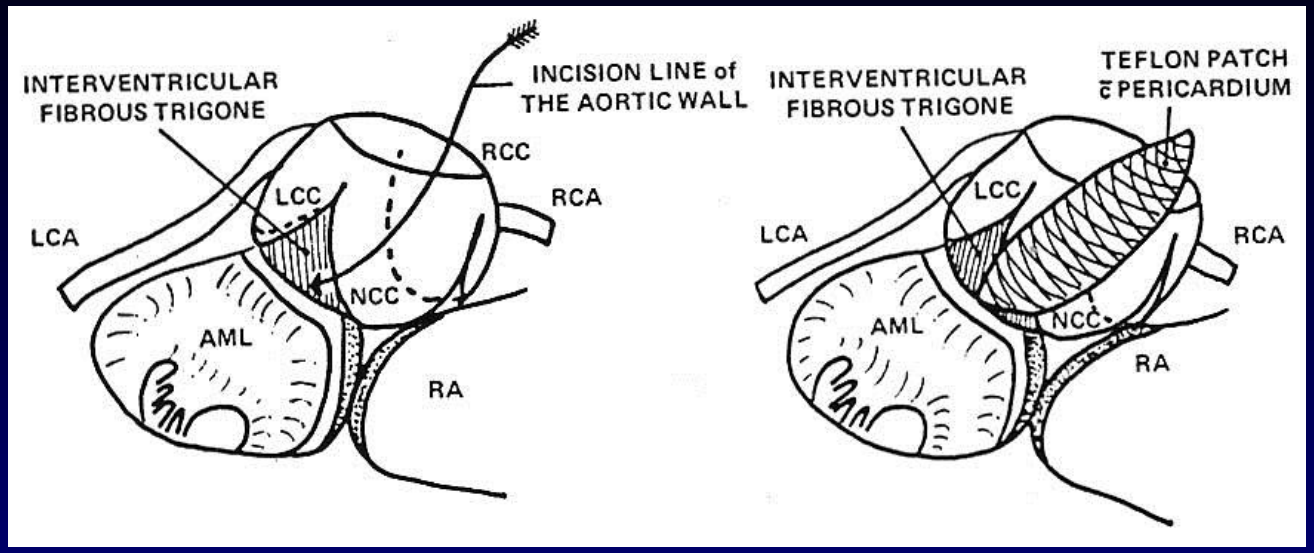
狭小弁輪に対する弁輪拡大

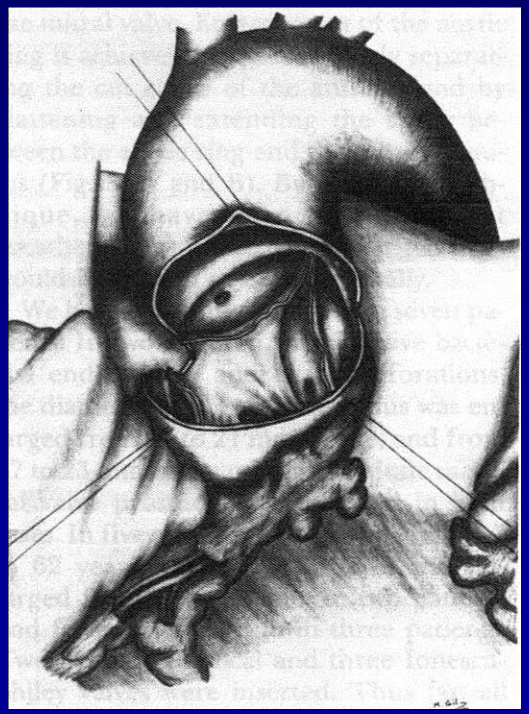
Nicks 法

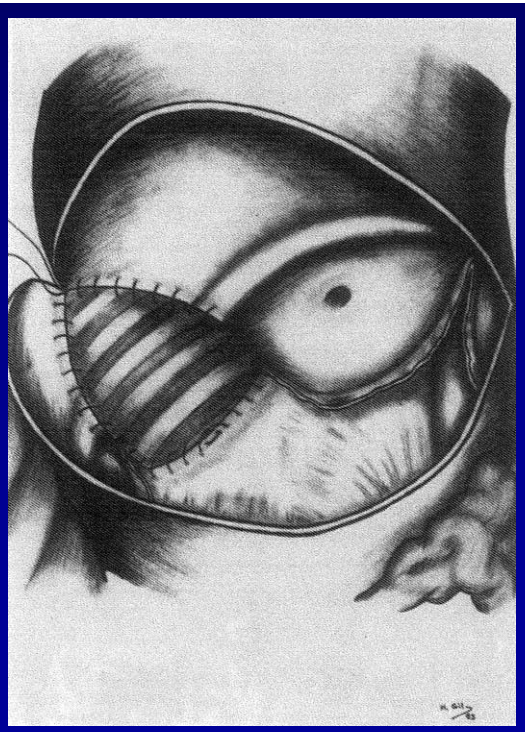


Nicks R, Cartmill T, Bernstein L. Thorax. 1970;25:339-46.

狭小弁輪に対する弁輪拡大





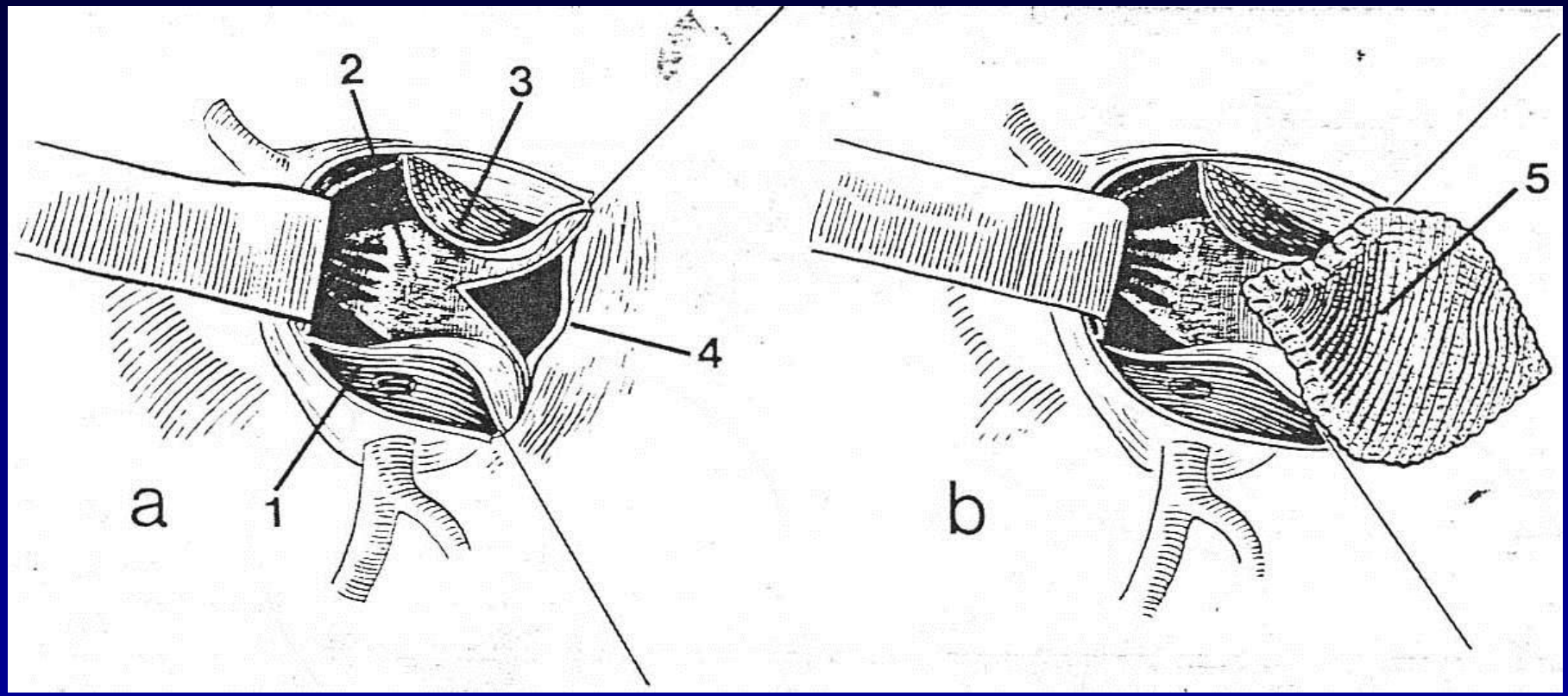


Mori T, et al. Ann Thorac Surg. 1981;31:111-6.

