# Recent Advances in Angiography

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## Visualization of blood vessel in human

*in Jan. 1896*

*Haschek E. A contribution to the practical use of the photography according to Roentgen. Wien Klin Wochenschr 1896; 9:63*

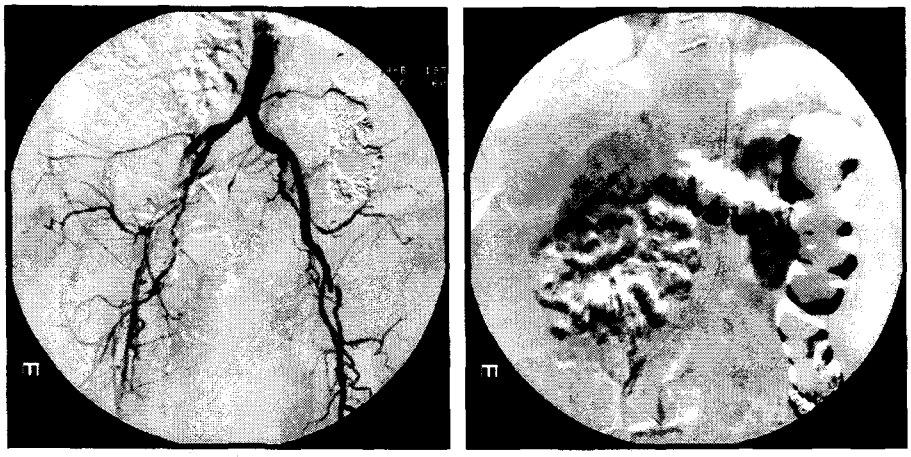
## Angiography

- Conventional X-ray angiography
- Digital subtraction angiography(DSA)
- Color Doppler imaging/ Duplex sonography(CDI)
- CT angiography(CTA)
- MR angiography(MRA)

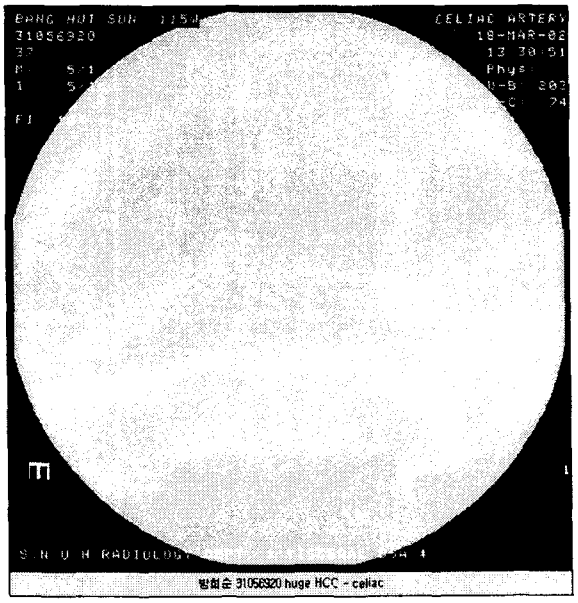
## Digital System for DSA

- Digitation / Pixel matrix
- Image-processing hardware
- Imaging-processing algorithms
  - Temporal subtraction
- Image display
- On-line disk storage
- Archival storage

# DSA artifact

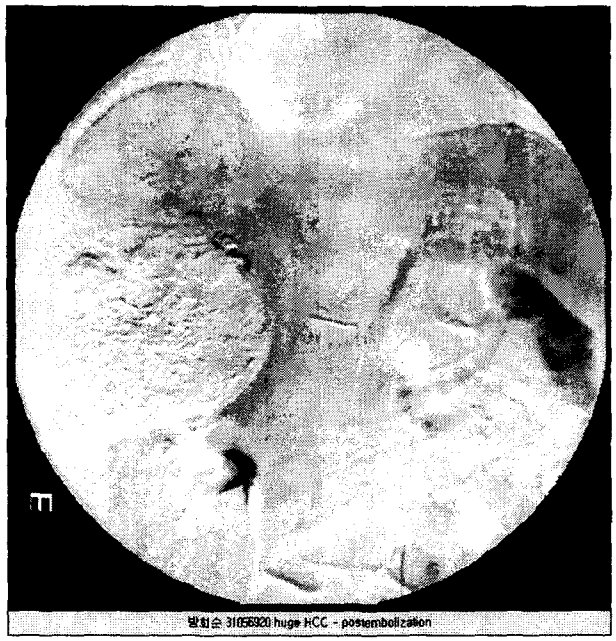


# DSA




HCC
Pre-Emb

**DSA**




HCC
Post-Emb

# Color Doppler imaging/ Duplex sonography(CDI)

# Duplex sonography

- Gray-scale B-mode imaging
- Color flow imaging
- Pulsed Doppler spectral waveform analysis
  - Sample volume
  - Doppler angle < 60°
  - Subjective to experience

# Doppler Sono

- Velocity
  - $\Delta f = 2f_0 V \cos\theta / C$, $V = C(\Delta f) / 2f_0 \cos\theta$
  - $f_0$:freq of transmitted sd.
  - V:velocity of blood cell
  - cos $\theta$:angle between sd. beam & flow
  - $\Delta f$:frequency shift
  - C:velocity of sd. in tissue

# Doppler indices

- **PI: pulsatility index**
  - **PI=peak to peak velocity / mean velocity**
- **DF: damping factor**
  - **DF=proximal PI / distal PI**
- **RI: resistive index**
  - **RI=PSV-EDV / PSV x100**

