# 冠脉CTA成像及诊断

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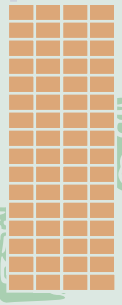
# 冠脉成像技术

- 检查设备
- 检查流程及注意事项
- 重建技术
- 伪影识别

# 探测器（硬件）分布示意图

**4排螺旋CT**
**20mm**



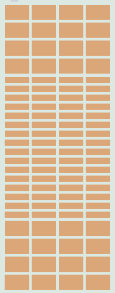
16×1.25
4×5mm

40s

**40-60** beats

120-150ml

**16排螺旋CT**
**20mm**



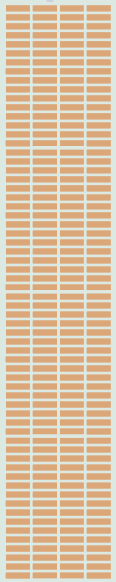
16×0.625+8×1.25mm

20s

**20-30** beats

80ml

**64排螺旋CT**
**40mm**



64×0.625mm

5s

**5-8** beats

50ml

时间空间分辨率不足
病人配合明显困难

→

屏气差，心率不
齐影响仍然存在

→

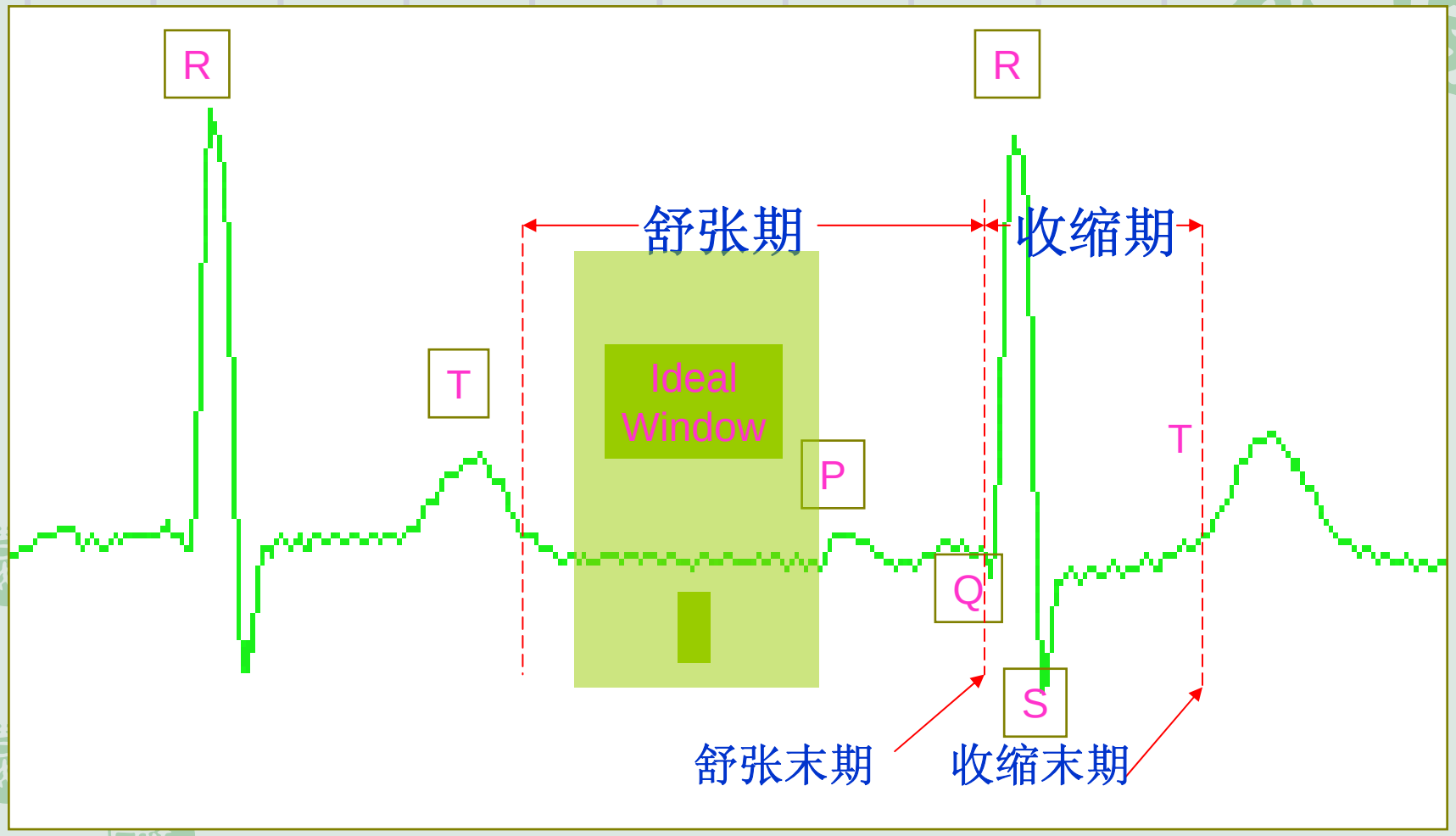
真正各向同性，
屏气缩短

# 运动脏器（冠脉）成像

- 呼吸运动　　单次屏气　门控技术
- 心脏波动　　心电同步技术

  前瞻性ECG触发

  回顾性心电门控


R
R
舒张期
收缩期
T
Ideal
Window
P
T
Q
S
舒张末期
收缩末期

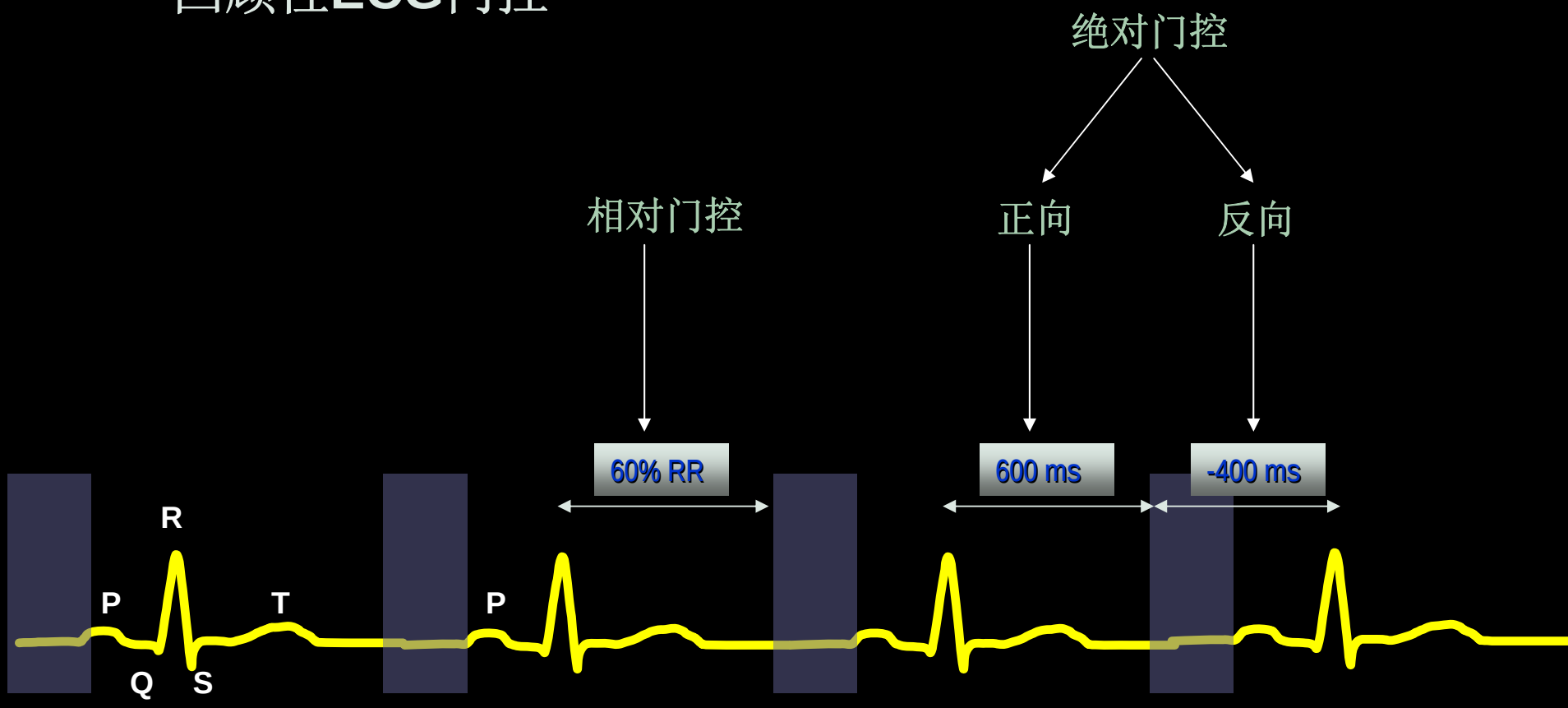
# 前瞻性ECG触发

- 轴位扫描，并非3d容积扫描
- 剂量少
- 心率依赖
- 层厚大，Z轴分辨率不够

# 回顾性ECG门控

- 慢速进床螺旋扫描
- 同步记录心电图—回顾分配数据
- 保证空间分辨率和扫描容积兼顾
- 射线剂量大，**ECG－modulated mA**
- 可行功能成像

# 回顾性ECG门控



# 检查流程

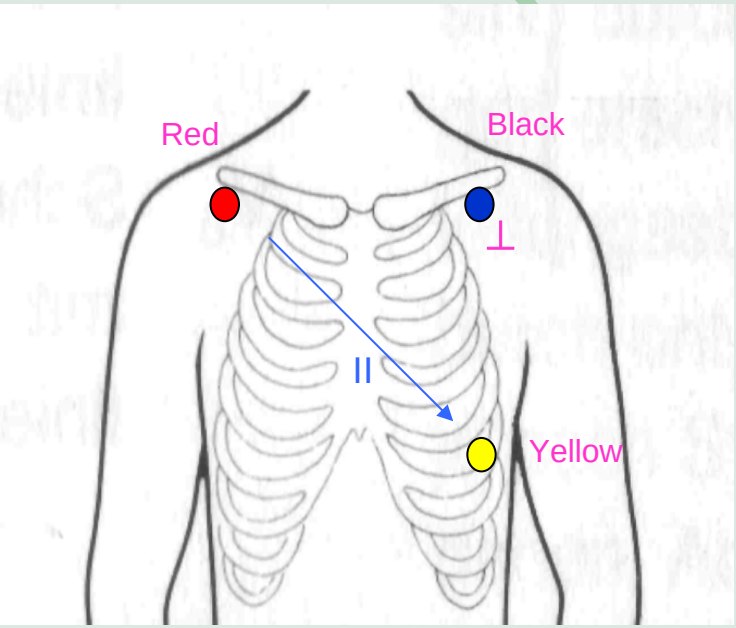
- 病人准备
  - 提前1小时到达，静坐休息
  - 心率较快患者（>65bpm）
    - 排除禁忌症
      - BBB 心功能不全 低血压 病窦综合症 慢阻肺和哮喘
    - β-受体阻滞剂（倍他洛克）25mg，检查前1h
    - 积极抢救，阿托平v 1－2mg 异丙肾上腺素
- 检查前硝酸甘油运用
  - 目的：扩血管

# 检查流程

- 检查前硝酸甘油运用
  - 目的：扩血管
  - 舌下含服 0.3-0.6mg 2－30分钟
  - 严格控制服用时间，不能过早过晚
  - 禁用：
    - 严重低血压
    - 急性心肌梗死伴低充盈压
    - 肥厚梗阻型心肌病、缩窄性心包炎或心包填塞
    - 严重贫血
    - 青光眼；颅内压增高
  - 不良反应：头痛，低血压，心率加快

# 检查准备

- 电极置放
  - 两侧锁骨下和左侧肋弓下
  - 避免脱落，注意皮肤清洁
  - 观察基线平稳否
- 呼吸培训
  - 一般屏气时间10秒左右
  - 注意观察*屏气效果*屏气后心率变化规律



# 扫描流程

- 定位片

↓

- 非门控低剂量螺旋扫描或冠脉积分

↓

- **Timing Bolus**（主动脉根部）

↓

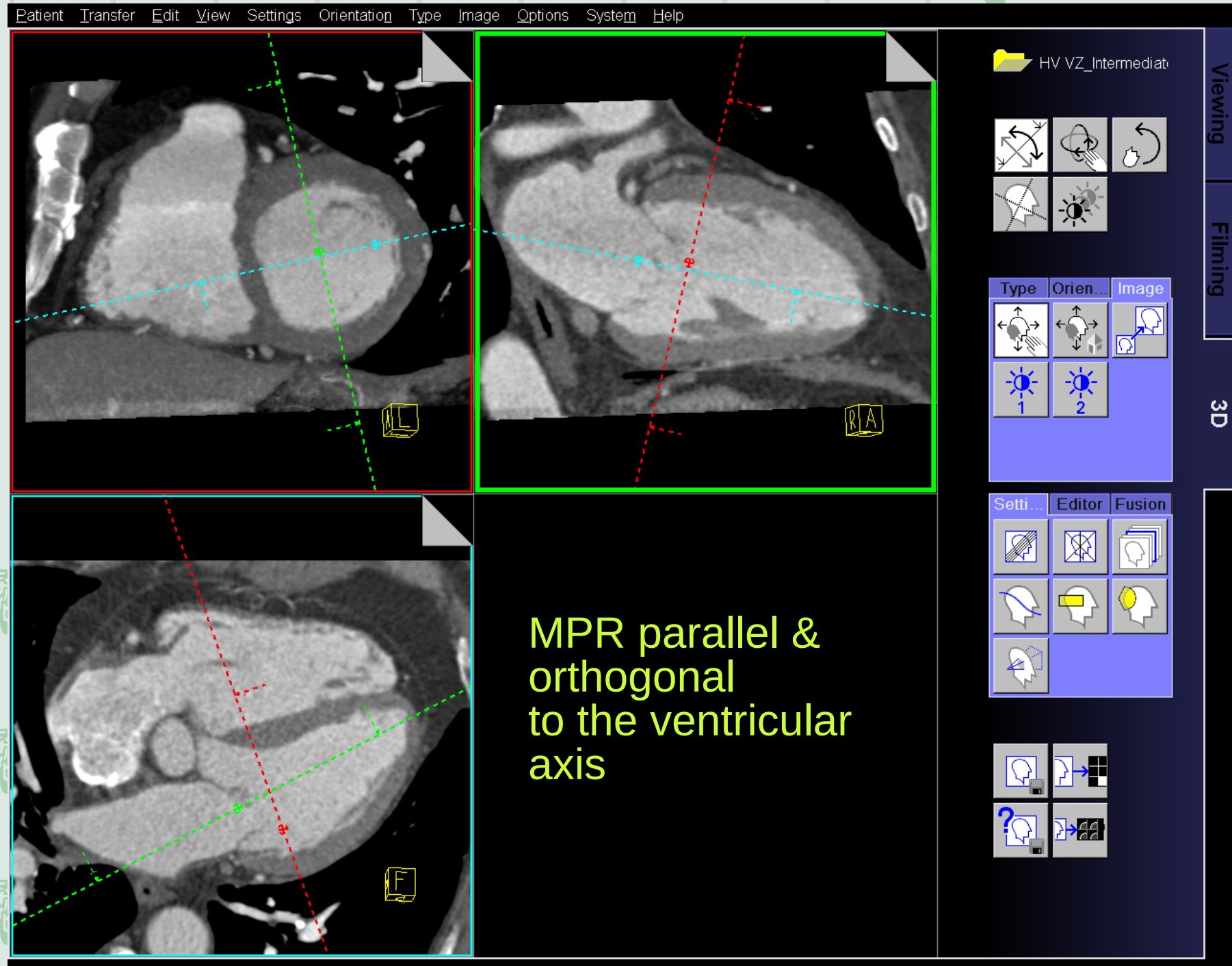
- 冠脉造影

# 造影剂

- 碘浓度：370mgI/ml
- 注射器：双桶　单桶
  - 20/90ml造影剂
  - 20/60ml生理盐水
- 速率：单相 5ml/s
- 剂量：检测/成像
  - 造影剂20/65ml，盐水20/30－40ml
  - 峰值时间过长或过短，相应增加或减少造影剂量

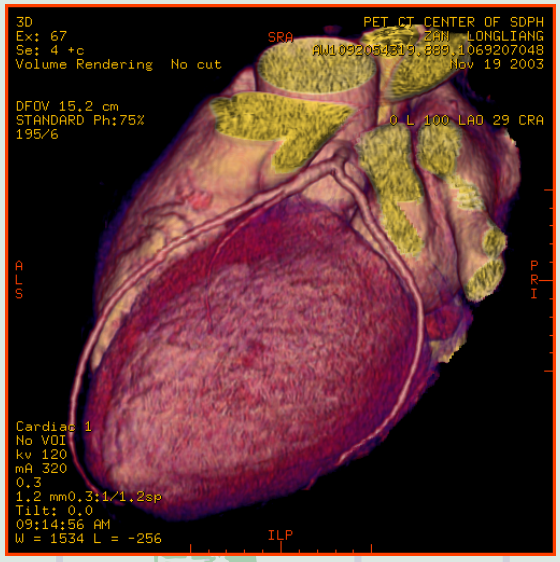
# 冠脉造影

- 心率＜70bpm，SSEG单扇区采集模式
- 90＞心率≥70bpm，SSB双扇区采集模式
- 心率＞90bpm，SSB四扇区采集模式
- 重建扇区越多，要求心率越稳定
- 心率不稳，必要时可通过override尝试