Nuñez L, et al.
Tex Heart Inst J. 1983;10:301-3.

狭小弁輪に対する弁輪拡大

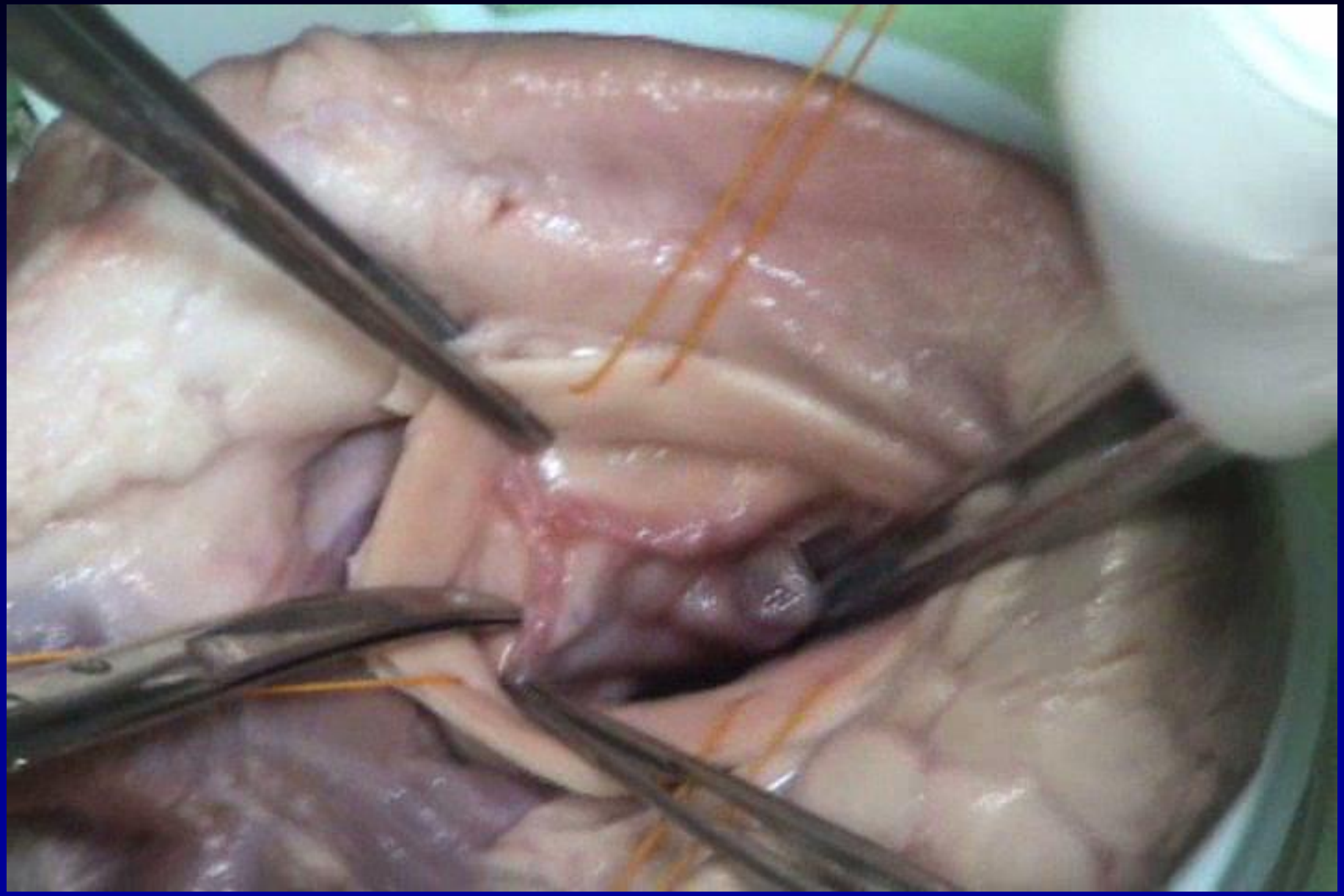
Manouguian 法



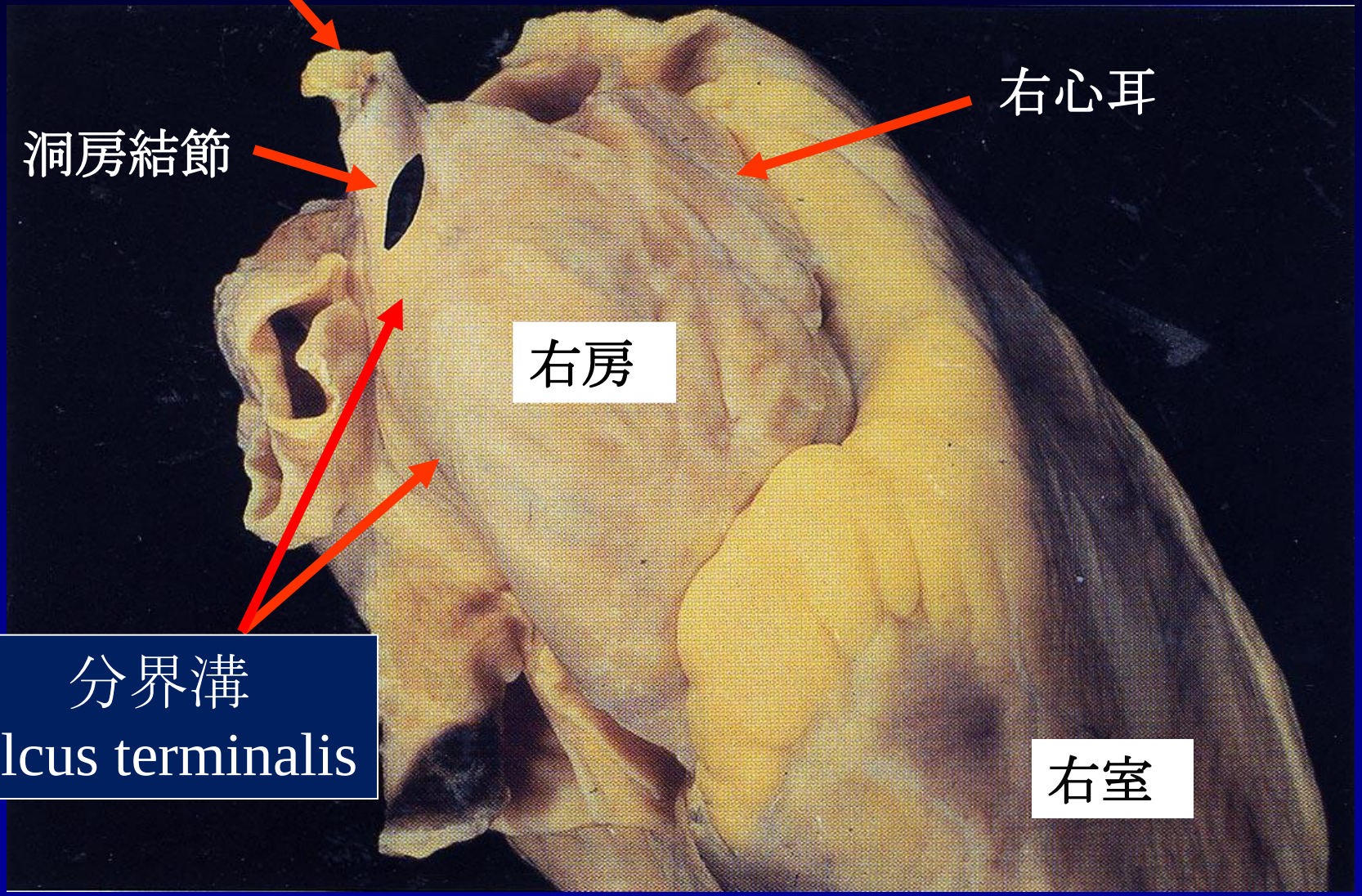
4 の部位は Interatrial bundel 前方の危険地帯！！

Manouguian S, Seybold-Epting W. JTCS. 1979;78:402-12.

