

GE Healthcare

Spectral Imaging in clinical practice



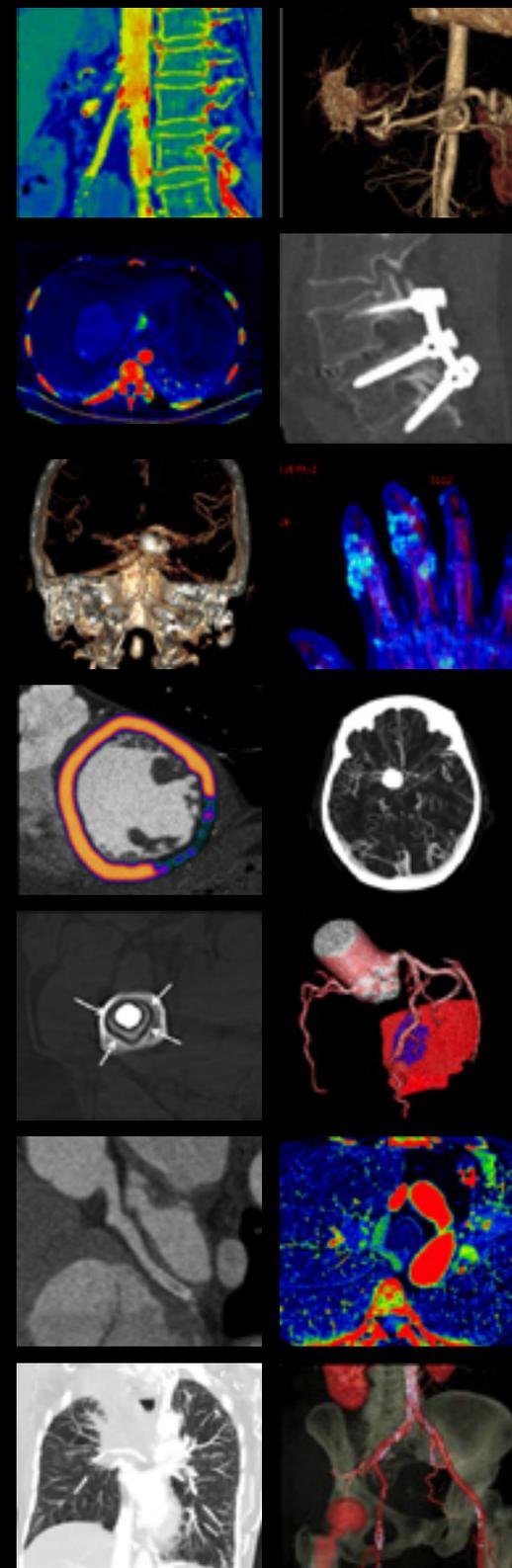
Introduction

CT has long been considered an excellent method for viewing high-resolution images of human anatomy in a non-invasive manner. It has been used in conjunction with PET and MRI—devices that can image tissue and organ function—to bring together anatomic and morphologic information for a more precise patient diagnosis and treatment plan.

We see CT closing the gap between anatomical and functional imaging thanks in part to advances in spectral CT and the introduction of Gemstone* Spectral Imaging (GSI) on the Discovery* CT750 HD scanner. GSI is changing the way radiologists across the world utilize CT imaging in clinical practice.

The purpose of this review is to provide an overview of the most relevant clinical applications for the use of GSI in clinical practice:

- In oncology, to help detect, characterize and improve lesion follow-up
- In vascular imaging to help optimize contrast media, improve vessel assessment or provide additional perfusion information
- For metal artifact reduction in head, abdominal or musculoskeletal imaging
- In cardiac imaging for coronary assessment improvement and myocardial perfusion
- For material decomposition such as kidney stone or gout characterization



About Gemstone Spectral Imaging

Gemstone Spectral Imaging (GSI) is a dual-energy scan mode that acquires data of an object by rapidly switching between low kVp and high kVp energies at a rate of 0.25 msec. This generates data with different attenuation values based on the corresponding energy levels. The result is a near-perfect, simultaneous dual-energy acquisition at the full 50 cm scan field of view (SFOV) producing projection (raw) data at two different energy levels that has virtually no misregistration. This enables raw data-based reconstruction of dual-energy data with the associated benefits of quantitative material decomposition and beam-hardening reduction from monochromatic energy synthesis.