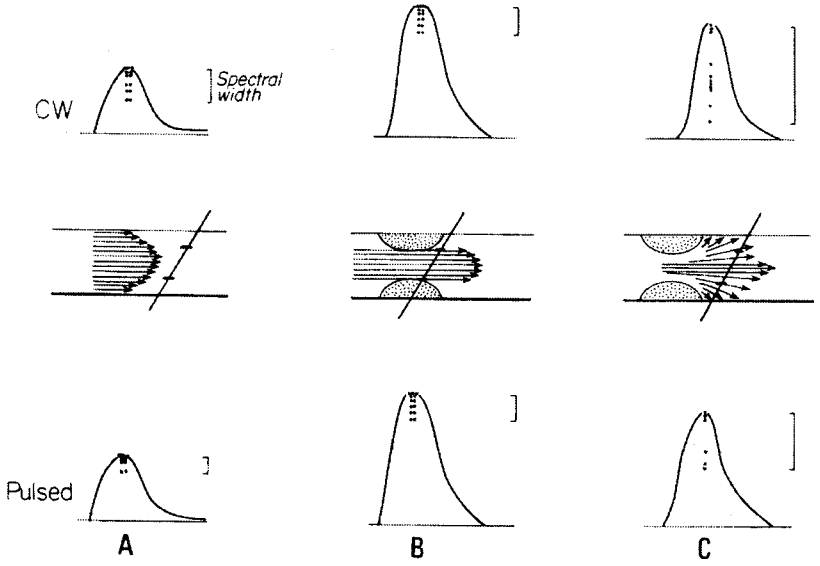
# ICA Stenosis Grading Criteria/UOW

**TABLE 12–1.** ORIGINAL UNIVERSITY OF WASHINGTON INTERNAL CAROTID ARTERY STENOSIS GRADING CRITERIA*

| DIAMETER REDUCTION (%) | DOPPLER FREQUENCY SHIFT (kHz)† |
|---|---|
| 0 | Peak systolic frequency < 4 kHz; no spectral broadening |
| 1–15 | Peak systolic frequency < 4 kHz; spectral broadening only in deceleration phase of systole |
| 16–49 | Peak systolic frequency < 4 kHz; spectral broadening throughout systole |
| 50–79 | Peak systolic frequency > 4 kHz; end-diastolic frequency < 4.5 kHz |
| 80–99 | End-diastolic frequency > 4.5 kHz |
| Occlusion | No internal carotid flow signal; flow to zero in common carotid artery |

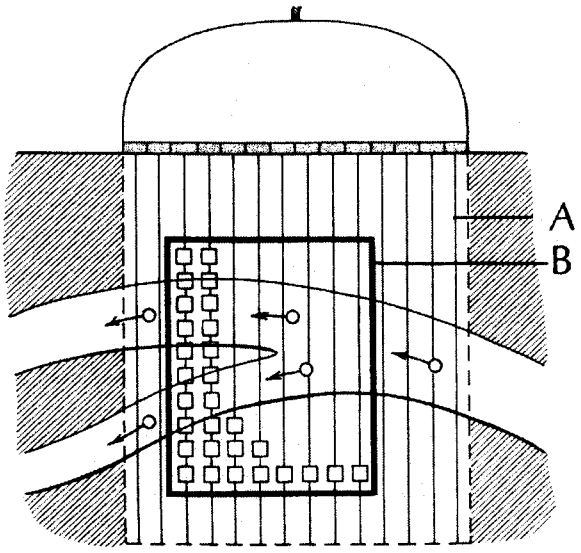
4KHz=equivalent to 125cm/sec *Rutherford RB. Vascular Surgery 2000:193*

