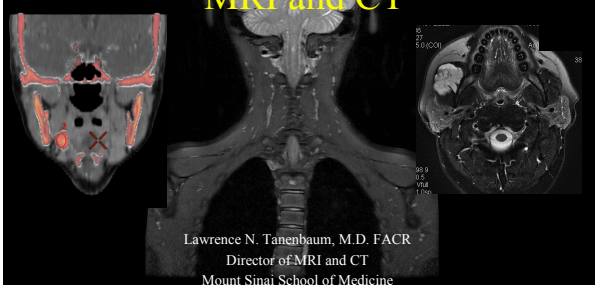
Optimizing Head and Neck MRI and CT



Lawrence N. Tanenbaum, M.D. FACR
Director of MRI and CT
Mount Sinai School of Medicine
New York, New York

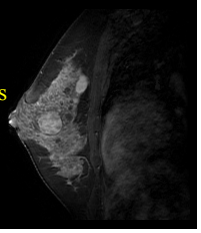
Opportunities in head and neck imaging

- MRI
  - Fat-water separation imaging
  - Radial imaging
  - ~~Optimized DWI~~
- CT
  - Dual energy imaging
  - Dose optimization

Fat-water separation

Chemical shift based imaging

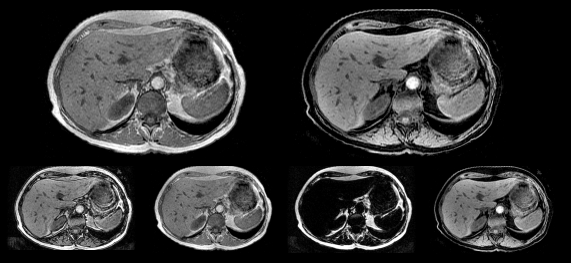
- Dixon techniques for water and fat separation
  - IDEAL, FLEX, DIXON
  - Proset, Water excitation, PASTA
- T1W, T2W, 2D, 3D imaging
- insensitive to field inhomogeneities
- little SNR loss or contrast change



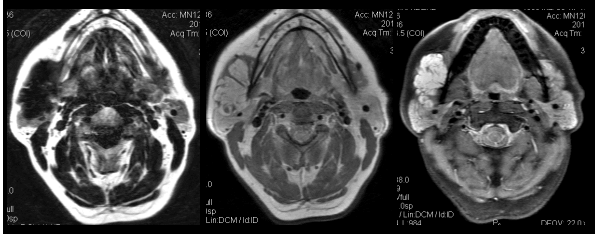
Fat-water separation

Chemical shift based imaging

- enhanced 2 point (GRE) and 3 point (FSE) Dixon reconstructions
- Water, fat, in phase and out of phase imaging via TE manipulation

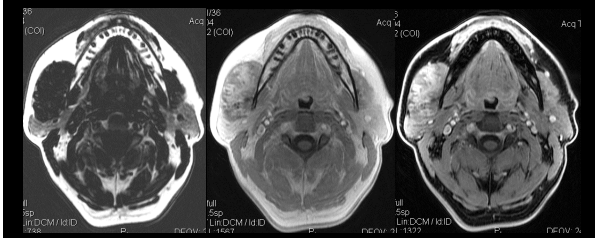


Fat-water separation imaging – T1 FSE

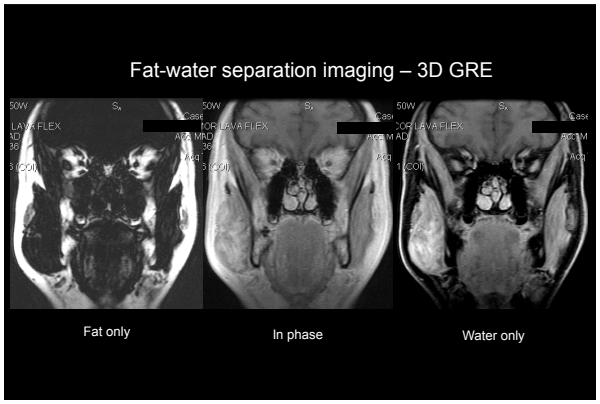


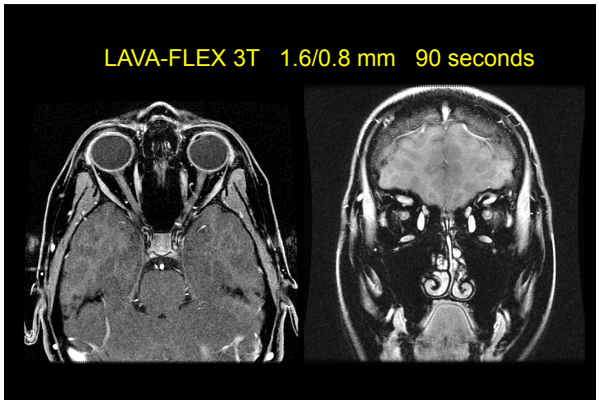
Fat only | In phase | water only

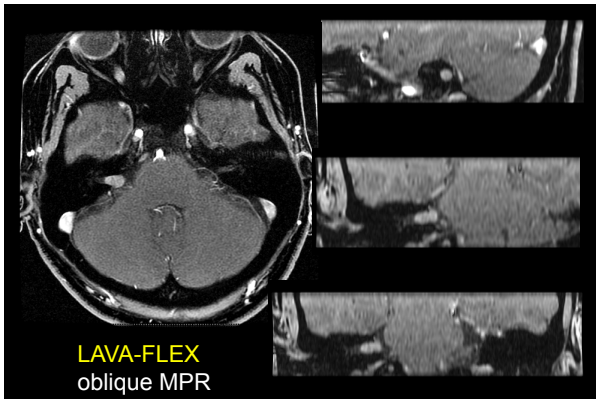
Fat-water separation imaging – 3D GRE

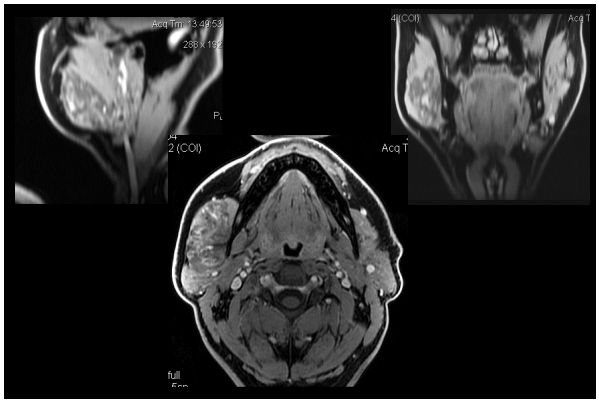


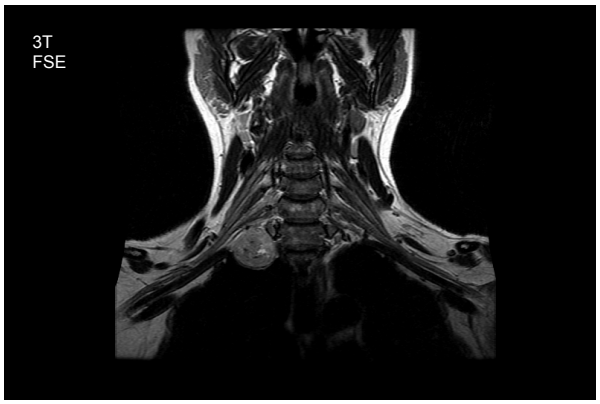
Fat only | In phase | Water only


Fat-water separation imaging – 3D GRE
Fat only
In phase
Water only


LAVA-FLEX 3T 1.6/0.8 mm 90 seconds

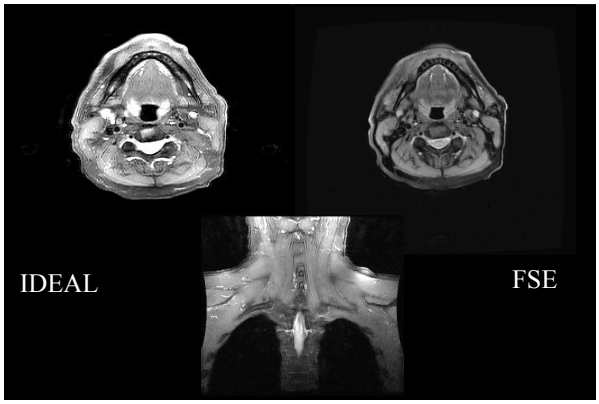

LAVA-FLEX
oblique MPR

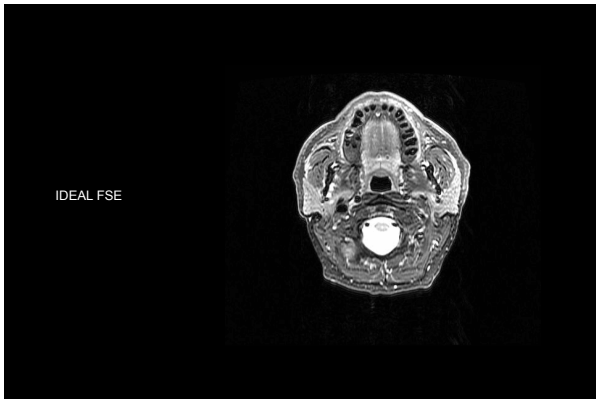


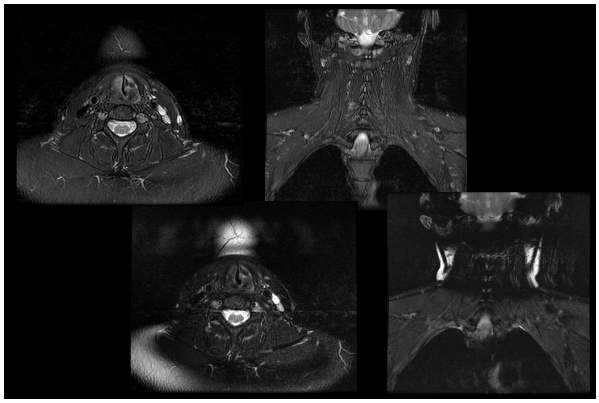

3T
FSE

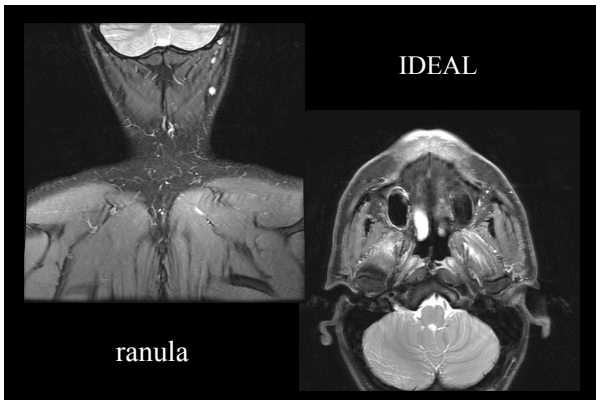

2 point
GRE
Chemical shift
(LAVA-FLEX)