Projection-based reconstruction is used to process the data. Based on known attenuation curves, the process mathematically transforms low and high kVp attenuation measurements into effective material density (MD) basis-pair images. This is also known as material decomposition. GSI produces these MD pairs which are not available with conventional contrast-enhanced CT imaging. The make-up or composition of the MD pairs can be selected based on the clinical question being investigated and materials of interest, such as iodine-water, iodine-calcium, or water-calcium.

GSI also produces a monochromatic image, which is synthesized from the MD images and depicts how the object would look if the X-ray source produced only X-ray photons at a single energy.

Specific tools have been created in the GSI Viewer to support the data analysis of this rich information. Tissue characterization can be aided with the help of Hounsfield unit (HU) spectral curves; metal artifact reduction is enabled by interactively switching to the optimal monochromatic energy level. Additionally, material identification is made possible by displaying the effective atomic number histograms of objects, particularly kidney stone.

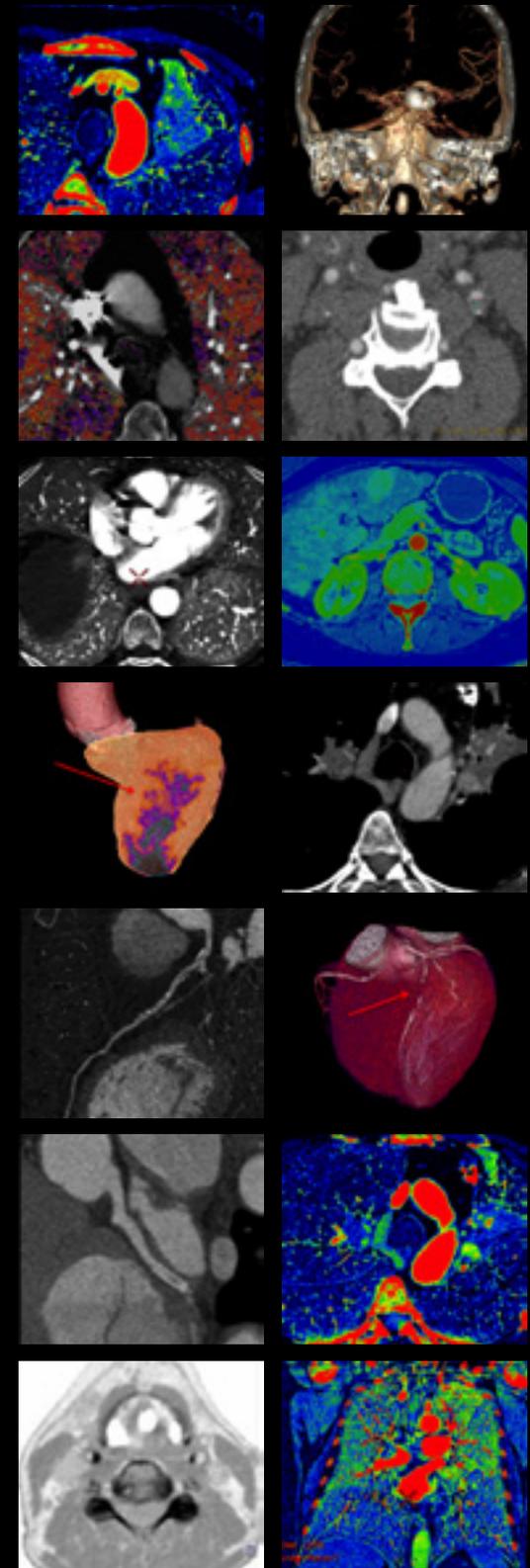


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RECENT GSI PUBLICATIONS



Oncology Imaging

Conventional CT imaging aids physicians, in general, with high sensitivity to detect lesions though they at times require additional workup for a conclusive diagnosis. Physicians using Conventional CT are challenged at detecting small subtly enhancing lesions, such as small hyper-vascular nodules or lymph nodes due to low contrast and high noise. Improvements in Low Contrast Detectability and Contrast to Noise Ratio are key components in improving their ability to detect subtle lesions.