## Doppler signal & spectral width at PS



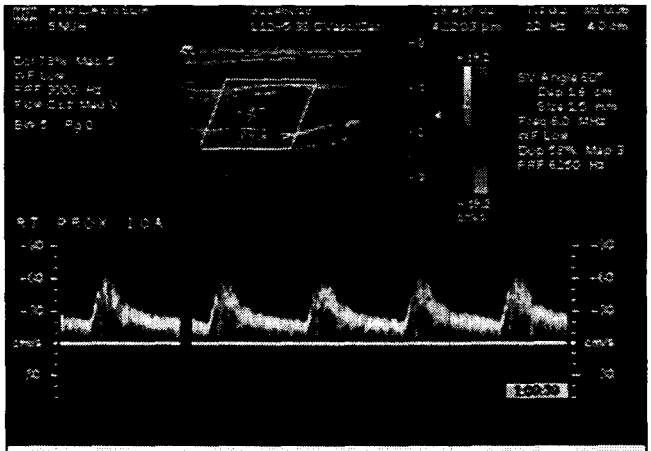

*Rutherford RB. Vascular Surgery 2000:133*

## Color-coded duplex system



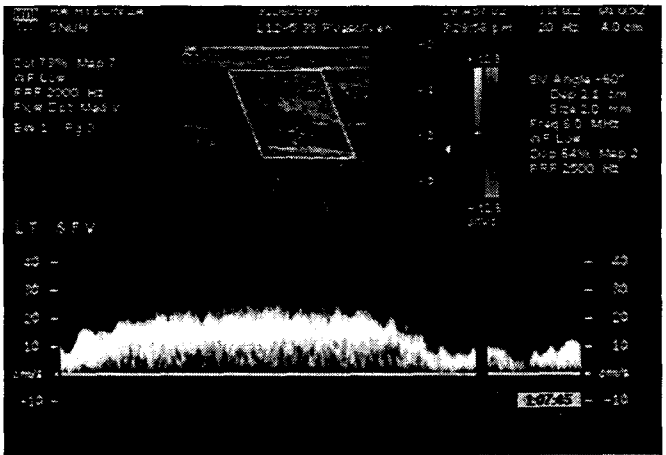

*Rutherford RB. Vascular Surgery 2000:134*

# Normal ICA



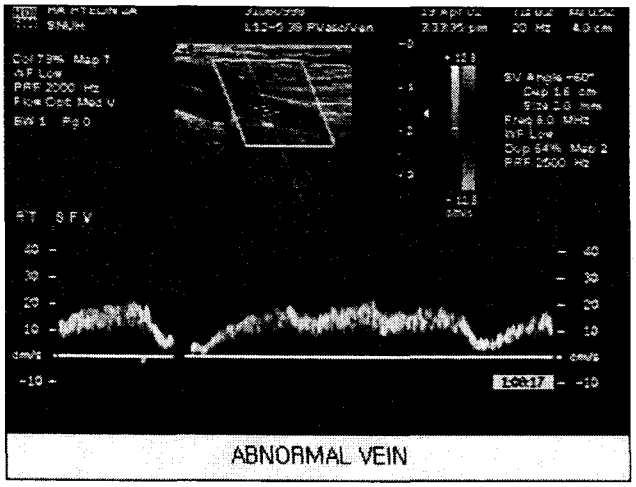
NORMAL ICA

# Normal SF vein



NORMAL VEIN

# Abnormal SF vein

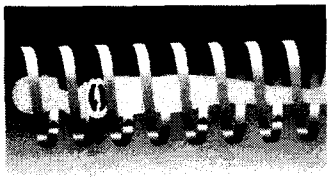


ABNORMAL VEIN

# CT angiography(CTA)

# Spiral CT

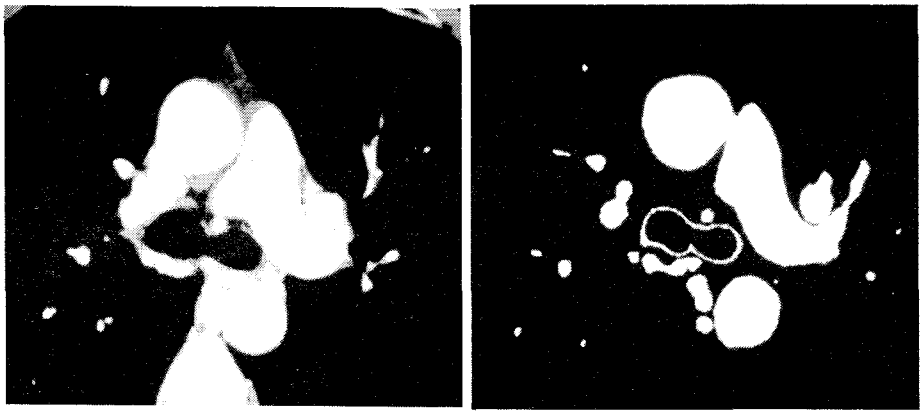
- High quality CT images
- Bolus administration of contrast agent using power injector
- Rapid scanning during maximum organ enhancement



# Steps of 3D Reconstruction

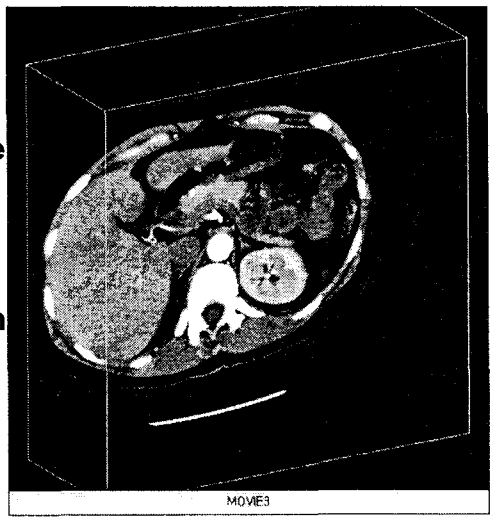
- Acquisition of volumetric data
- Determination of types of 3D recon.
- Preprocessing of data
  - Resizing, Image smoothing, Segmentation
- Volume formation
  - Stacking of the resultant data to form a volume
- 3D Image production

## Preprocessing of data



## Direct 3D

- Real-time 3D on the Operator's Console
- Can be built into the protocols
- Saves time
- 3D provides more tangible information to referring physicians



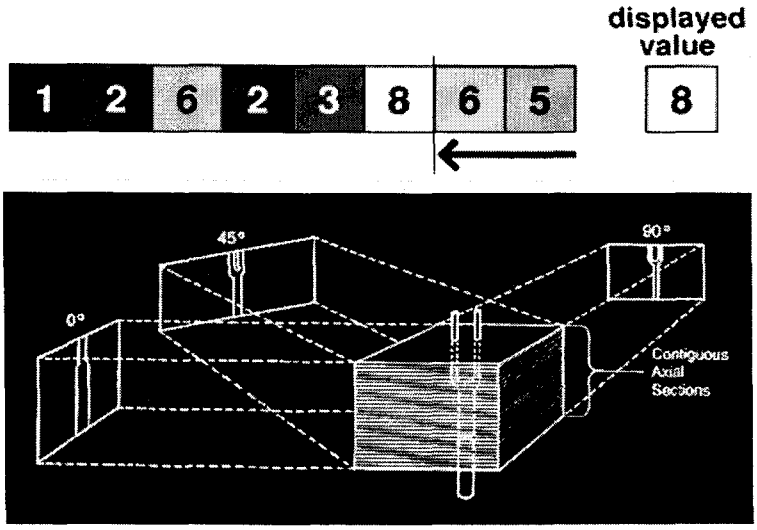
## Techniques of 3D Display

- Multiplanar Reformation (MPR)
- Maximum Intensity Projection (MIP) & Minimum Intensity Projection (MinIP)
- 3D Volume Rendering
- Shaded Surface Display (SSD)
- Ray Sum Technique
- Virtual Endoscopy