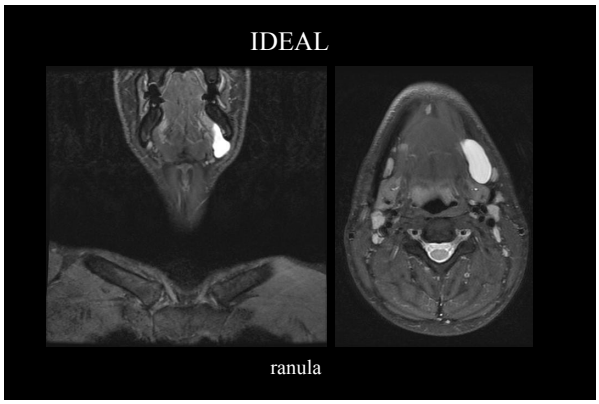

3 point FSE
Chemical shift
(IDEAL)
3T

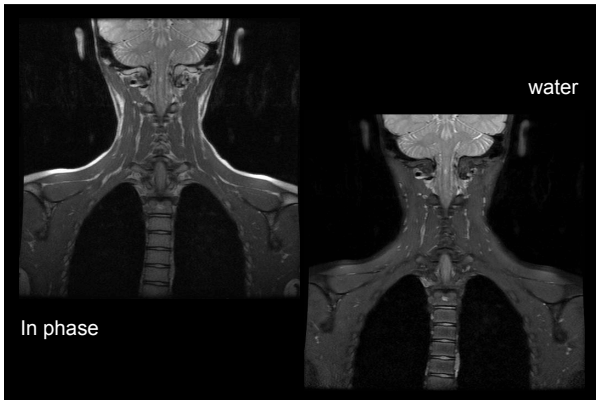

IDEAL
FSE

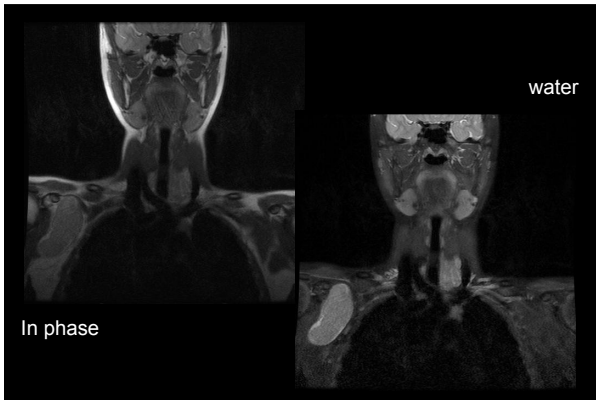

IDEAL FSE




IDEAL
ranula

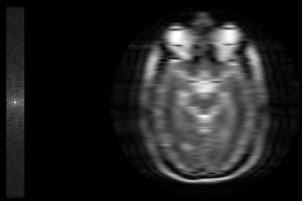

IDEAL
ranula





Radial imaging

- FSE
  - PROPELLER, BLADE
  - MultiVane, RADAR, JET
- 3D GRE (WIP)
  - GRASP VIBE

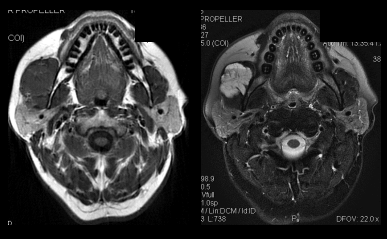


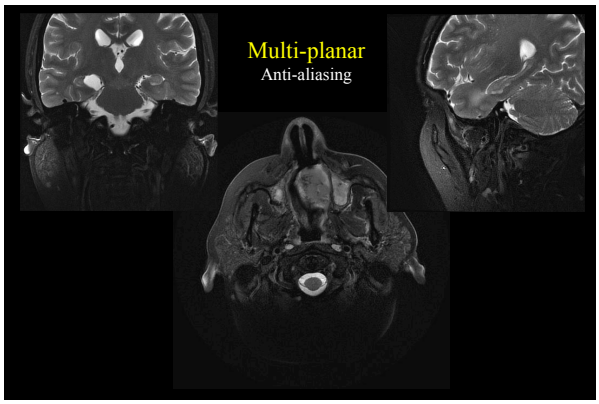
Radial imaging

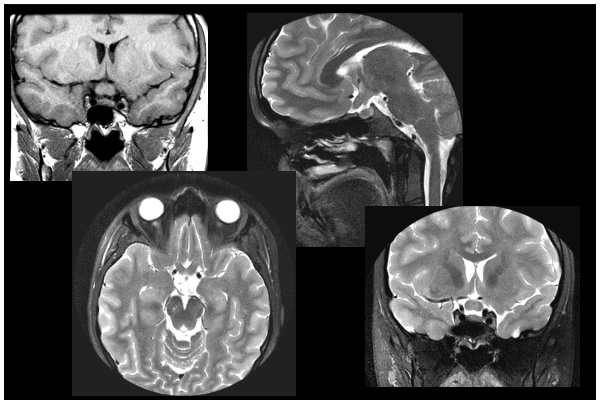
- Commonly used for brain imaging
- Increasing use in body and MSK

Radial imaging

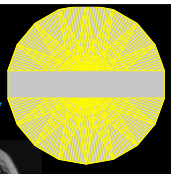
- Multiple contrasts
  - T1, T2, PD etc.



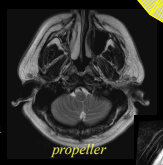


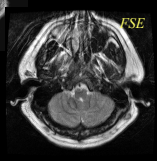


Propeller
modified radial *k*-space trajectory



- k-space center oversampling
  - inherently motion resistant
  - allows correction of data for rotation and translation motion





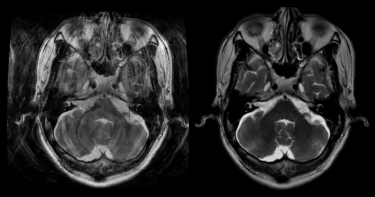
Forbes K, Pipe J, Bird CR, Heiserman J: Propeller MRI: Clinical testing of a novel technique for quantification and compensation of head motion. JMRI 2001

Propeller
motion correction

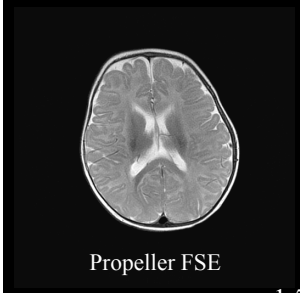
Forbes K, Pipe J, Bird CR, Heiserman J: Propeller MRI: Clinical testing of a novel technique for quantification and compensation of head motion. JMRI 2001

Radial imaging
impact in clinical practice

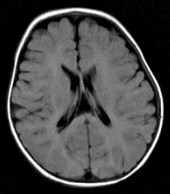
- routine imaging without motion artifact