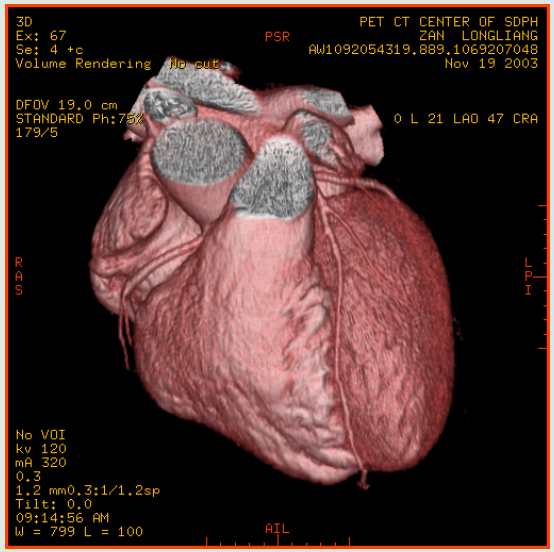



MPR parallel & orthogonal to the ventricular axis

# 慢心率成像（50～65次/分）

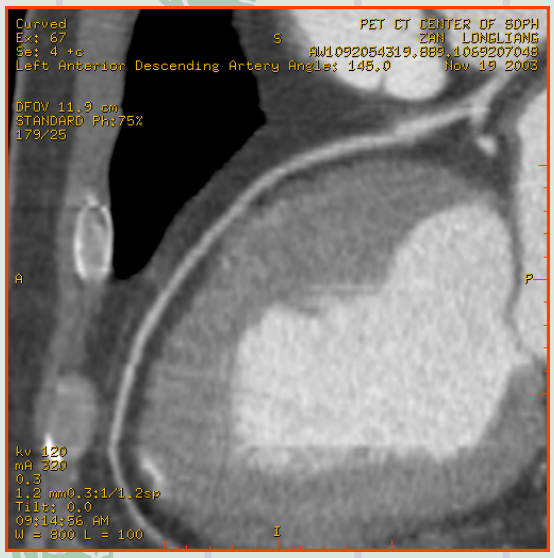


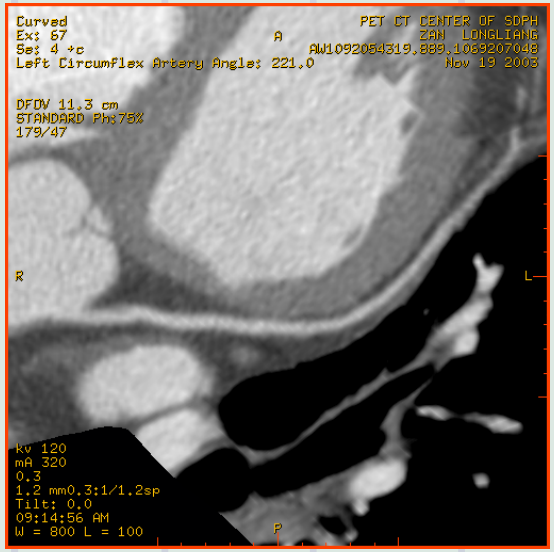

LAD

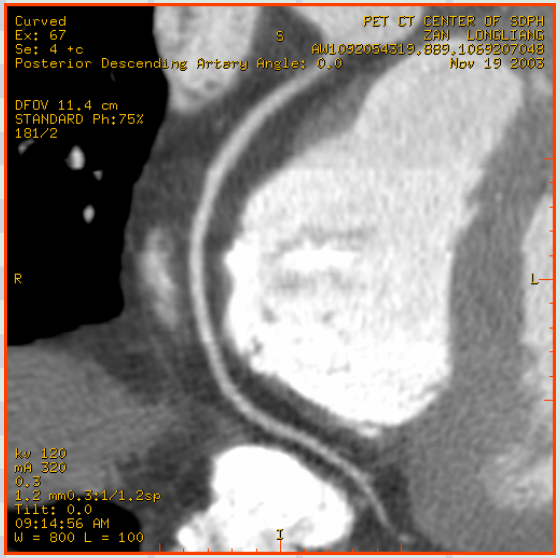



LCX

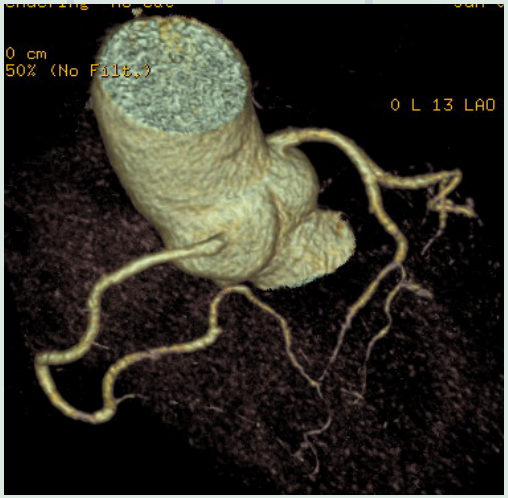

RCA

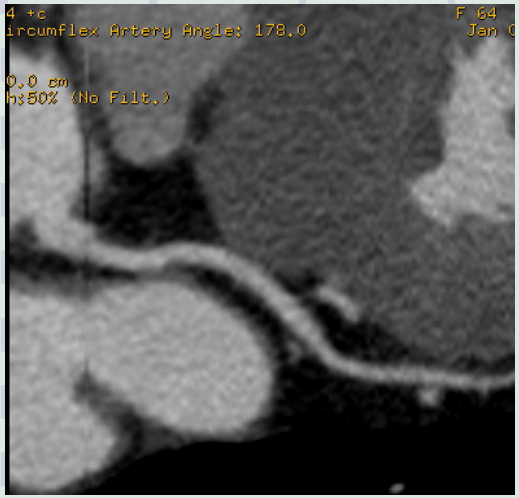


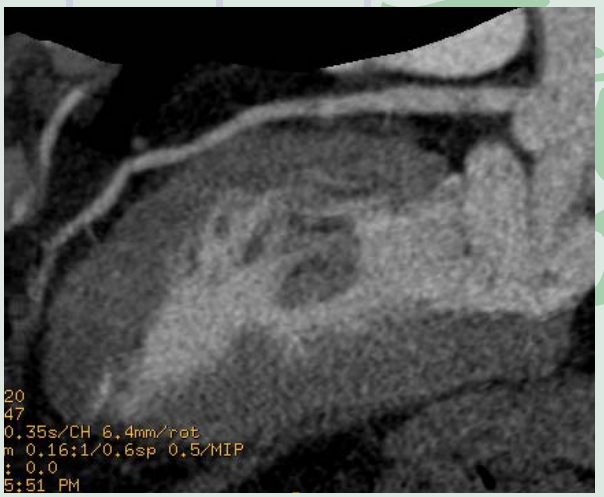



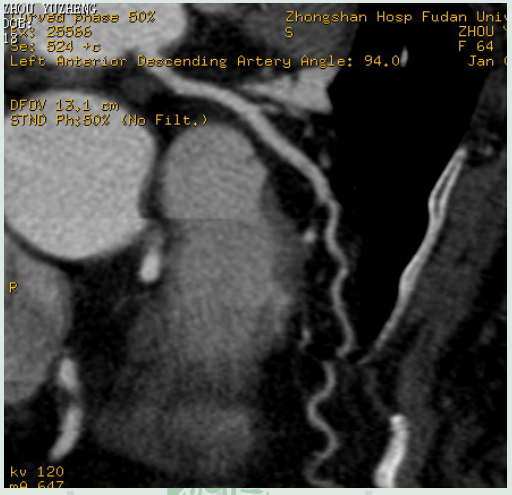



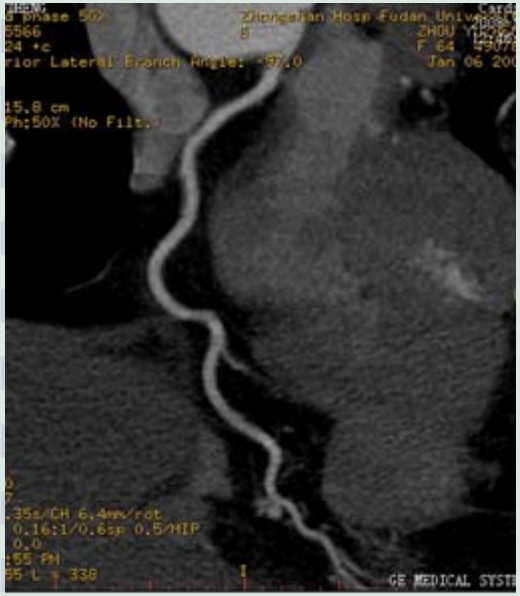
# 快心率成像

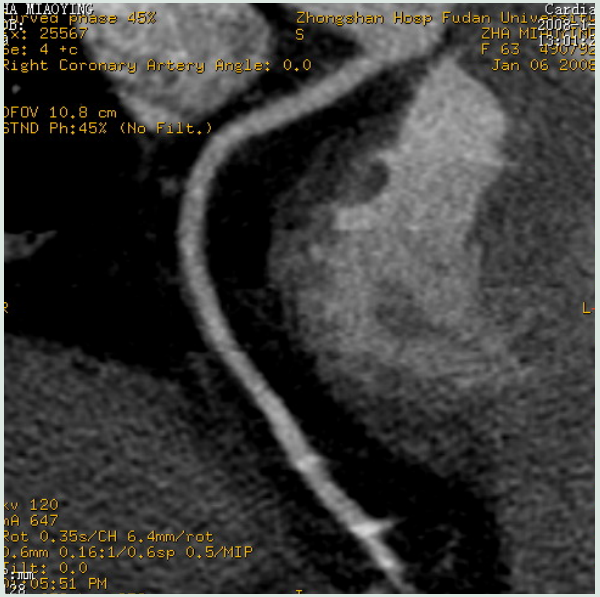


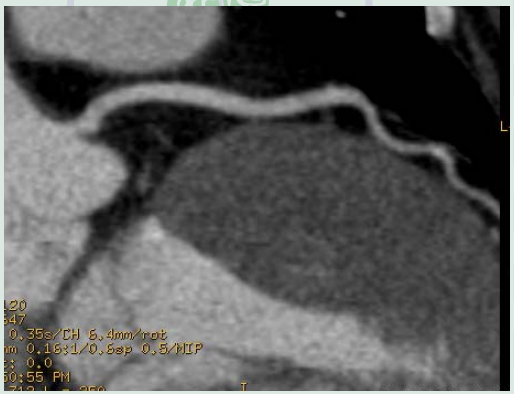



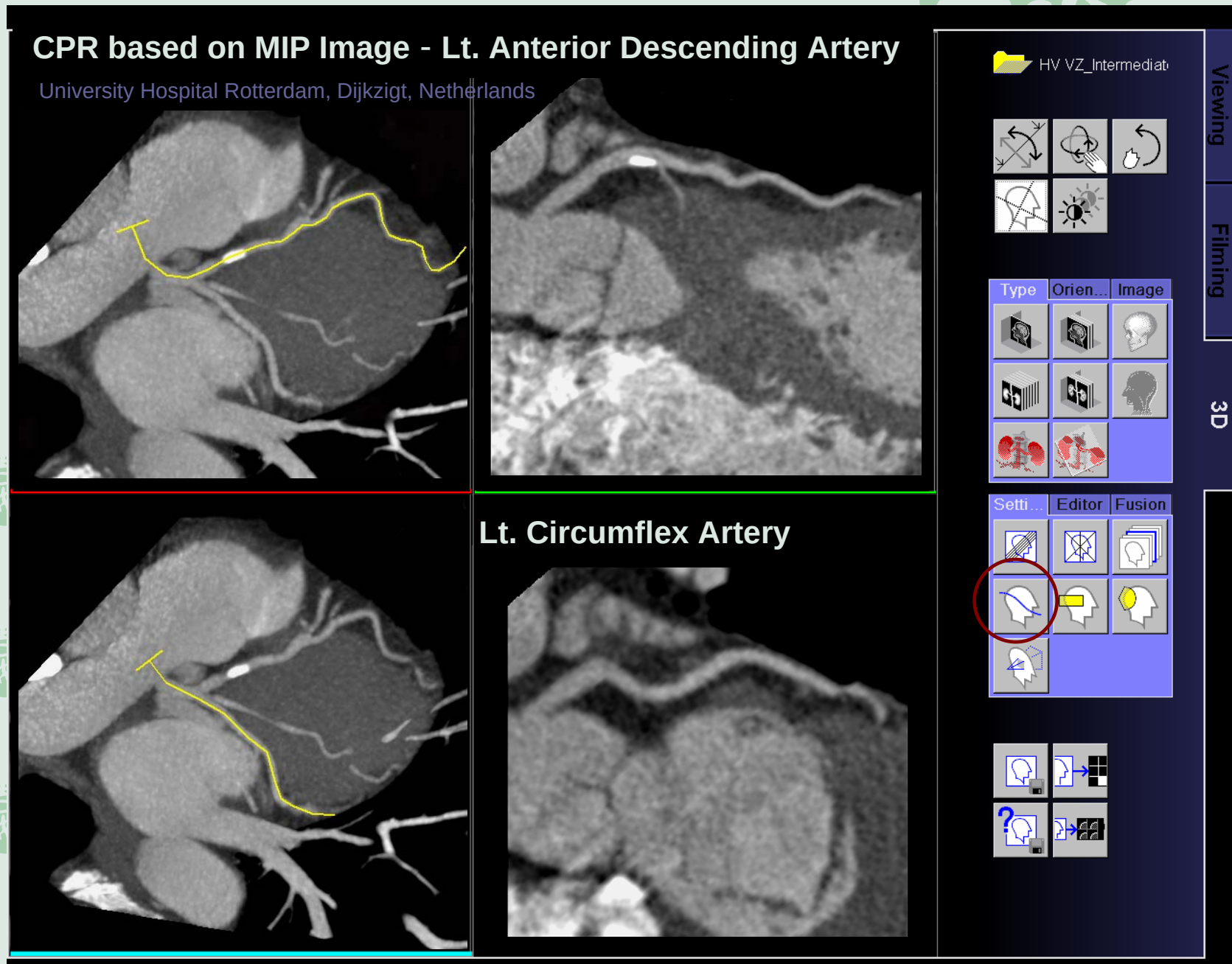

**HR 105~114次/分**

**HR 100~102次/分**

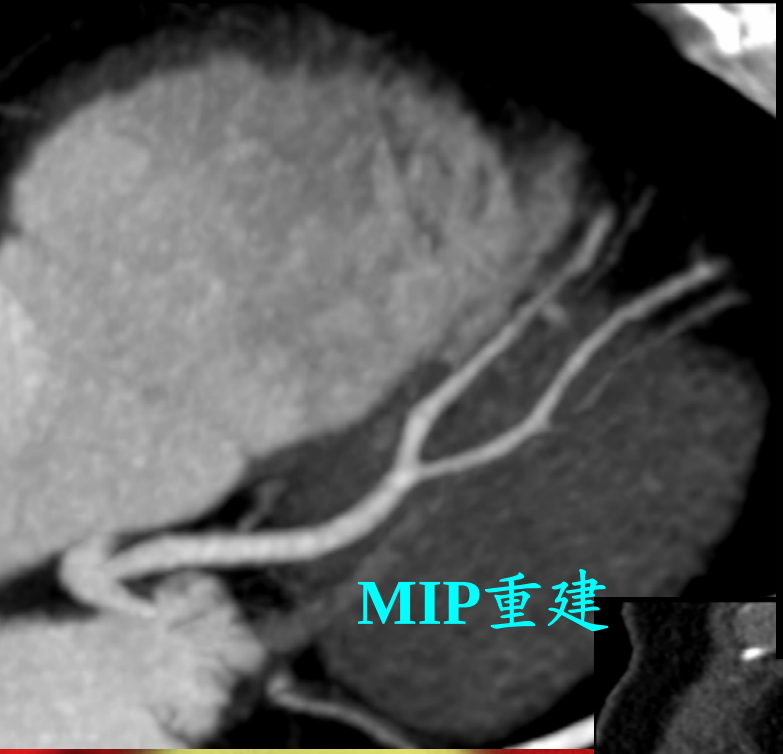
# 三维后处理技术

- **MPR** Multi-planar Reformats
- **CPR** Curved Planar Reformats
- **ThinMIP** Thin-slab Maximum Intensity Projection
- **VRT** InSpace - Volume Rendering Technique
- **Vessel Tracking and Analysis Software**

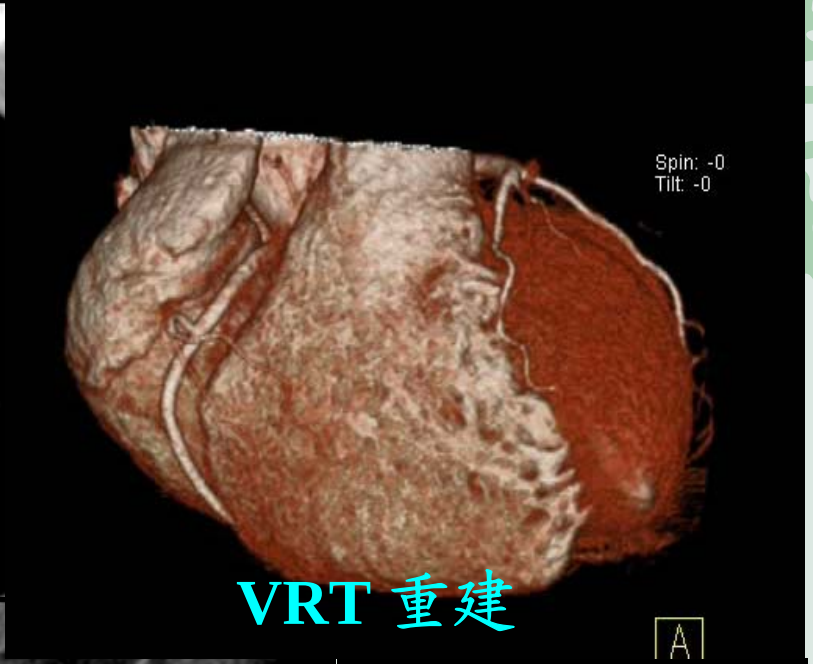
# 重建软件


CPR based on MIP Image - Lt. Anterior Descending Artery
University Hospital Rotterdam, Dijkzigt, Netherlands
Lt. Circumflex Artery
HV VZ_Intermediat
Viewing
Filming
3D
Type
Orien...
Image
Setti...
Editor
Fusion

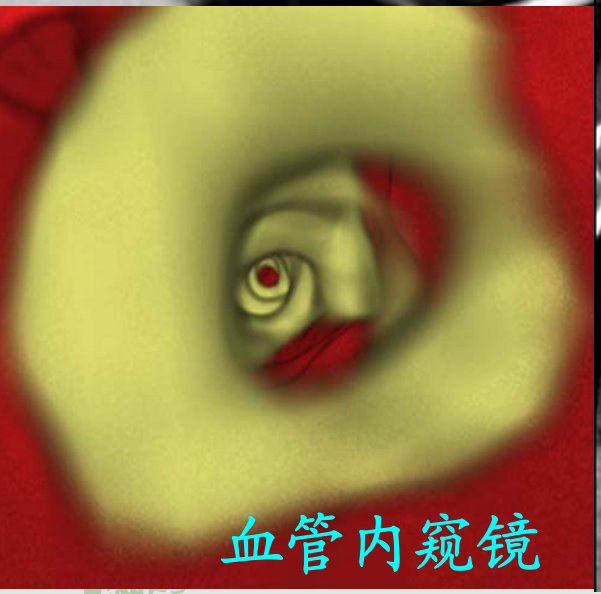
# 多种重建技术



MIP重建

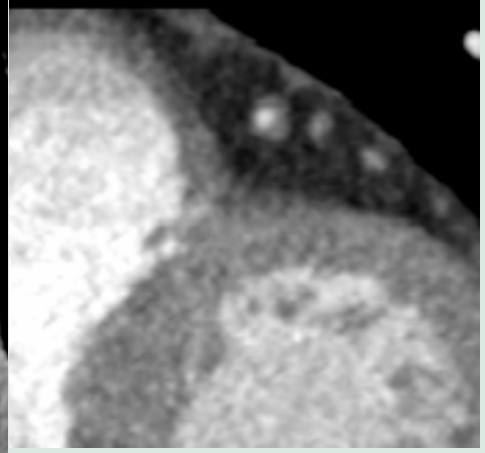



VRT 重建



血管内窥镜

曲面重建



血管横断面

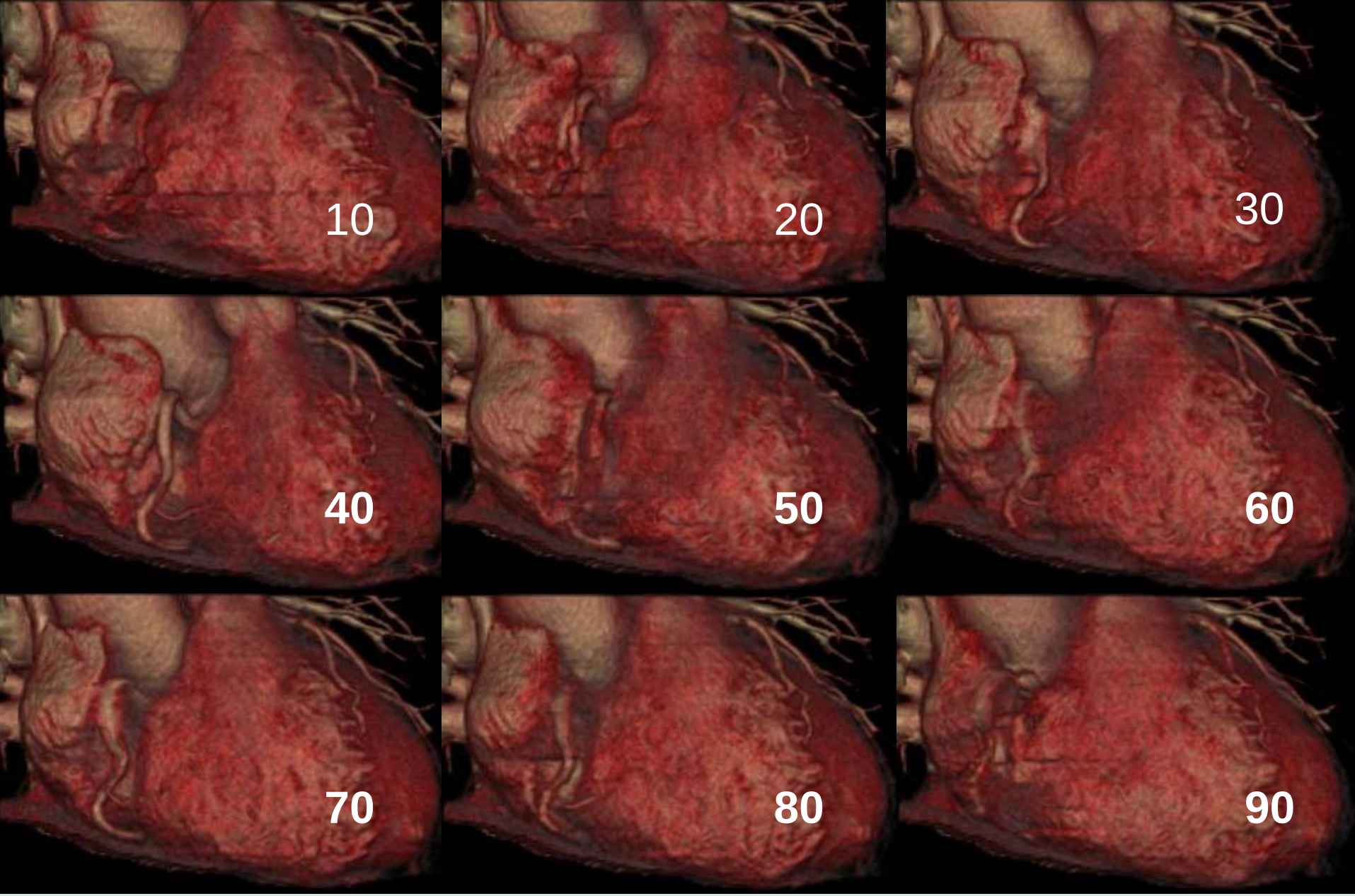
# 冠脉CTA成像中常见伪影

- 心脏搏动伪影、呼吸运动伪影
- 心律不稳
- 部分容积效应（高密度）
- 螺距选择
- 造影剂用法
- 被检者条件

# 心脏搏动

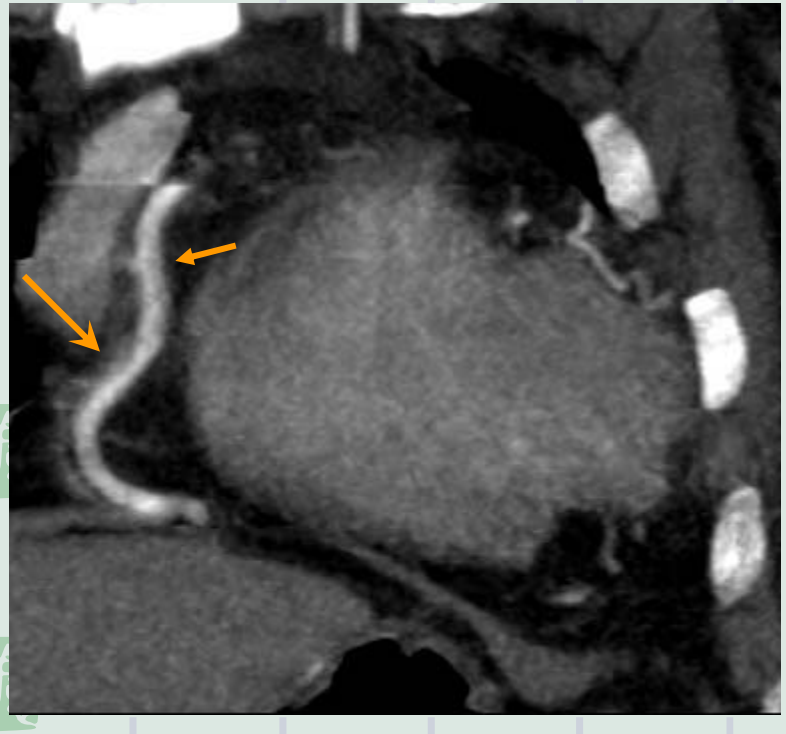
- 最常见、最重要
- 心脏充盈期（舒张期）影响相对较小
- RCA靠近心房最易受影响，而LAD位于心室表面相对影响较小
- 中等/快心率对不同冠脉采用不同时相重建是必要的
- 慢心率（50次/分）往往单个时相即可满足三支冠脉的显示


the mid-RCA. In theory, MIP obscures a kymographic gap perpendicular to the slab plane, since the appearances of thinslab MIP images depend on slab thickness and the orientation of the vessel of interest relative to the slab plane.

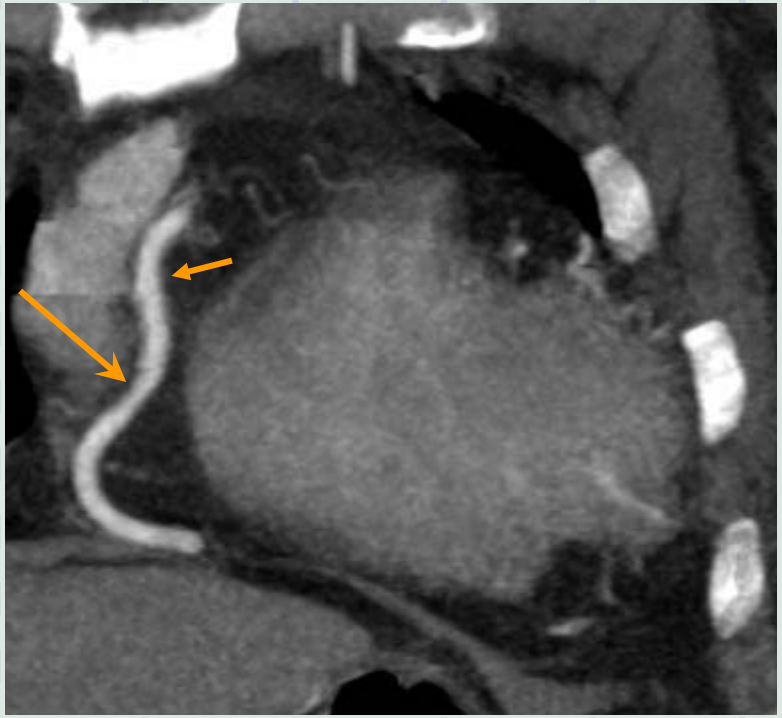



RCA为例，R-R间期（10-90%）不同VR图像

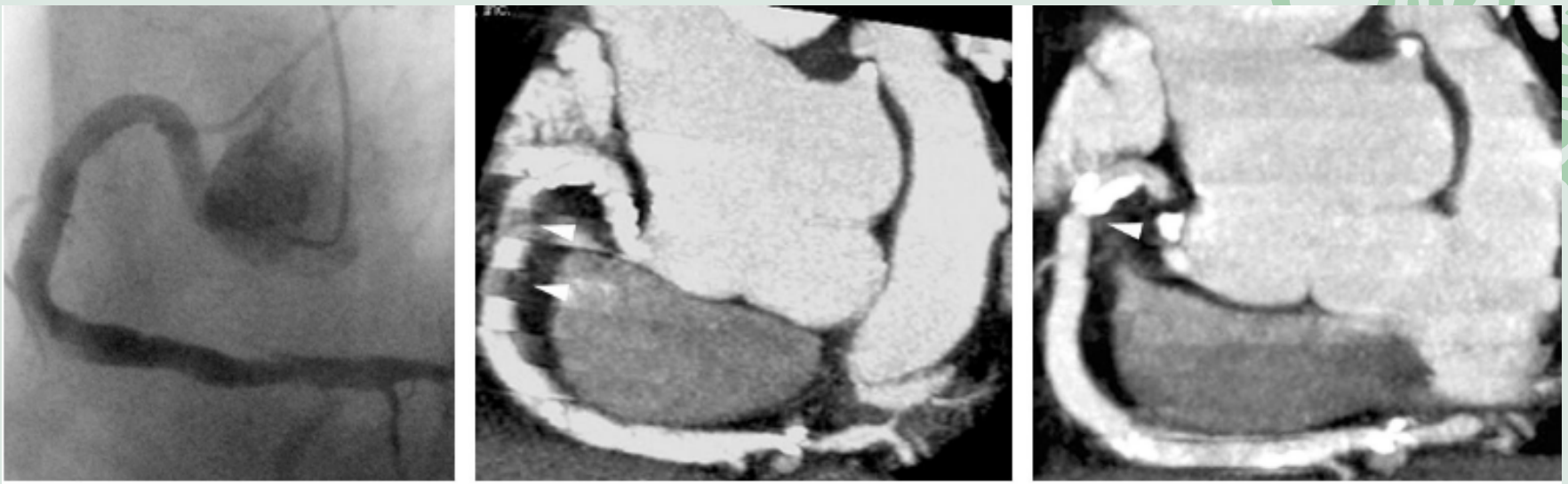
# 不同心脏周期对重建影响



时相45％



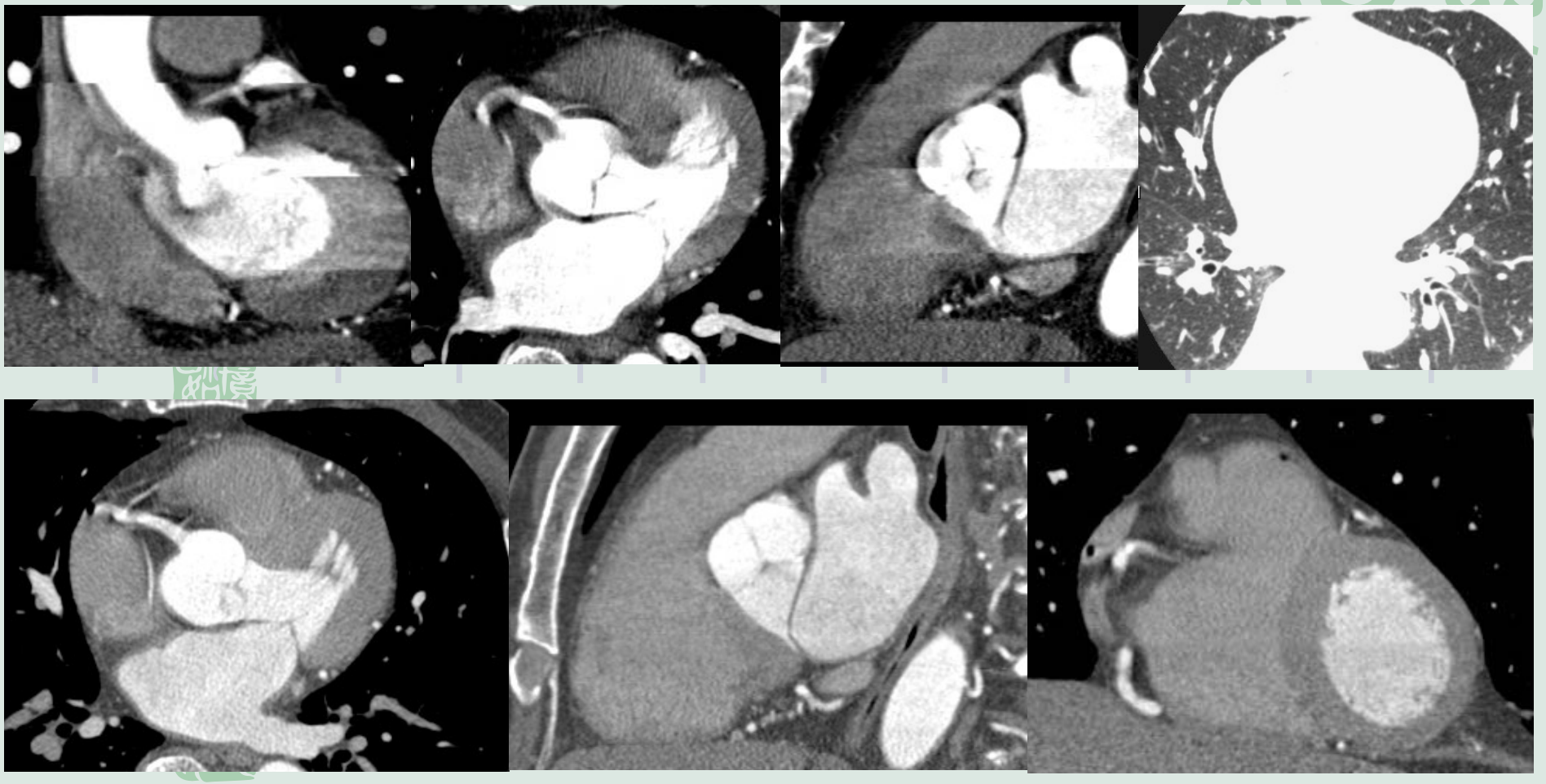
时相50％

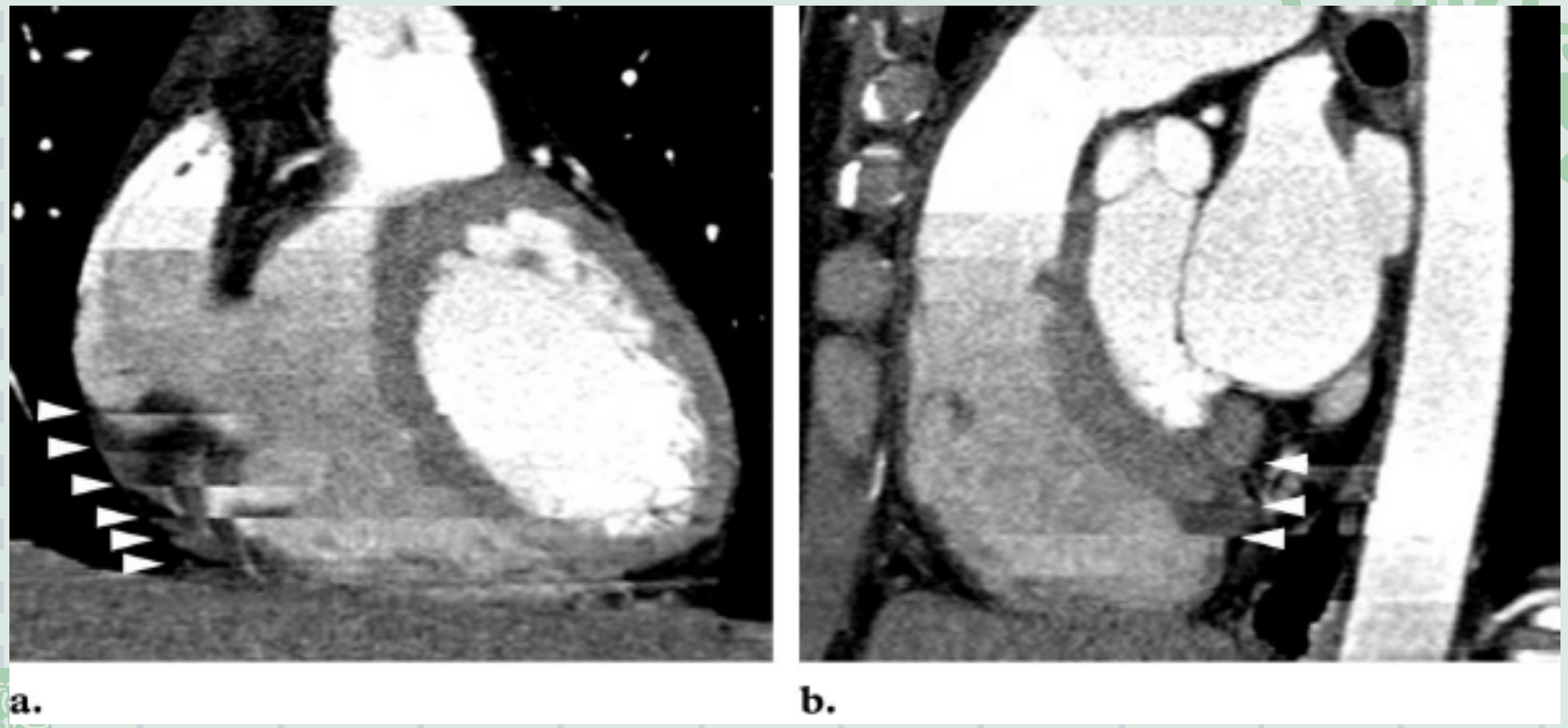


a. b. c.