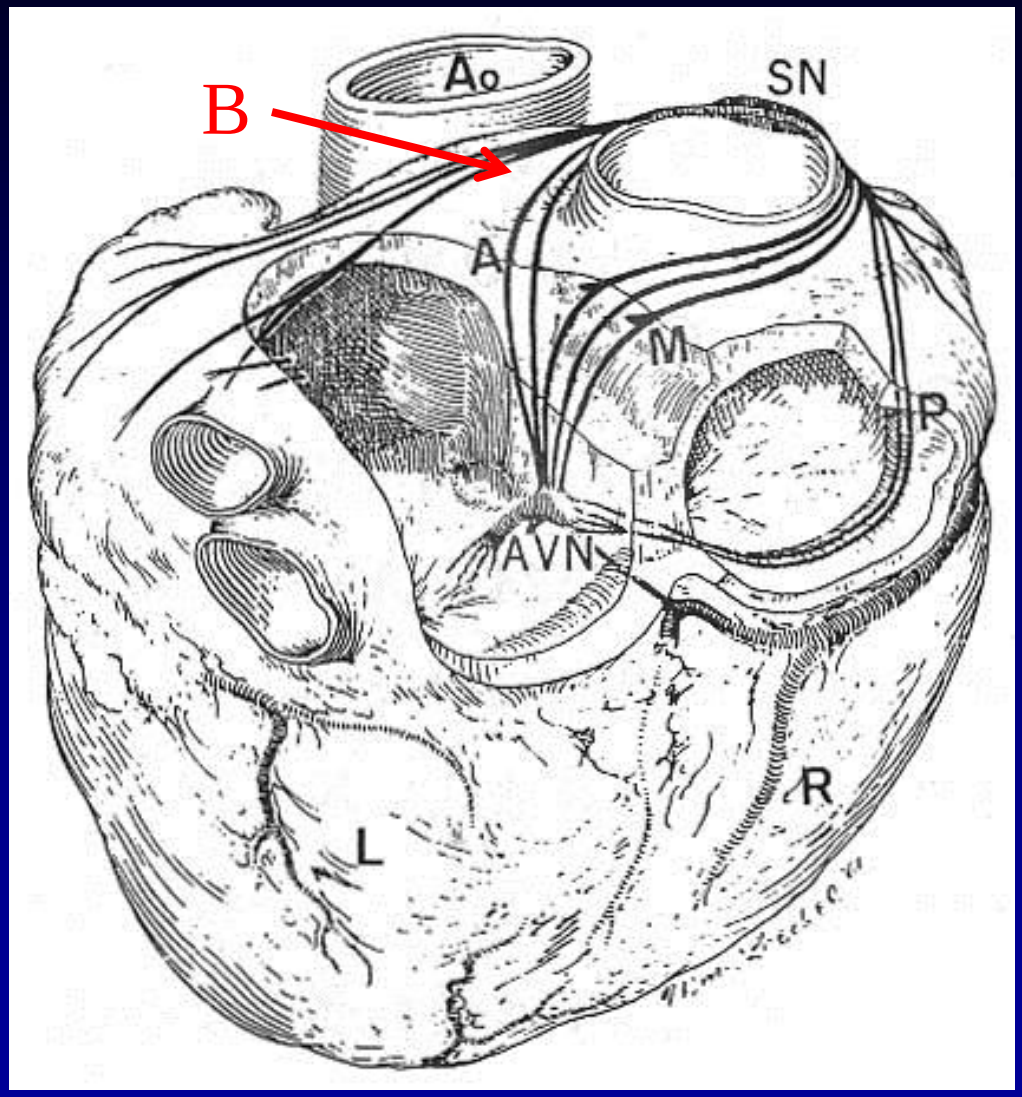
弁輪拡大



刺激伝導系：洞房結節



刺激伝導系：internodal pathway

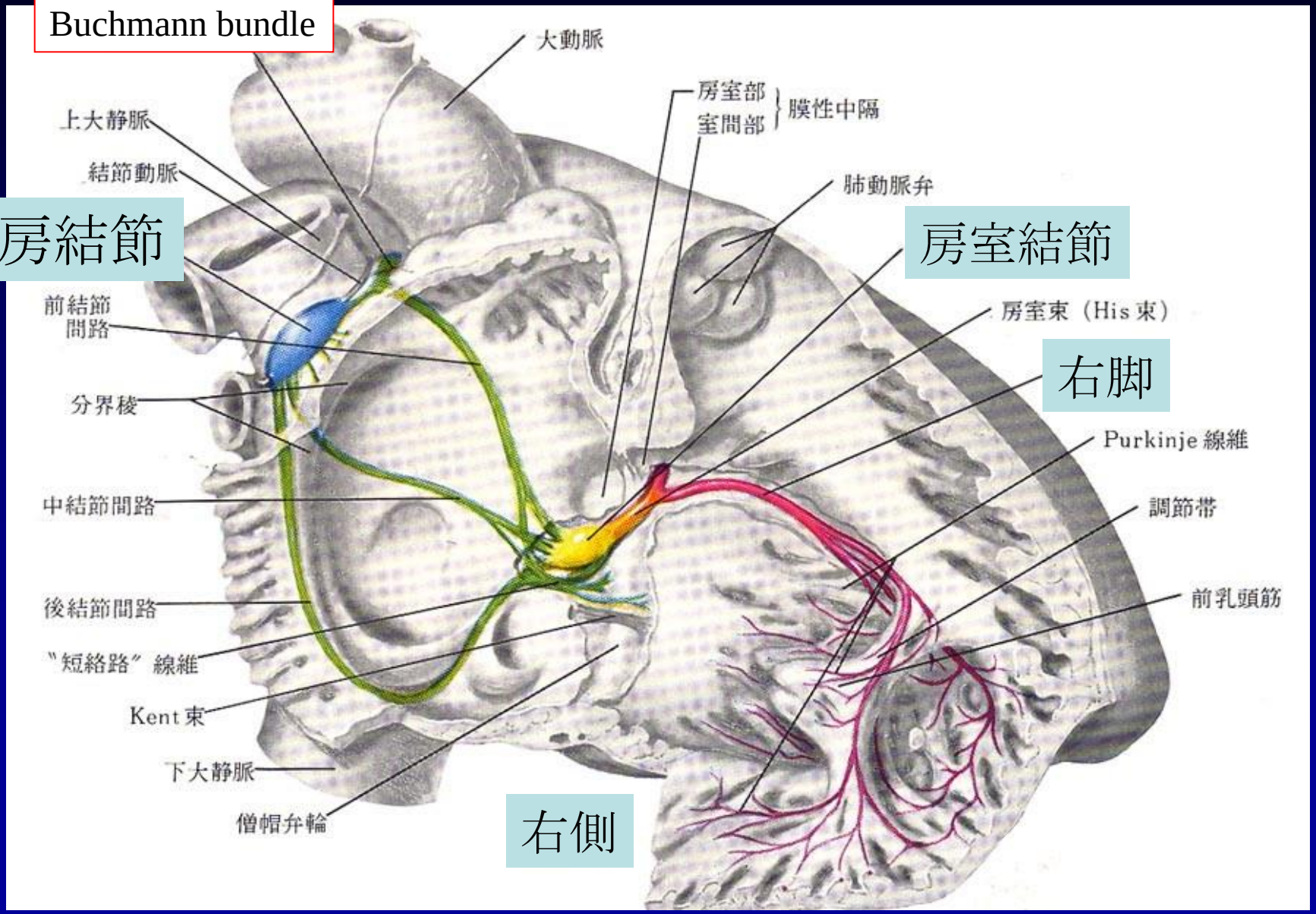


preferential pathway
‘not tracts, but only plain atrial myocardium’