3 months old unsedated



Propeller FSE

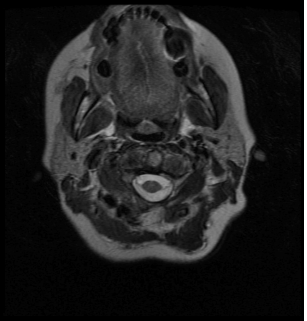


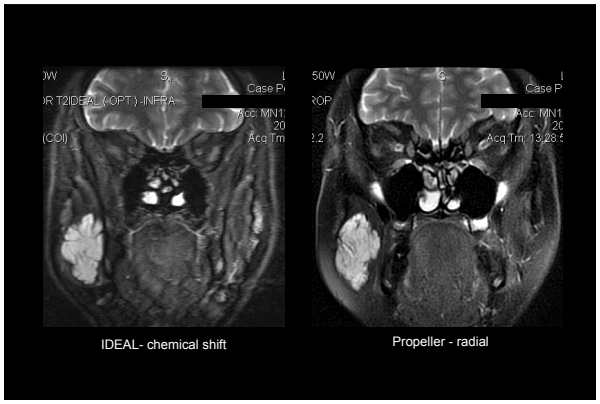
Propeller FLAIR

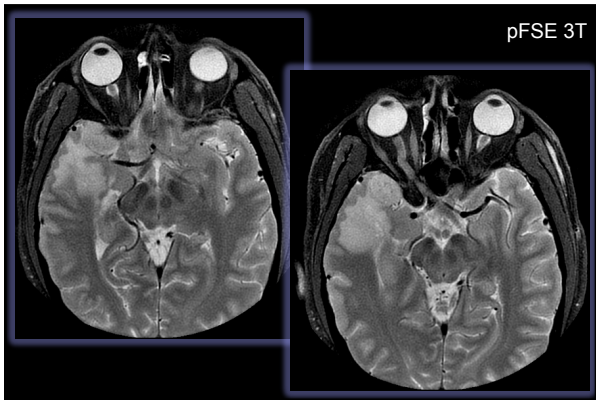
1.5T

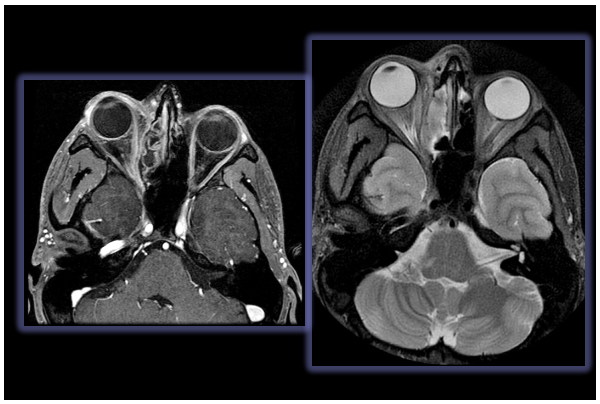
scan 14

scan 10





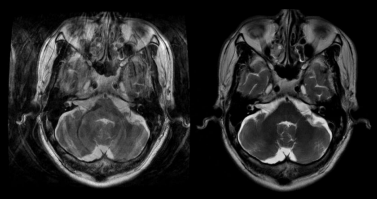


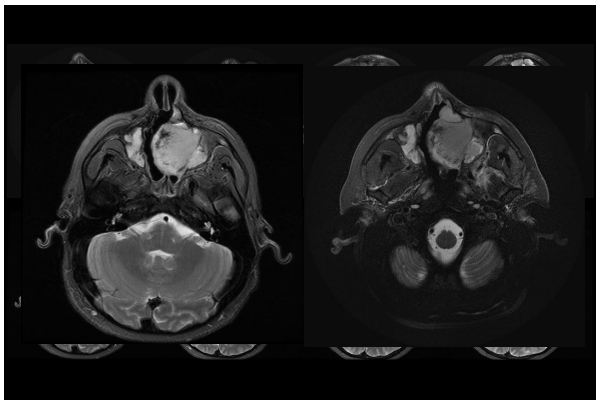


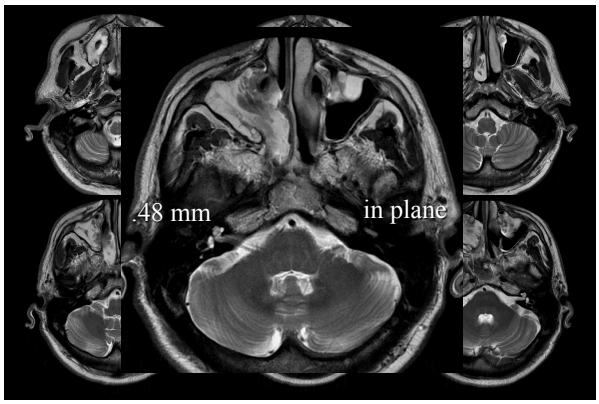
Radial imaging

impact in clinical practice

- high resolution imaging without ghosting



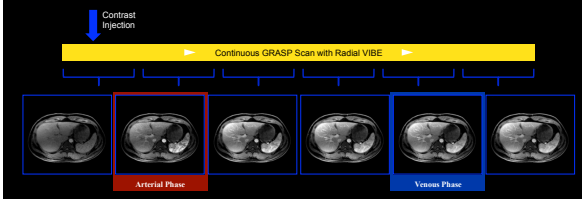




GRASP Method for DCE-MRI

Feng et al, ISMRM 2012: 1117

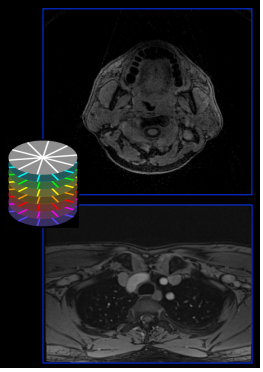
- Radial VIBE sequence with injection during continuous scan
- Desired temporal resolution can be selected retrospectively
- Compressed-Sensing reconstruction with temporal constraint



Courtesy Kai Tobias Block NYU CBI

Radial 3D GRE (WIP)

- Radial version of VIBE 3D GRE sequence
- Stack-of-stars k-space sampling
  - Chandarana et al, Inv Radiology 2011: 46
- Scan duration 4:40 min (for dynamic scan)
- No visible swallowing, respiration, or pulsation artifacts



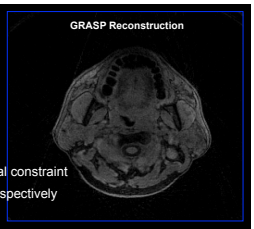
Courtesy Kai Tobias Block NYU CBI

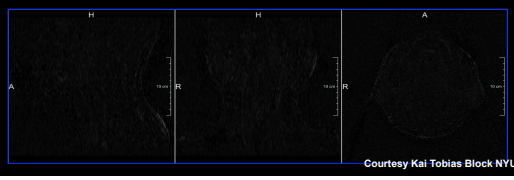
GRASP Method for DCE-MRI

Feng et al, ISMRM 2012: 1117

Dynamic CE Neck Imaging

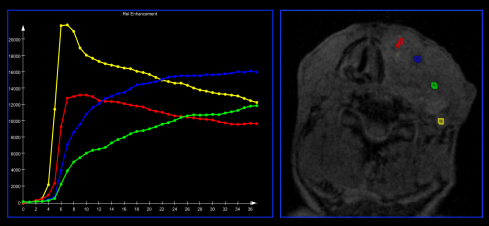
- Static high-resolution images on scanner
- Offline GRASP reconstruction for dynamic images
  - Compressed-Sensing reconstruction with temporal constraint
  - Desired temporal resolution can be selected retrospectively





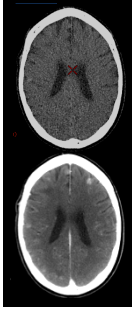
Courtesy Kai Tobias Block NYU CBI

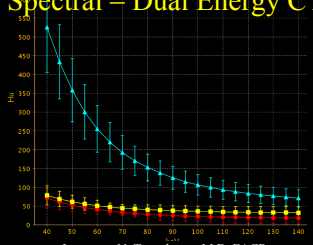
Dynamic CE Neck Imaging

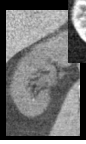


Courtesy Kai Tobias Block NYU CBI

Introduction to Spectral – Dual Energy CT





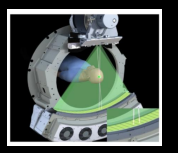


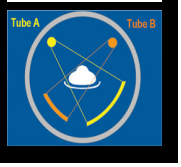
Lawrence N. Tanenbaum, M.D. FACR
Director of MRI and Computed Tomography
Mt. Sinai School of Medicine
www.drtmasters.com drt@drtmasters.com
New York, NY

Spectral imaging

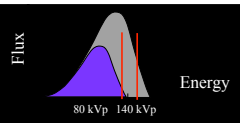
imaging techniques

- single source dual energy acquisition
  - switching @0.5msec
- dual source dual energy
  - two tubes
- dual layer detector
- two rotations

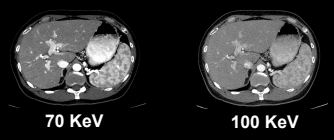




Spectral imaging
imaging techniques



- spectral imaging
  - material decomposition – tissue specific imaging
  - monochromatic imaging

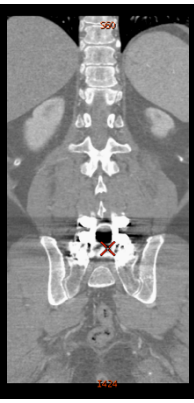


Monochromatic imaging
imaging impact

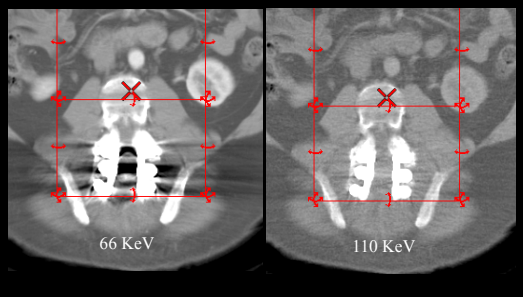
- similar contrast to polychromatic images
- imaging advantages
  - reduced beam hardening
  - improved low contrast resolution
  - adjustable contrast resolution
  - tissue characterization

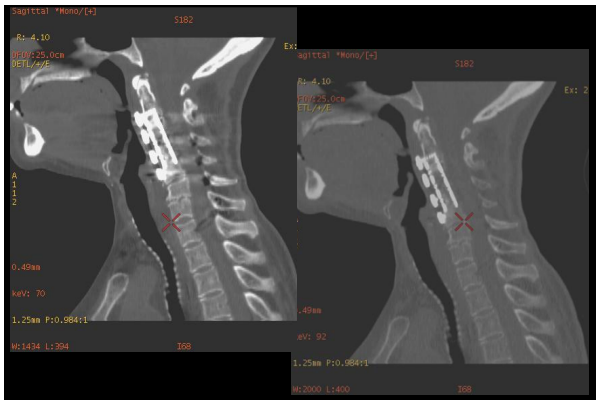
Diagnostic dilemmas

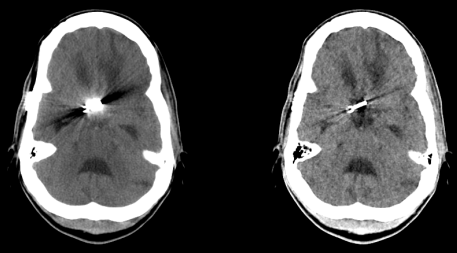
- beam hardening artifacts obscure anatomy