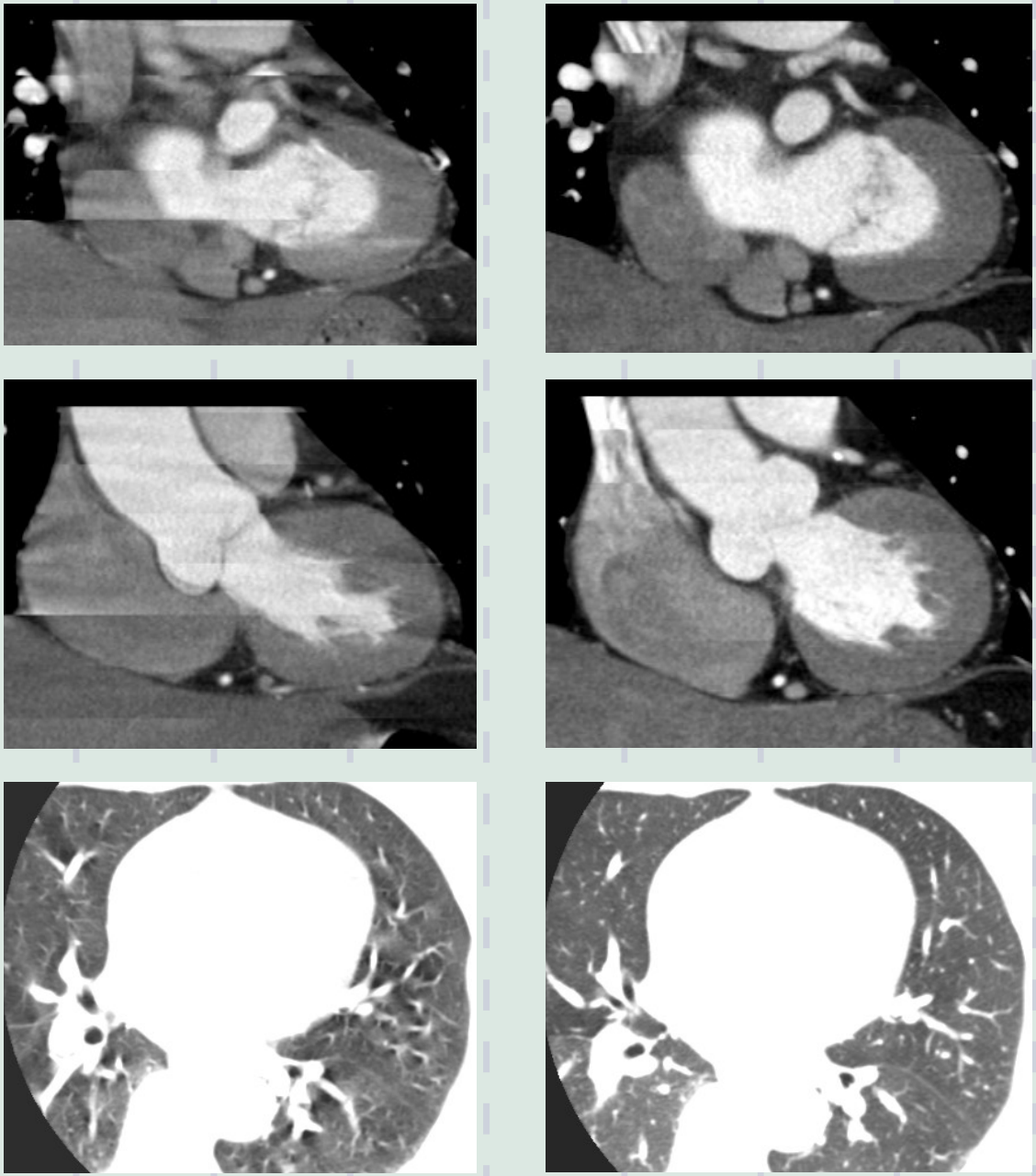
Nonassessable segments are attributable to extensive motion artifacts and section gaps, whereas pseudostenosis is produced by minor motion artifacts and section gaps

# 心率变化






Artifacts due to increased heart rate in a 46-year-old woman. The patient experienced alterations in heart rate in normal sinus rhythm during scanning, which was performed shortly after the sublingual administration of nitroglycerin. The patient's average heart rate was 51 bpm, increasing to 69 bpm in the last third of the acquisition. Coronal **(a)** and sagittal **(b)** reformatted images of the heart obtained from CT data demonstrate banding artifacts (arrowheads), which were observed only in the last third.



# 呼吸伪影

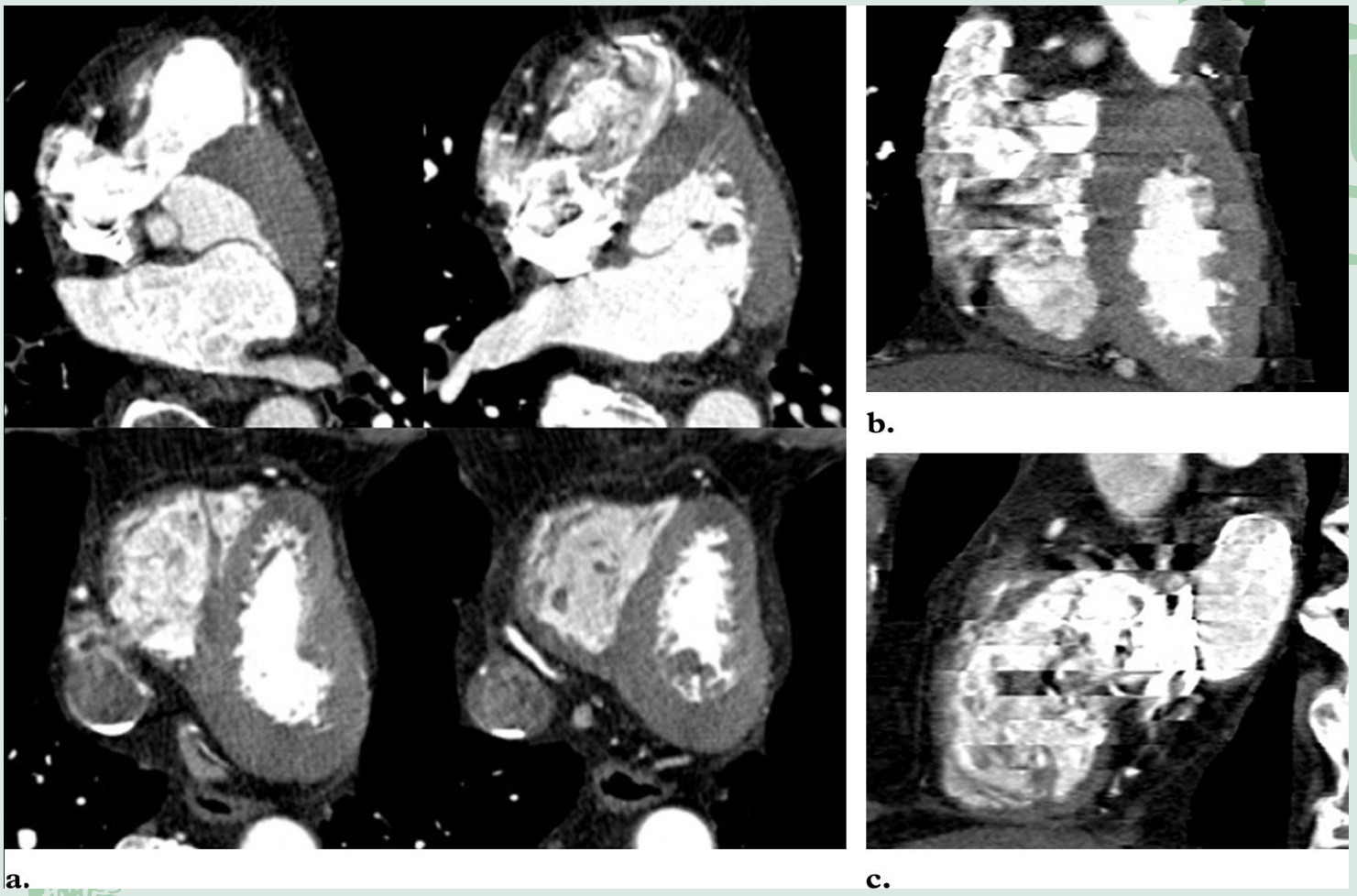
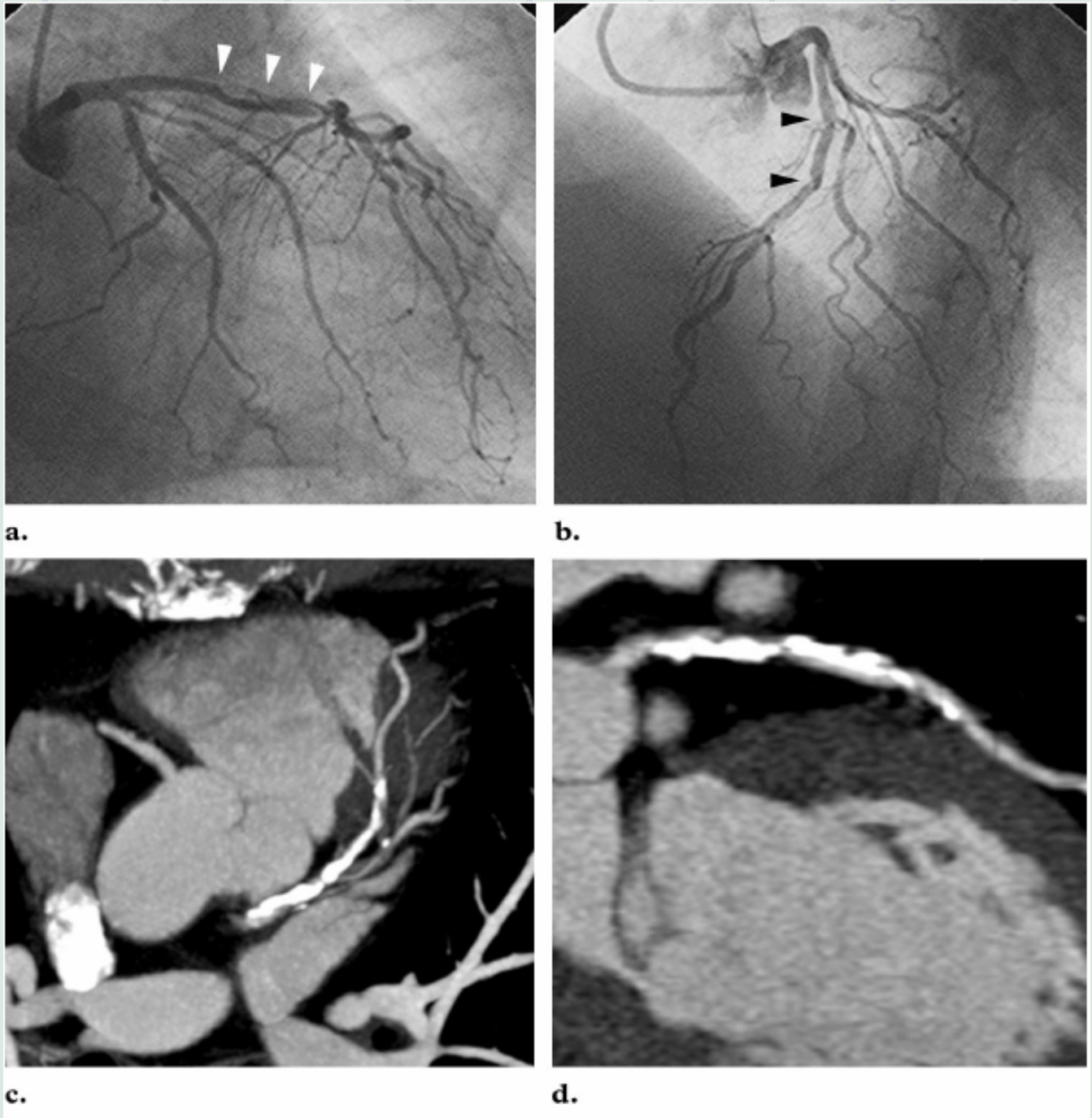
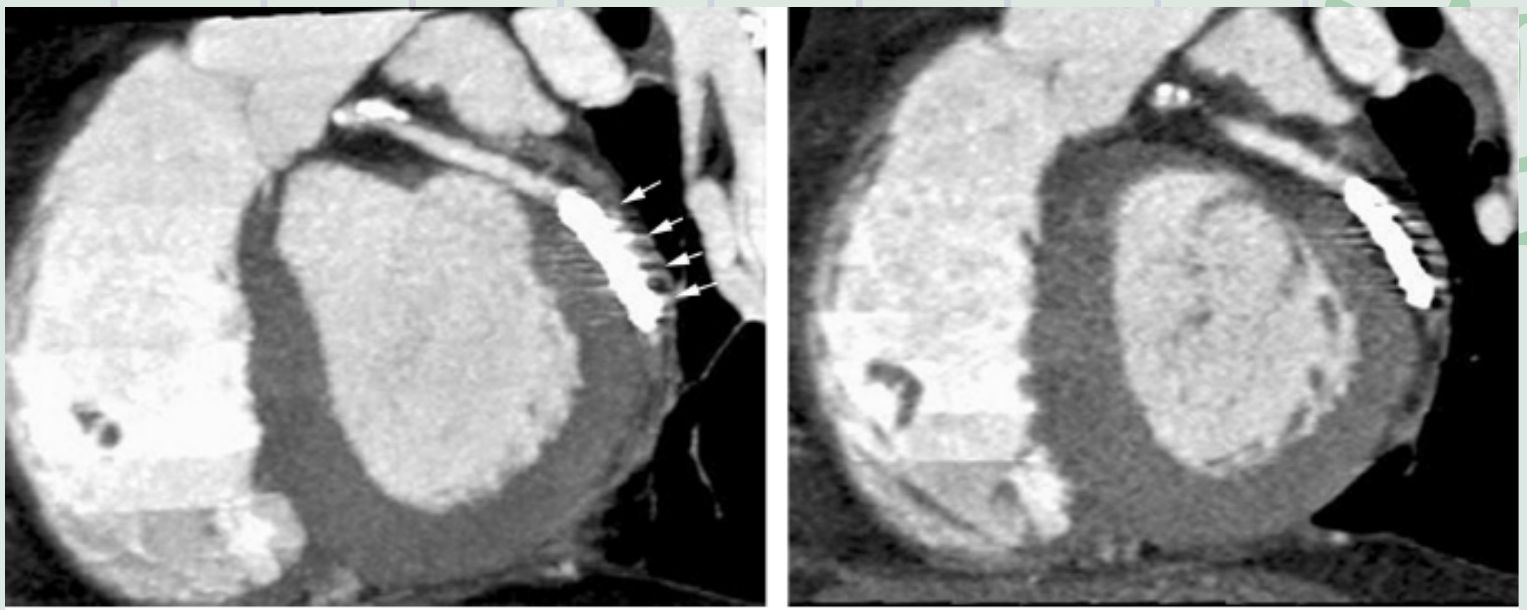



**Figure 7.** Artifacts due to incomplete breath holding. **(a)** Contiguous sections demonstrate almost no motion artifacts when each image is observed separately. **(b, c)** Coronal **(b)** and sagittal **(c)** reformatted images demonstrate banding artifacts with kymographic contours at the cardiac border. The patient had a heart rate of 58 bpm in normal sinus rhythm during scanning. Later, it was discovered that a microphone in the CT room was out of order and that breath-holding instructions had not been given to the patient.

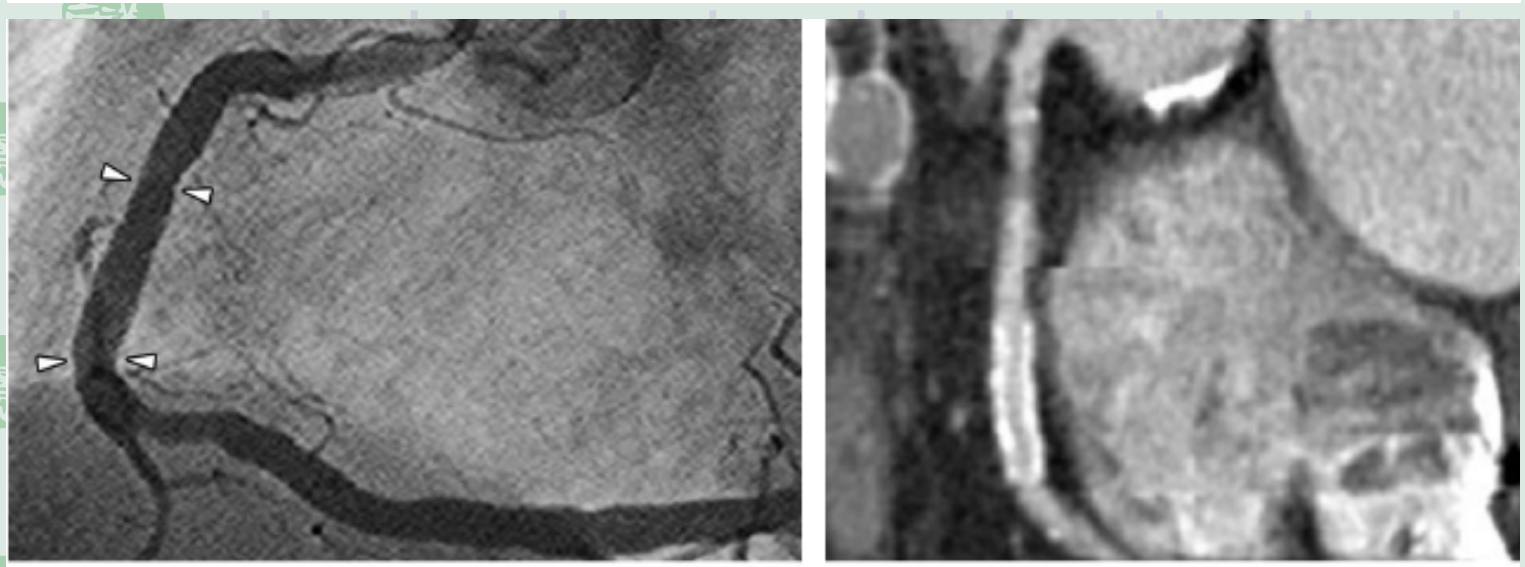



部分容积效应－高密度（钙化、金属支架）

无法观察管腔内情况

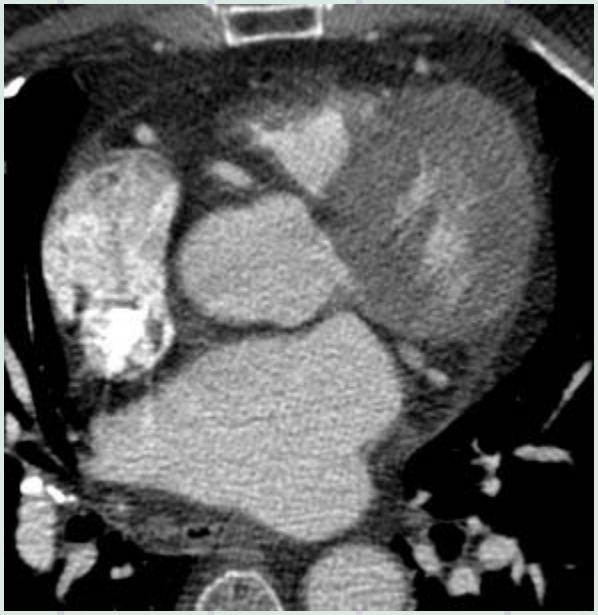


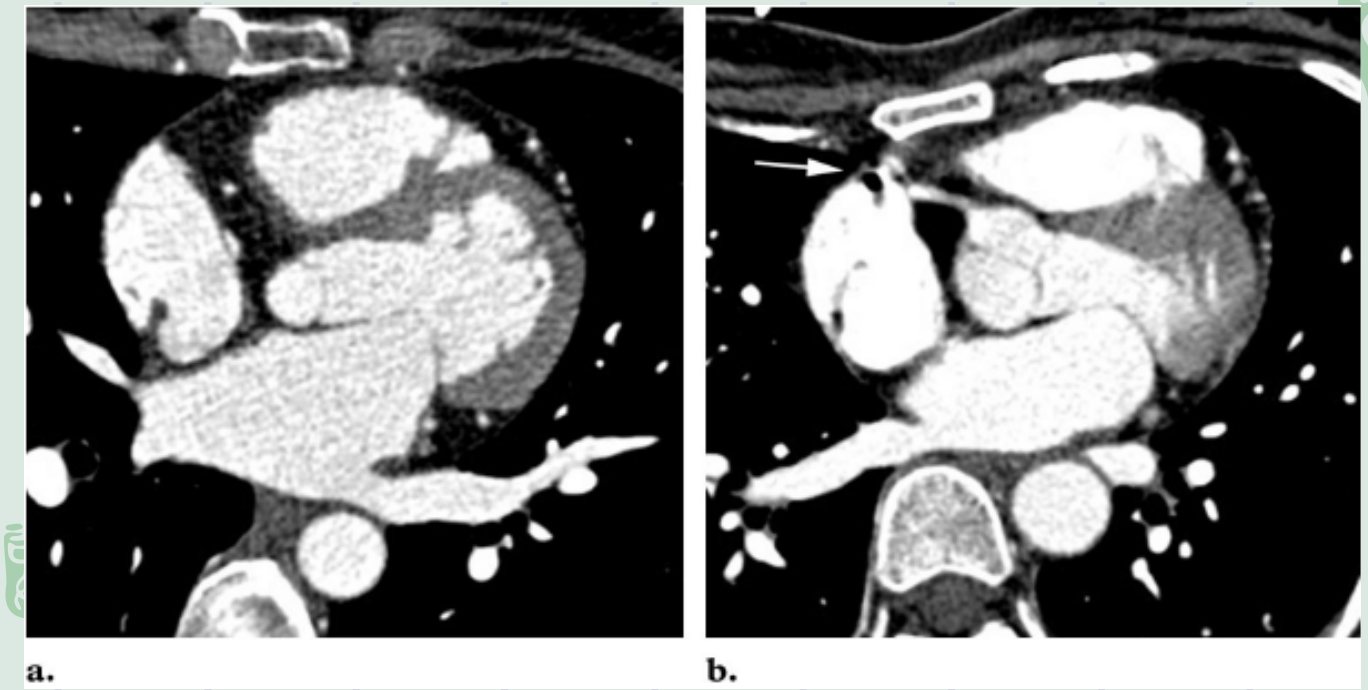
a. b.



a. c.