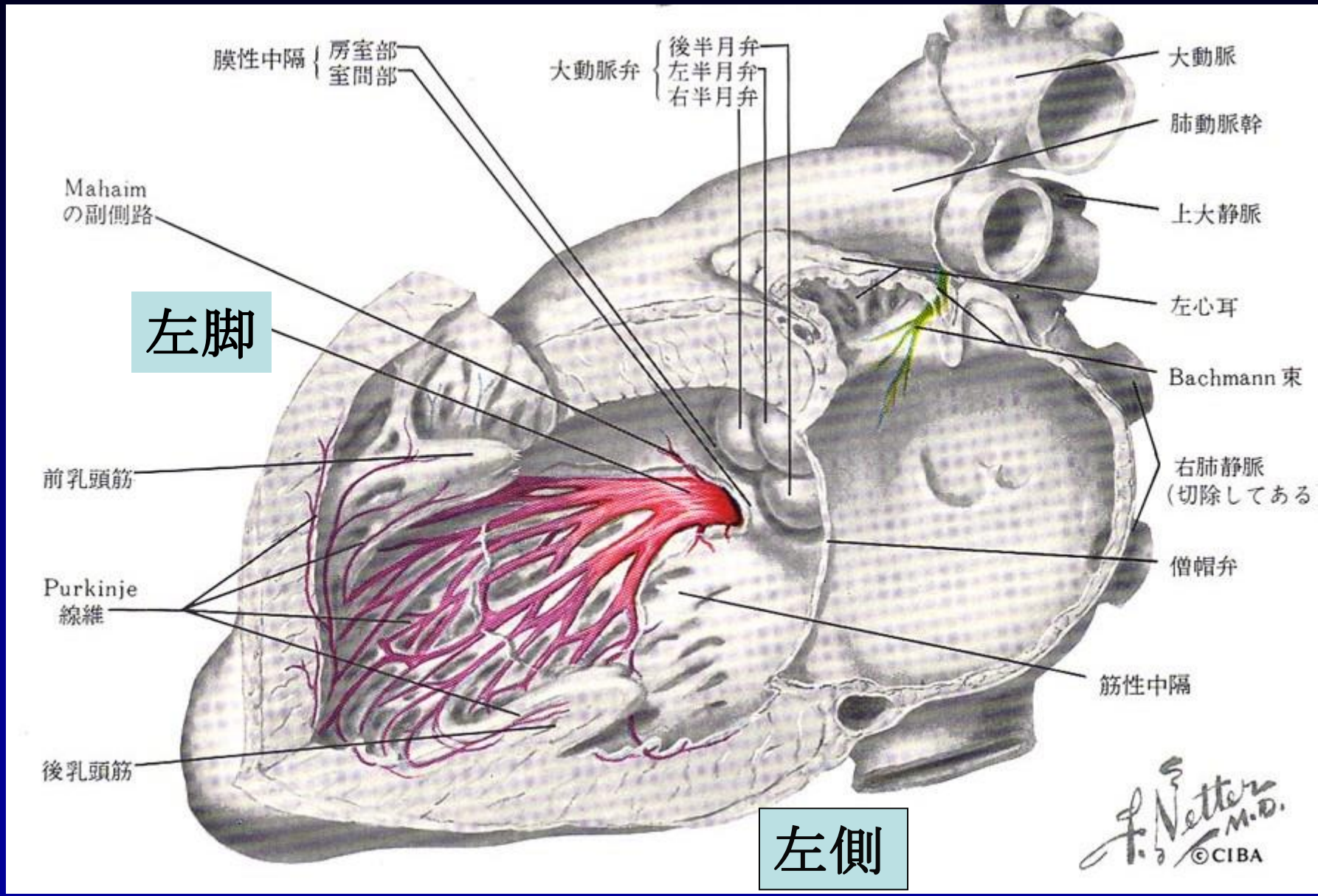
A : anterior INP
B : middle INP
P : posterior INP
(INP:internodal pathway)