## Multiplanar Reformation

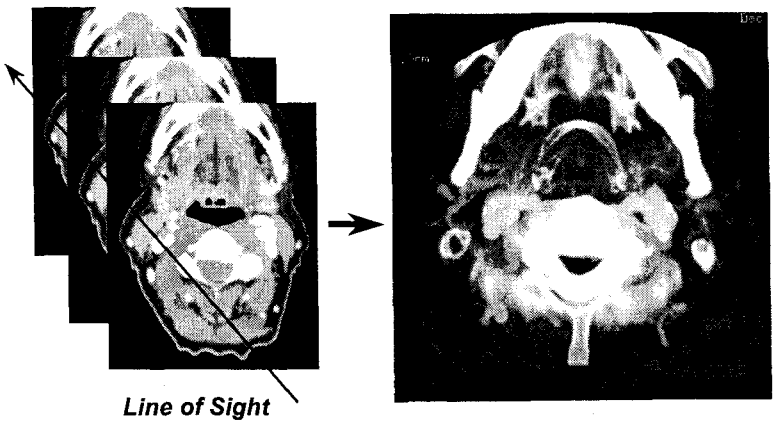
- Interactive viewing
- Reconstruction planes
  - Axial, coronal, sagittal
  - Oblique, double oblique
  - Curved planar reformation
  - Freehand drawing
- Special techniques
  - Display on 3D image
  - 3D MPR
  - Freely moving MPR plane on the volume

# MIP




# MIP

***Maximum attenuation value is mapped to a 2D gray scale image***



## MinIP

## Shaded Surface Display

# Volume Rendering

- Volume-based
- Entire volume data set
- Summation of the contribution of each voxels
- Percentage classification
- Minimize problems d/t partial volume averaging
- Increased computational requirements



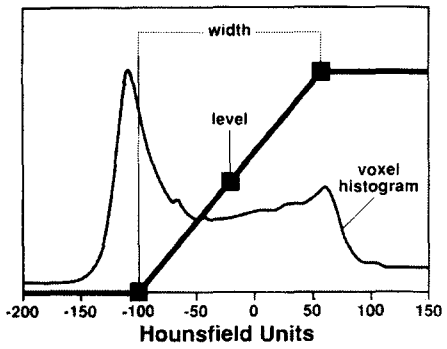
# Rendering Parameters

- Window width and level
- Opacity
- Brightness
- Color

*Volume Rendering*

# Window Width & Level

- Data segmentation on the basis of attenuation
- Setting the window width and level
- Mapping each voxel to corresponding gray-scale value
- Width: Contrast
- Level: Data inclusion
- Intraoperator variability
- Standard protocol

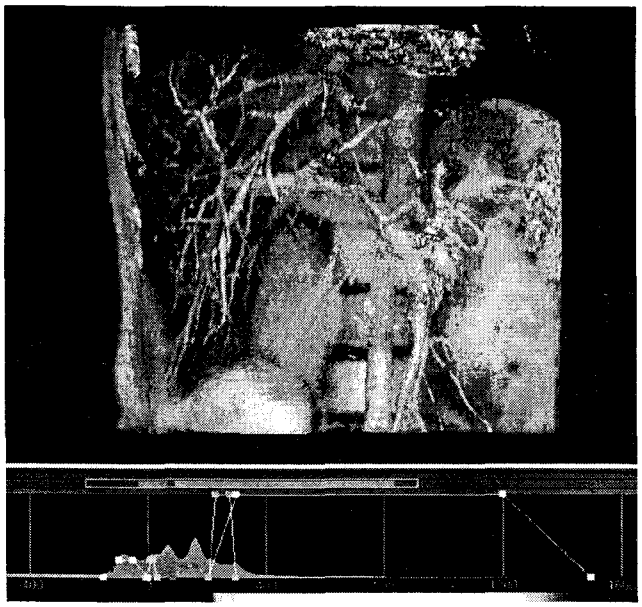



*Volume Rendering*

# Opacity

- Degree of obscuration between the closer and further to the user
- 0% (Transparent) to 100% (Obscured)
- Applications
  - Intravascular thrombus
  - Subcortical lesion
  - CT gastrography, bronchography, etc.

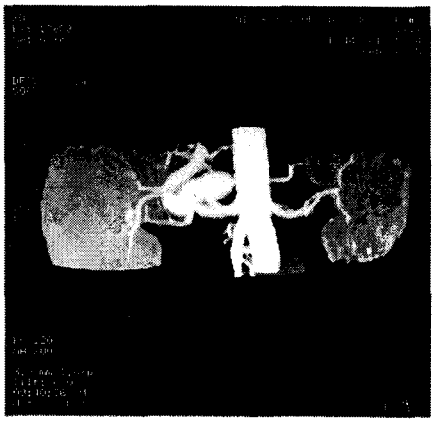
## Multiple Threshold & Color Coding



## RaySum Technique

- Adds the pixel values along the line of sight
- Resultant display is similar to an X-Ray image
- Looks *through* the vessel
- Excellent for displaying overlapping vessels

**MIP Projection**



**Raysum Projection**

## SnapShot Burst Imaging

**A retrospectively gated reconstruction, which uses data from up to 4 cardiac cycles within the same heart phase to produce an image.**