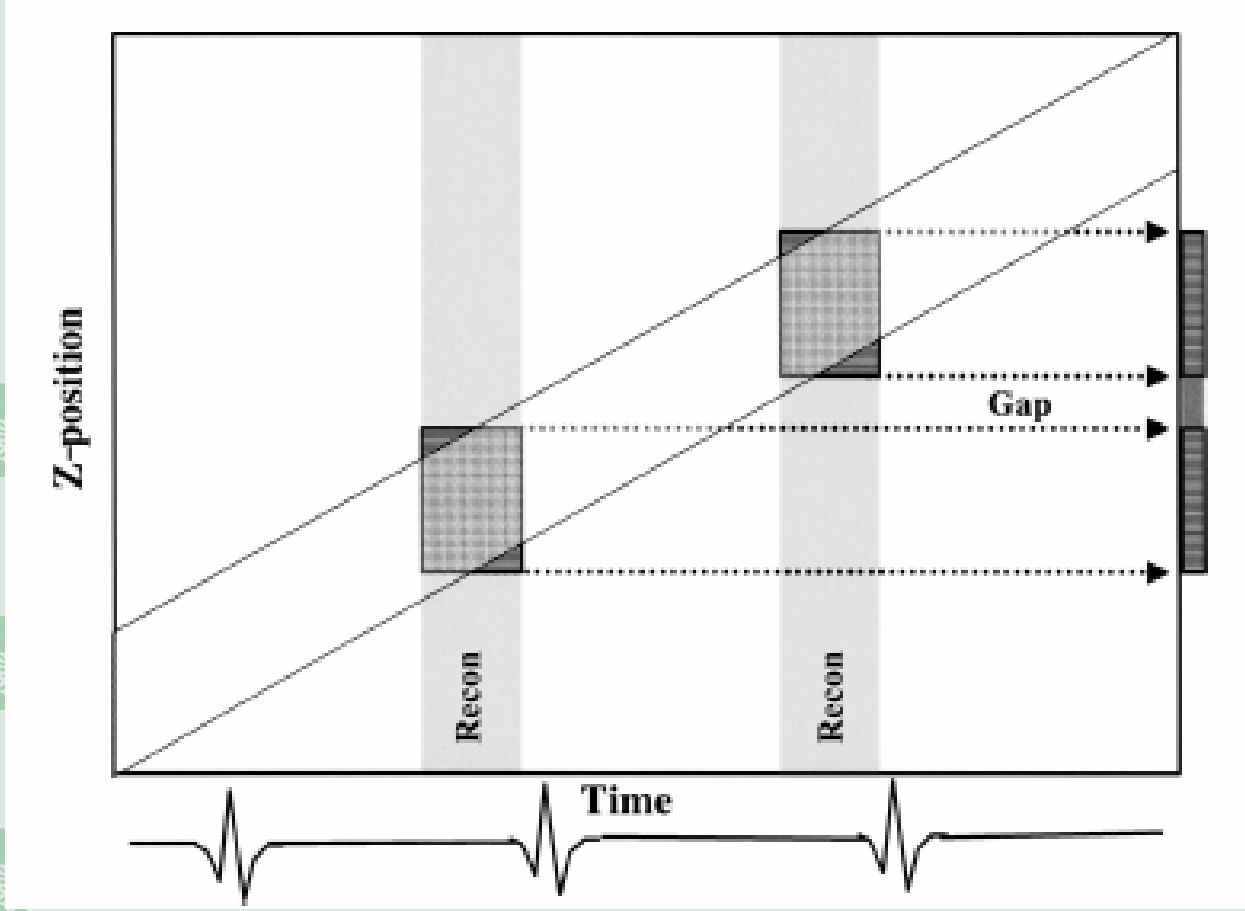
# 右房条形伪影

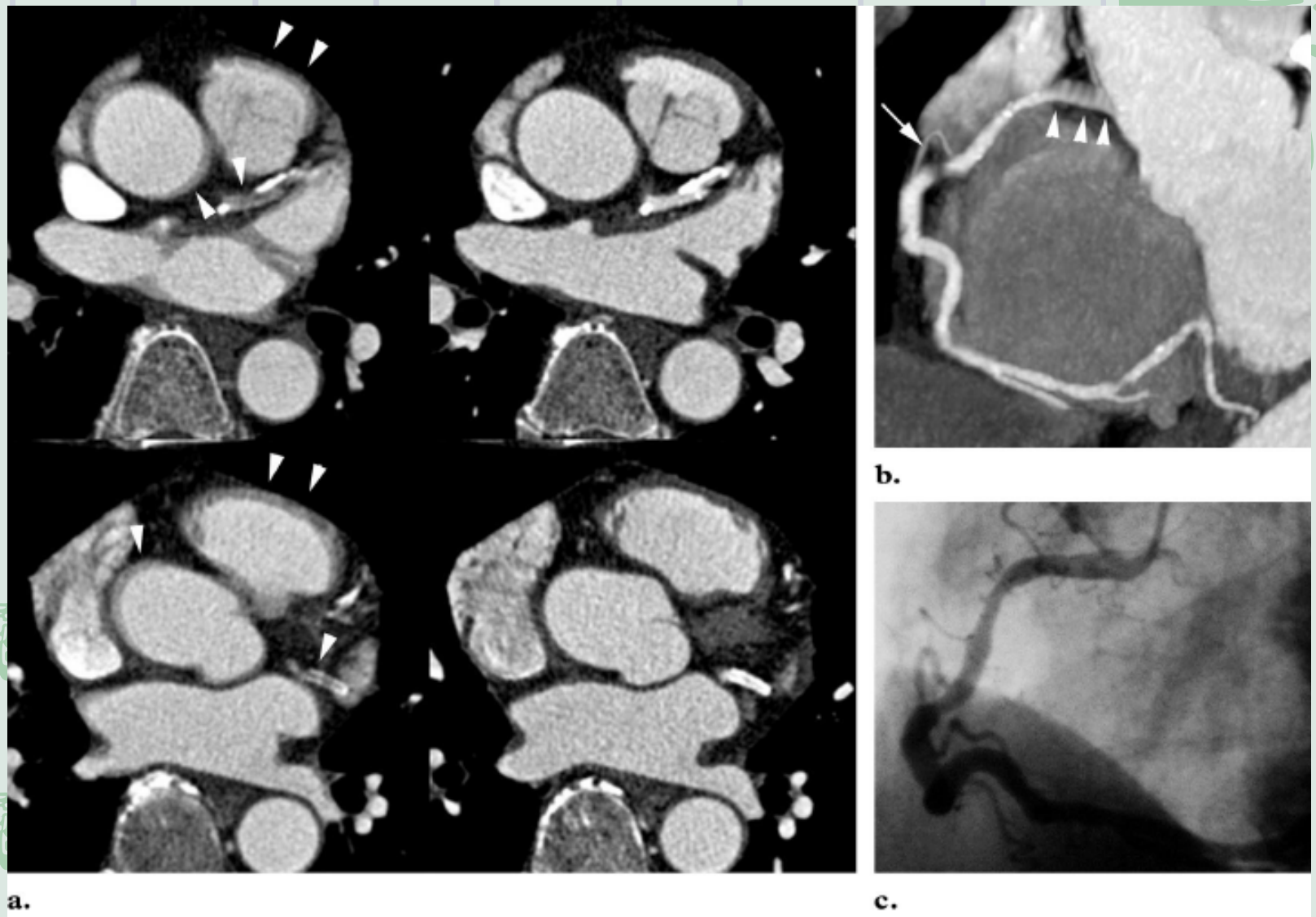




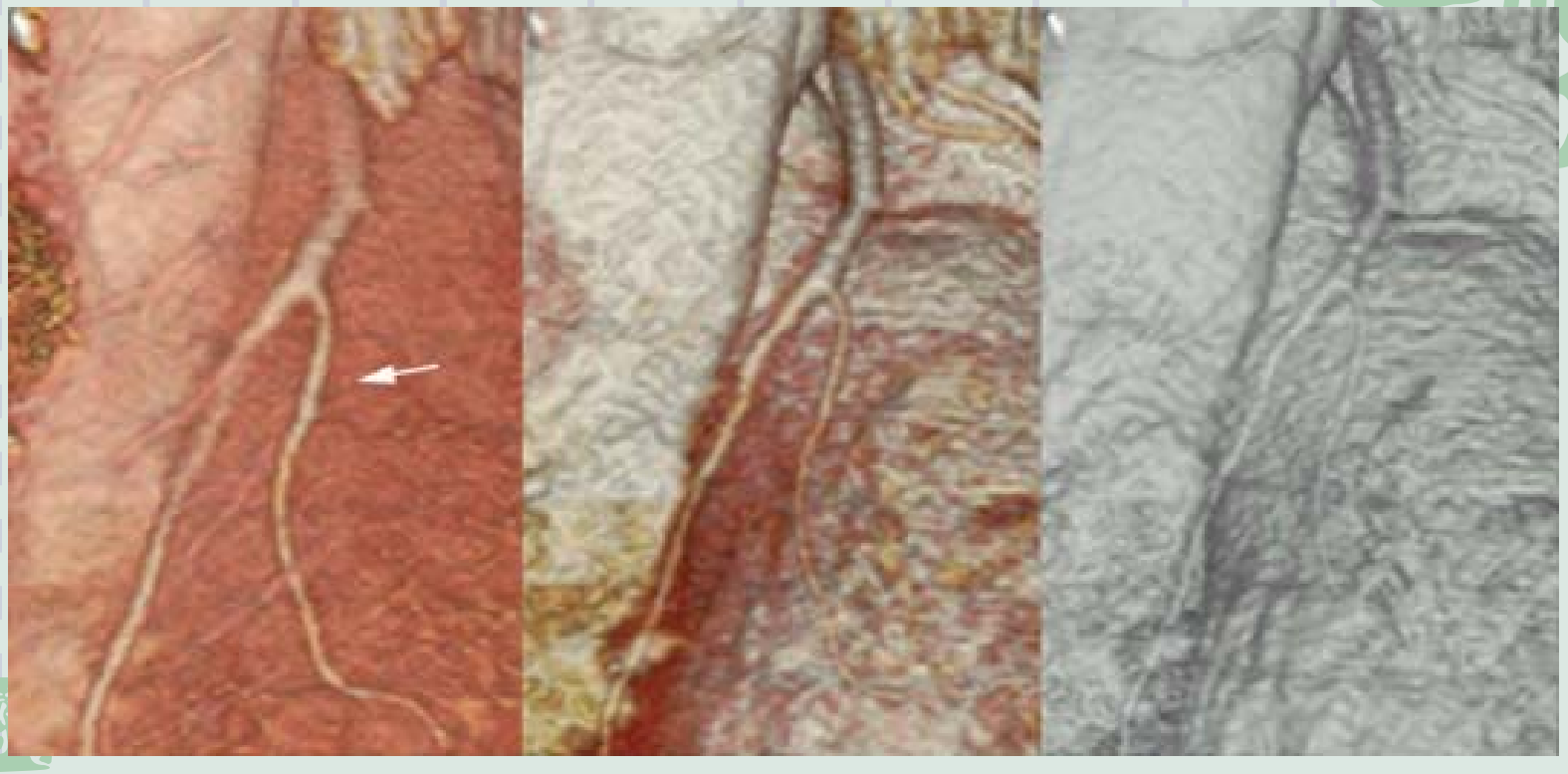

# Streak artifact

# 螺距的选择

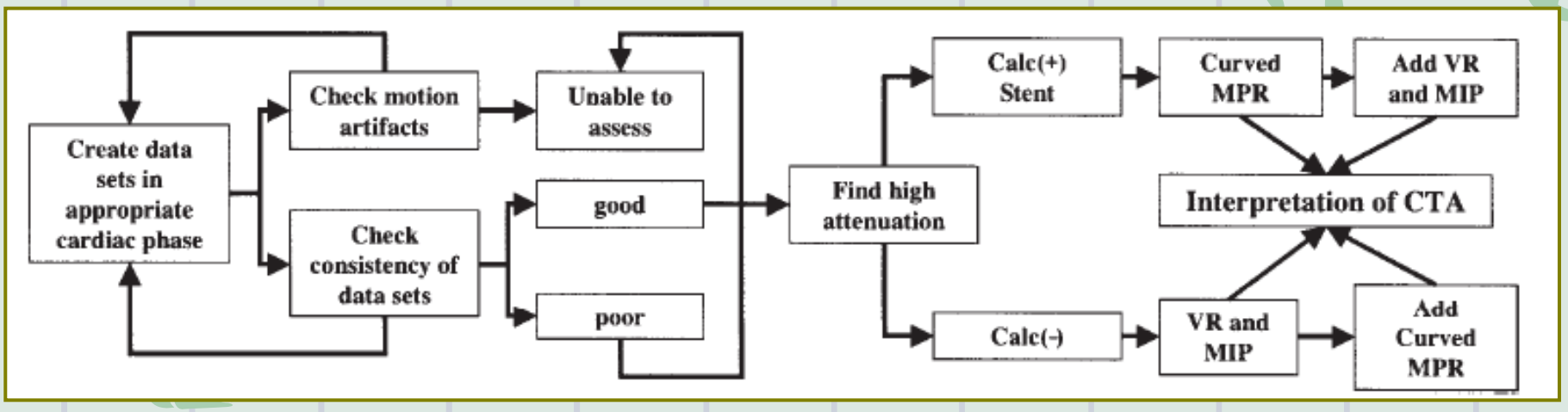





心率较慢，螺距较大，造成数据缺失，模糊伪影，假性狭窄



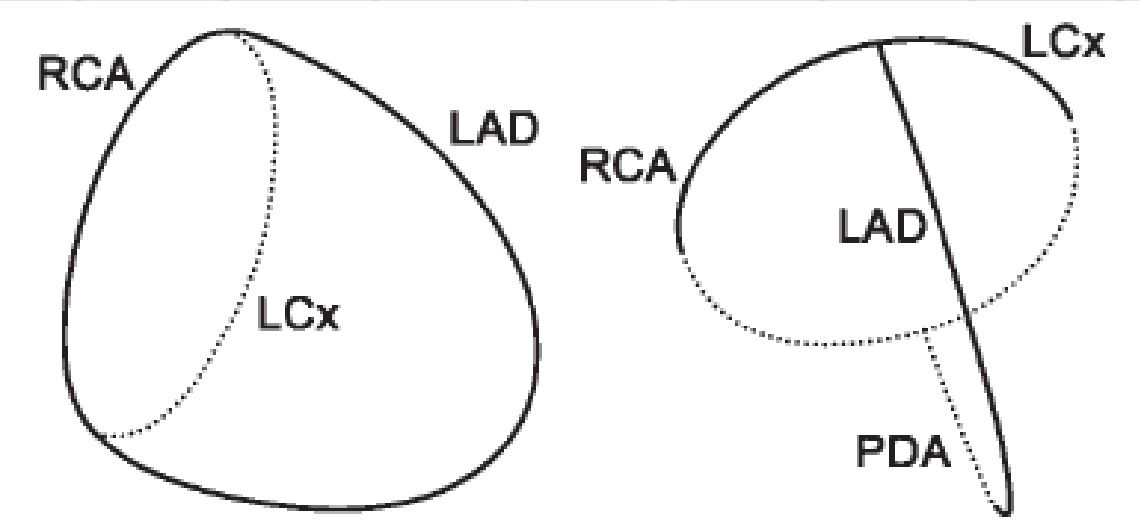
重建方法选择，VR的窗宽不同对管径的显示也不同，尤见于小血管


Create data sets in appropriate cardiac phase
Check motion artifacts
Check consistency of data sets
Unable to assess
good
poor
Find high attenuation
Calc(+) Stent
Calc(-)
Curved MPR
Add VR and MIP
VR and MIP
Add Curved MPR
Interpretation of CTA

# 临床应用

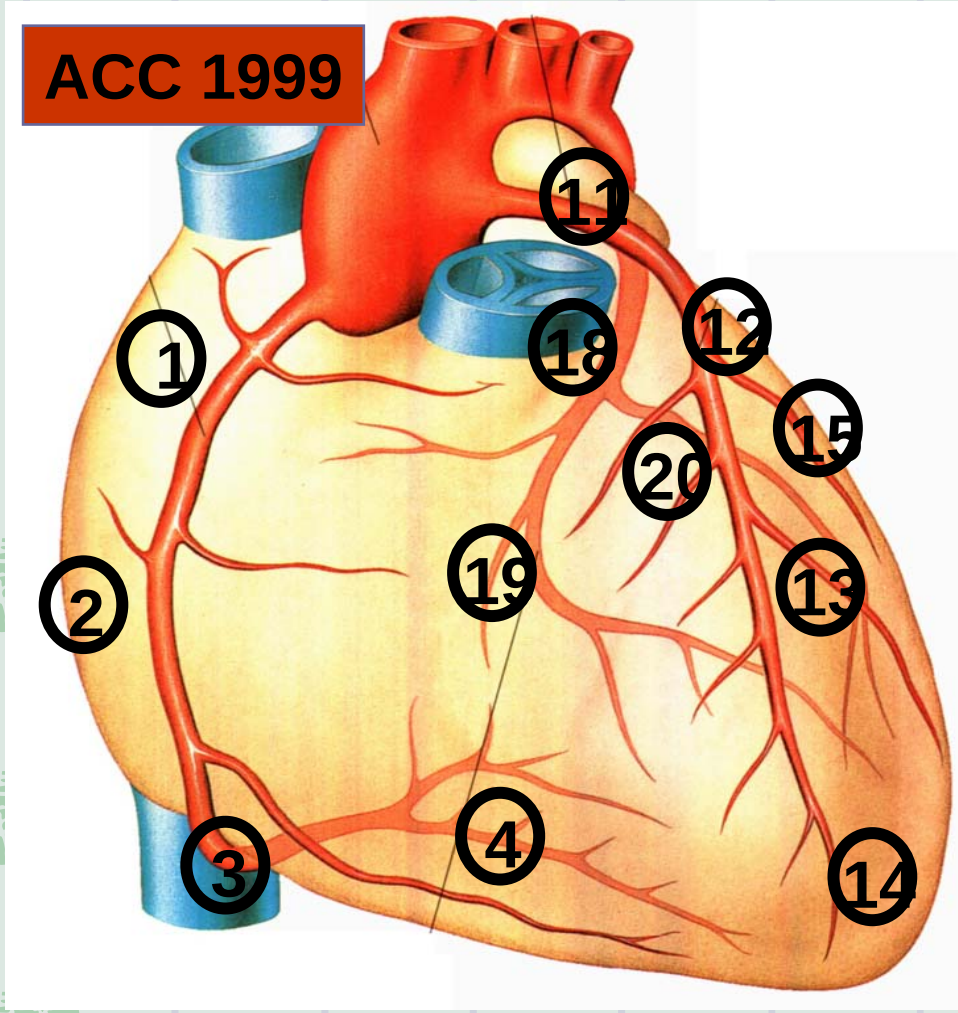
# 冠状动脉临床应用

- 正常解剖



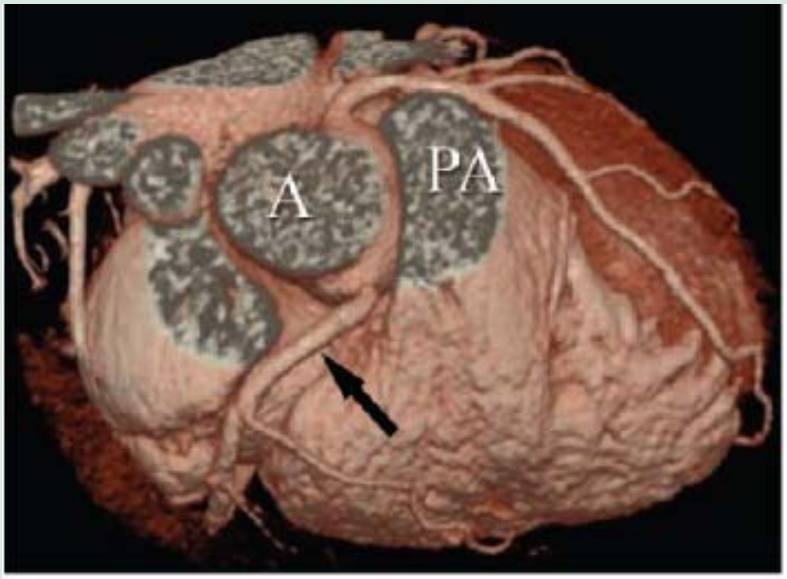

一个圆圈＋半个弧形（85％RCA 7~8%LCx 7-8%RCA+LCx）

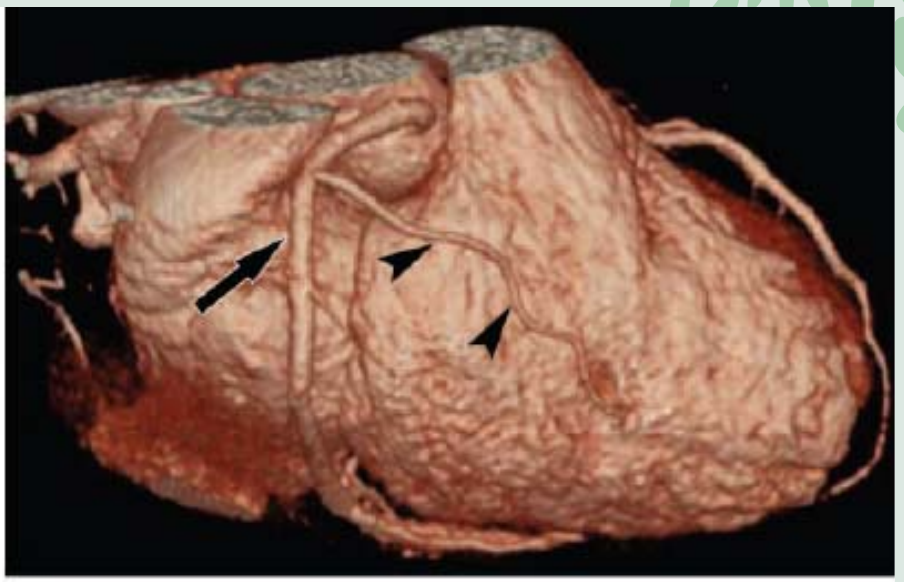
# 冠脉解剖图



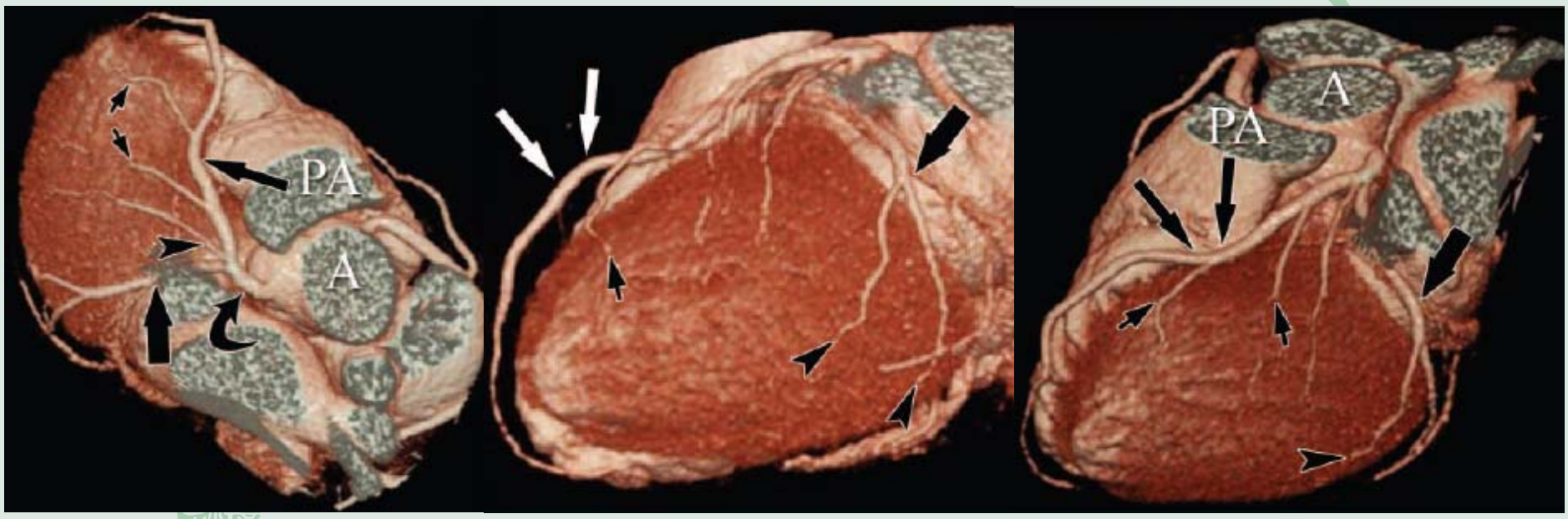

| | | |
|---|---|---|
| **RCA** | proximal | (1) |
| | middel | (2) |
| | distal | (3) |
| **LCA** | main | (11) |
| **LAD** | proximal | (12) |
| | middle | (13) |
| | distal | (14) |
| | Diagonal 1 | (15) |
| **LCX** | proximal | (18) |
| | distal | (19) |
| | Marginal 1 | |

# 右冠解剖



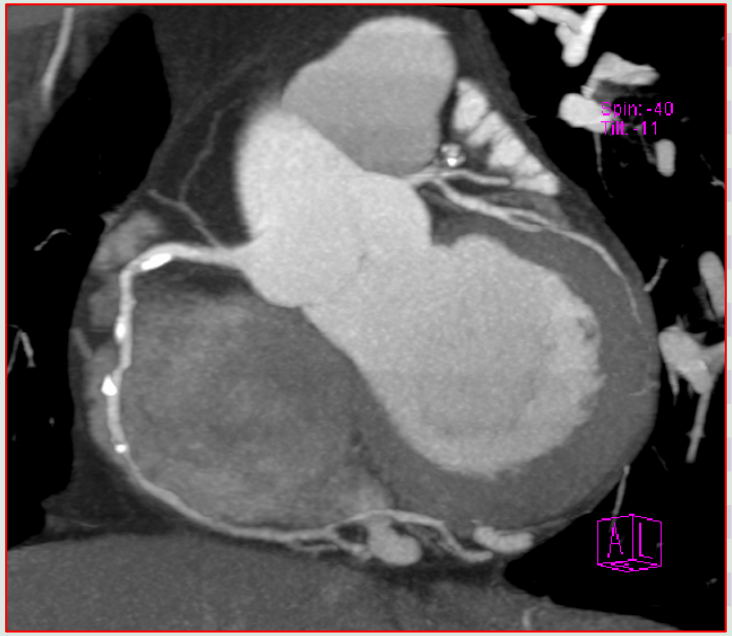



# 左冠解剖



# CT冠脉成像

- 冠脉管腔开放度
- 斑块的非侵入性成像
- 支架，搭桥术后随访
- 冠脉先天异常

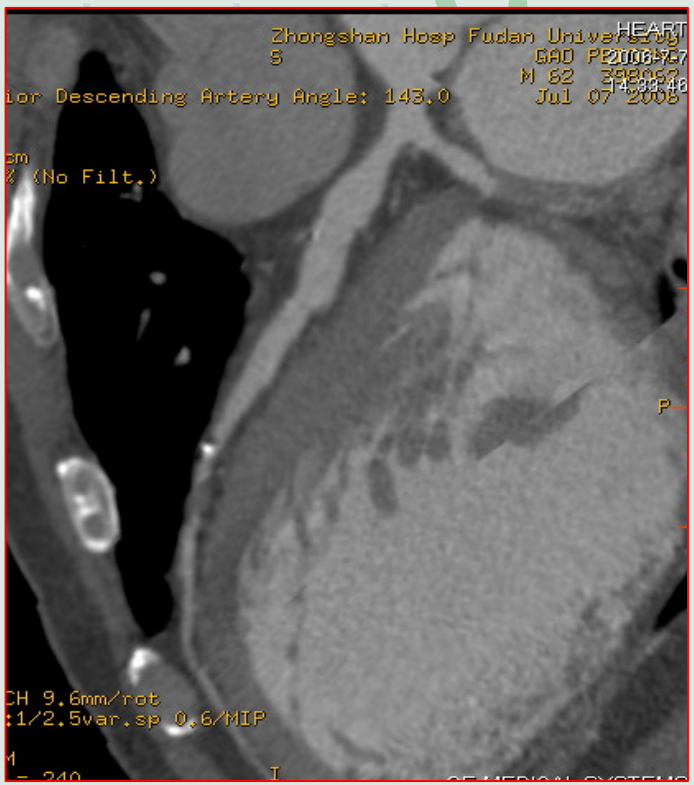




钙化斑块影响管腔
开放程度观察

# 冠脉动脉瘤


FOV 15.0 cm
TND Ph:75% (No Filt.)
51/6
L
w 120
A 697
ot 0.35s/CH 9.6mm/rot
0.24:1/2.5var.sp 0.6/MIP
42:00 PM
256 1200 L = 240
I
GE MEDICAL SYSTEMS


Zhongshan Hosp Fudan Univ
HEART
GAD
ior Descending Artery Angle: 143.0
Jul 07 2006
(No Filt.)
P
CH 9.6mm/rot
:1/2.5var.sp 0.6/MIP
I

# 斑块成像

- MI仅1/3直接源自冠脉狭窄
- 急性冠脉事件主要原因----易损斑块（多为富含脂质斑块），及继发破溃，形成血栓
- 钙化斑块多为稳定斑块
- 重塑（正性）----斑块逃脱检出（DSA）

# 斑块成像

- 根据密度差异
  - 富脂肪斑块50 ± 12HU
  - 纤维为主斑块89 ± 31HU
  - 钙化斑块> 120HU
  - 混合斑块

## 和IVUS对照：

所有斑块检出敏感性82％，特异性88％，

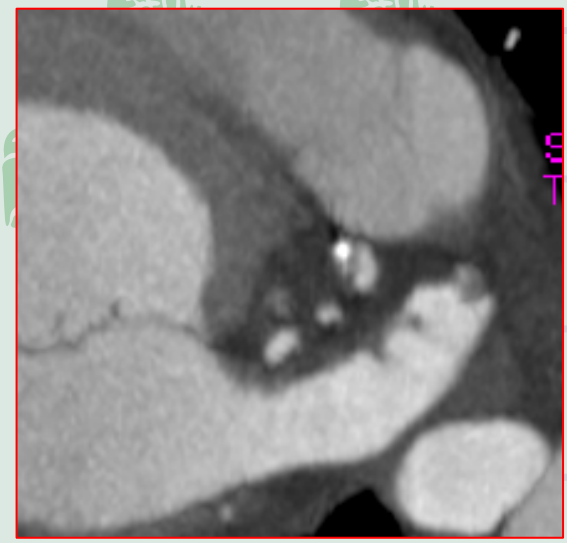
钙化斑块敏感性94％，特异性94％，

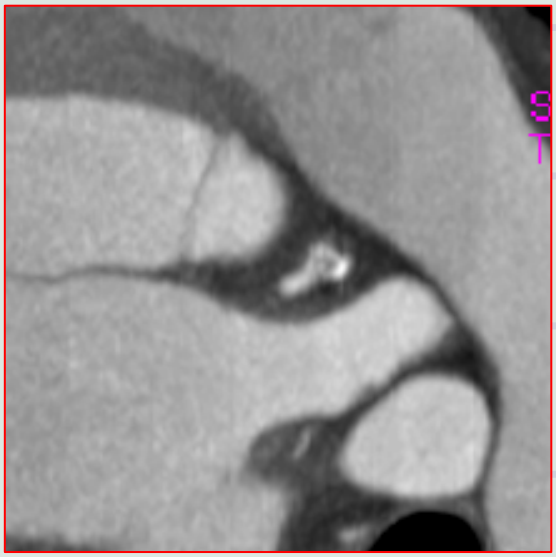
含有非钙化斑块的敏感性78％，特异性87％

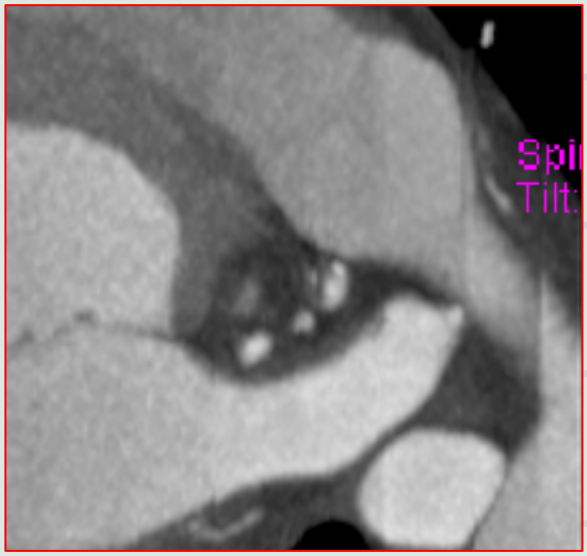
全部非钙化斑块的敏感性仅53％，

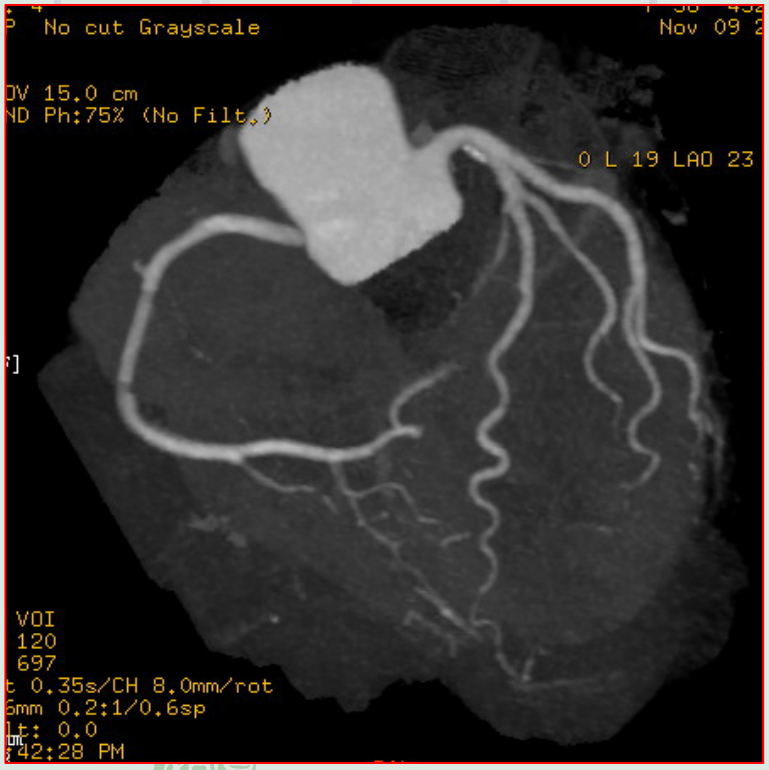
MDCT明显低估了斑块容积

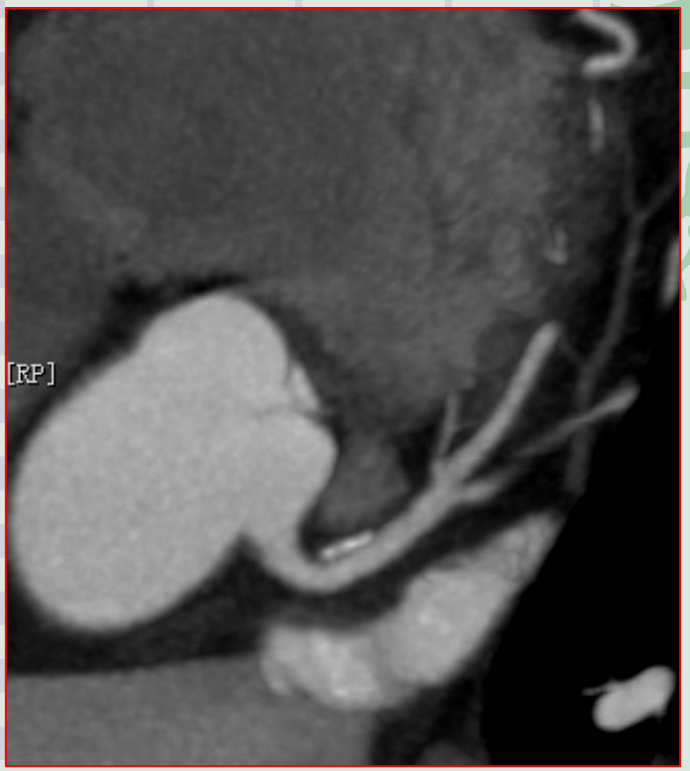
——Achenbach S, Moselewski F, Ropers D,et al. Detection of calcified and noncalcified coronary atherosclerotic plaque by contrast-enhanced, submillimeter multidetector spiral computed tomography: a segment-based comparison with intravascular ultrasound. Circulation 2004;109: 14 – 17.