Spectral imaging
monochromatic imaging reduces beam hardening

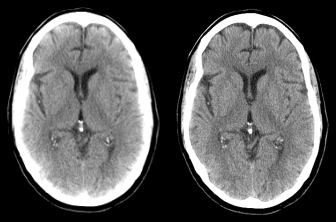






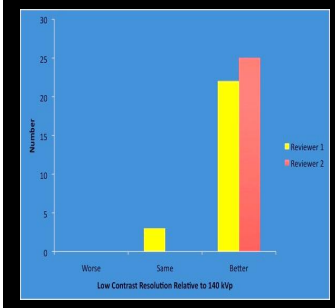
Spectral imaging

- flexible use of monochromatic imaging improves low contrast resolution

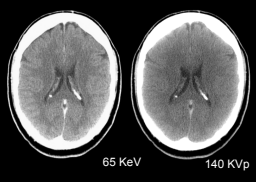


140kVp 65 keV

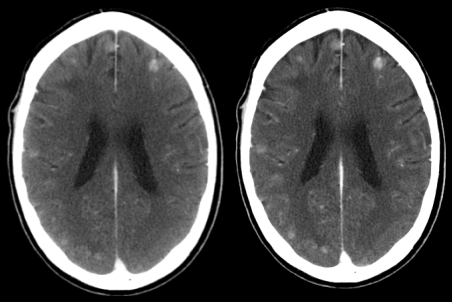
Results – Low Contrast Resolution



Monochromatic 65 KeV CT images were felt to provide better or similar low contrast resolution relative to 140 KVp.



65 KeV 140 KVp

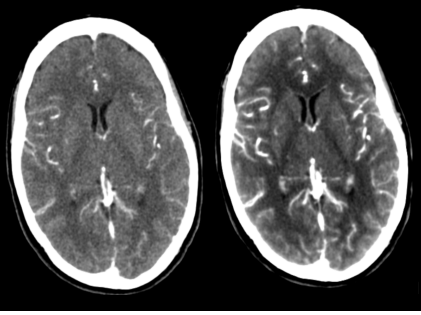


140kVp 65 kev

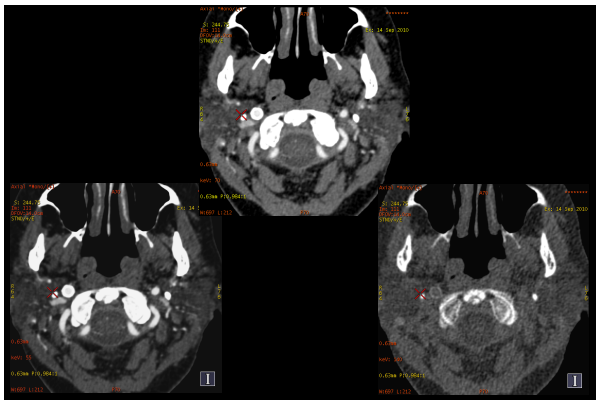
Spectral imaging

monochromatic imaging enhances iodine visualization

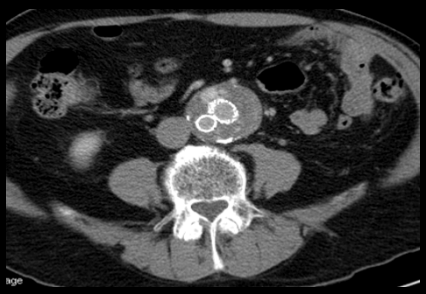
80 keV



60 keV



Endoleak

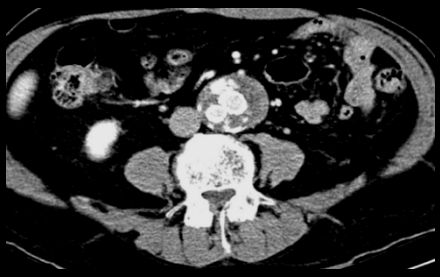


140 KVp – 30 cc

Endoleak

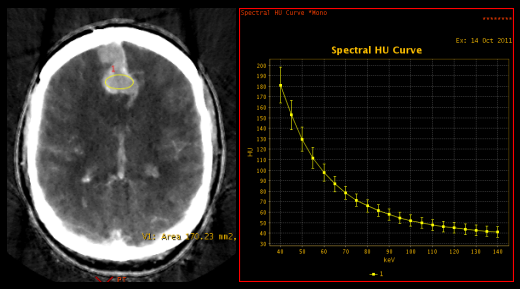
60 KeV– 30 cc

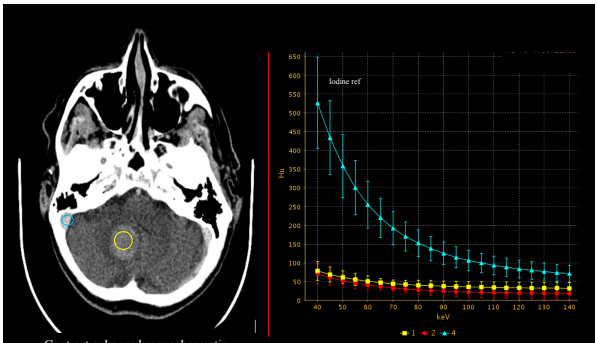
Endoleak



50 KeV– 30 cc

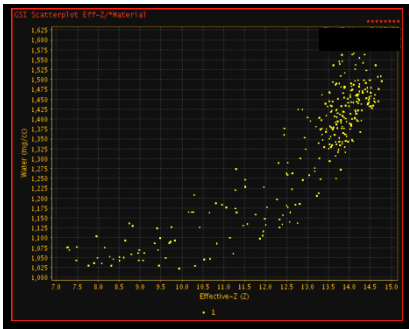
Spectral HU assessment

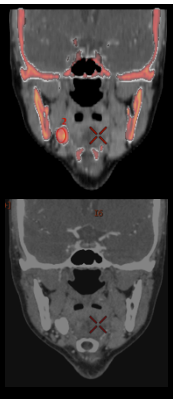




Contrast enhanced monochromatic

Prof. Garcier CHU Clermont-Ferrand, France



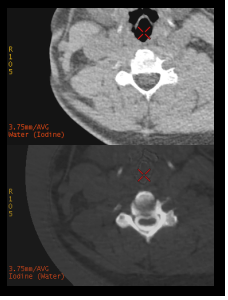


atomic number discrimination

Spectral imaging

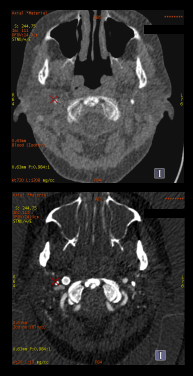
imaging techniques

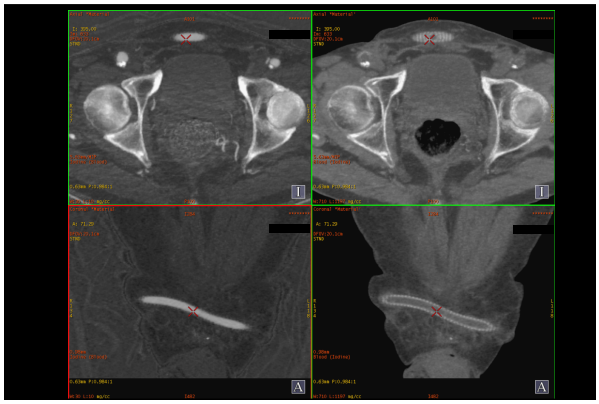
- monochromatic imaging
- material decomposition / density
  - tissue characterization
  - material specific imaging

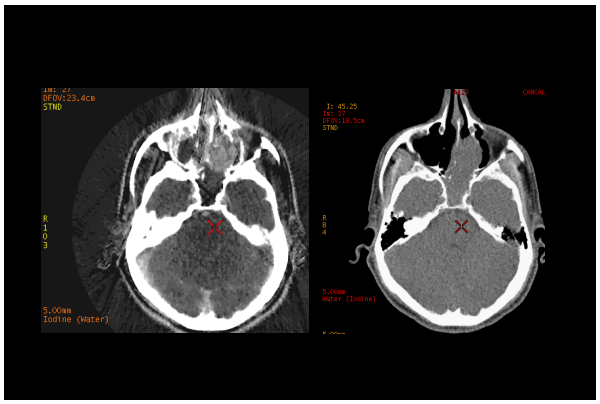


Spectral imaging
tissue characterization

- material decomposition pairs
  - discrimination based on atomic number
  - centered on one element, minimizing the other
    - water centered / iodine minimized
    - iodine centered / calcium minimized