- **Used for patients with heart rates of 65-110 bpm**
- **Temporal resolution ~ 125ms to ~65ms**
- **0.5 or 0.6 sec scanning**

# SnapShot Clinical Examples

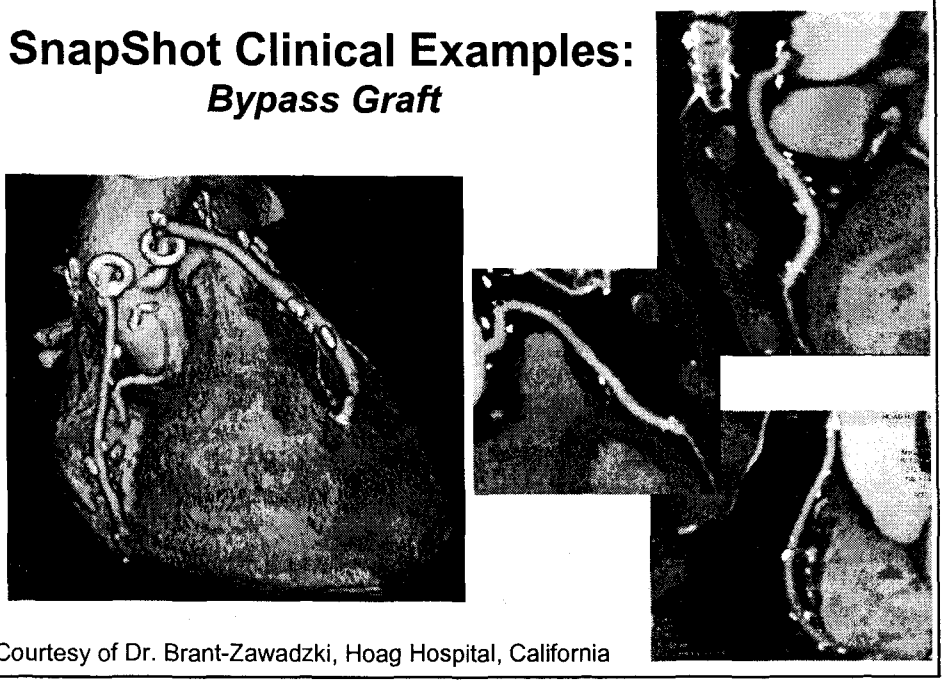
## *LAD and LCx Coronary Arteries*

Curved Reformation

Courtesy of Dr. Brant-Zawadzki, Hoag Hospital, California

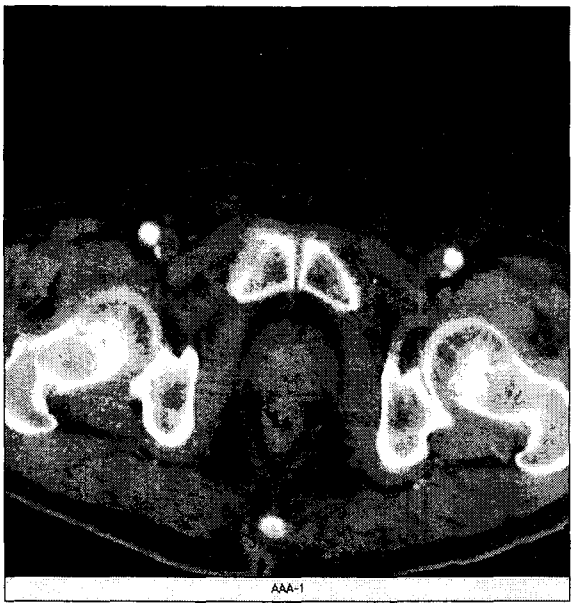
# SnapShot Clinical Examples:

## *Bypass Graft*



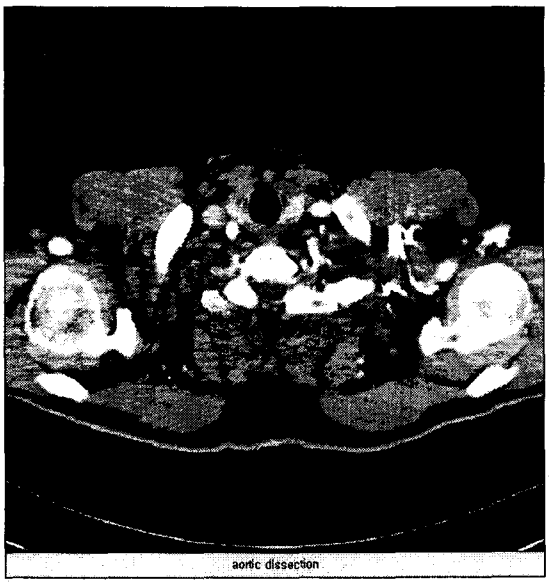
Courtesy of Dr. Brant-Zawadzki, Hoag Hospital, California