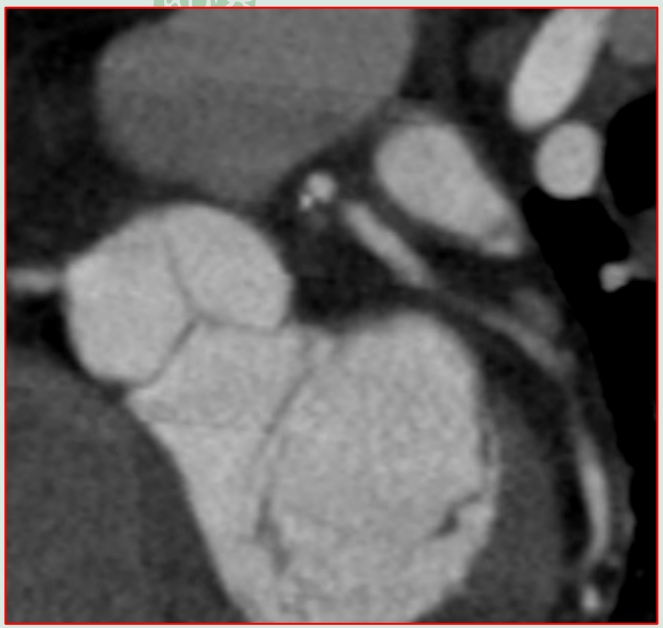




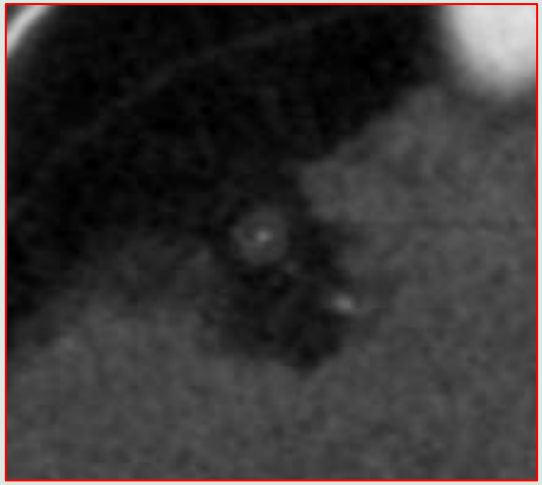


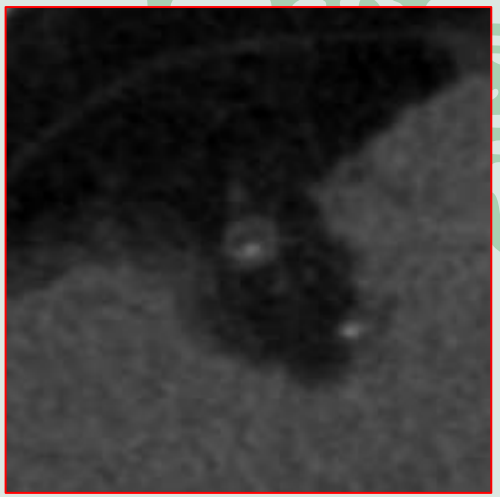

No cut Grayscale
Nov 09 2
DV 15.0 cm
ND Ph:75% (No Filt.)
0 L 19 LAO 23
VOI
120
697
t 0.35s/CH 8.0mm/rot
6mm 0.2:1/0.6sp
Lt: 0.0
42:28 PM

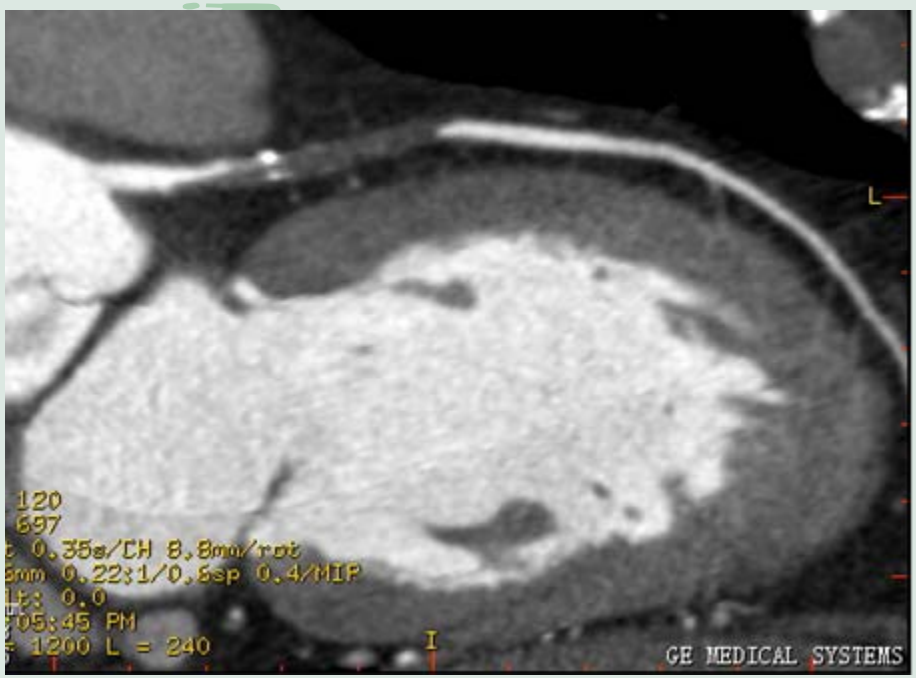

[RP]




cm
5% (No Filt.)
/CH 8.8mm/rot
2:1/0.6sp 0.4/MIP
PM
L = 324
GE MEDICAL SYSTE



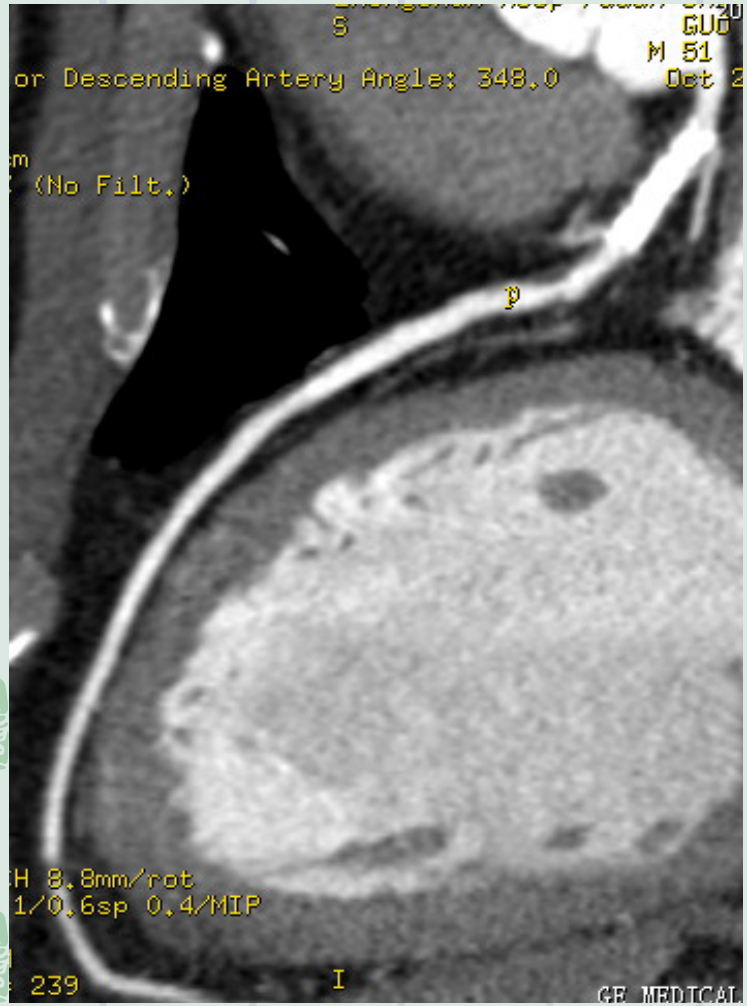


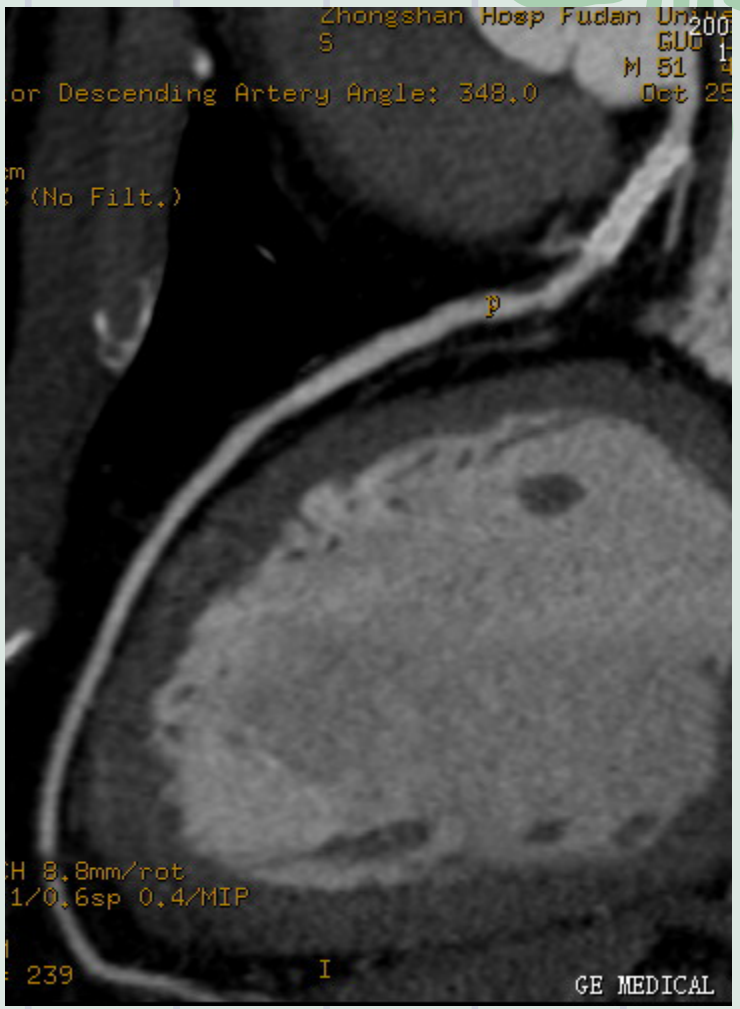

120
697
0.35s/CH 8.8mm/rot
0.22:1/0.8sp 0.4/MIP
0.0
05:45 PM
1200 L = 240
GE MEDICAL SYSTEMS

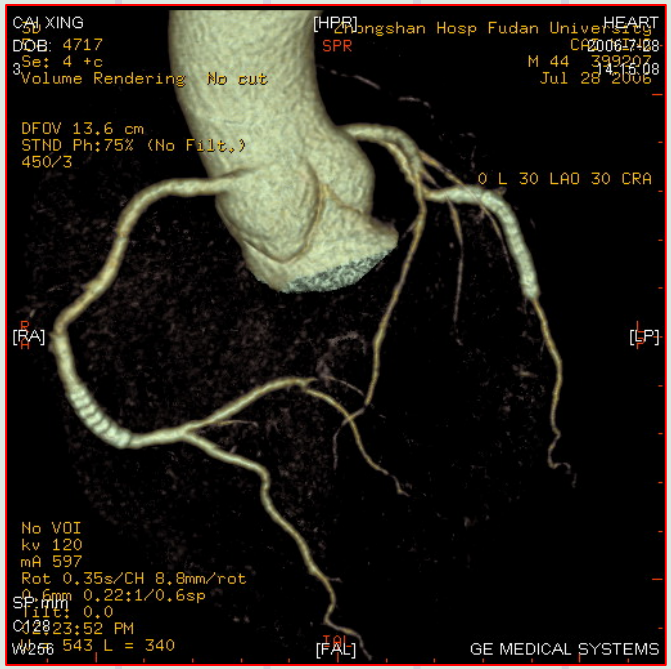
低密度斑块

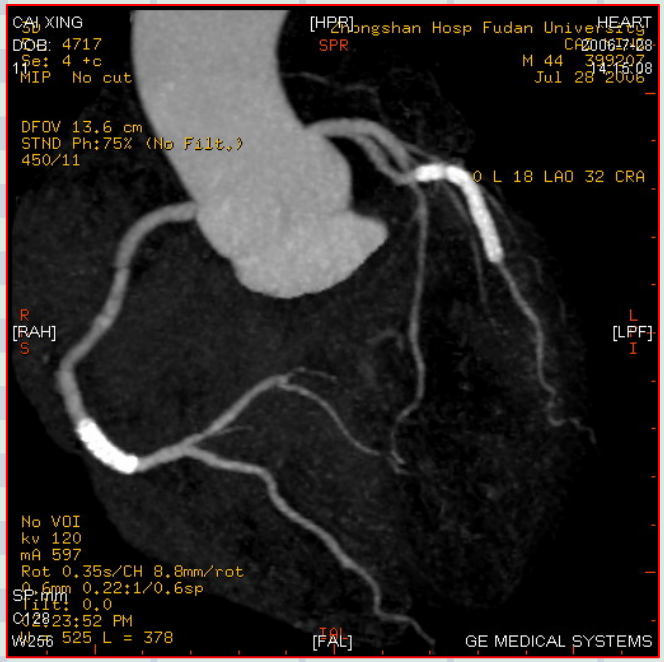
# 支架术后评价

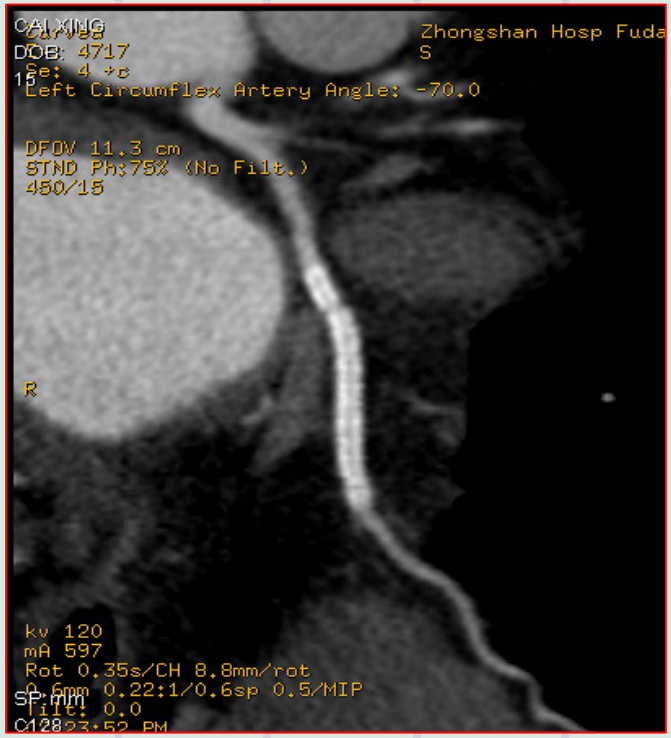
- 支架开放度，支架内再狭窄，
- 分辨率要求高，金属往往夸大狭窄程度
- 根据支架材质密度，涂膜用料，需考虑容积效应影响

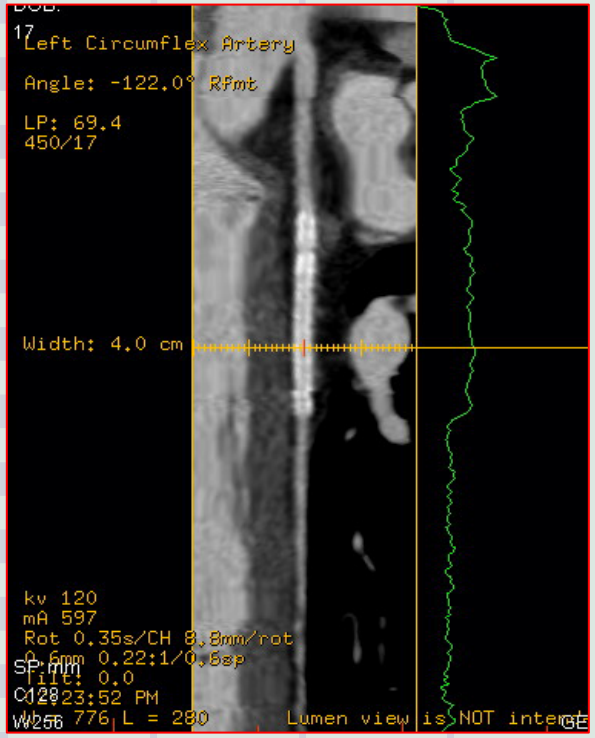

S
GUO
M 51
or Descending Artery Angle: 348.0
(No Filt.)
p
H 8.8mm/rot
1/0.6sp 0.4/MIP
239
I
GE MEDICAL


Zhongshan Hosp Fudan Univ
S
GUO
M 51
or Descending Artery Angle: 348.0
(No Filt.)
p
H 8.8mm/rot
1/0.6sp 0.4/MIP
239
I
GE MEDICAL

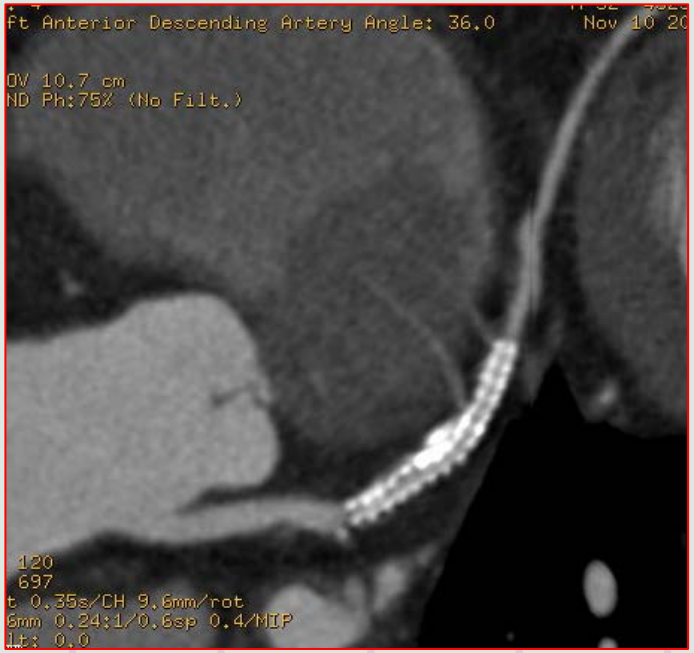

CAI XING
DOB: 4717
Se: 4 +c
Volume Rendering No cut
[HPR]
HEART
SPR
Zhongshan Hosp Fudan University
M 44
Jul 28 2006
DFOV 13.6 cm
STND Ph:75% (No Filt.)
450/3
0 L 30 LAO 30 CRA
[RA]
[LP]
No VOI
kv 120
mA 597
Rot 0.35s/CH 8.8mm/rot
0.6mm 0.22:1/0.6sp
Filt: 0.0
23:52 PM
W:256 543 L = 340
[FAL]
GE MEDICAL SYSTEMS


CAI XING
DOB: 4717
Se: 4 +c
MIP No cut
[HPR]
HEART
SPR
Zhongshan Hosp Fudan University
M 44
Jul 28 2006
DFOV 13.6 cm
STND Ph:75% (No Filt.)
450/11
0 L 18 LAO 32 CRA
[RAH]
[LPF]
No VOI
kv 120
mA 597
Rot 0.35s/CH 8.8mm/rot
0.6mm 0.22:1/0.6sp
Filt: 0.0
23:52 PM
W:256 525 L = 378
[FAL]
GE MEDICAL SYSTEMS

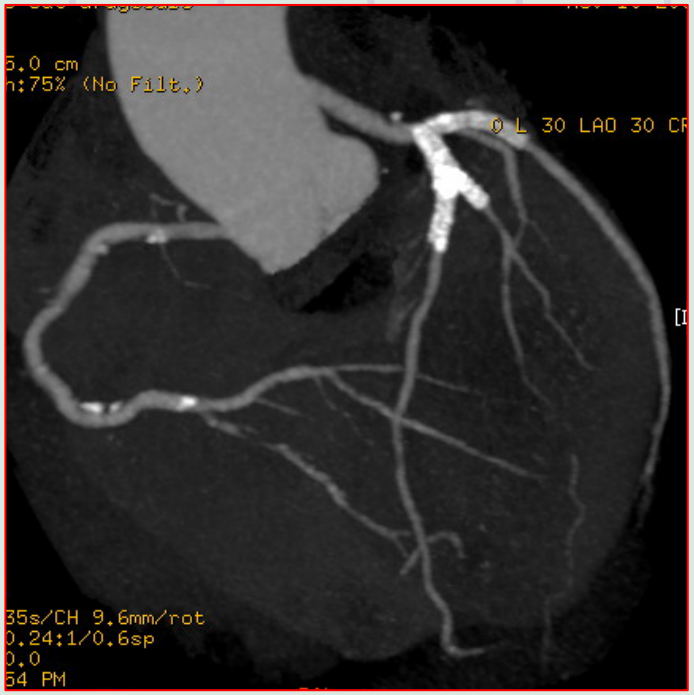

CAI XING
DOB: 4717
Se: 4 +c
Zhongshan Hosp Fuda
Left Circumflex Artery Angle: -70.0
DFOV 11.3 cm
STND Ph:75% (No Filt.)
450/15
R
kv 120
mA 597
Rot 0.35s/CH 8.8mm/rot
0.6mm 0.22:1/0.6sp 0.5/MIP
Filt: 0.0
23:52 PM


Left Circumflex Artery
Angle: -122.0° RPmt
LP: 69.4
450/17
Width: 4.0 cm
kv 120
mA 597
Rot 0.35s/CH 8.8mm/rot
0.6mm 0.22:1/0.6sp
Filt: 0.0
23:52 PM
W:256 776 L = 280
Lumen view is NOT interpr

# 冠脉支架术后

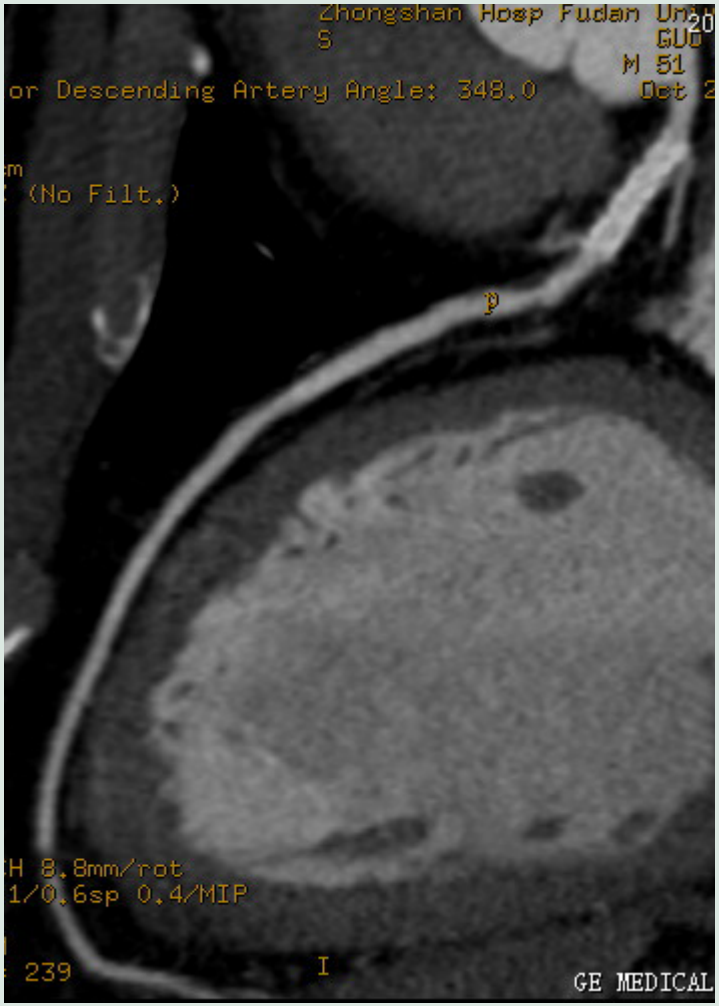

ft Anterior Descending Artery Angle: 36.0
Nov 10 20
OV 10.7 cm
ND Ph:75% (No Filt.)
120
697
t 0.35s/CH 9.6mm/rot
6mm 0.24:1/0.6sp 0.4/MIP
Lt: 0.0

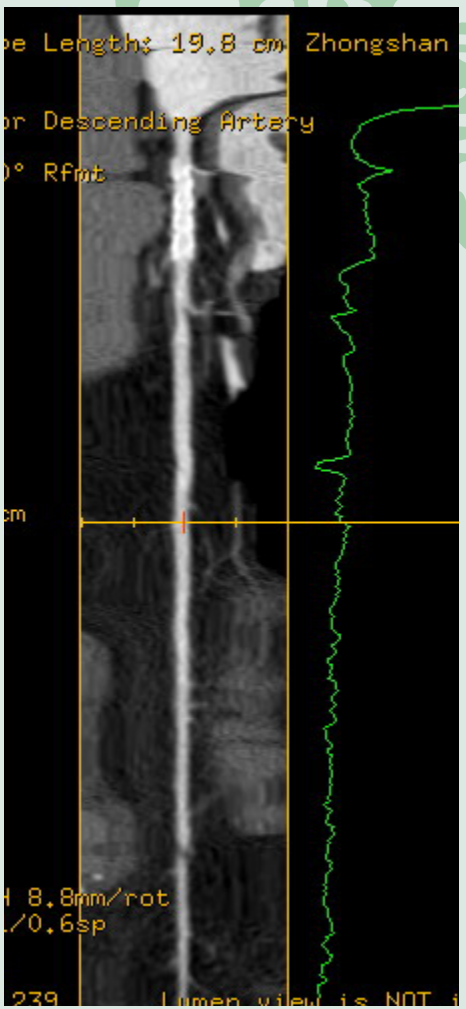

0
7
.35s/CH 9.6mm/rot
0.24:1/0.6sp 0.4/MIP
0.0
:54 PM
207 L = 410
GE MEDICAL SYSTE