B : Bachmann bundle

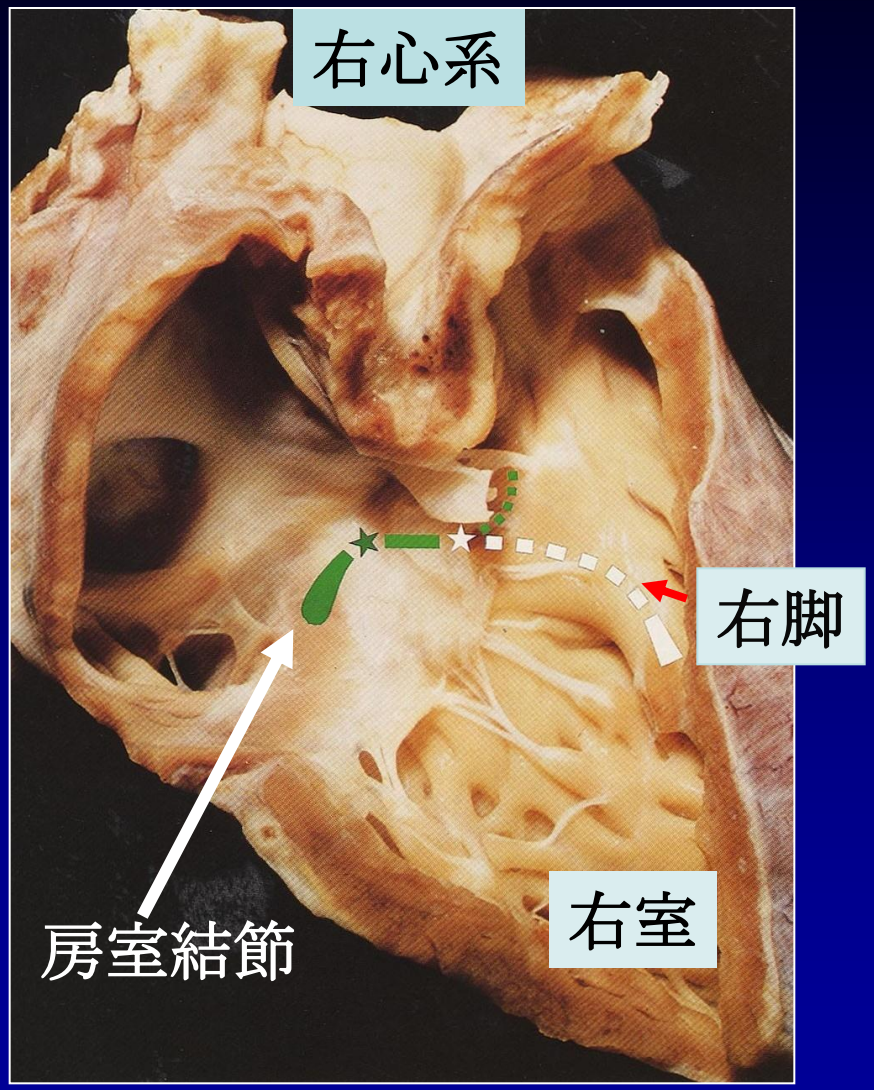
刺激伝導系

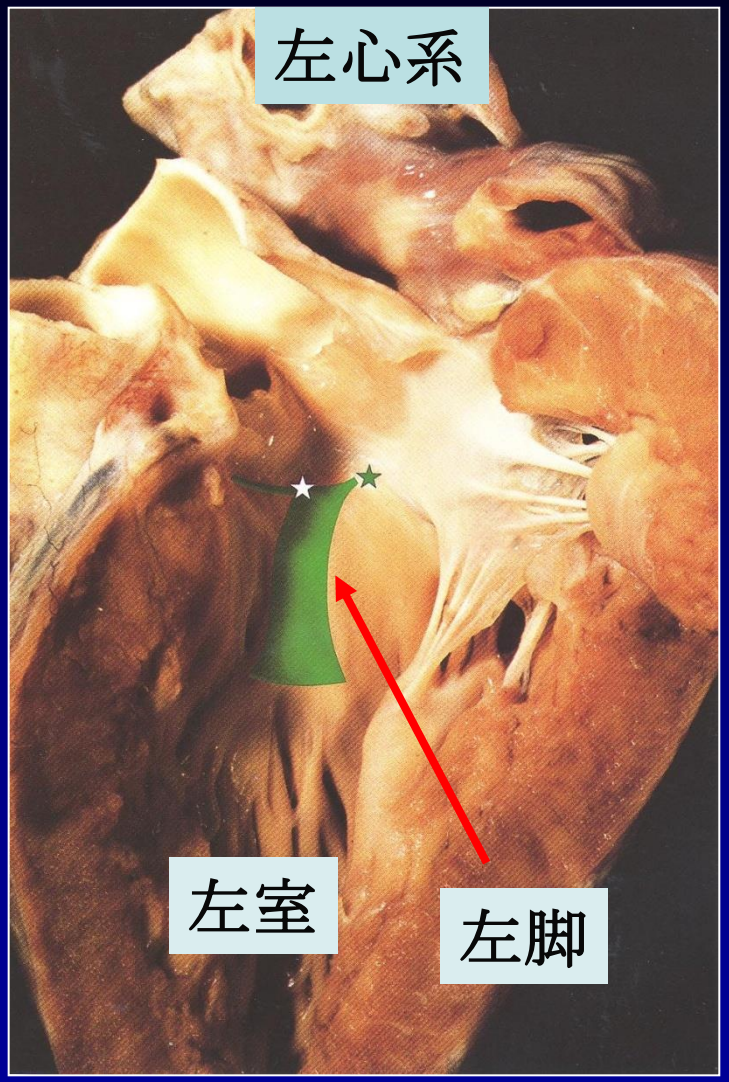

Buchmann bundle
大動脈
房室部
室間部
膜性中隔
上大静脈
結節動脈
肺動脈弁
洞房結節
房室結節
前結節
間路
房室束（His 束）
右脚
分界稜
Purkinje 線維
中結節間路
調節帯
後結節間路
前乳頭筋
〝短絡路〞線維
Kent 束
下大静脈
僧帽弁輪
右側

刺激伝導系


膜性中隔
房室部
室間部
大動脈弁
後半月弁
左半月弁
右半月弁
大動脈
肺動脈幹
上大静脈
Mahaim
の副側路
左脚
左心耳
Bachmann 束
右肺静脈
(切除してある
前乳頭筋
僧帽弁
Purkinje
線維
筋性中隔
後乳頭筋
左側
F. Netter M.D.
©CIBA