# AAA



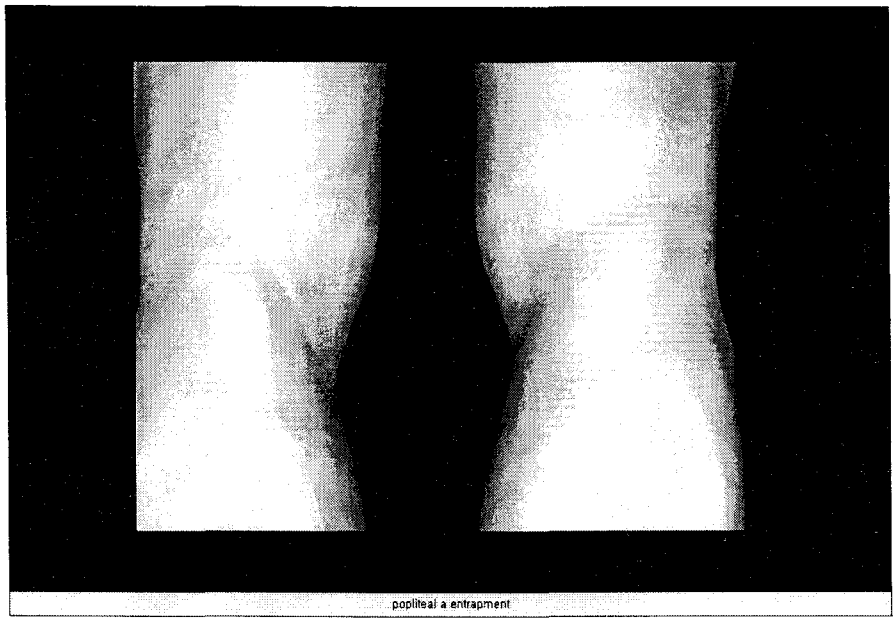
AAA-1

# Aortic dissection



aortic dissection

## Popliteal a. entrapment syndrome



popliteal a entrapment

## MR angiography(MRA)

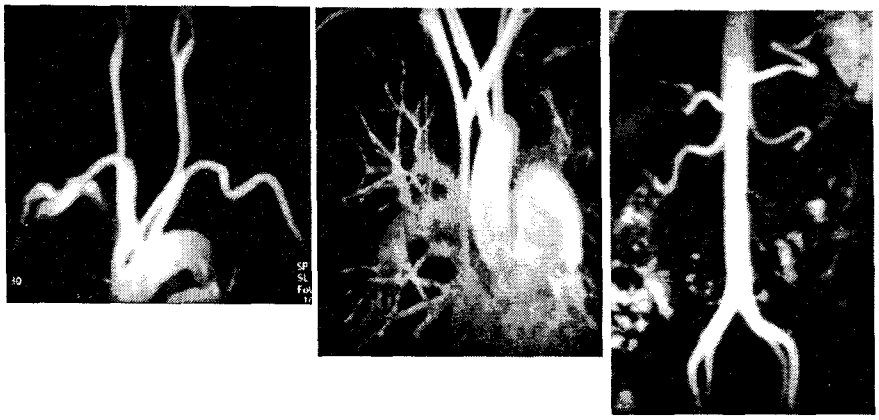
## MR Angiography

- Time-of-flight technique
- Phase contrast technique
- Gd-enhancement & subtraction
- Background supression techniques

## Technique of Gd-E MRA

- Gd-DTPA: 0.2 mmol/kg
- Subtraction: Pre-, Post-injection 2cc/sec, acq-imm. after
- 3D-FISP, TR/TE/FA: 9.3/2.9/30-40
- Coronal slab: 80-112/20-28(4mm thick)
- FOV: 375X500 mm
- Time of acq.- 01:02

## Gd-E MR angiography



## MR Angiography

*MRA of thoracic aorta in patient with coarctation.*

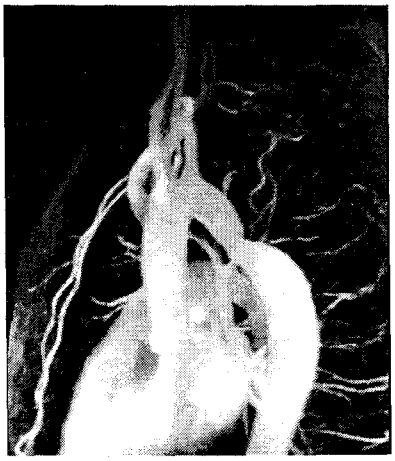
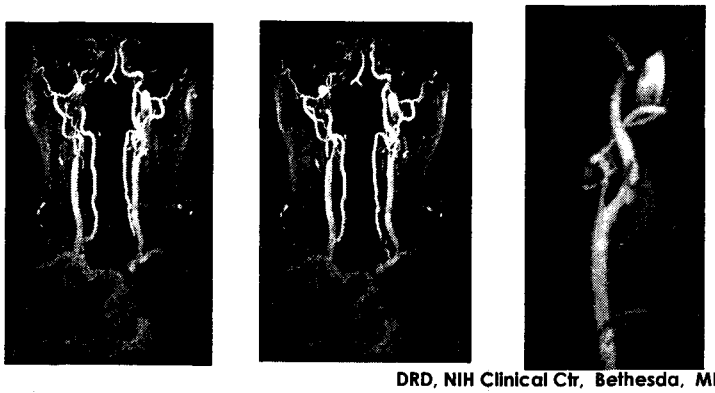


Image courtesy of Univ. Dept. Of Radiology, Cambridge, UK

GE Medical Systems

## MR Angiography - *Elliptical Centric View Ordering*



DRD, NIH Clinical Ctr, Bethesda, MD

- 32 X 84 X 256 / 1.0 NEX acquisition
- allows longer scan times : 41 sec acquisition
- 0.625 mm/pixel spatial resolution
- little or no signal from jugular veins