5.0 cm
h:75% (No Filt.)
0 L 30 LAO 30 CR
35s/CH 9.6mm/rot
0.24:1/0.6sp
0.0
54 PM

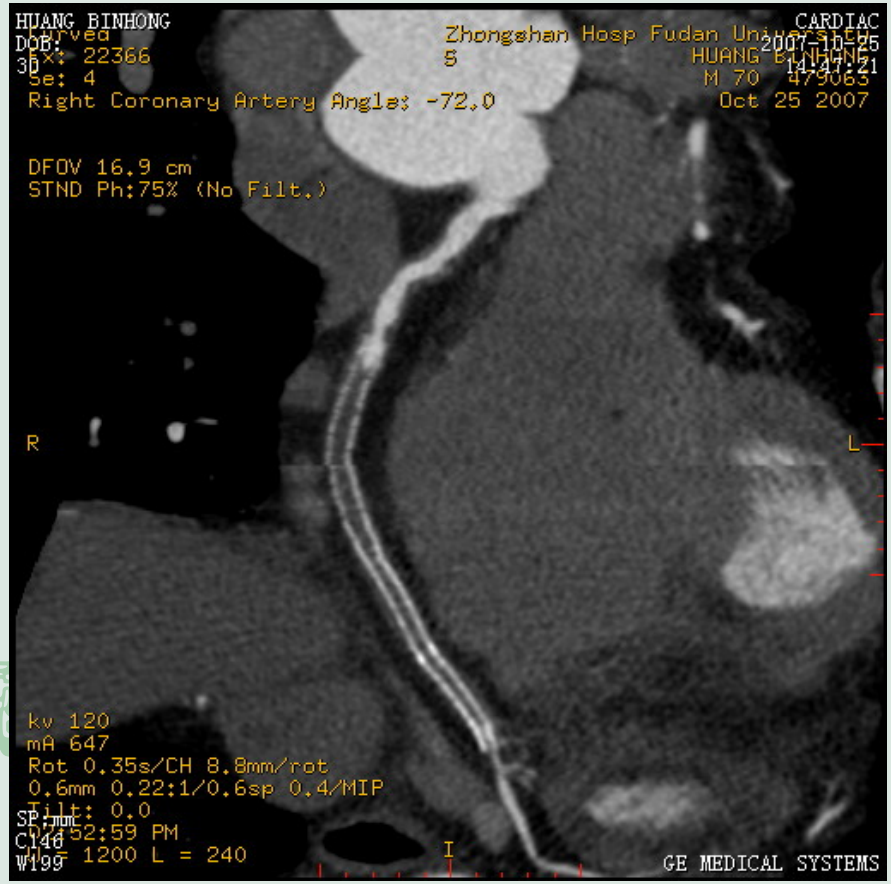
# 支架腔内情况

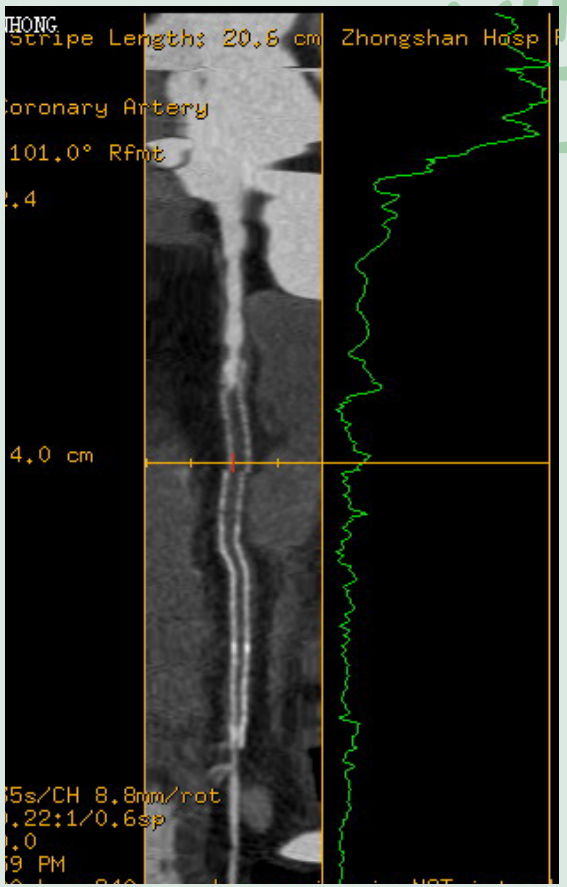

Zhongshan Hosp Fu
A
rior Descending Artery Angle: 47.0
cm
5% (No Filt.)
/CH 8.8mm/rot
2:1/0.6sp 0.4/MIP
AM
= 240
P


Zhongshan Hosp Fudan Uni
S
GUO
M 51
or Descending Artery Angle: 348.0
(No Filt.)
P
H 8.8mm/rot
1/0.6sp 0.4/MIP
239
I
GE MEDICAL


e Length: 19.8 cm
Zhongshan
r Descending Artery
° Rfmt
cm
8.8mm/rot
/0.6sp
239

# 支架下方斑块形成


HUANG BINHONG
DOB:
Ex: 22366
Se: 4
Right Coronary Artery Angle: -72.0
Zhongshan Hosp Fudan Univ
CARDIAC
2007-10-25
HUANG BINHONG
M 70
Oct 25 2007
DFOV 16.9 cm
STND Ph:75% (No Filt.)
R
L
kv 120
mA 647
Rot 0.35s/CH 8.8mm/rot
0.6mm 0.22:1/0.6sp 0.4/MIP
Tilt: 0.0
W = 1200 L = 240
I
GE MEDICAL SYSTEMS


Stripe Length: 20.6 cm
Zhongshan Hosp
Coronary Artery
101.0° Rfmt
4.0 cm
5s/CH 8.8mm/rot
22:1/0.6sp

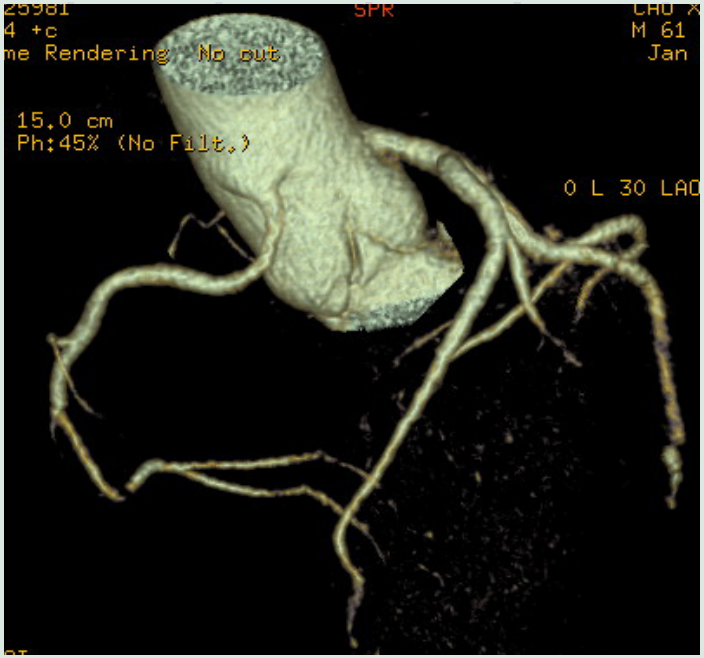
# 支架内血栓形成

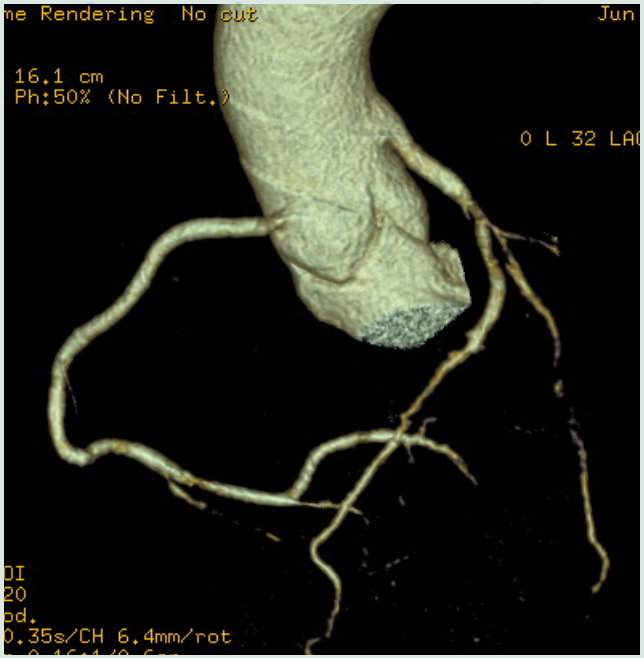
# 冠状动脉变异

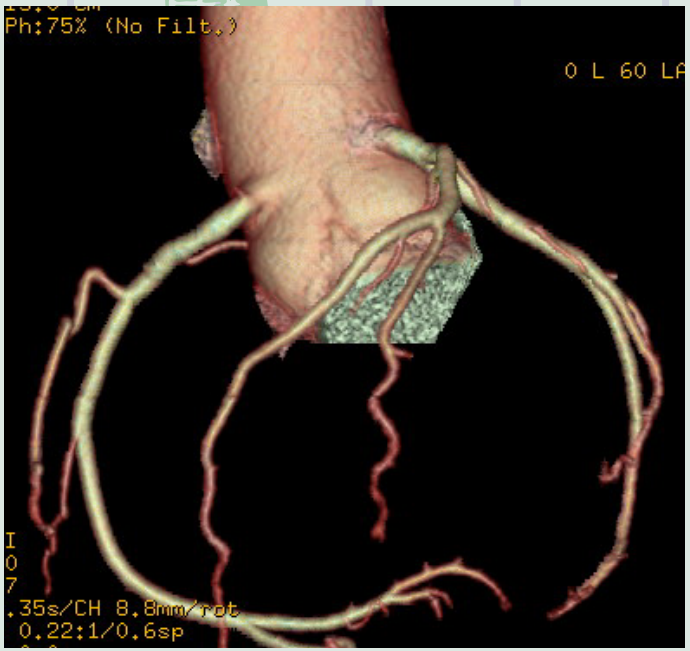
- 分类
  - 起始点异常
  - 行程异常
  - 终点异常

| Coronary Artery Anomalies |
|---|
| Anomalies of origin |
| High takeoff |
| Multiple ostia |
| Single coronary artery |
| Anomalous origin of coronary artery from pulmonary artery* |
| Origin of coronary artery or branch from opposite or noncoronary sinus and an anomalous (retroaortic, interarterial,* prepulmonic, septal [subpulmonic]) course |
| Anomalies of course |
| Myocardial bridging* |
| Duplication of arteries |
| Anomalies of termination |
| Coronary artery fistula* |
| Coronary arcade |
| Extracardiac termination |

Source.—Reference 13.
*Hemodynamically significant anomalies, which might be responsible for myocardial perfusion abnormalities.


SPR
M 61
Jan
me Rendering No cut
15.0 cm
Ph:45% (No Filt.)
0 L 30 LAO

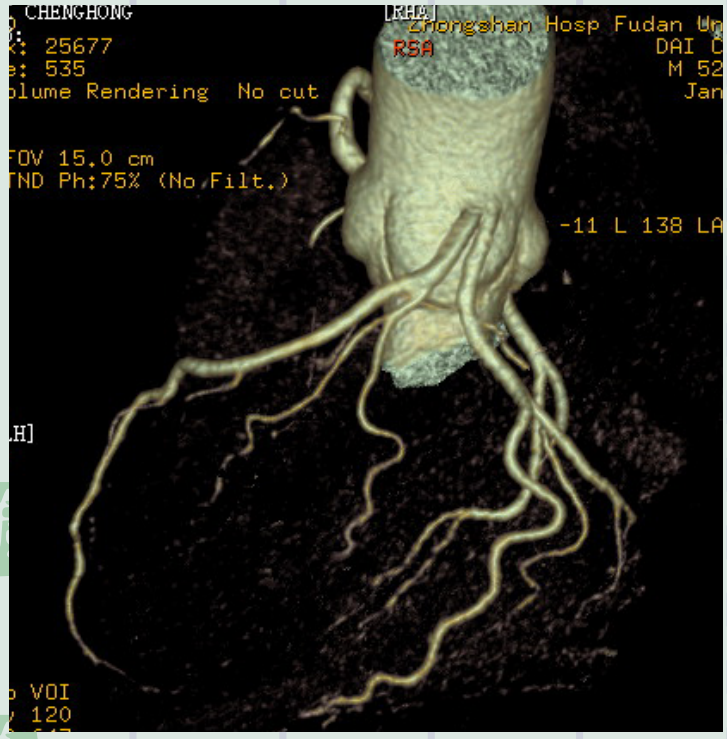

me Rendering No cut
Jun
16.1 cm
Ph:50% (No Filt.)
0 L 32 LA
0.35s/CH 6.4mm/rot

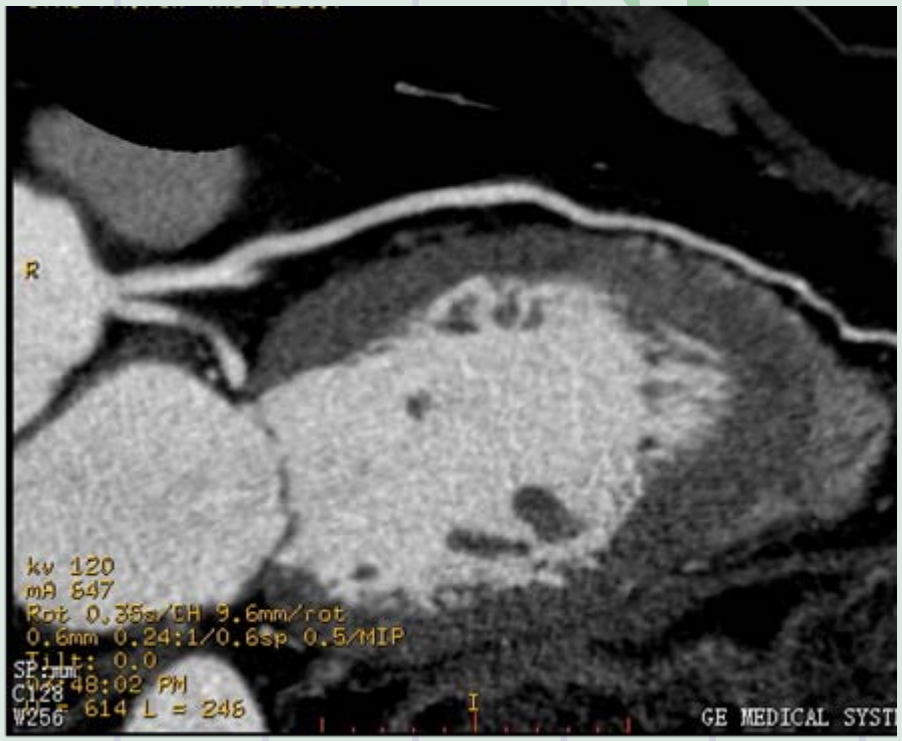

Ph:75% (No Filt.)
0 L 60 LA
.35s/CH 8.8mm/rot
0.22:1/0.6sp


First Diagonal
90.0 °
un 06 2007

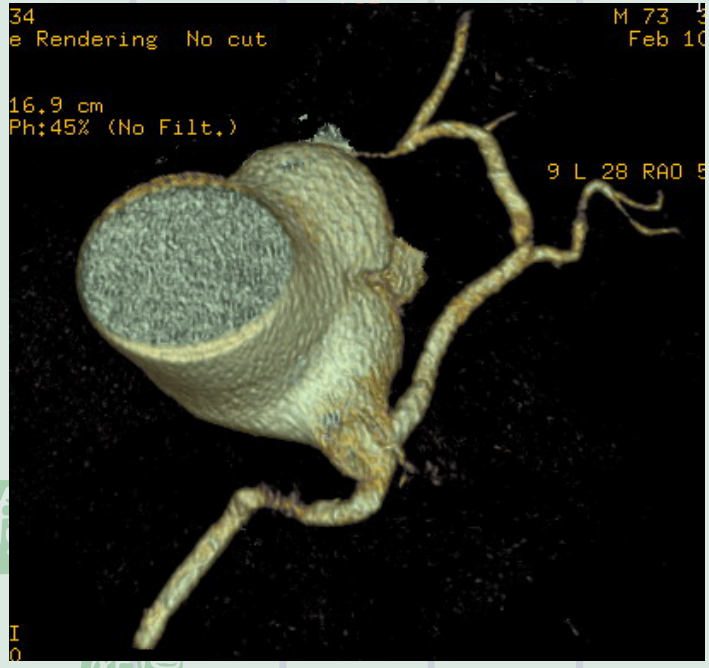
起点高位

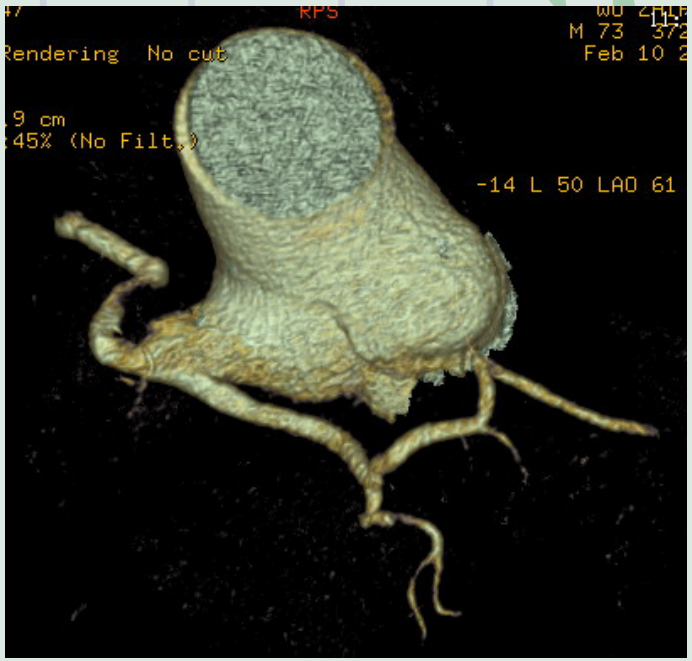
# 多起源


CHENGHONG
25677
535
olume Rendering No cut
FOV 15.0 cm
TND Ph:75% (No Filt.)
RSA
-11 L 138 LA
VOI
120

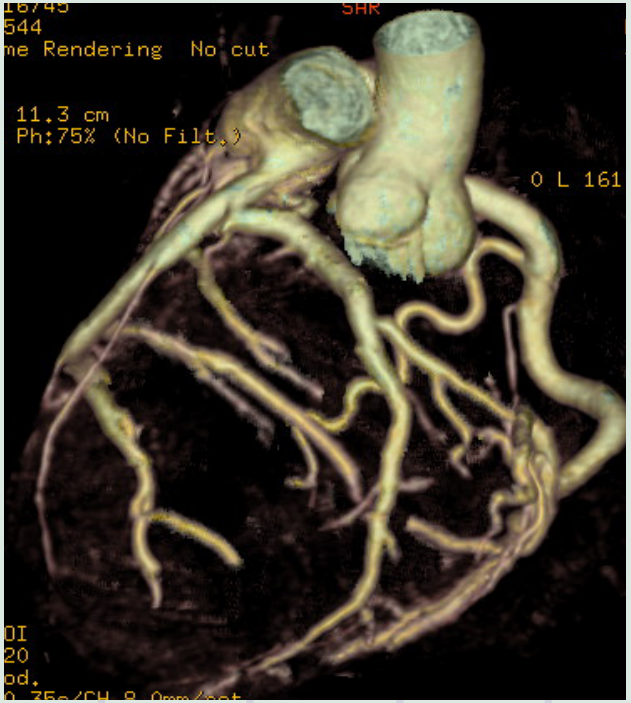

R
kv 120
mA 647
Rot 0.35s/CH 9.6mm/rot
0.6mm 0.24:1/0.6sp 0.5/MIP
Tilt: 0.0
48:02 PM
C128
W256
614 L = 246
GE MEDICAL SYST

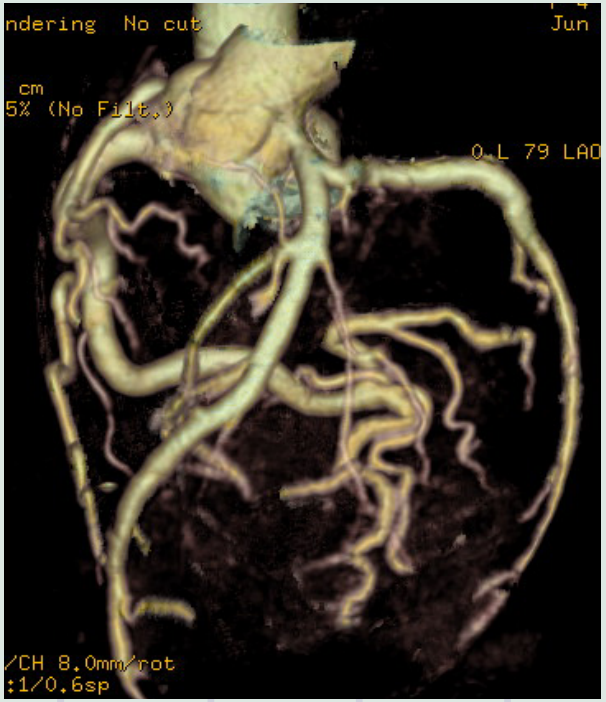
# 单支冠脉

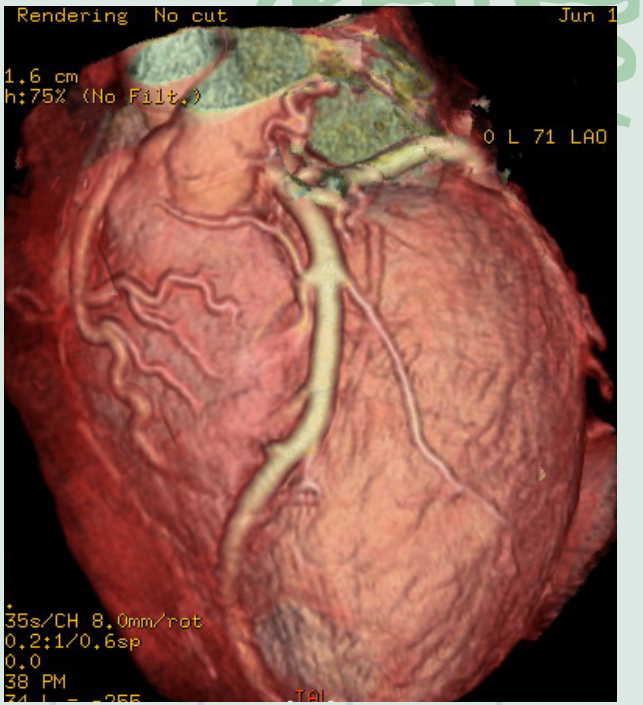

34
e Rendering No cut
M 73
Feb 1
16.9 cm
Ph:45% (No Filt.)
9 L 28 RAO 5

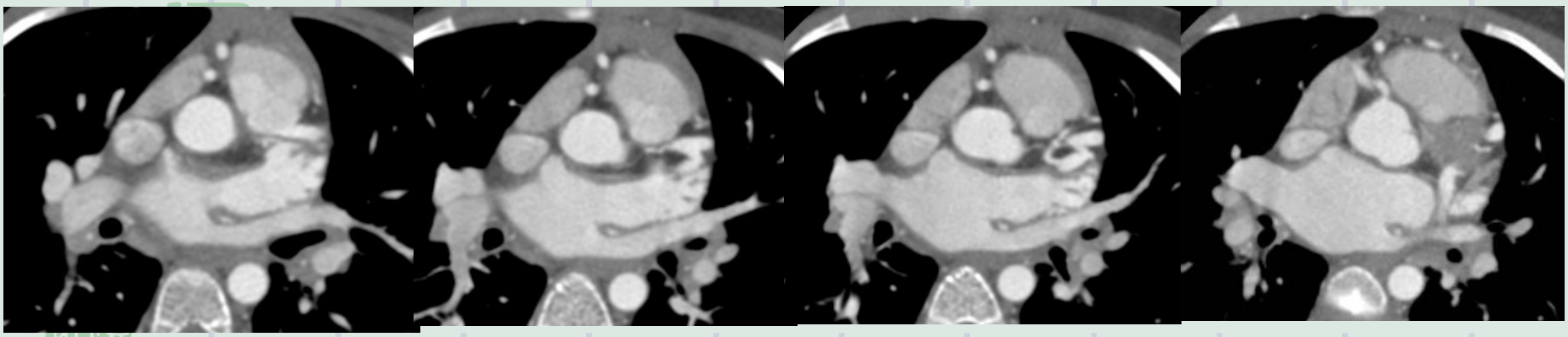

RPS
Rendering No cut
M 73
Feb 10
9 cm
45% (No Filt.)
-14 L 50 LAO 61

# 冠脉发自肺动脉



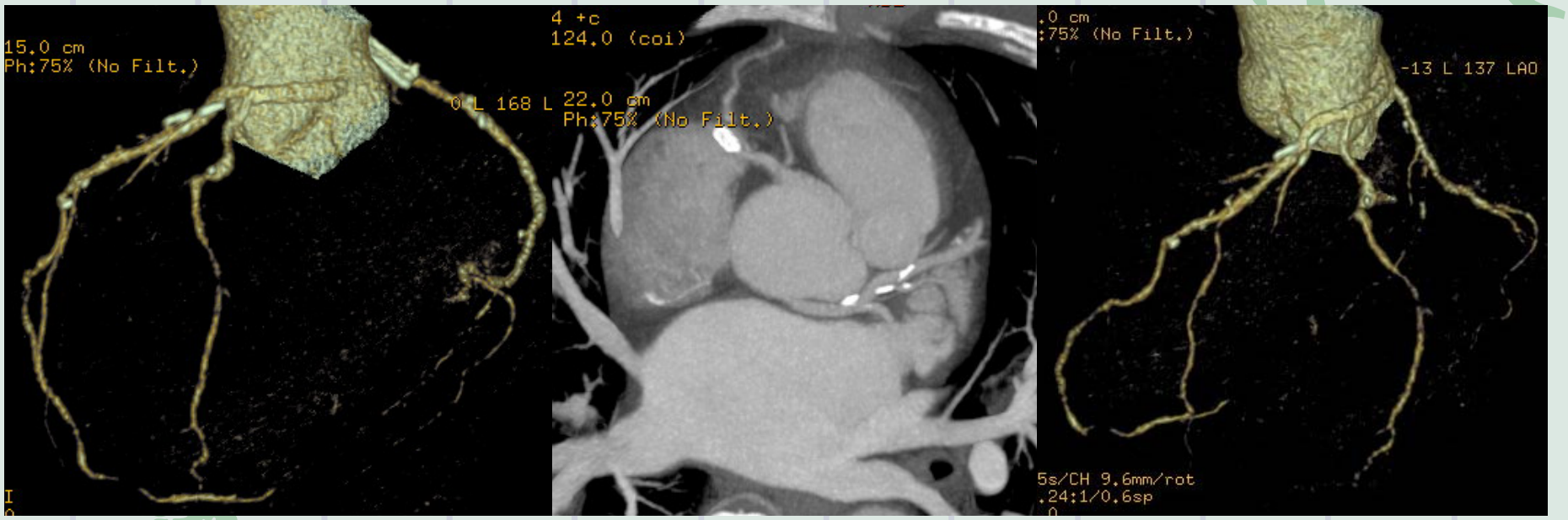



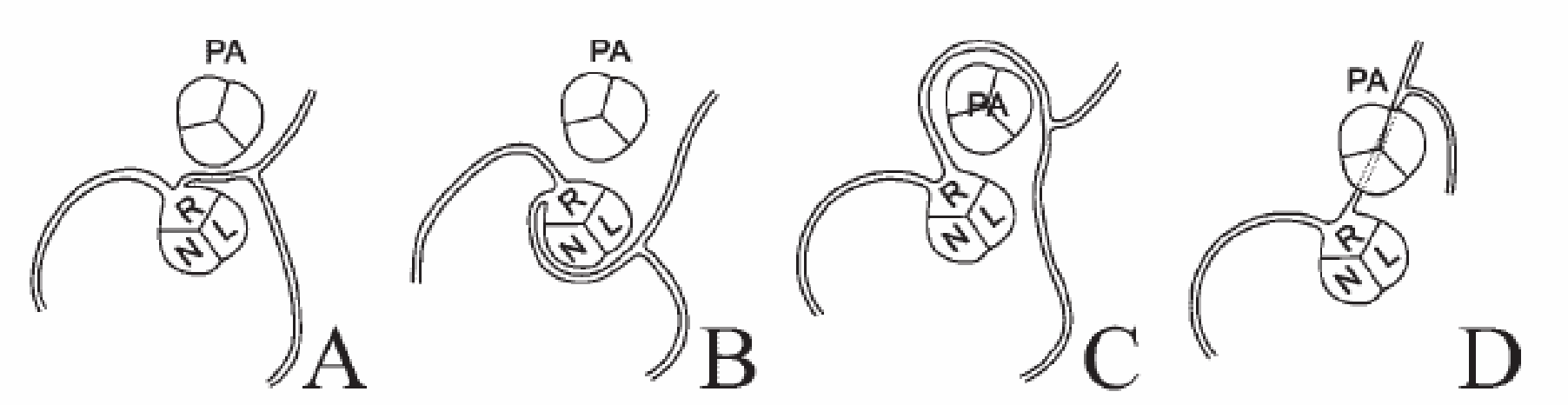



**Bland-White-Garland syndrome**

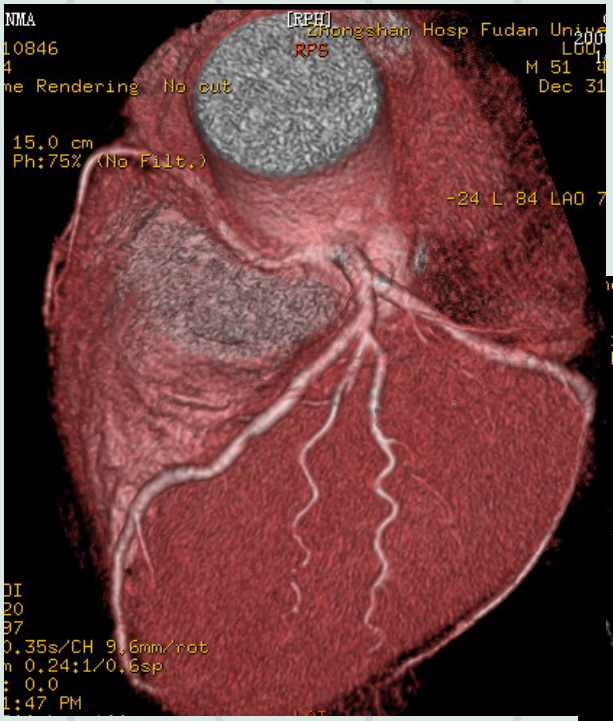
# 起源异常冠状窦

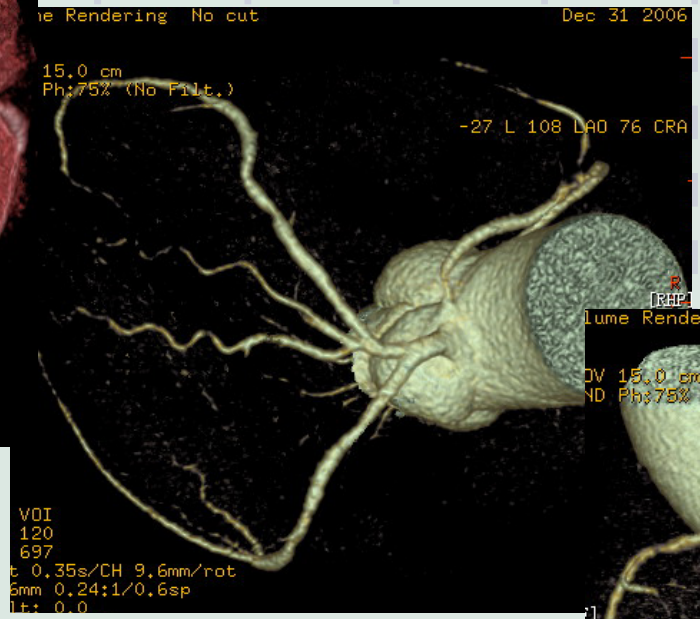

15.0 cm
Ph:75% (No Filt.)
0 L 168 L
4 +c
124.0 (coi)
22.0 cm
Ph:75% (No Filt.)
.0 cm
:75% (No Filt.)
-13 L 137 LAO
5s/CH 9.6mm/rot
.24:1/0.6sp