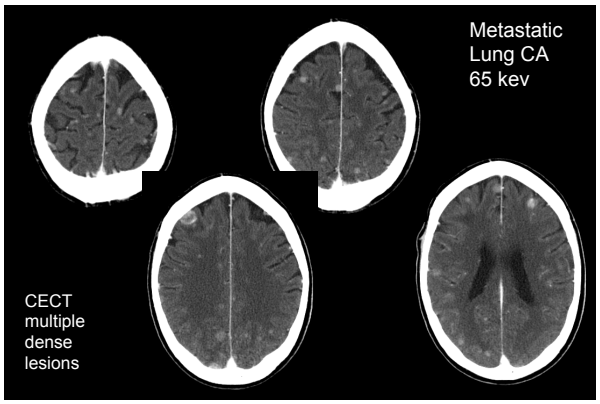


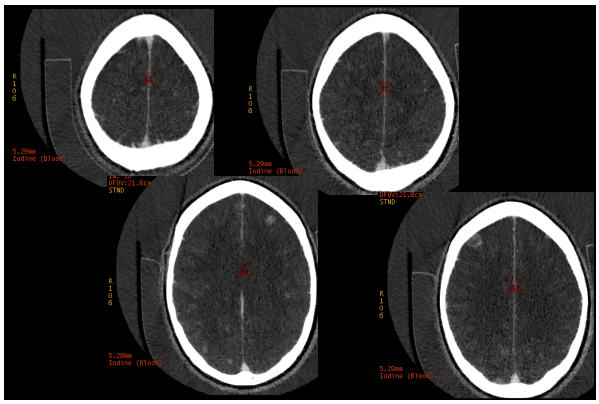


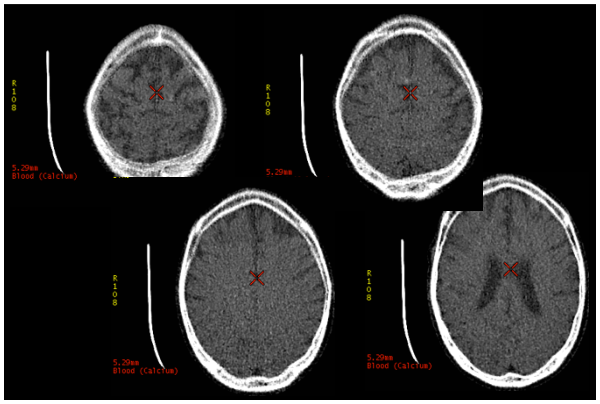


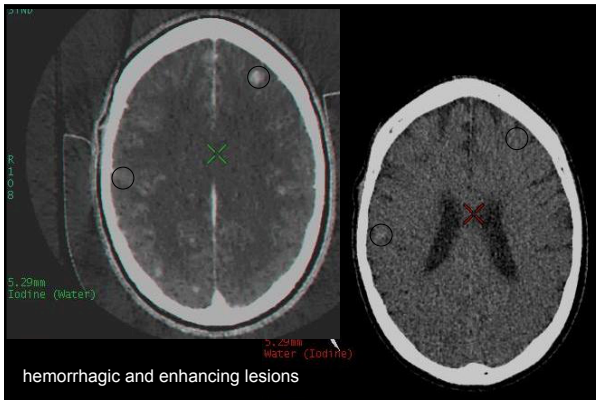
Spectral imaging
tissue characterization

- tissue characterization
  - cyst vs. solid
  - enhancing vs. nonenhancing
  - blood vs. contrast
  - calcium vs. blood
  - calcium vs. contrast



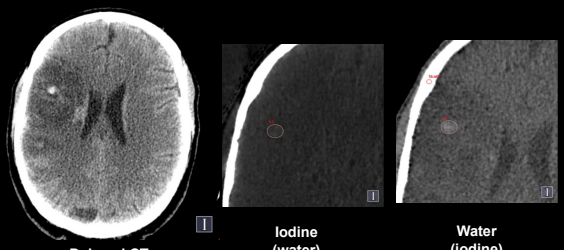






hemorrhagic and enhancing lesions

Material Decomposition
CVA -blood vs. contrast



Delayed CT after contrast

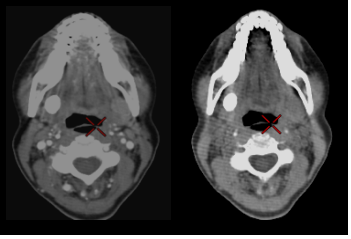
Iodine (water)

Water (iodine)

Dr. Dushyant Sahani, Mass General Hospital

Virtual unenhanced imaging

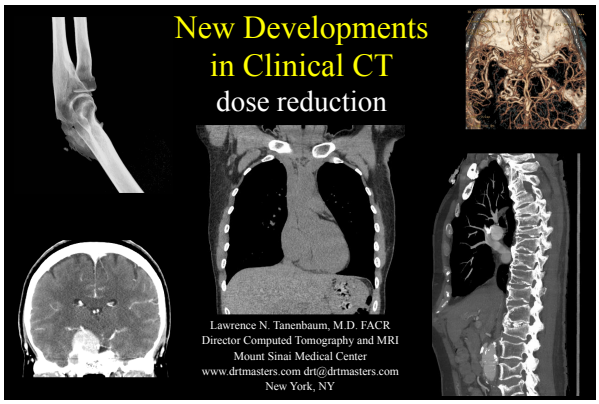
- may allow reduce need for multiphase scanning
- Monochromatic
- Material basis



Spectral CT

- similar functionality
- imaging advantages
  - reduced beam hardening
  - improved low contrast resolution
  - adjustable contrast resolution
  - tissue characterization

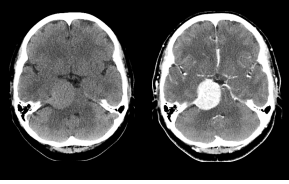
New Developments in Clinical CT
dose reduction



Lawrence N. Tanenbaum, M.D. FACR
Director Computed Tomography and MRI
Mount Sinai Medical Center
www.drtmasters.com drt@drtmasters.com
New York, NY

Dose Reduction in Clinical CT

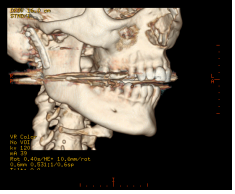
- Existing protocol review - ALARA
- Dose modulation
- Novel reconstruction/ processing methods



dose reduced
ASIR

Protocol review
opportunities

- Lower mAs (higher NI)
  - dose reduction proportional to drop in mAs
  - sinus, temporal bone, skeletal, screening chest studies



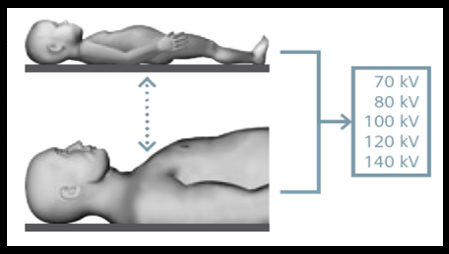
16 mAs

Protocol review
opportunities

- Lower kVp
  - 17% drop from 120 to 100 kV yields an almost 40% reduction in dose
  - pediatrics, thinner patients, vascular apps

100 kV

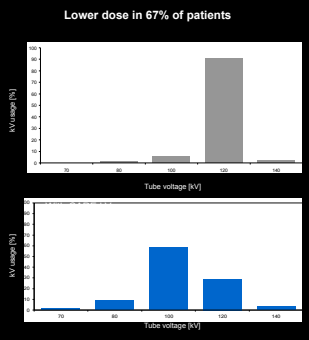
kV reduction



* Dose saving potential may vary depending on body region.
1: Vollmer SV, Kalender WA. Reduction of dose to the female breast in thoracic CT: a comparison of standard-protocol, bismuth-shielded, partial and tube-current-modulated CT examinations. Eur Radiol. 2008 Aug 18(8):1674-82.

Courtesy Siemens

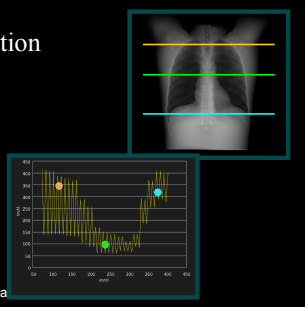
Auto kV selection



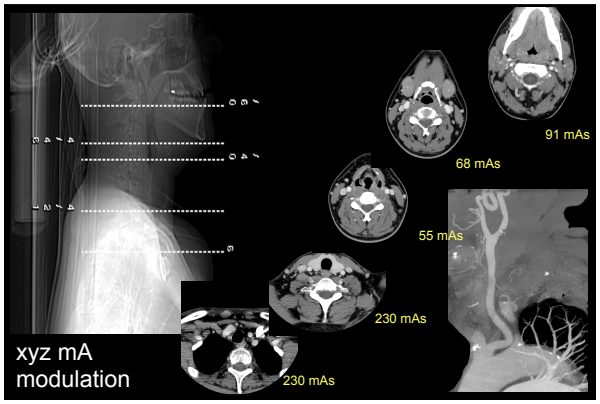
Courtesy Siemens and C. McCullough, Mayo Clinic, Rochester, MN, USA

Dose modulation

- x-y-z current modulation
  - in and through plane
  - mA



Courtesy Toshiba

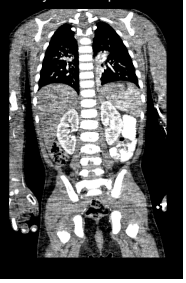


FBP

filtered back projection

- many assumptions made
  - beam is perfect at the level of the voxel
  - focal spot on the x-ray tube is a point source
  - a perfect voxel at the level of the patient and the detector
  - assumptions not optimal especially with sub-mm acquisitions
- important information untapped
  - noise information
  - information about adjacent voxels
- low computational demand

very low dose peds FBP



Novel reconstruction/ processing methods

- assumptions / errors made in image reconstructions introduce noise

Novel reconstruction/ processing methods

- novel reconstruction methods have the capability to recognize and remove image noise

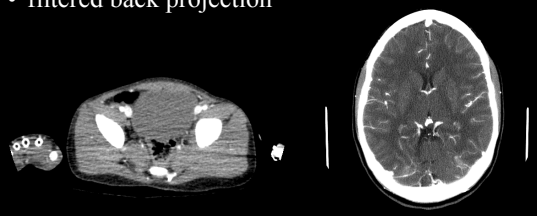
- GE
  - ASIR
  - MBIR / Veo
- Siemens
  - IRIS
  - Sapphire
- Philips
  - iDOSE
- Toshiba
  - AIDR
- Vital
  - SPD

Novel reconstruction/ processing methods

- lower noise data allows substantial reduction in dose necessary to maintain quality clinical images

Image reconstruction

- filtered back projection



very low dose FBP (peds)

40% dose reduced FBP

Iterative Reconstruction

- ASIR cycles between the slice data & the raw data until it comes up with an image that approximates the model.
- kind of Bayesian analysis in which the algorithm predicts the correct noise and attenuation information (prior).
- with each pass, learns if noise is too high or too low, and then tries again, gradually approaching the truth and adjusting the image as a result.