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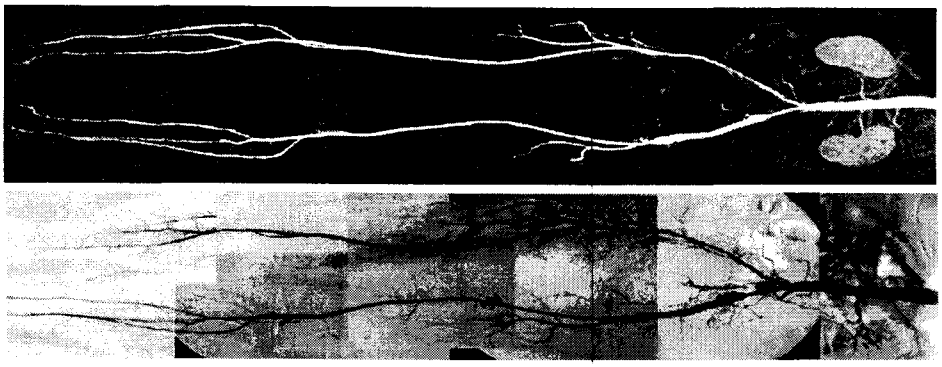
## MR Angiography - Bolus Chased Peripheral MRA



Images courtesy of CHU Nancy, FR

- 3 stations; 14 seconds per station, 5 seconds between stations
- Single Gad. injection, 30ml, 0.8ml/sec. , 40 slices / 4mm / Zipx2 / 72 sl. recon. / 256x192
- Scan parameters : TR=4.3ms / TE=1.4ms / 35° FA / 62kHz BW / FOV = 42cm / 0.75 Ph. FOV

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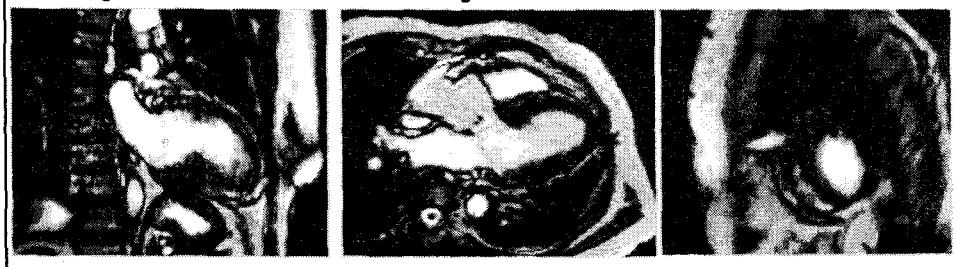
## Case History: CoA

- 63-year-old female patient
- intractable hypertension during 30yrs
- to rule out renovascular hypertension