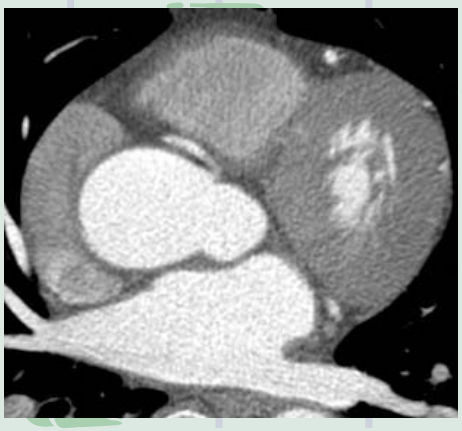
# 冠脉异常起源伴走行异常

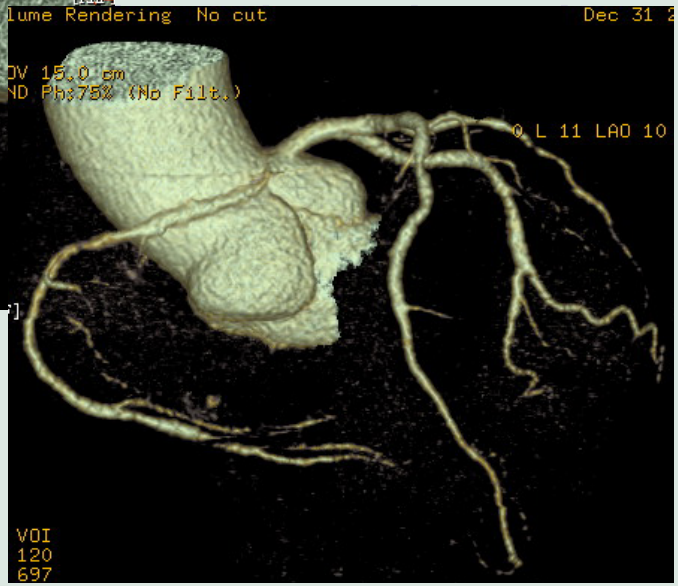


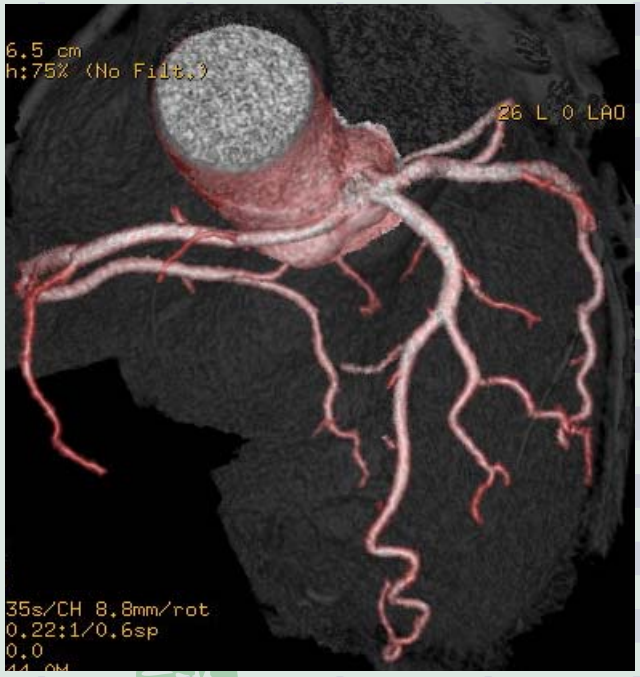
# 冠脉异常起源伴走行异常

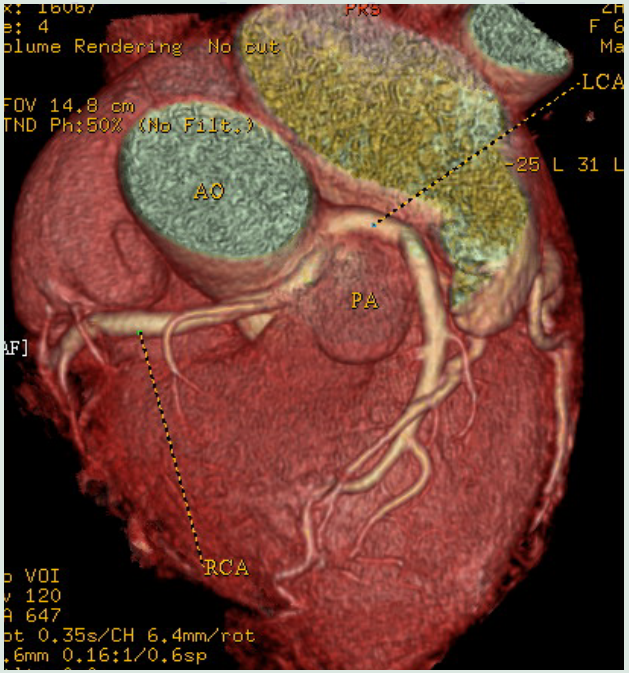


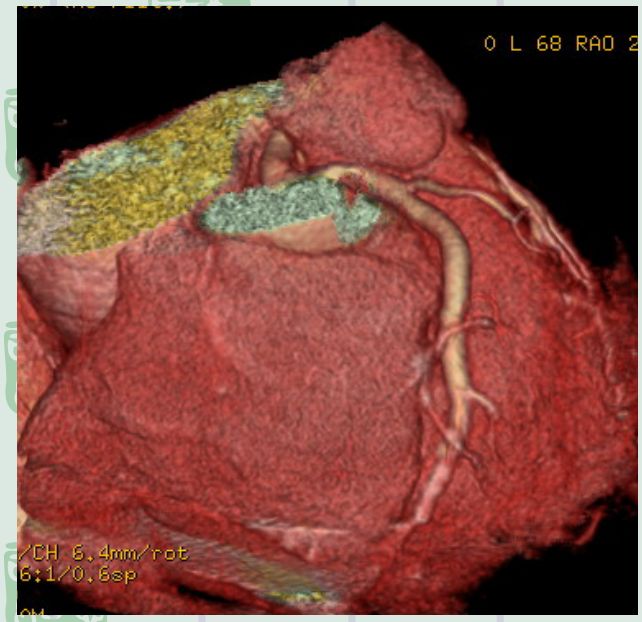





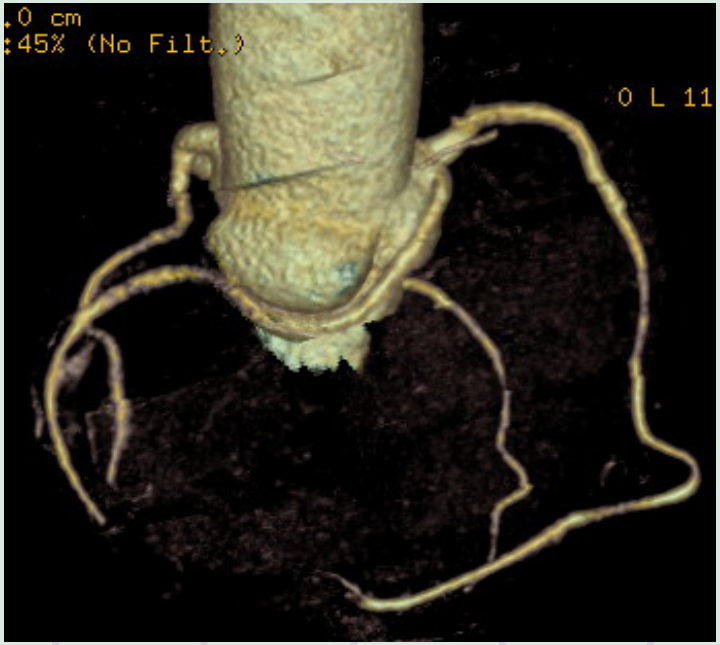

6.5 cm
h:75% (No Filt.)
26 L 0 LAO
35s/CH 8.8mm/rot
0.22:1/0.6sp
0.0

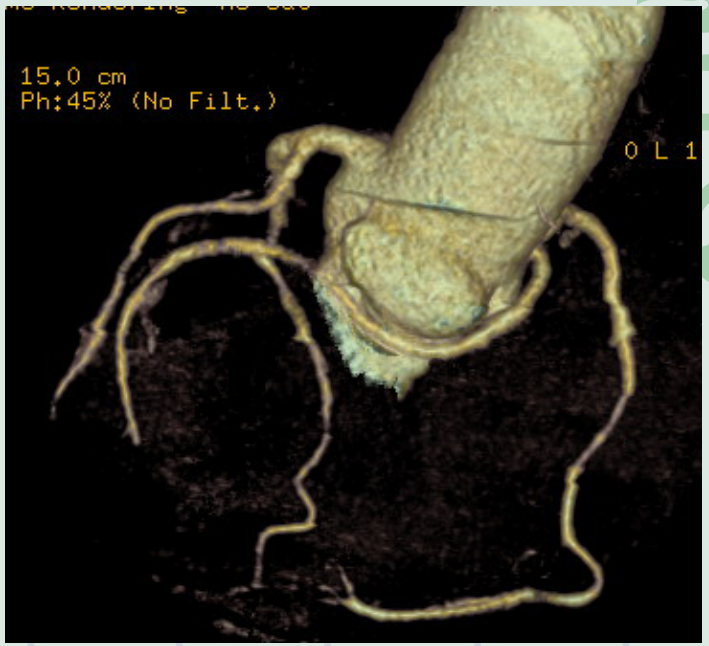

Volume Rendering No cut
FOV 14.8 cm
TND Ph:50% (No Filt.)
LCA
-25 L 31 L
AO
PA
RCA
VOI
120
647
0.35s/CH 6.4mm/rot
6mm 0.16:1/0.6sp

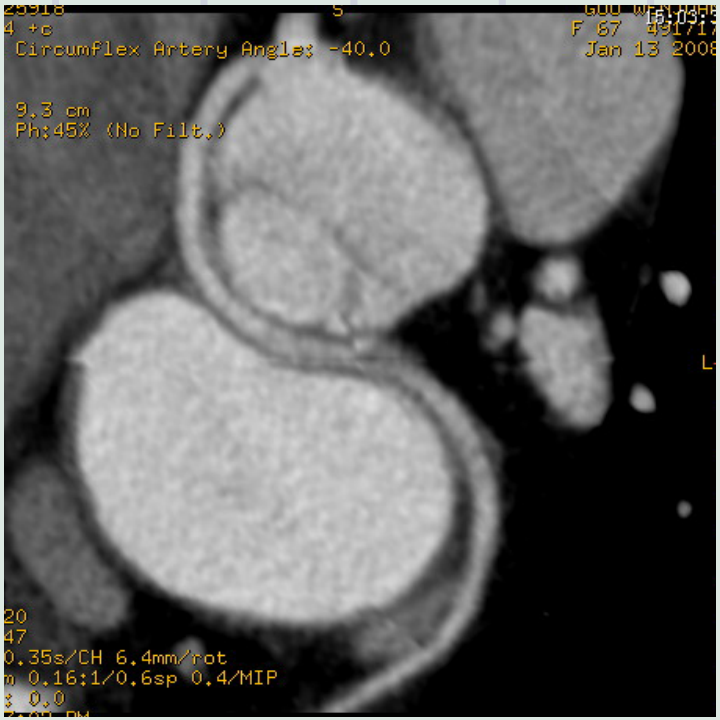

0 L 68 RAO
/CH 6.4mm/rot
6:1/0.6sp

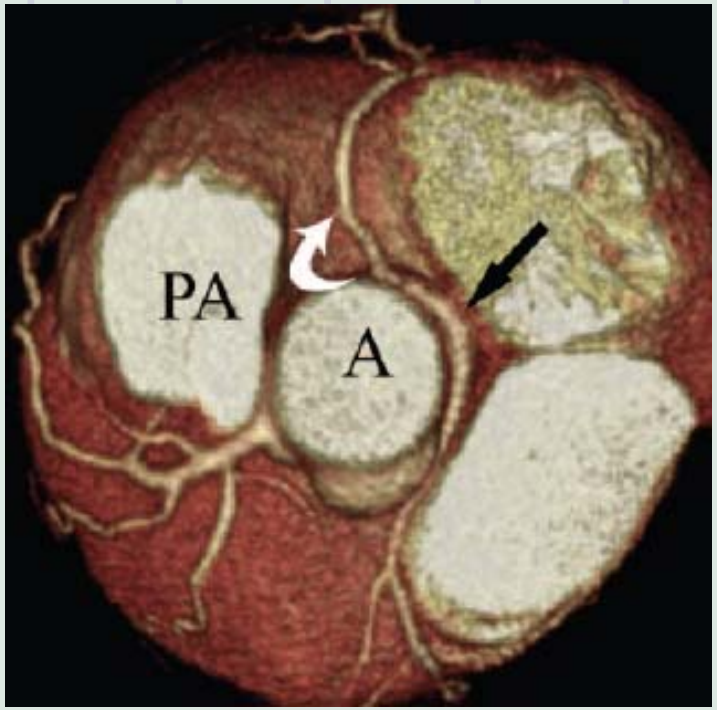

0 L 84 RA
/CH 6.4mm/rot
6:1/0.6sp

# 走行关系

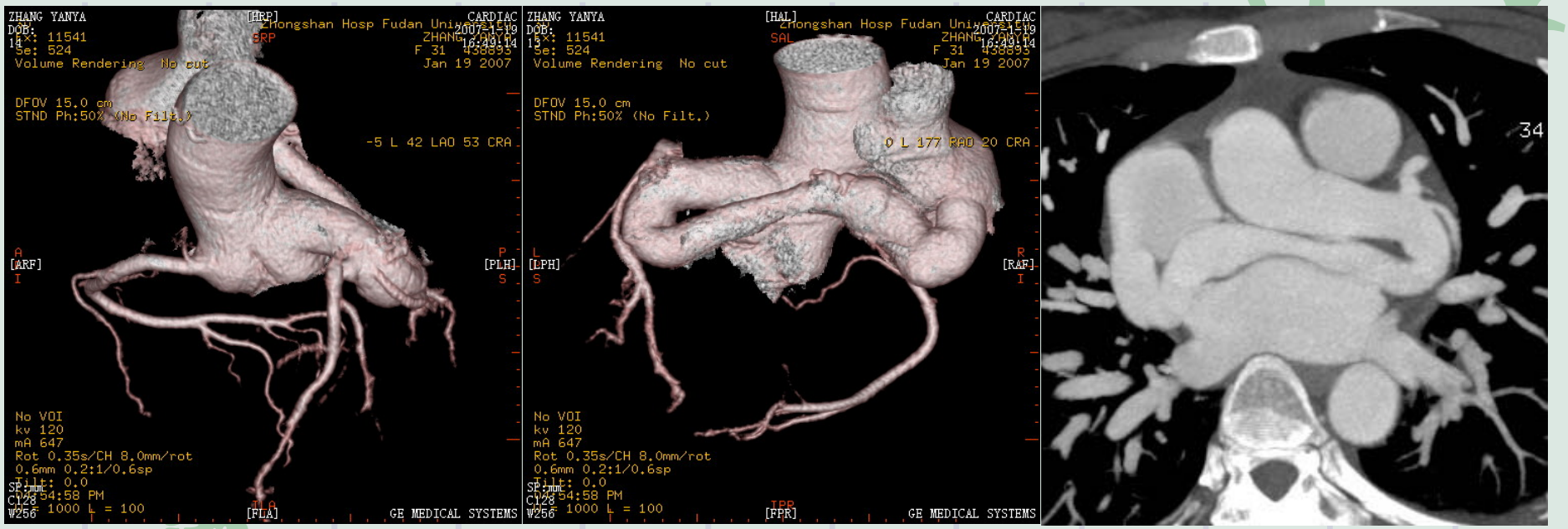

.0 cm
:45% (No Filt.)
0 L 11


15.0 cm
Ph:45% (No Filt.)
0 L 1

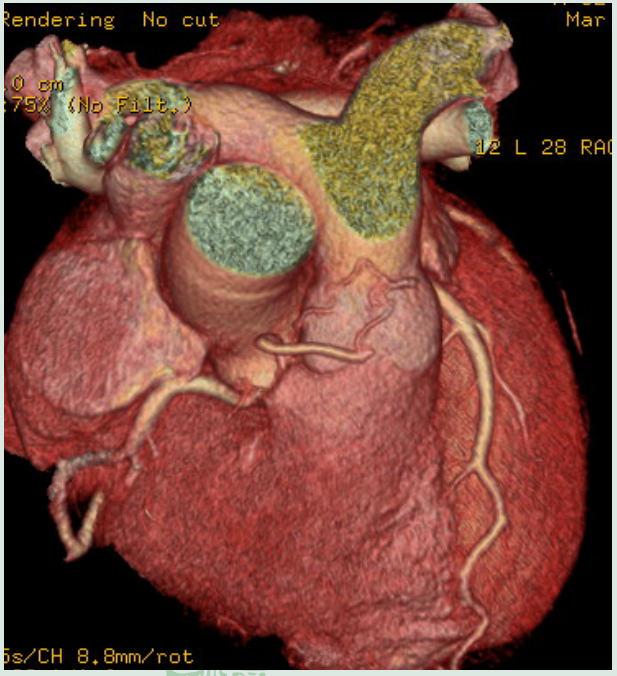

4 +c
Circumflex Artery Angle: -40.0
F 67
Jan 13 2008
9.3 cm
Ph:45% (No Filt.)
20
47
0.35s/CH 6.4mm/rot
m 0.16:1/0.6sp 0.4/MIP


PA
A

# 异常交通（瘘）


ZHANG YANYA
DOB:
Ex: 11541
Se: 524
Volume Rendering No cut
[ARP]
CARDIAC
Zhongshan Hosp Fudan Univ
2007-1-19
ZHANG YANYA
16:49:14
F 31 438893
Jan 19 2007
DFOV 15.0 cm
STND Ph:50% (No Filt.)
-5 L 42 LAO 53 CRA
[ARF]
[PLH]
No VOI
kv 120
mA 647
Rot 0.35s/CH 8.0mm/rot
0.6mm 0.2:1/0.6sp
Tilt: 0.0
54:58 PM
W256 L = 100
[PLA]
GE MEDICAL SYSTEMS
[HAL]
SAL
0 L 177 RAO 20 CRA
[LPH]
[RAF]
[FPR]
34

# 异常交通

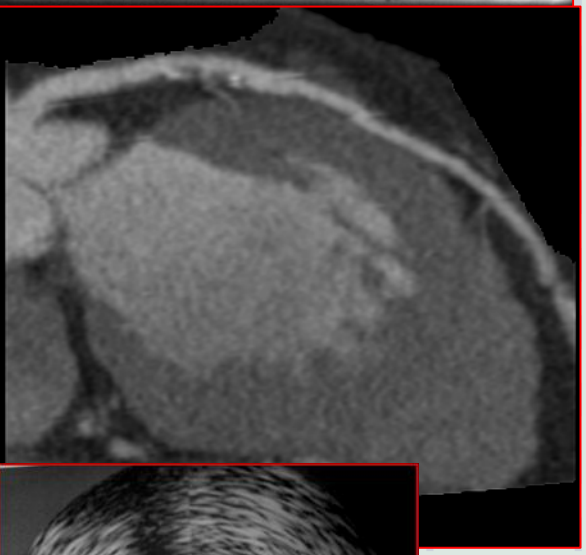

Rendering No cut
Mar
75% (No Filt.)
12 L 28 RA
5s/CH 8.8mm/rot

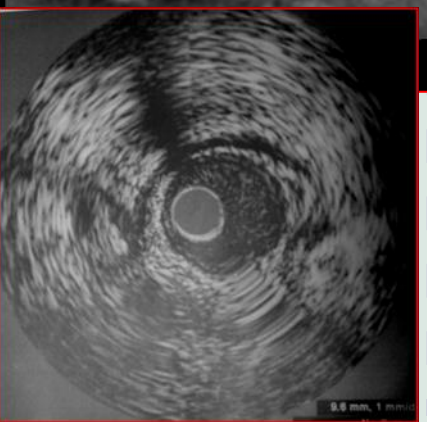

LIN DAYONG
Chongshan Hosp Fudan Univ
SPR
Volume Rendering No cut
DFOV 11.3 cm
STND Ph:45% (No Filt.)
0 L 17 LAO 42
[RAF]
Heart 3
No VOI
kV 120
mA 647
Rot 0.35s/CH 9.6mm/rot
0.6mm 0.24:1/0.6sp
Tilt: 0.0
W256 F 1534 L = -255
[FAL]
GE MEDICAL SYST

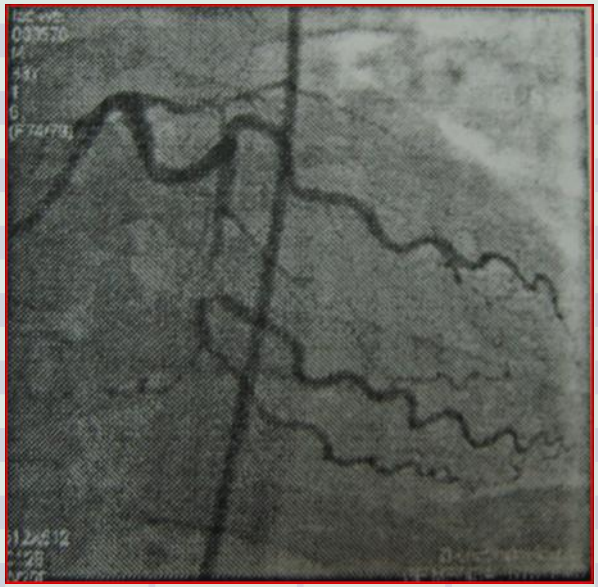

SKP
ering No cut
(No Filt.)
0 L 129 LAO 3
H 9.6mm/rot
1/0.6sp

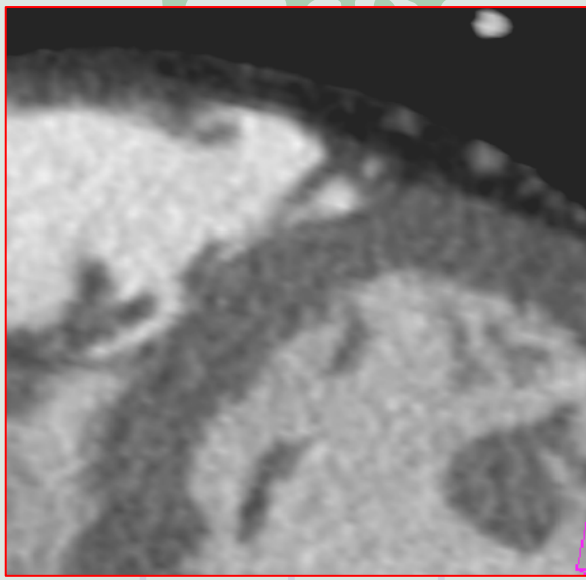
# 心肌桥

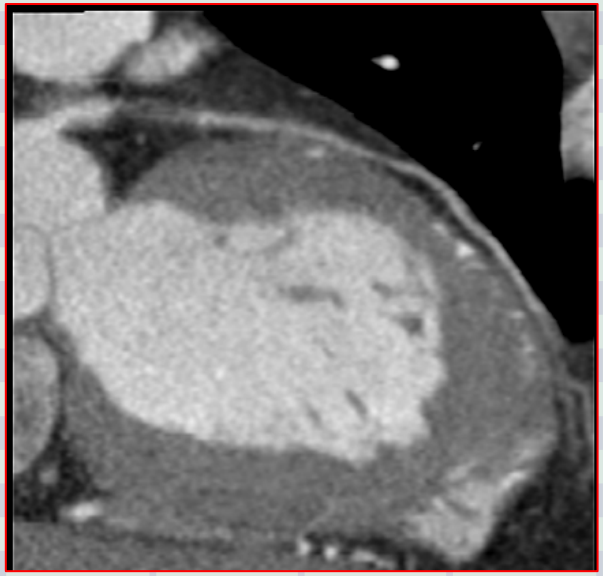
- 左前降支中段，发生率约30％左右
- 桥血管段受保护，近端粥样硬化好发部位
- 造影和血管内超声：特征性表现
- 无创性CT横断位成像，利于心肌桥检出

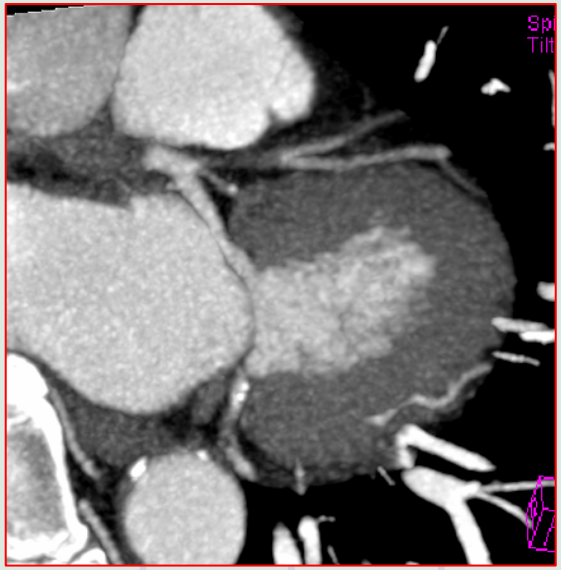


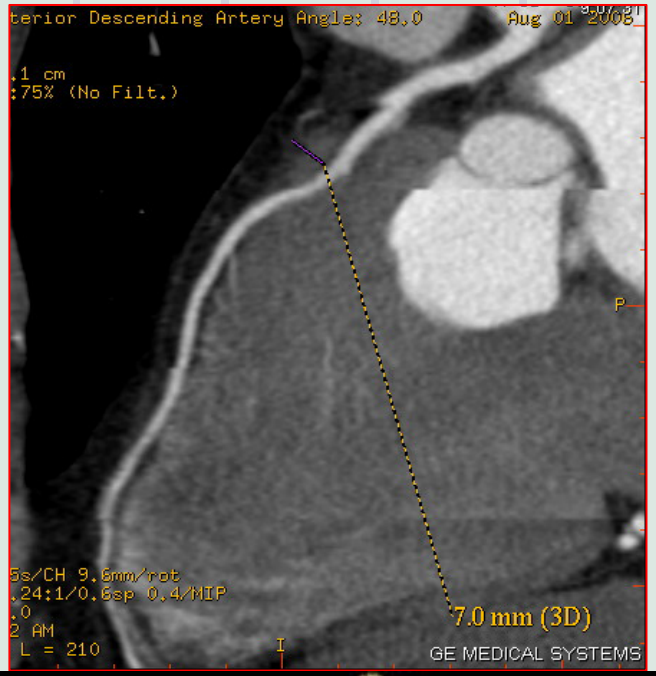











terior Descending Artery Angle: 48.0
Aug 01 2008
.1 cm
:75% (No Filt.)
P
5s/CH 9.6mm/rot
.24:1/0.6sp 0.4/MIP
.0
2 AM
L = 210
I
7.0 mm (3D)
GE MEDICAL SYSTEMS