ASIR

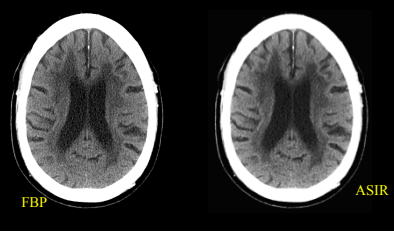
adaptive statistical iterative reconstruction

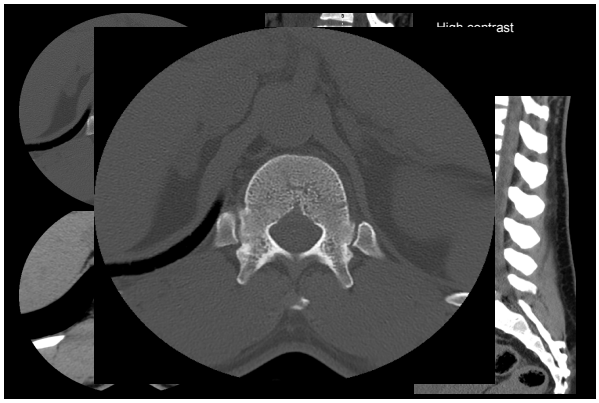
- simple ***model-based*** reconstruction algorithm that performs some algebraic computations to compare image data to a noise model.
- recognizes and removes noise
- maintains low noise levels at substantially lower doses for all CT applications

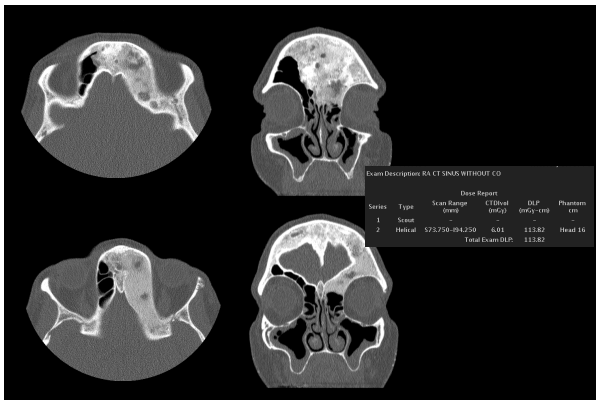
ASIR

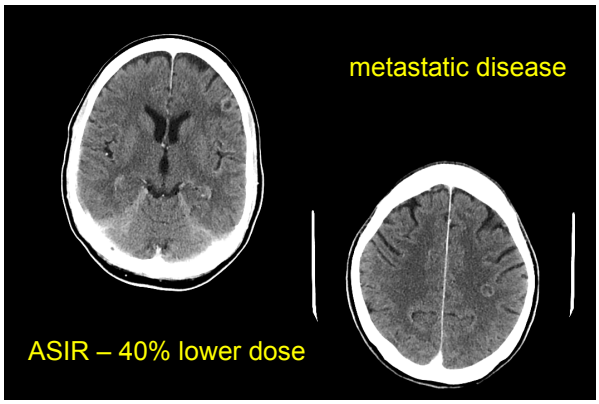
adaptive statistical iterative reconstruction

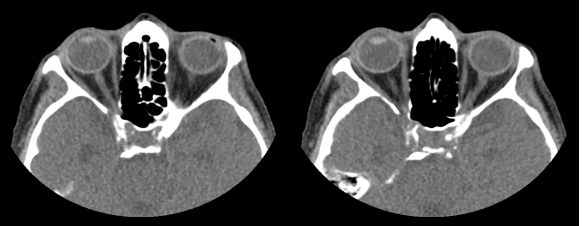
- maintains low noise levels and low/high contrast resolution at 50% lower dose indices than traditional FBP reconstructions







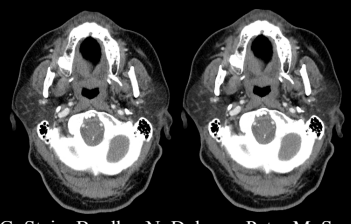




20 mAs ORBIT

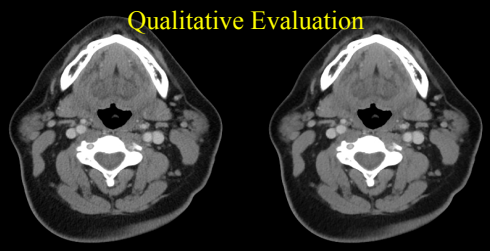
Adaptive Statistical Iterative Reconstruction Allows Lower Radiation Dose Neck CT

Paper 131



Evan G. Stein, Bradley N. Delman, Peter M. Som, Puneet S. Pawha, Lawrence N. Tanenbaum
Mount Sinai Medical Center
New York, NY

ASIR v. FBP
Qualitative Evaluation

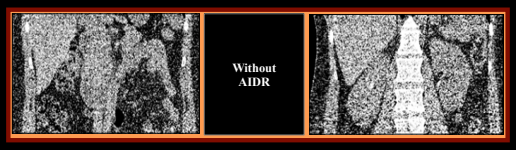


FBP Reconstruction ASIR Reconstruction

Results

- Dose reduced nearly 50% over conventional protocol
- Noise reduced 10-15% with ASIR over FBP
- ASIR preferred or equal to FBP in vast majority of cases

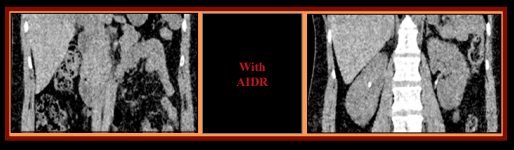
Iterative Reconstruction



Scan Mode	Collimation	Reconstruction	kVp	mA	Rotation Time	Scan Range	CTDIvol.c	DLP.c	Effective Dose	k Factor
Volume	0.5mm x 320	With AIDR	100	50	0.5 s	160 mm	2.8 mGy	44.6 mGy•cm	0.7 mSv	0.015*

Courtesy Toshiba

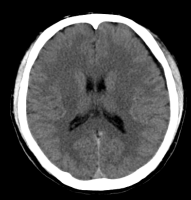
Iterative Reconstruction



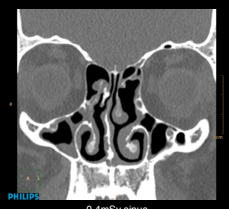
Scan Mode	Collimation	Reconstruction	kVp	mA	Rotation Time	Scan Range	CTDIvol.c	DLP.c	Effective Dose	k Factor
Volume	0.5mm x 320	With AIDR	100	50	0.5 s	160 mm	2.8 mGy	44.6 mGy•cm	0.7 mSv	0.015*

Courtesy Toshiba

iDOSE
Iterative reconstruction



1.5mSv routine brain



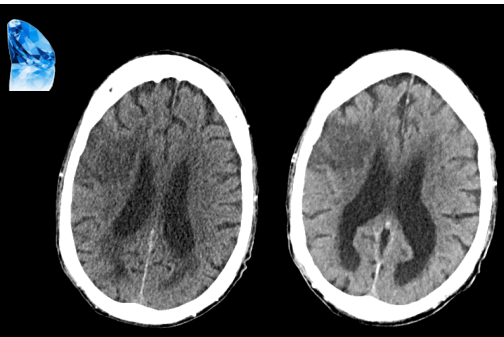
0.4mSv sinus

Courtesy Phillips

Dose reduced FBP

iDOSE

Courtesy Phillips



FBP

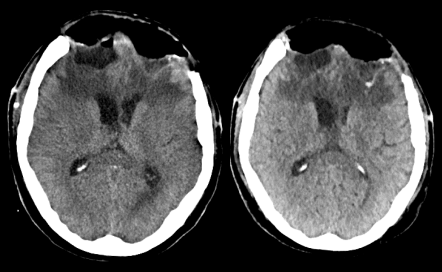
SAFIRE 4

Standard WFBP

100 kV, 107 effective mAs
CTDIvol: 5.32 mGy
DLP: 186 mGy*cm
2.6 mSv

SAFIRE

Courtesy of Siemens and Chelsea & Westminster Hsp. / London, United Kingdom



Total mAs 11882 Total DLP 951

	Scan	kV	mAs / ref.	CTDIvol	DLP	TI	cSL
Patient Position H-SP							
AP TOPO	1	120				2.8	0.6
LAT TOPO	2	120				2.8	0.6
BPI Head	3	120	350	47.42	951	1.0	0.6

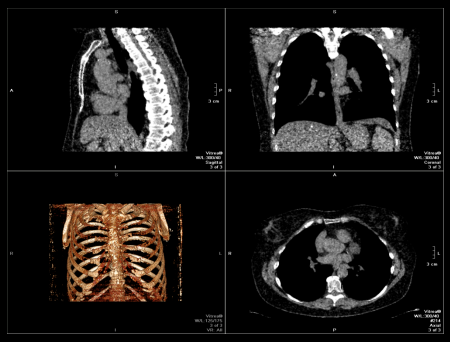
Total mAs 1235 Total DLP 324 mGy.cm

	Scan	kV	mAs / ref.	CTDIvol* mGy	DLP mGy.cm	TI s	cSL mm
Patient Position H-SP							
Topogram AP	1	120	34 mA	0.28 S	7	2.7	0.6
Topogram LAT	2	120	34 mA	0.28 S	7	2.7	0.6
Head	3	100	205 / 205	17.66 S	310	0.5	0.6

3D-Structure Preserving Denoising Filter (SPD)

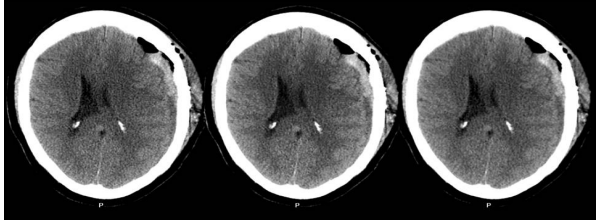
- Processing applied after the image is generated
- Vendor agnostic