## Cine MRI

Vertical Long-axis view | Horizontal Long-axis view | Short-axis view

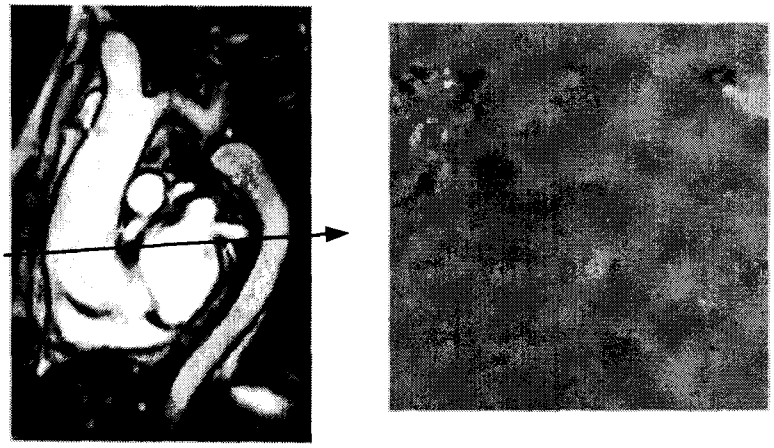


Functional parameters
by Short-axis Cine MRI

Stroke Volume = 75.7 ml
Ejection Fraction = 74.9%
Mass = 181 gm

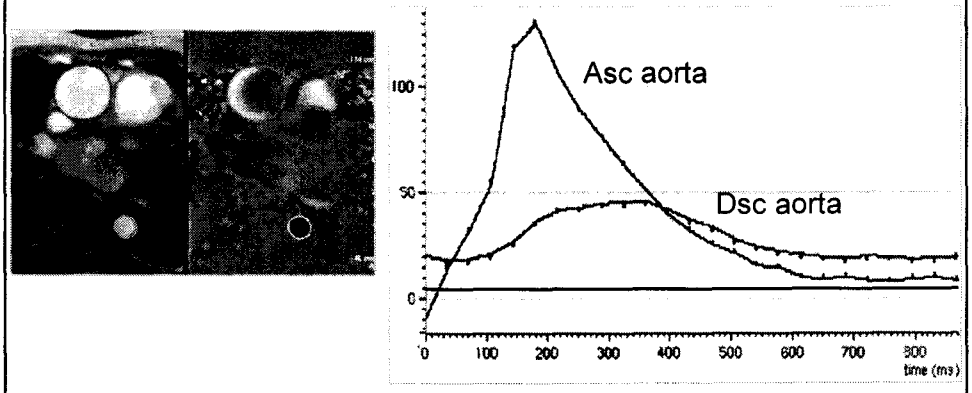
## Velocity encoded MRI

*Phase contrast MRI*

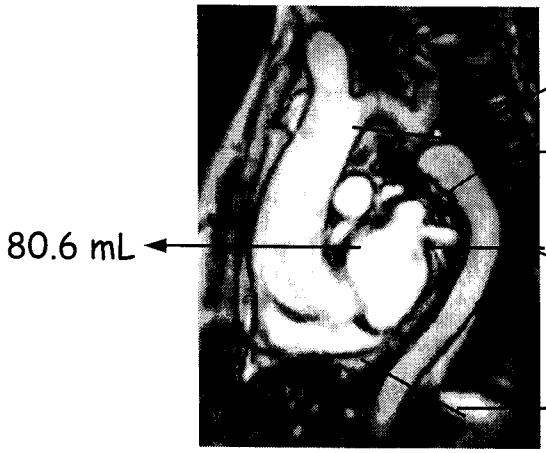


## VENC MRI

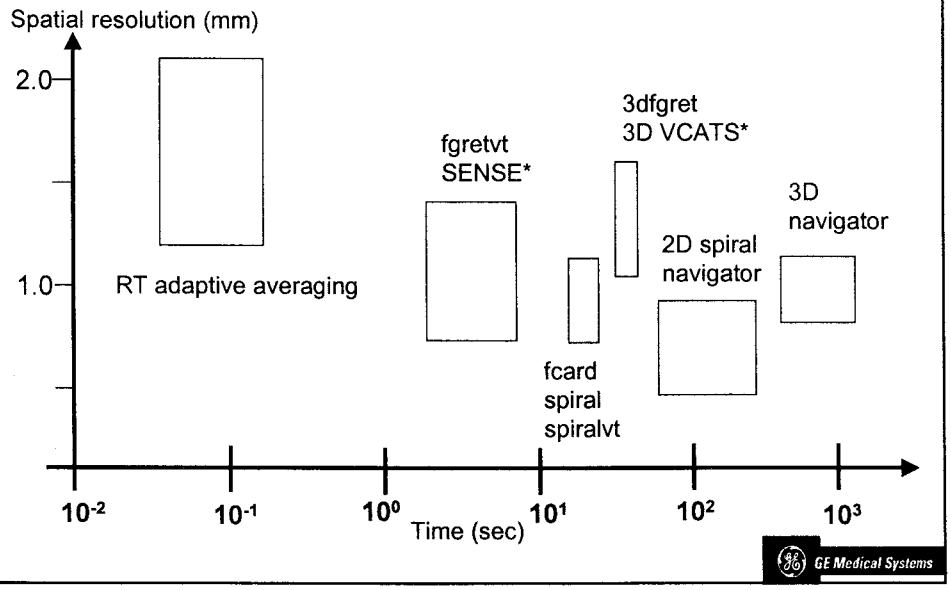
*Analysis*



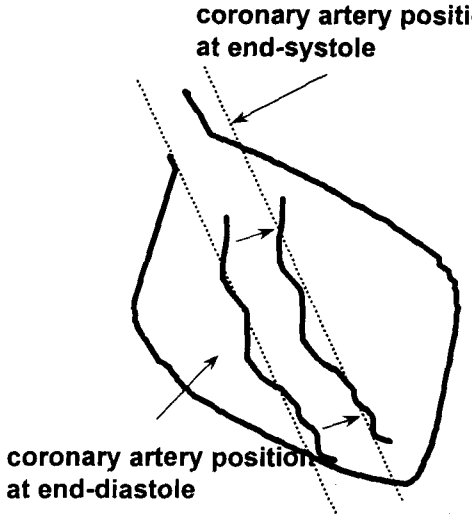
## Stroke Volume Profile by VENC MRI




## Coronary Artery Imaging Development Strategy *Image Acquisition Time and Spatial Resolution*



# Fastcard Vessel Tracking




No Vessel Tracking

Vessel Tracking

# Coronary MRA - 2D Spiral Vessel Tracking

- Non-contrast
- Acquisition plane follows motion of coronary arteries
- 0.83 mm spatial resolution

Image courtesy of Dr. Vince Ho, Uniformed Services University of the Health Sciences (USUHS) /National Naval Medical Center (NNMC) Bethesda, MD

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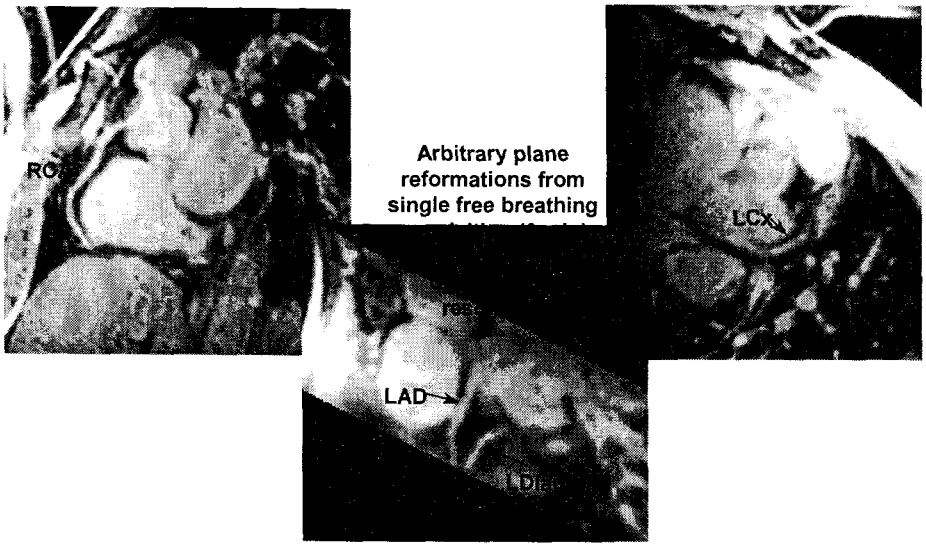
## Coronary MRA - 3D Navigator Technique




Images courtesy of Cardiac Energetics, NHLBI

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## Problems in vascular imaging

- What is the true gold standard?
- Surgically excised Specimen
  - Enbloc endarterectomy specimen
- Contrast angiography: 2-D nature
- Risk of angiography→era of CTA, MRA & Duplex
- Functional information?