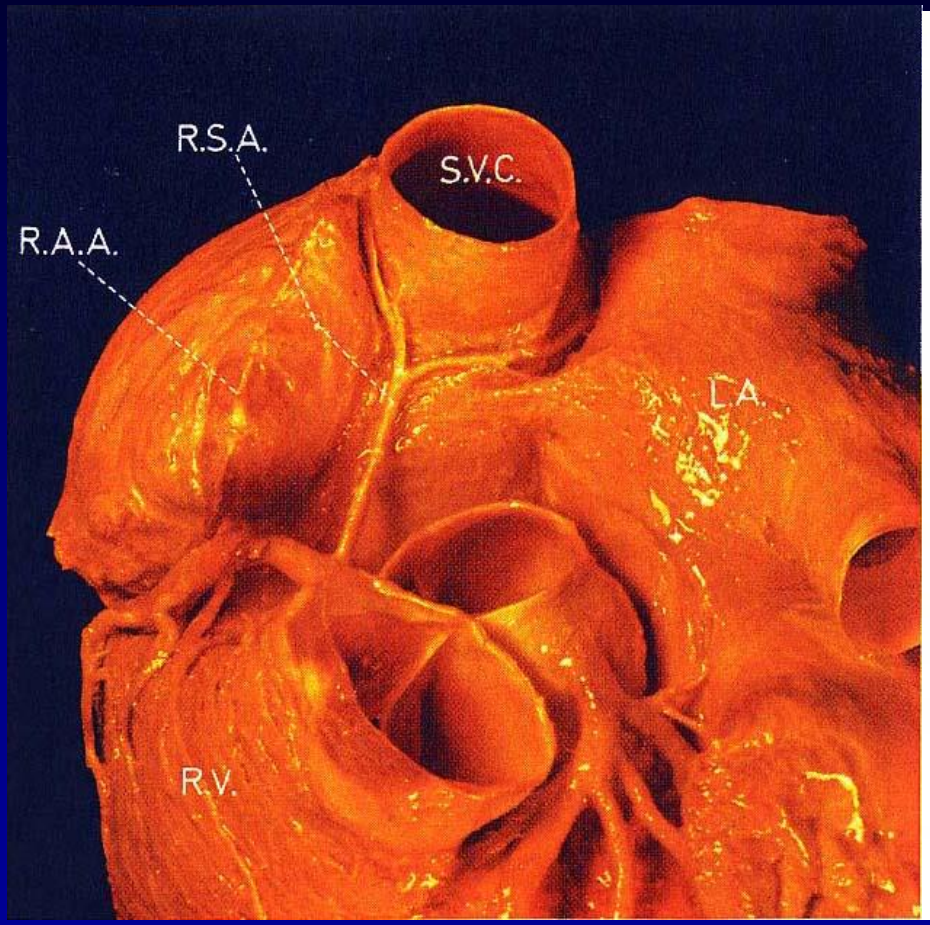
刺激伝導系

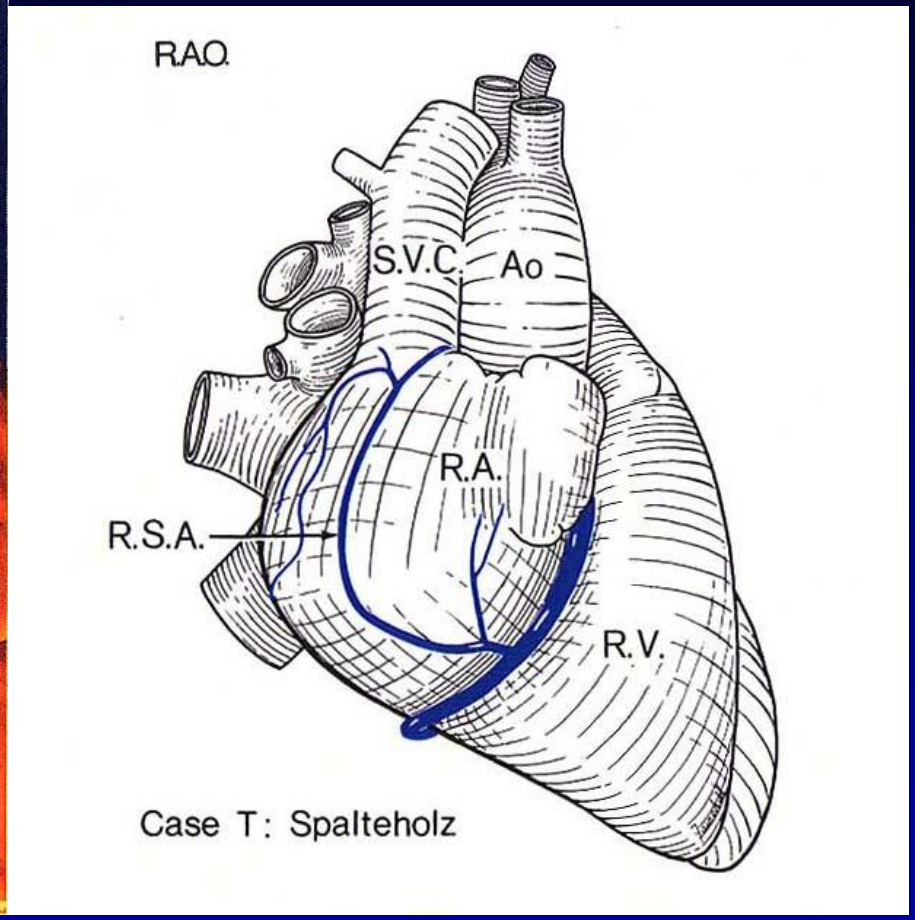




★：穿通枝　　★：右脚起始部

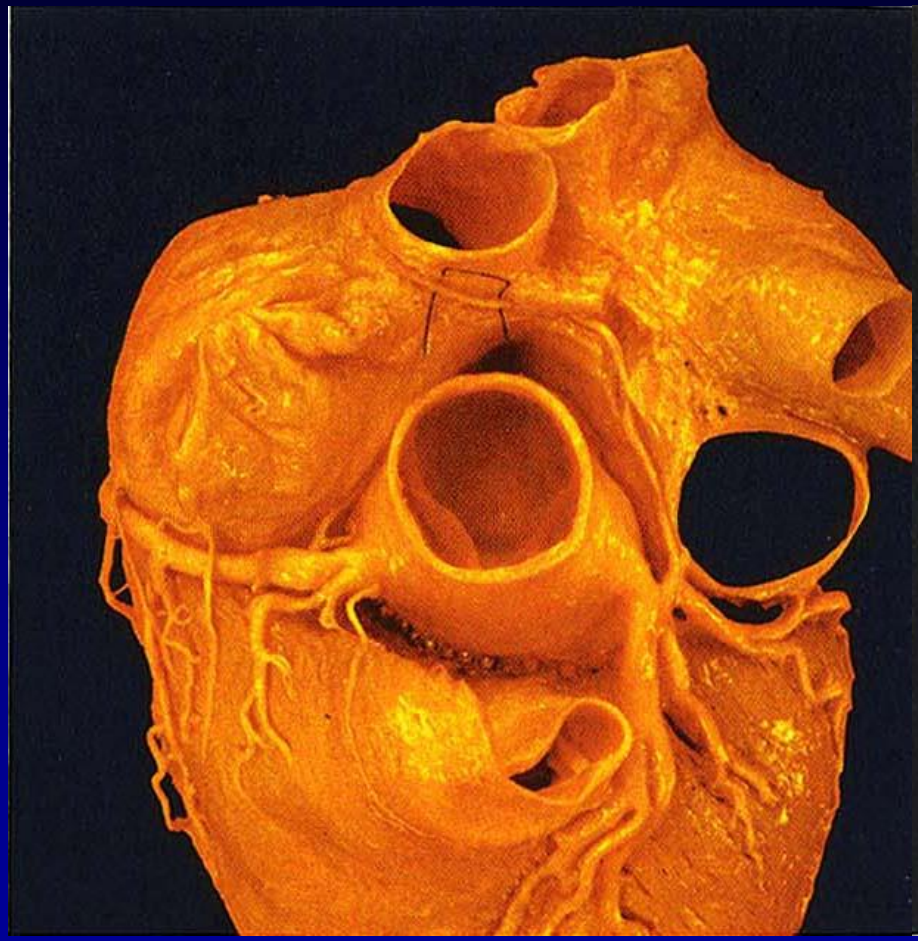
Right sinus node artery : 48 %

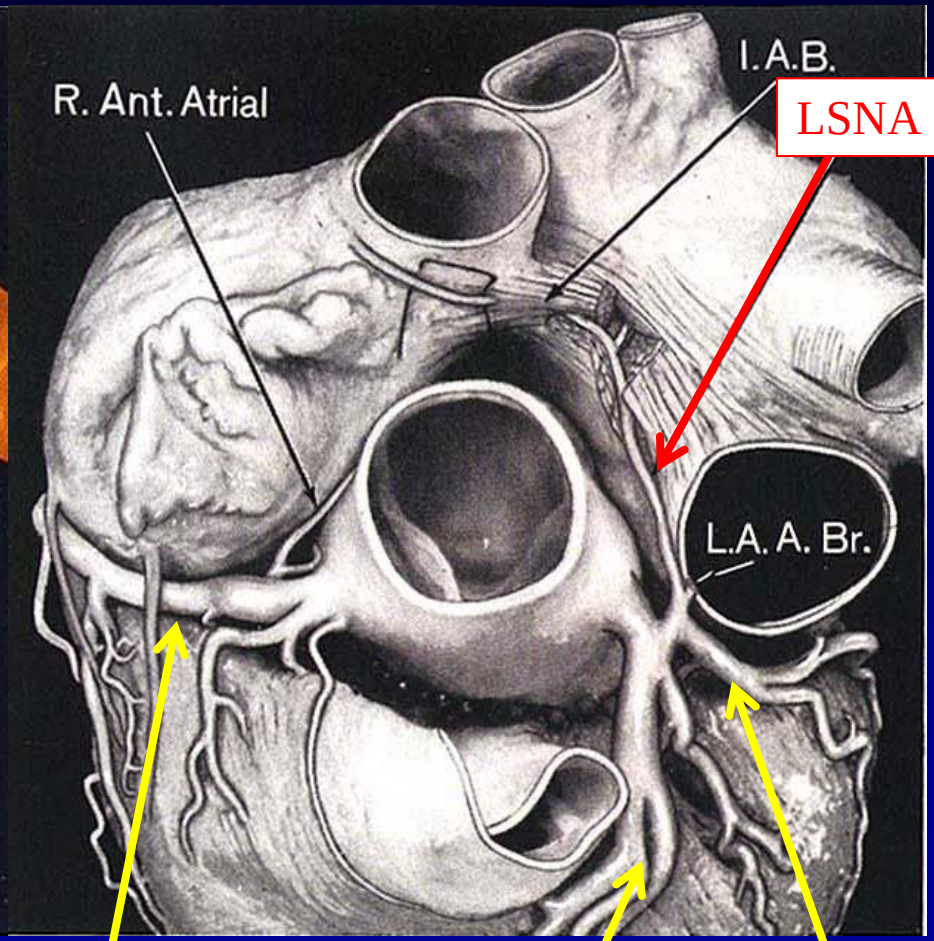