Courtesy Vital



Courtesy Vital Images

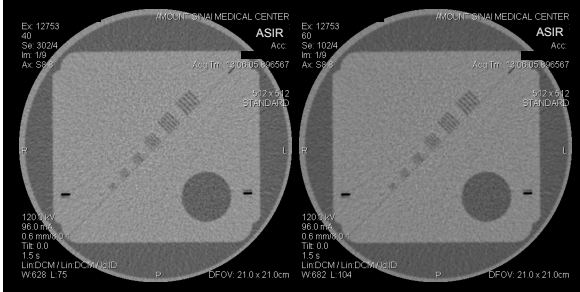
Comparisons



Iterative reconstruction

what's next

- ASIR at 30-40% (and analogues) used widely at 40-50% dose reduction
- Higher levels of iterative reconstruction enable greater dose reduction
- ASIR levels of 60+% now in routine use with dose reductions of 60+%
- ASIR levels approaching 100% may be appropriate for pediatric, perfusion imaging

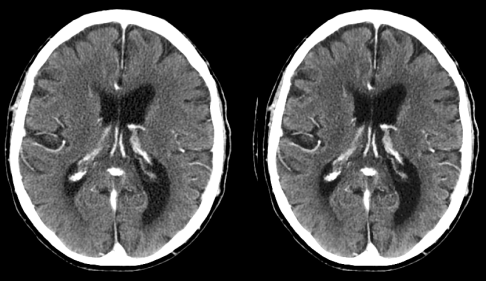


ASIR 40 ASIR 60

Dose reduced
No ASIR

Dose reduced
40% ASIR

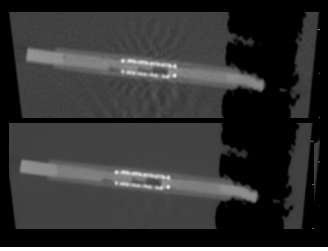
Dose reduced
100% ASIR



ASIR

adaptive statistical iterative reconstruction

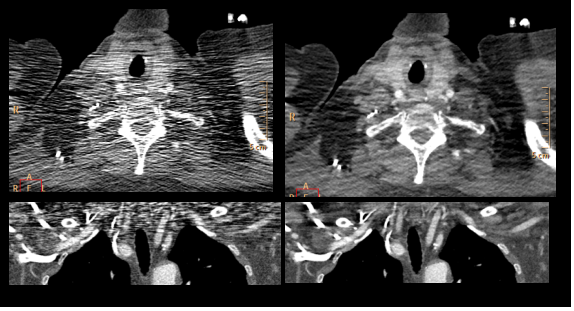
- less artifact than traditional FBP reconstructions



FBP

ASIR

IDOSE
Streak artifact removal



Iterative reconstruction

MBIR -model-based iterative reconstruction

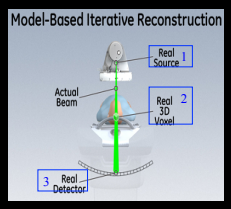
- There are two components in noise:
  - Photon flux -- less photons lead to greater noise in the signal is higher than if it had very high photons.
  - Scanners -- convert x-ray photons into light photons, then using a photodiode, convert that into an electrical signal
    - the photodiode and the digitization process introduces noise

Thibault JB, Sauer KD, Bouman CA, et al: A three-dimensional statistical approach to improved image quality for multislice helical CT. Med Phys 34:4526, 2007

MBIR

model-based iterative reconstruction

- MBIR algorithm models two parts of the CT system:
  - system optics or geometry
  - system statistics such as image noise
- MBIR is much more complex than FBP and ASIR due to multiple iterations from multiple models.

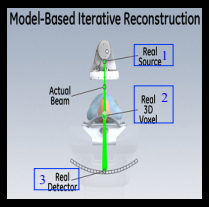


Thibault JB, Sauer KD, Bouman CA, et al: A three-dimensional statistical approach to improved image quality for multislice helical CT. Med Phys 34:4526, 2007

MBIR

model-based iterative reconstruction

- Unlike FBP, which relies on assumptions about the x-ray beam, MBIR analyzes the beam at three points
  - at the focal spot
  - as it passes through the patient's body
  - at the level of the x-ray detector
- models these points three-dimensionally with multiple iterations



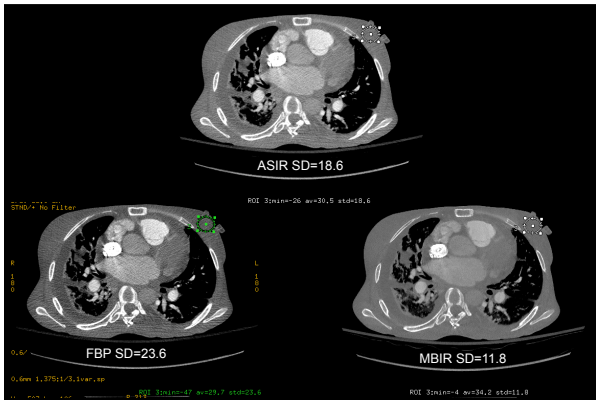
Thibault JB, Sauer KD, Bouman CA, et al: A three-dimensional statistical approach to improved image quality for multislice helical CT. Med Phys 34:4526, 2007

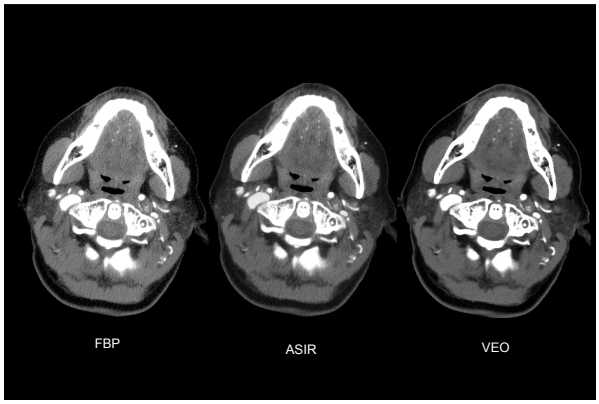
Radiation Dose

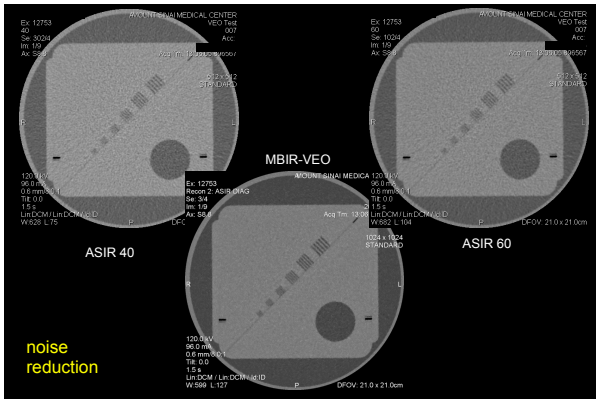
MBIR

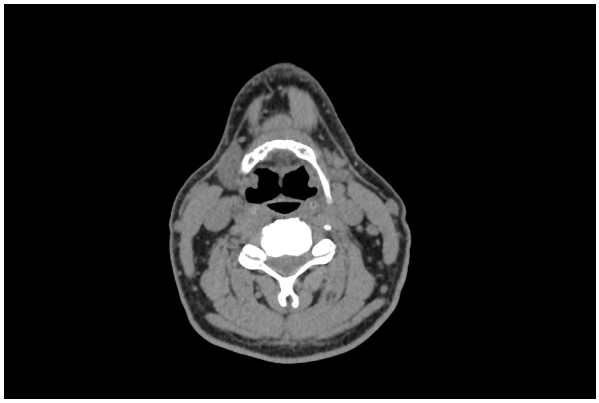
- Based on phantom and preliminary patient data, recent works suggest that dose can be reduced by about 75% and maintain the image quality currently obtained with 100% filtered back projection.

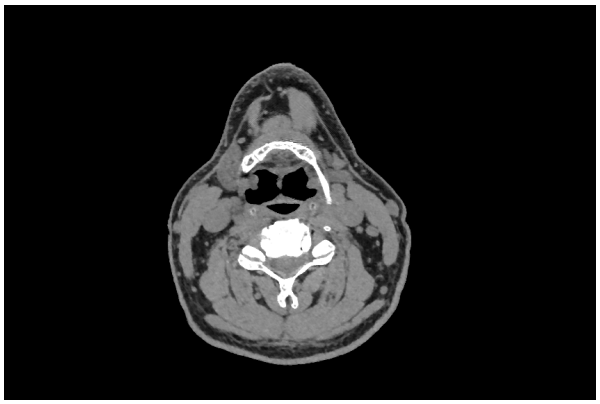
Thibault JB, Sauer KD, Bouman CA, et al: A three-dimensional statistical approach to improved image quality for multislice helical CT. Med Phys 34:4526, 2007