R
L
kv 120
mA 697
Rot 0.35s/CH 8.0mm/rot
0.6mm 0.2:1/0.6sp 0.5/MIP
Filt: 0.0
10:15 PM
W 1200 L = 240
I
GE MEDICAL SYSTEMS

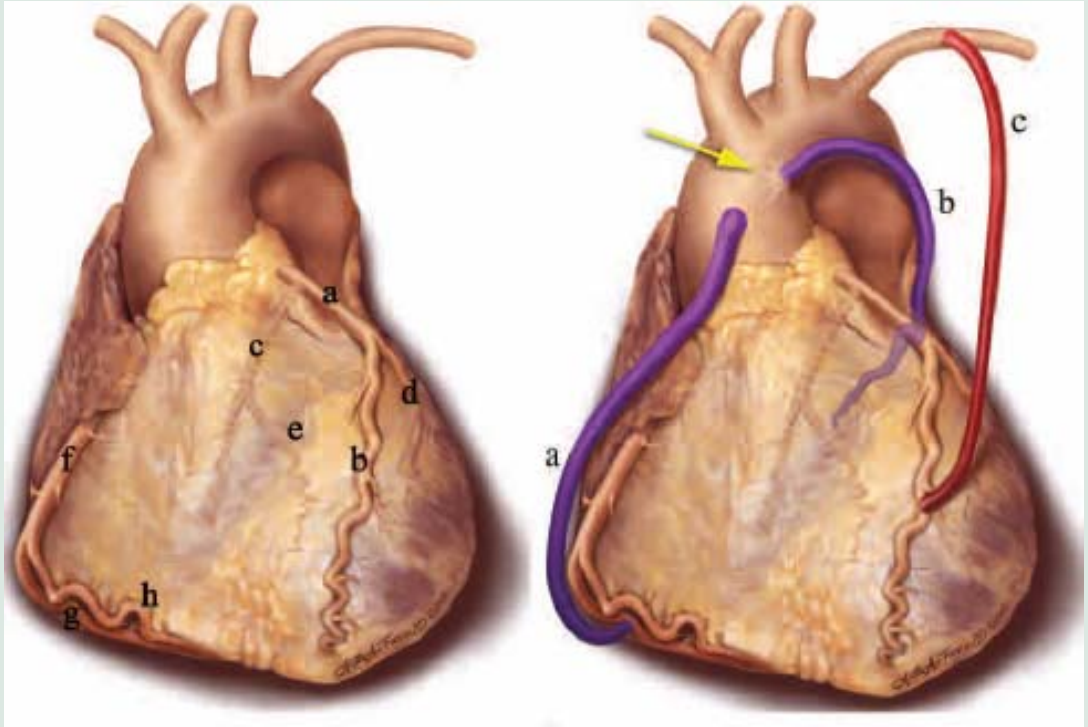

DFOV 19.0 cm
STND Ph:75% (No Filt.)
450/4
0 L 72 L
A
[ARF]
I
No VOI
kv 120
mA 597
Rot 0.35s/CH 7.2mm/rot
0.6mm 0.18:1/0.6sp
Filt: 0.0
22:12 PM

# 冠脉搭桥评价

- 检查方法
  - 检查目的
    - 评价桥血管
    - 评价术后相关并发症
  - 注意事项
    - 扫描范围
    - 重建方法
      - MRP
      - VR

# 冠脉搭桥

- 手术方式
  - 静脉桥
    - 选择的血管
    - 优缺点
  - 动脉桥
    - 选择的血管
    - 优缺点

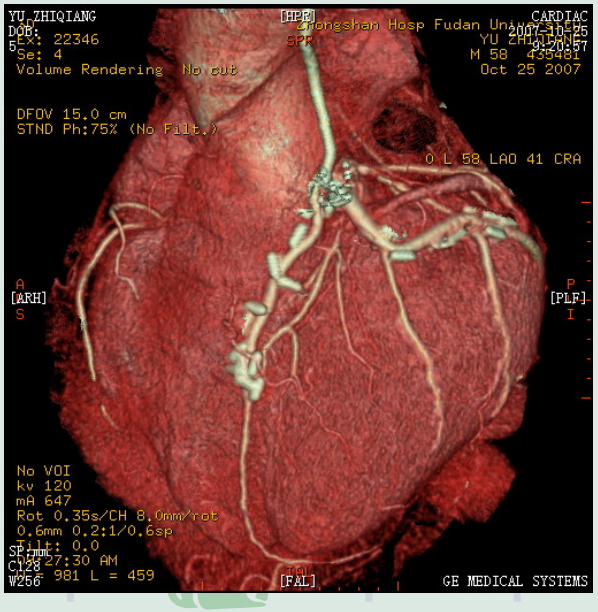


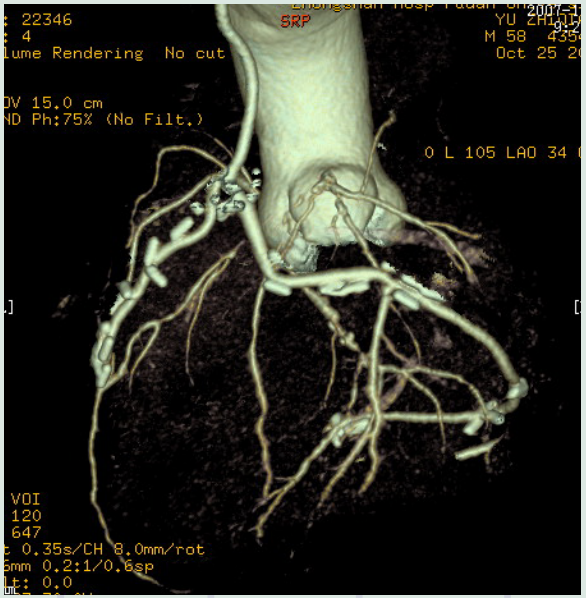
# 搭桥血管

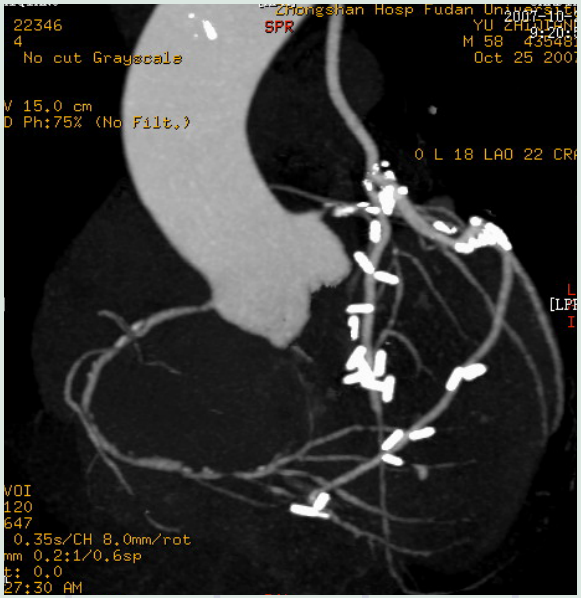
- 常见的搭桥方式
  - LIMA－LAD狭窄远端血管
  - AO/LIMA－RA－D1/Rumas－OM1－PDA
  - AO－SVG－D1/Rumas－OM1－PDA
  - AO－SVG－RCA－PDA
- 余搭桥血管
  - RIMA－游离血管/连接血管（类似RA）
  - 胃网膜血管

LIMA—RA—D1/Rumas—OM1—PDA

↘ LAD



# 冠脉搭桥并发症

- 早期
  - 血栓形成
  - 桥血管位置异常或扭结
  - 桥血管痉挛
  - 医源性并发症
  - 心包积液、胸腔积液
  - 胸骨感染
  - 肺栓塞
- 晚期
  - 血管狭窄闭塞
  - 桥血管动脉瘤

# 搭桥后血栓形成

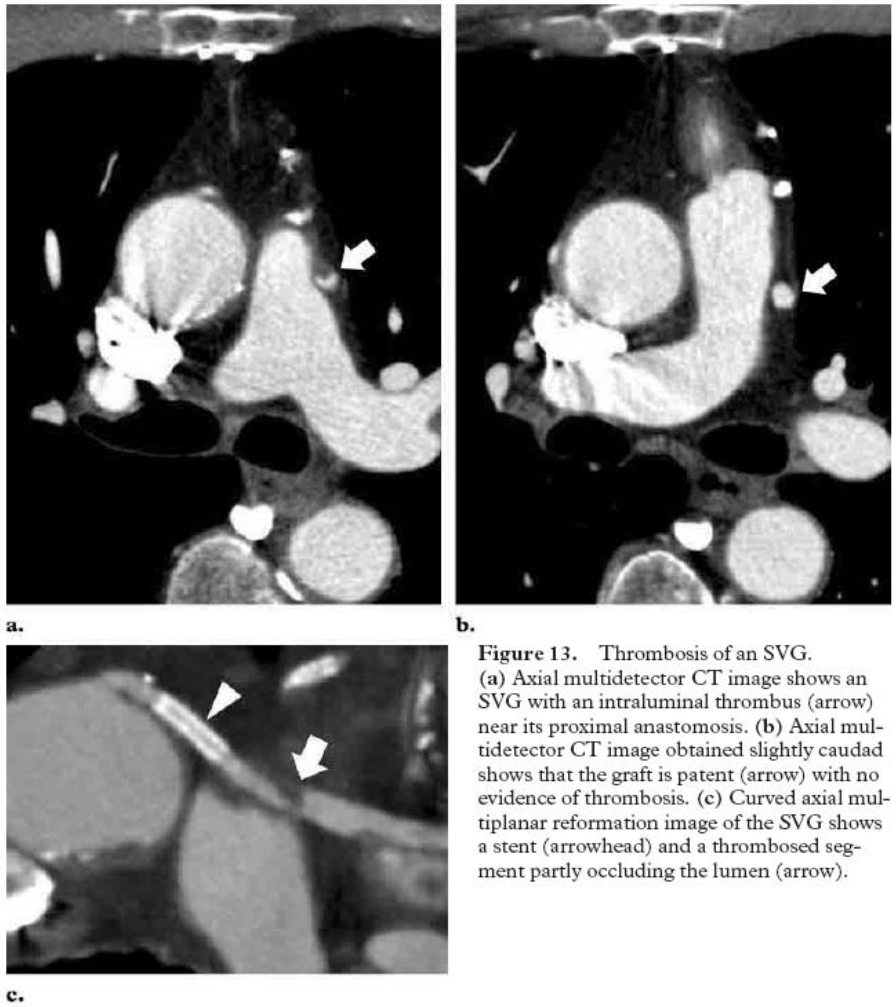
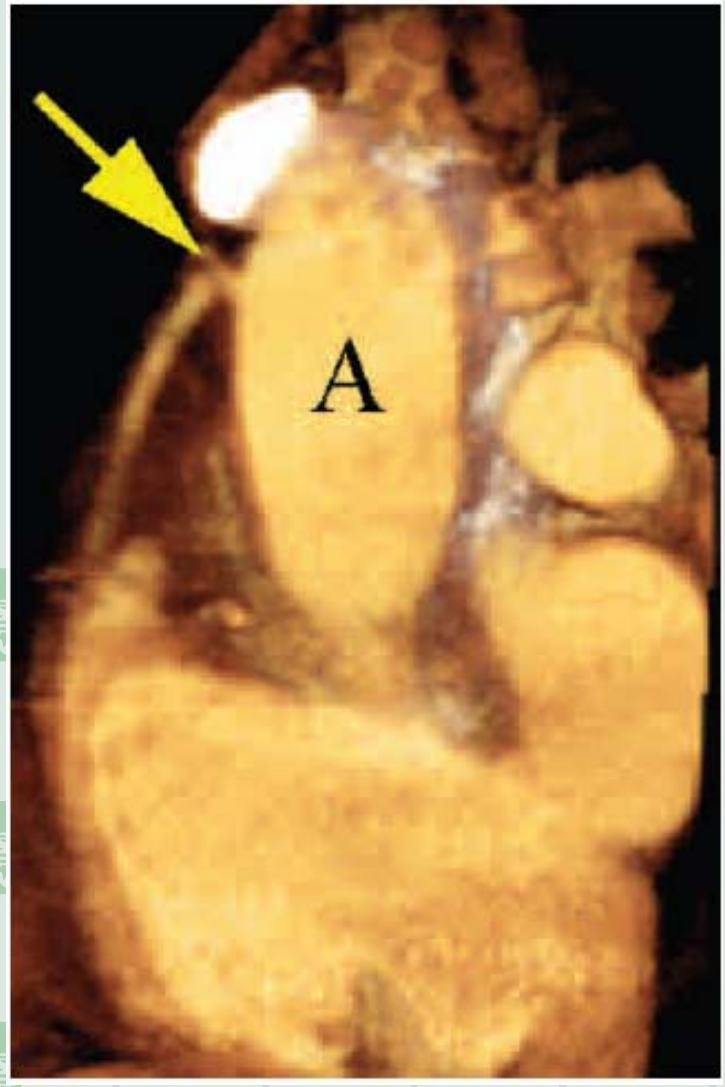



**Figure 13.** Thrombosis of an SVG. (**a**) Axial multidetector CT image shows an SVG with an intraluminal thrombus (arrow) near its proximal anastomosis. (**b**) Axial multidetector CT image obtained slightly caudad shows that the graft is patent (arrow) with no evidence of thrombosis. (**c**) Curved axial multiplanar reformation image of the SVG shows a stent (arrowhead) and a thrombosed segment partly occluding the lumen (arrow).

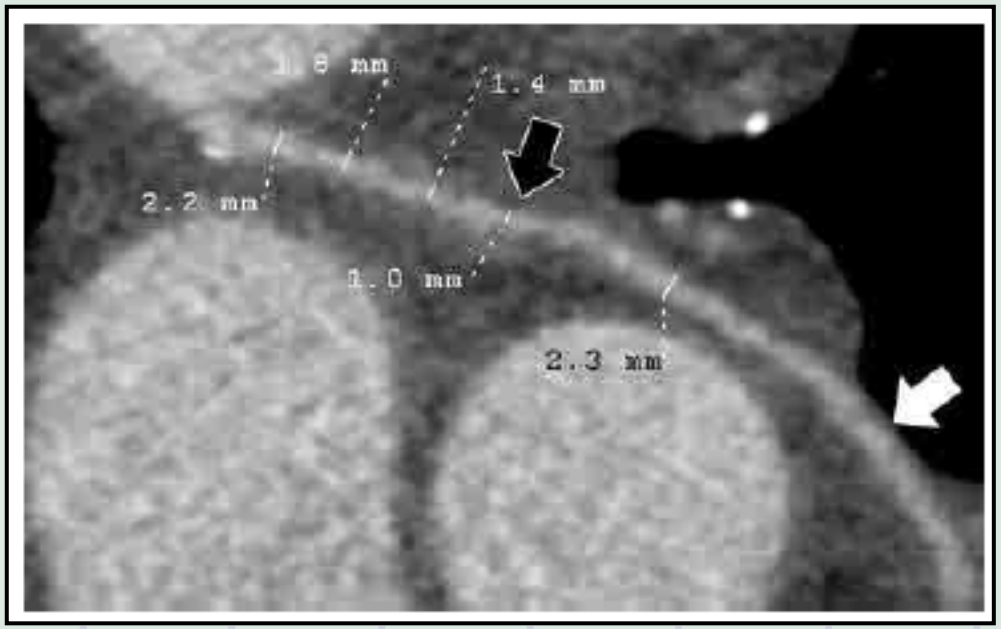
- 发生时间
- 发生率
- 发生机制
- 表现

# 桥血管位置异常或扭结



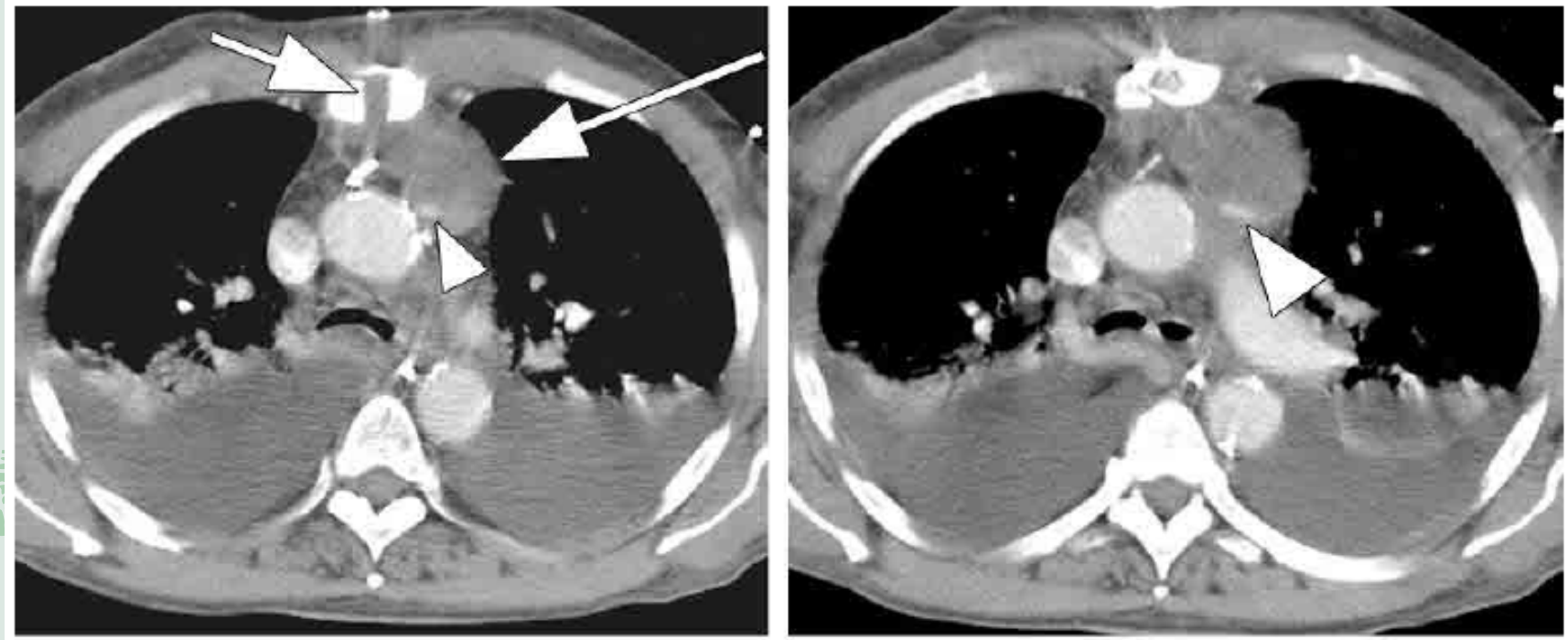

- 选择适度的静脉桥血管
  - 过长
  - 过短
- 吻合口角度

# 桥血管痉挛

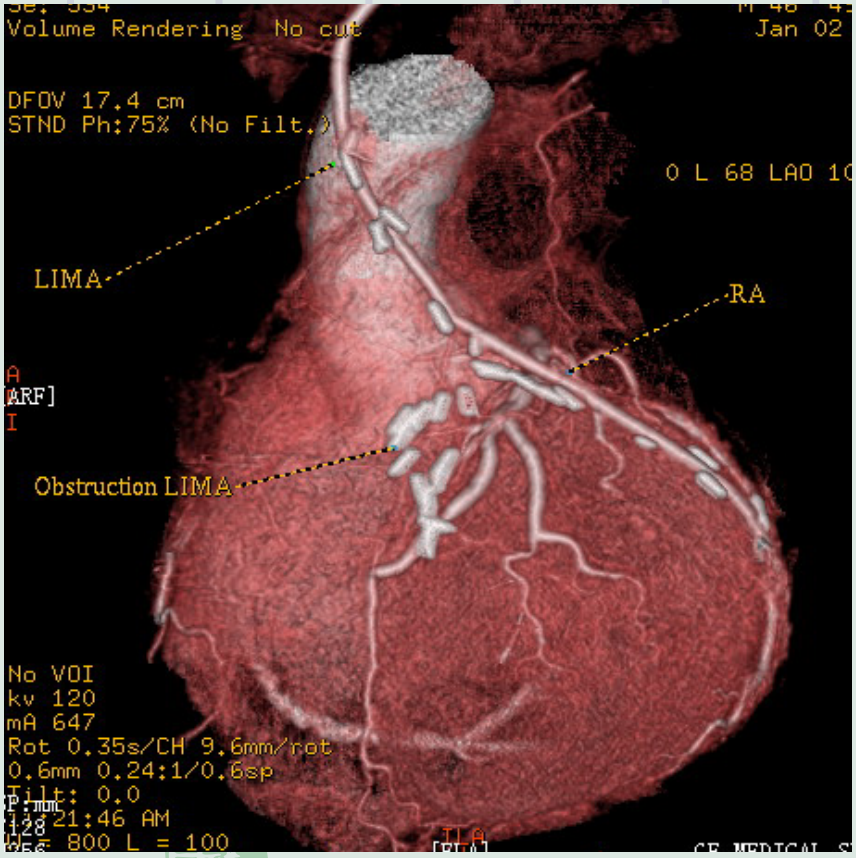


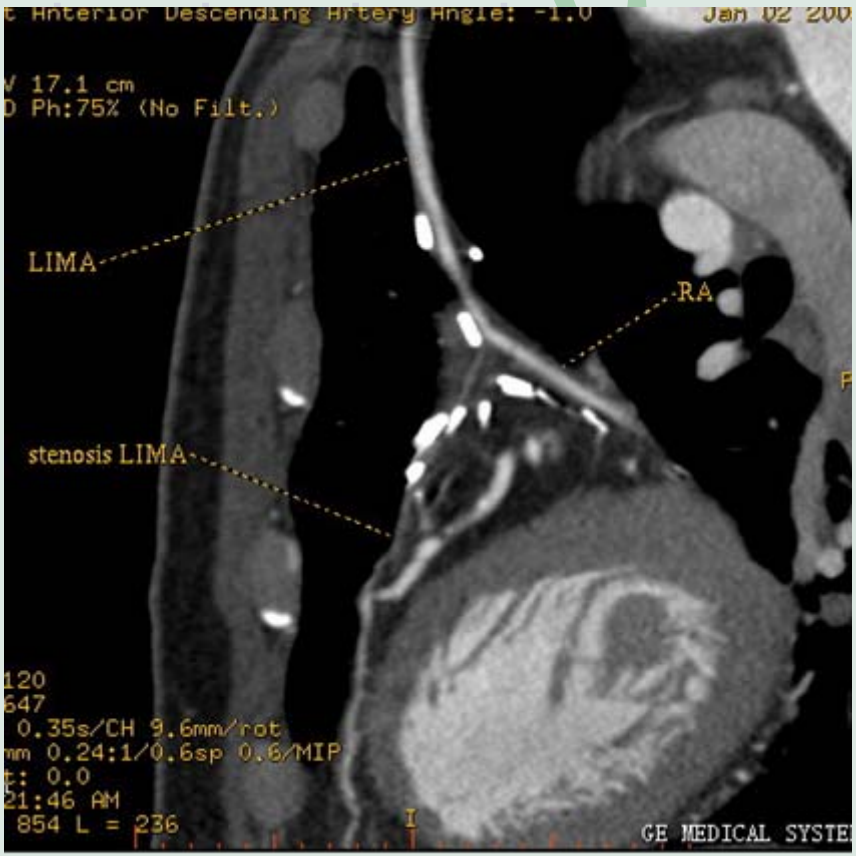

- 桡动脉最易术后痉挛

# 胸骨感染

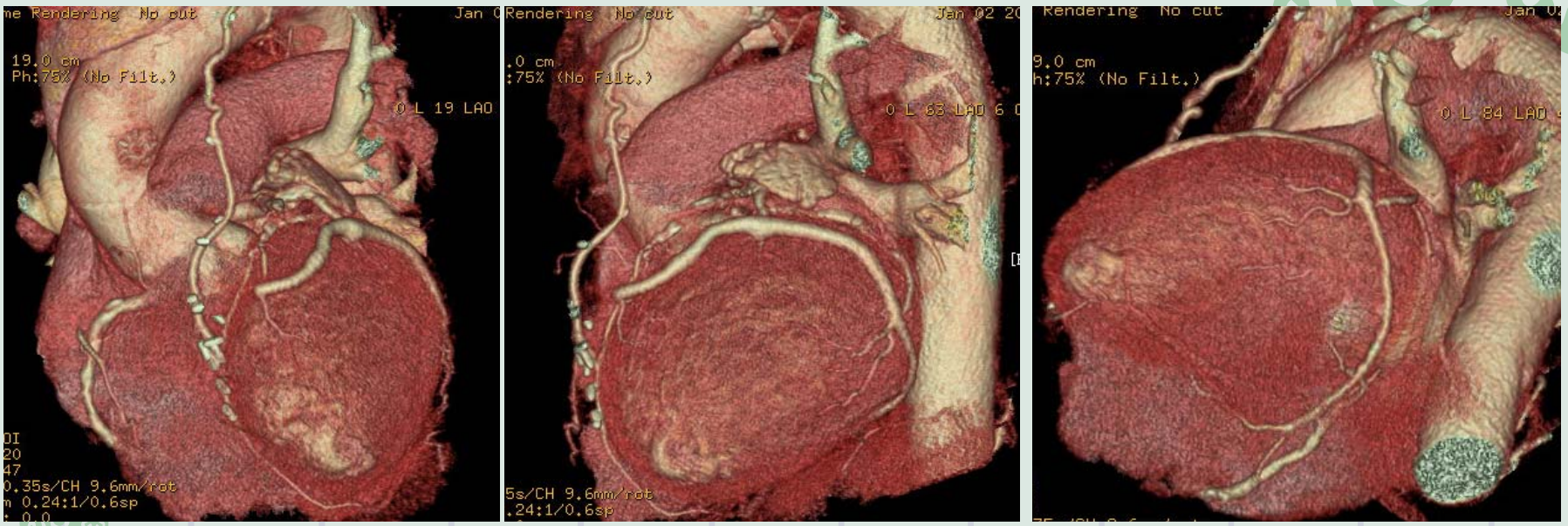


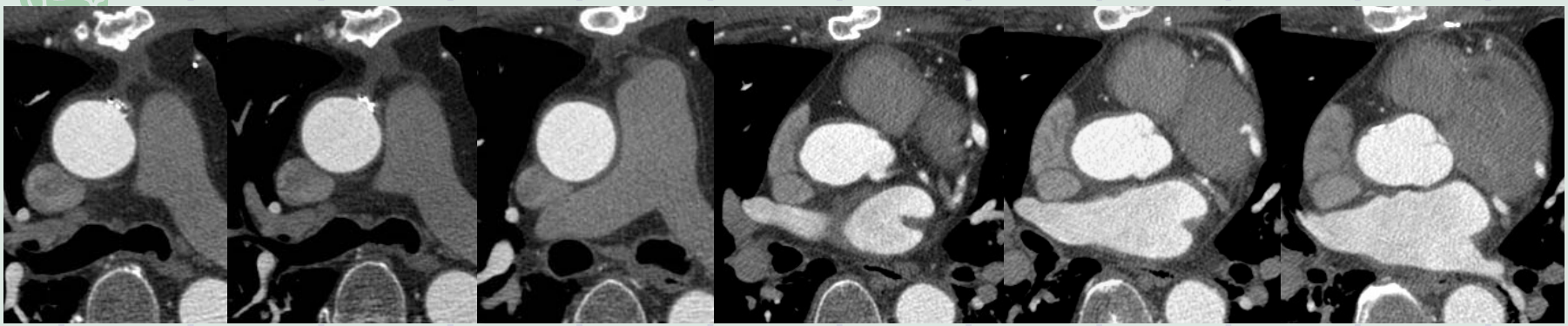
# 桥血管狭窄


Volume Rendering No cut
Jan 02
DFOV 17.4 cm
STND Ph:75% (No Filt.)
0 L 68 LAO 10
LIMA
RA
Obstruction LIMA
No VOI
kv 120
mA 647
Rot 0.35s/CH 9.6mm/rot
0.6mm 0.24:1/0.6sp
Tilt: 0.0
21:46 AM
800 L = 100


Anterior Descending Artery Angle: -1.0
17.1 cm
Ph:75% (No Filt.)
LIMA
RA
stenosis LIMA
120
647
0.35s/CH 9.6mm/rot
0.24:1/0.6sp 0.6/MIP
0.0
21:46 AM
854 L = 236
GE MEDICAL SYSTE

# 桥血管闭塞


Rendering No cut
19.0 cm
Ph:75% (No Filt.)
0 L 19 LAO
0.35s/CH 9.6mm/rot
0.24:1/0.6sp
Rendering No cut
.0 cm
:75% (No Filt.)
0 L 83 LAO
5s/CH 9.6mm/rot
.24:1/0.6sp
Rendering No cut
9.0 cm
h:75% (No Filt.)
0 L 84 LAO



# 桥血管动脉瘤