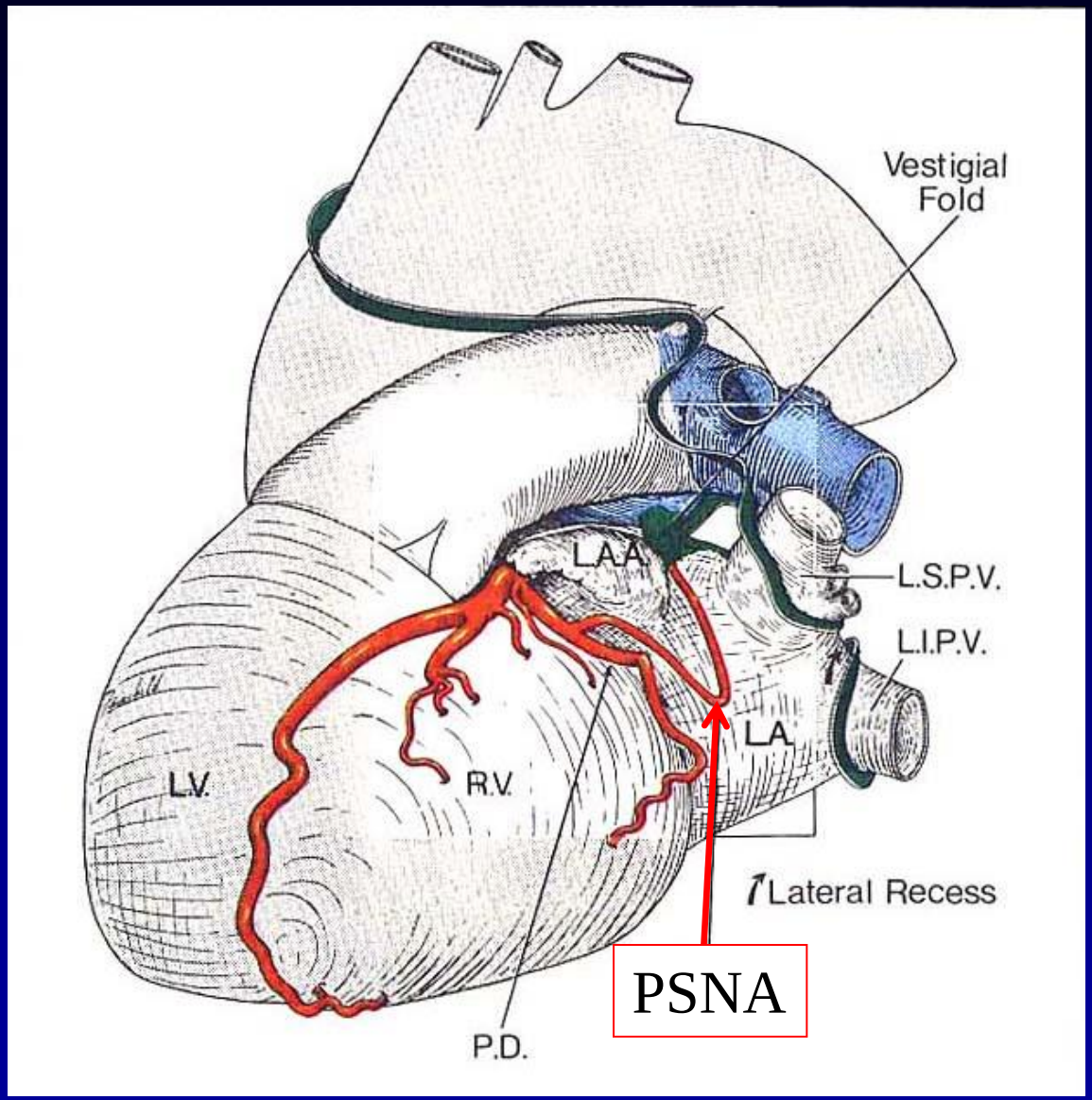
usual type **rare type**

Left sinus node artery (LSNA) : 30 %



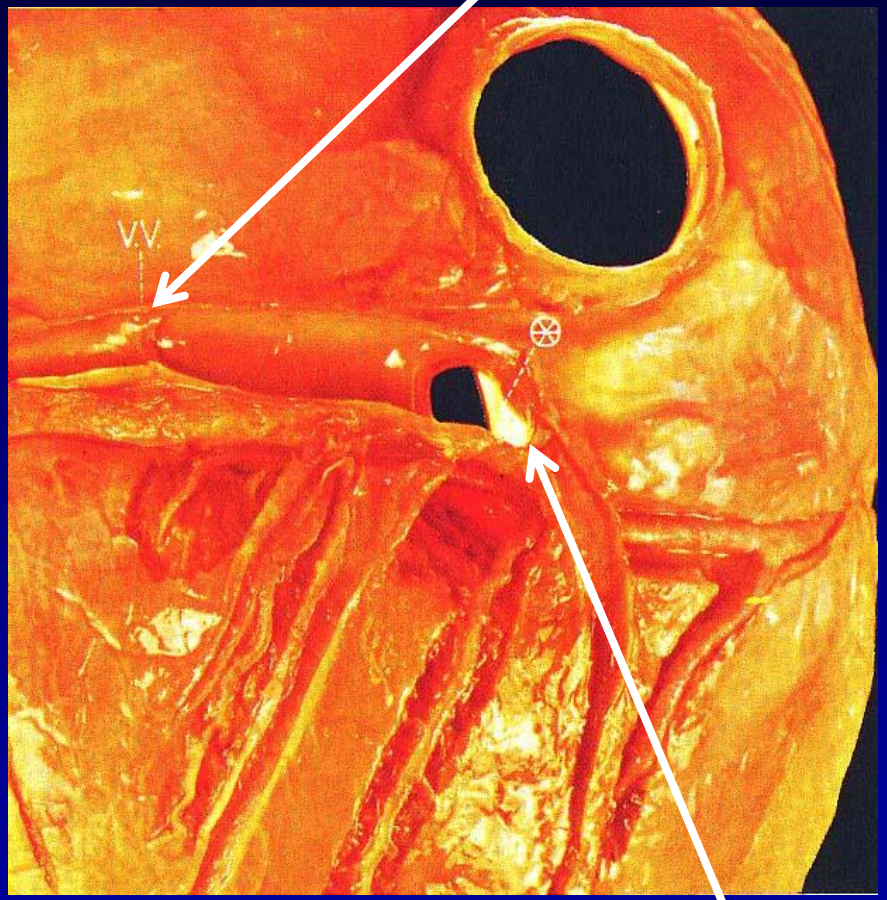


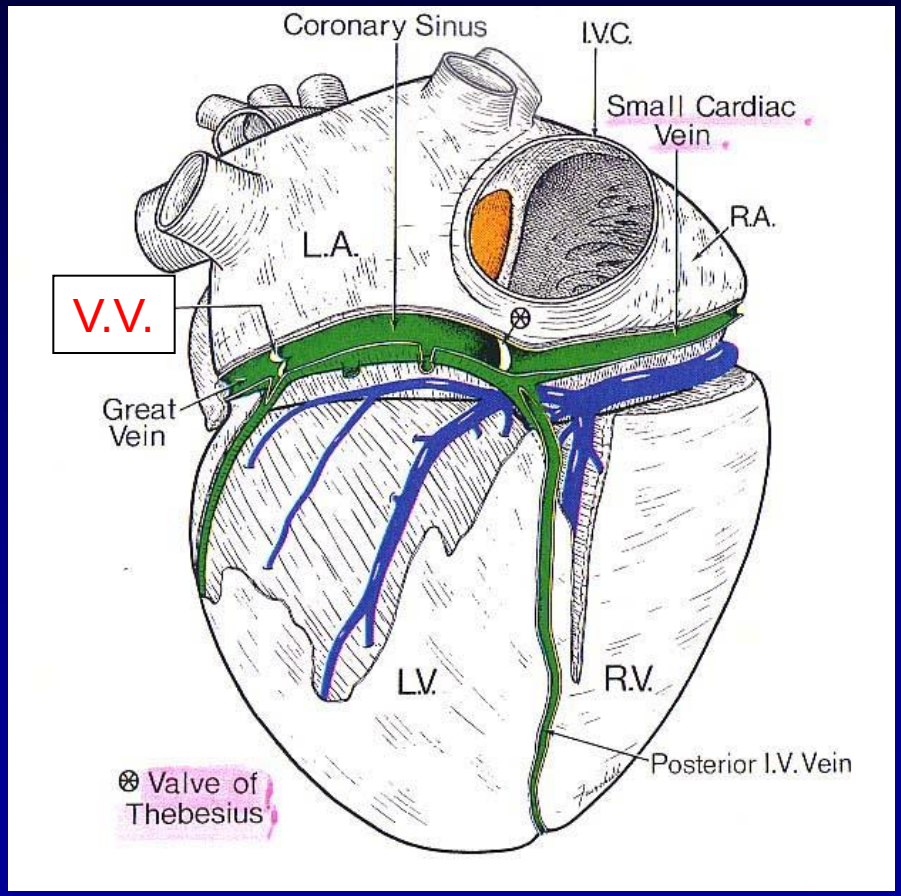
Posterior sinus node artery (PSNA) : 22 %