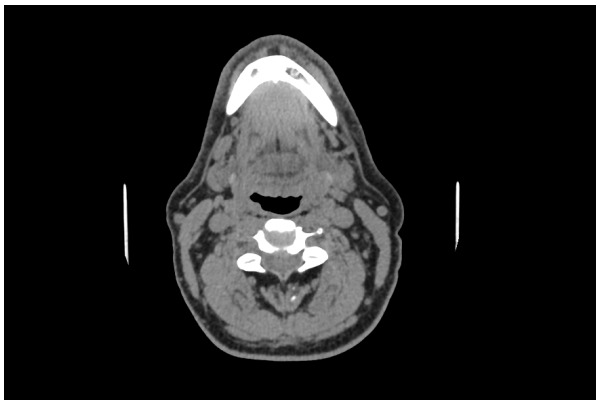

ASIR SD=18.6
FBP SD=23.6
MBIR SD=11.8

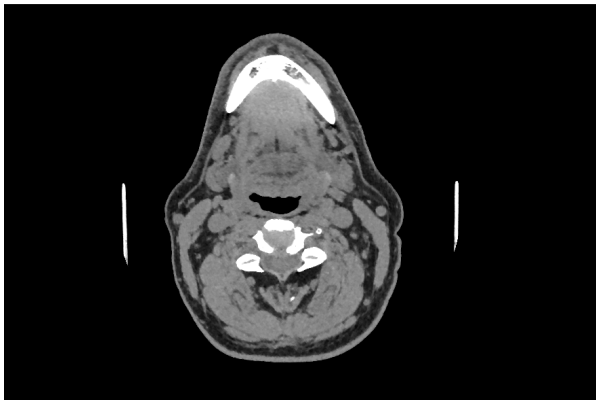

FBP
ASIR
VEO

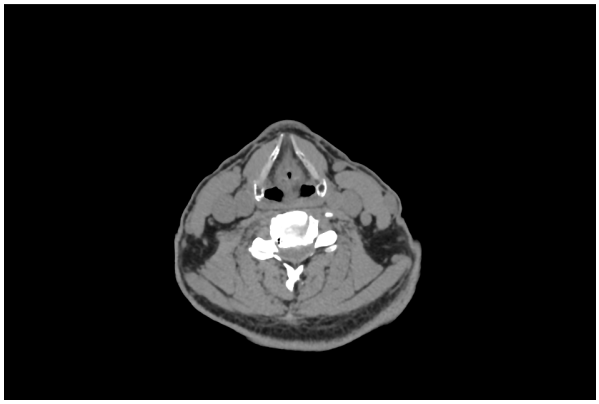

MBIR-VEO
ASIR 40
ASIR 60
noise
reduction

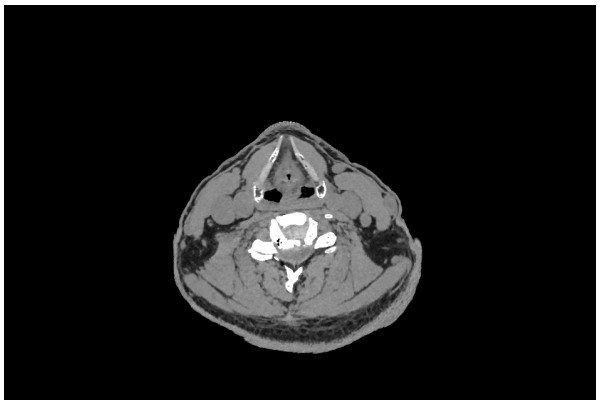


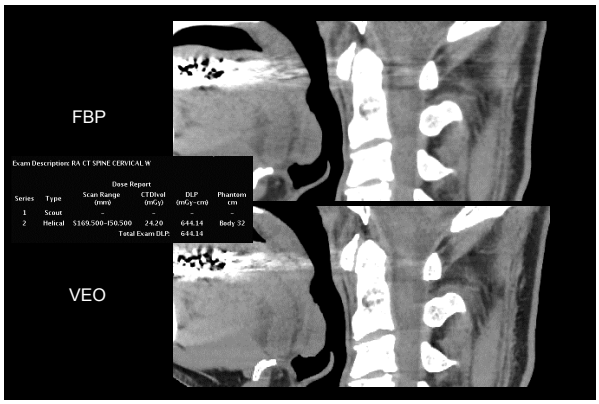


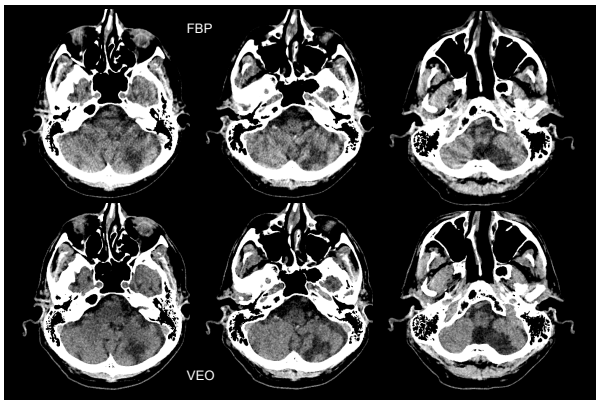


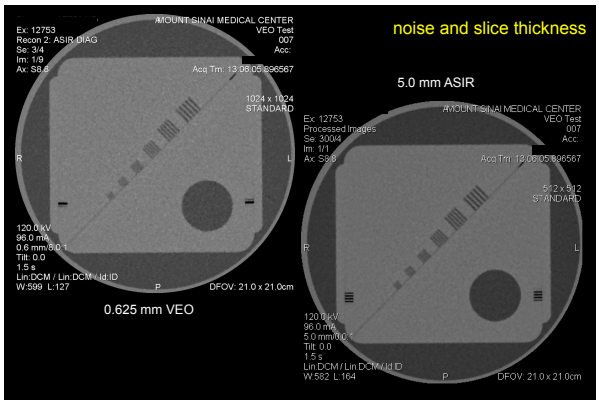




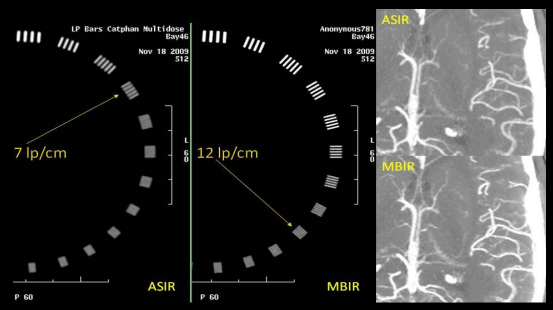



FBP
Exam Description: RA CT SPINE CERVICAL W
Dose Report
Series Type Scan Range (mm) CTDIvol (mGy) DLP (mGy-cm) Phantom cm
1 Scout – – – –
2 Helical S169:500–150:500 24.20 644.14 Body 32
Total Exam DLP: 644.14
VEO

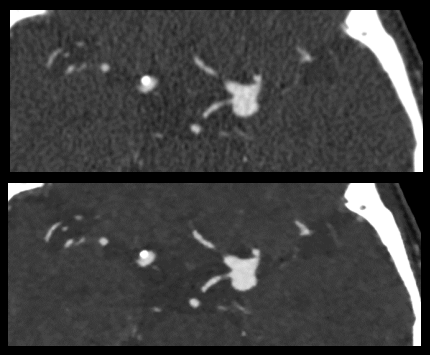

FBP
VEO

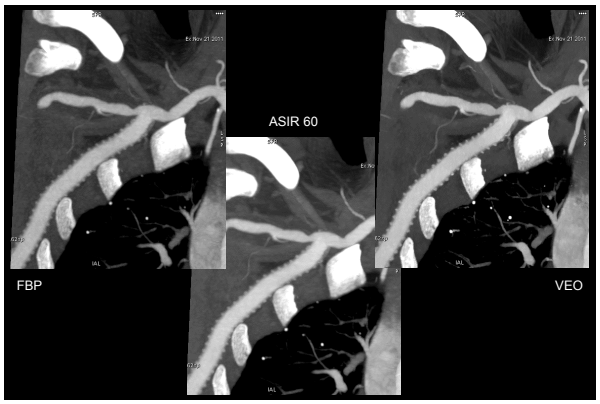

noise and slice thickness
MOUNT SINAI MEDICAL CENTER
VEO Test
Ex: 12753
Recon 2: ASIR DIAG
Se: 3/4
Im: 1/9
Ax: S8.8
007
Acc:
Acq Tm: 13:08:05.896567
1024 x 1024
STANDARD
R
L
120.0 kV
96.0 mA
0.6 mm/0.0 1
Tilt: 0.0
1.5 s
Lin:DCM / Lin:DCM / Id ID
W:599 L:127
P
DFOV: 21.0 x 21.0cm
0.625 mm VEO
5.0 mm ASIR
MOUNT SINAI MEDICAL CENTER
VEO Test
Ex: 12753
Processed Images
Se: 30004
Im: 1/1
Ax: S8.8
007
Acc:
Acq Tm: 13:08:05.896567
512 x 512
STANDARD
R
L
120.0 kV
96.0 mA
5.0 mm/0.0 1
Tilt: 0.0
1.5 s
Lin:DCM / Lin:DCM / Id ID
W:582 L:164
P
DFOV: 21.0 x 21.0cm

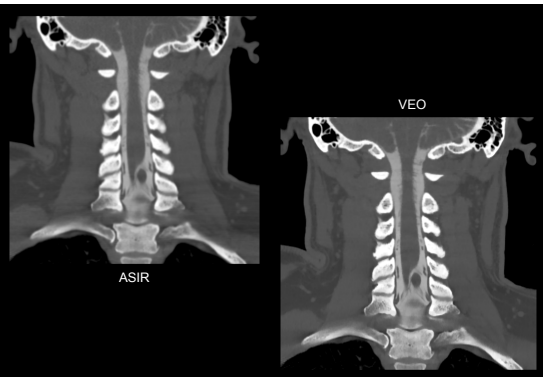
ASIR vs. MBIR



- Reconstruction of phantom images with MBIR boosted spatial resolution to 11 lp/cm from the 7 lp/cm resolved by ASIR reconstruction.



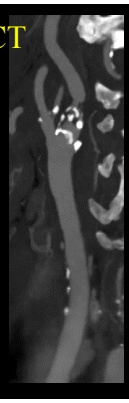




Dose Reduction in Clinical CT

summary

- Existing protocol review - ALARA
- Dose modulation
- Iterative reconstruction



Opportunities in head and neck imaging

- MRI
  - Fat-water separation imaging
  - Radial imaging
- CT
  - Dual energy imaging
  - Dose reduction techniques

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