心臓解剖検定問題－１：7つ目のValve

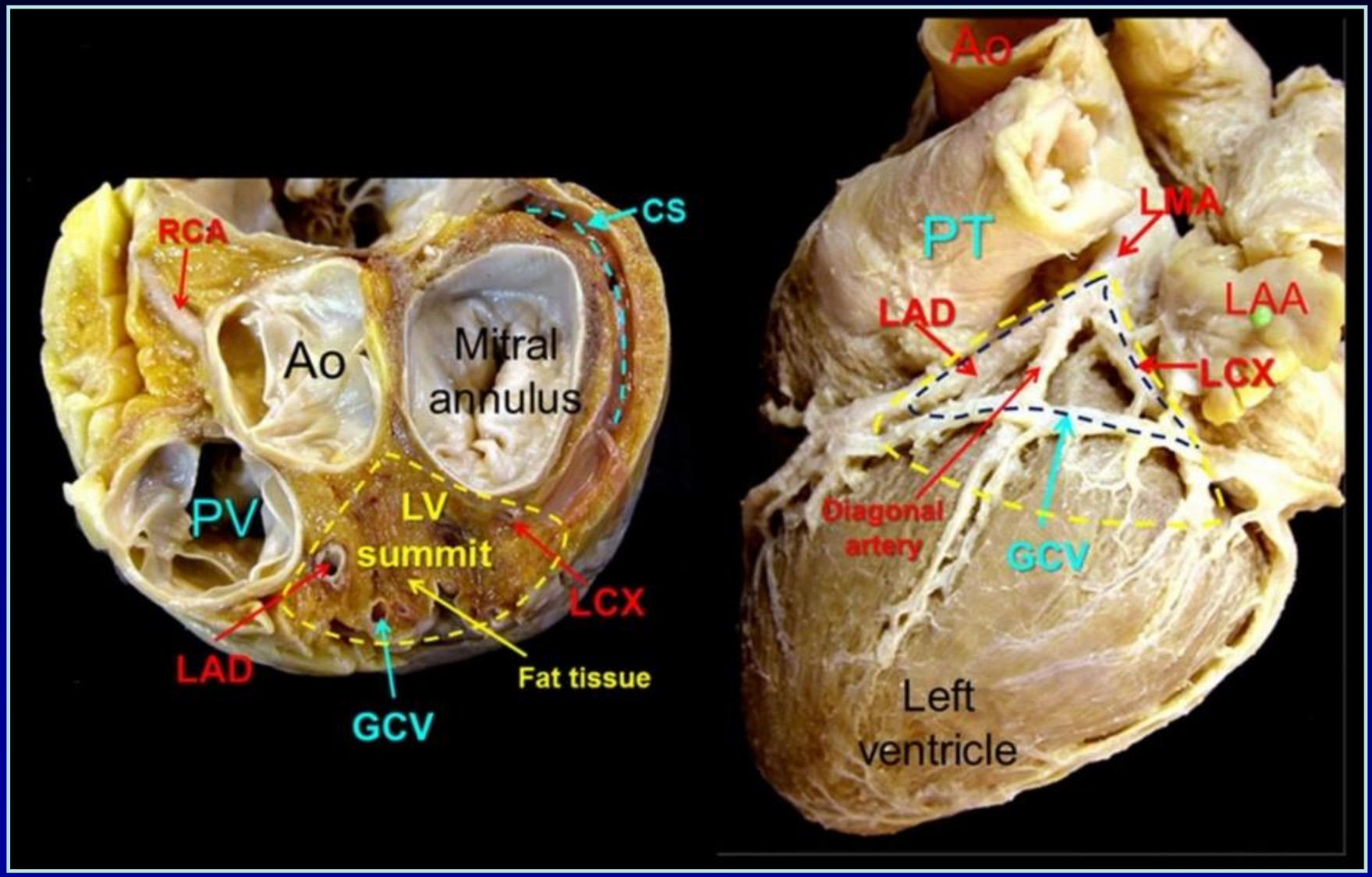
Valve of Vieussens : function ?



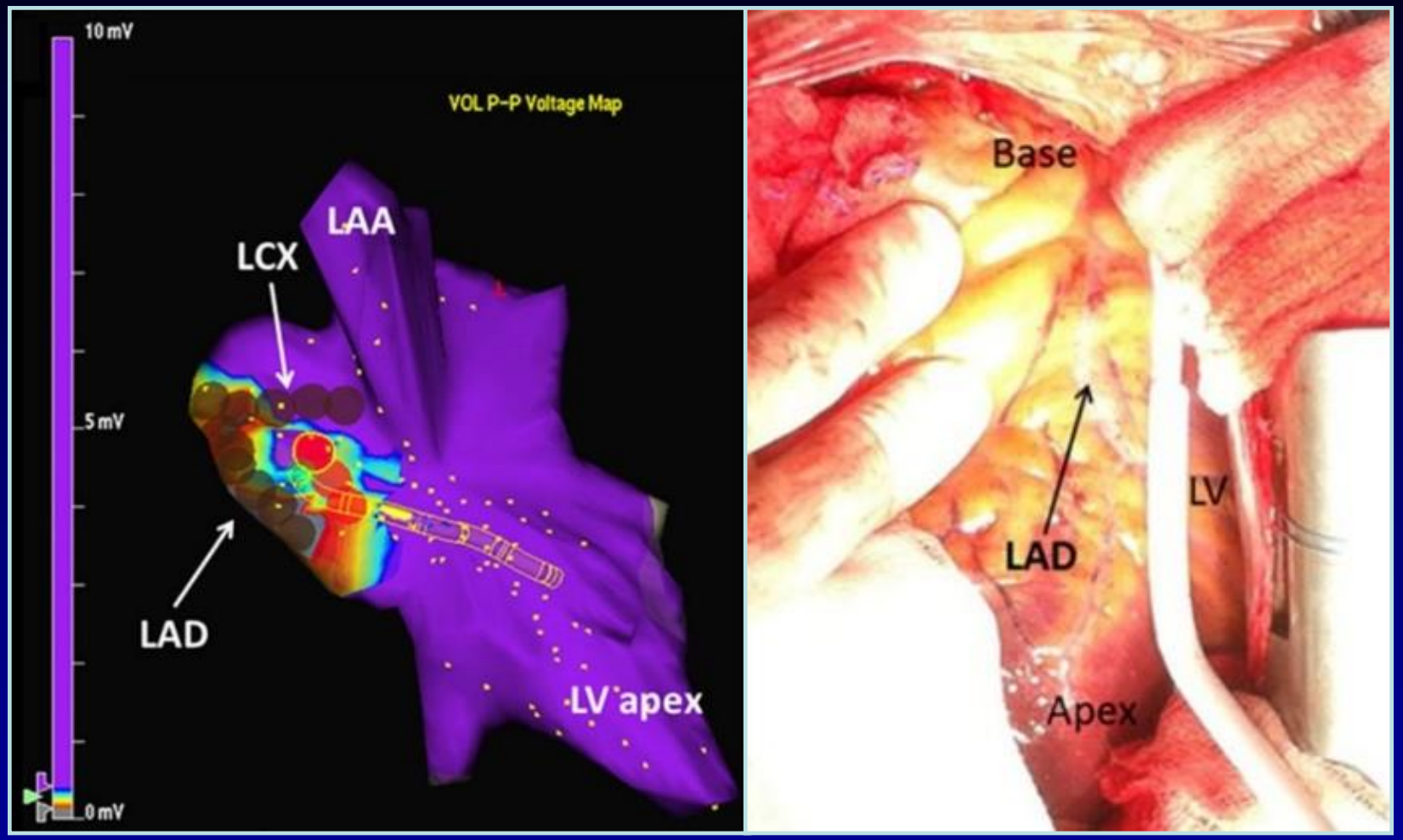


Valve of Thebesius

心臓解剖検定問題－3 Triangle of Brocq and Mouchet



Triangle of Brocq and Mouchet



心外膜側からのCryoablation失敗→Alcohol injection

Atienza F et al. Circ Arrhythm Electrophysiol. 2013;6(6):e80-4

手術における転ばぬ先の杖

↓

外科解剖！

Textbook からの知識

1) Cardiac Anatomy, Robert.H. Anderson and Anton E. Becker
2) Heart and Coronary Arteries, Wallace A. McAlpine

↓

臨床的意義を考える

↓

術野にて三次元的に把握

The operative procedure can be precise and perfect only if it is based upon the surgeon's profound knowledge of normal anatomy.

John W. Kirklin, M.D.

appeared on the foreword of
'Heart and Coronary Arteries'
written by Wallace A. McAlpine, M.D.

御清聴、有難うございました。