GSI's unique ability to provide accurate raw data-based monochromatic images allows physicians to optimize Contrast to Noise ratio for multiple types of structures. By lowering the spectral energy or keV, physicians can increase the contrast in images thereby becoming more sensitive to contrast enhancement, which may improve lesion detection and visualization.

Increasing physicians specificity when using CT imaging may help to reduce the need for additional examinations. This may help in reducing costs and hospital stays. To this end, GSI Material Decomposition images allow to extract quantitative material information from the images, in order to provide additional information for differential diagnosis.

Finally, GSI VUE produces virtual unenhanced images from a contrast-enhanced CT. These images have CT numbers similar to those of a conventional 120kVp- non contrast acquisition.



CASE STUDY

Evaluation of chest lesions

PATIENT HISTORY

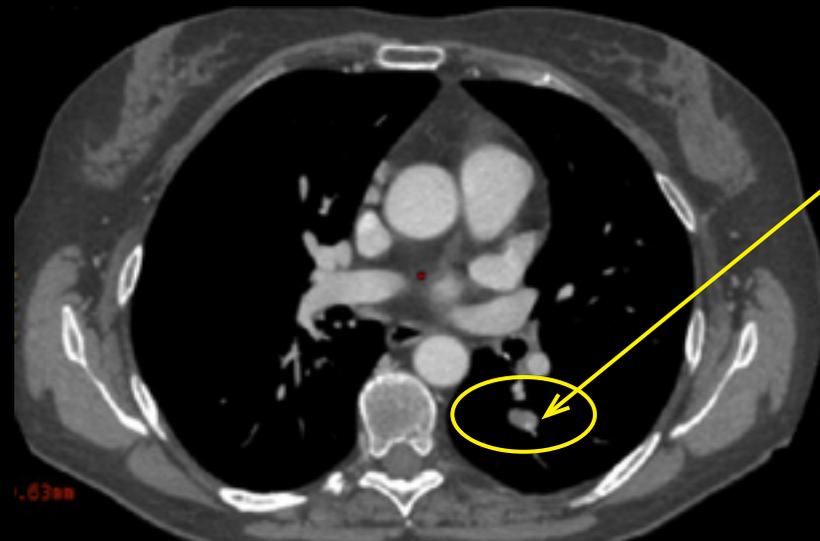
- ~50y female with Ovarian cancer
- Chest CT for detection of metastasis

ACQUISITION

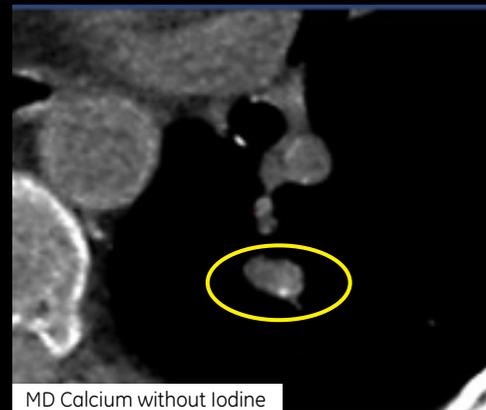
- GSI - 1
- 630 mA
- Rotation time: 0.5 sec - Pitch: 0.984:1
- Slice thickness: 0.625 mm
- Recon: STD

CONCLUSION

- Material Decomposition images help to characterize the lesion
- Calcium (Iodine) and Iodine (Calcium) images provided info to identify a calcification in the lesion, whereas conventional images with standard CT numbers could not differentiate calcium deposits vs iodine

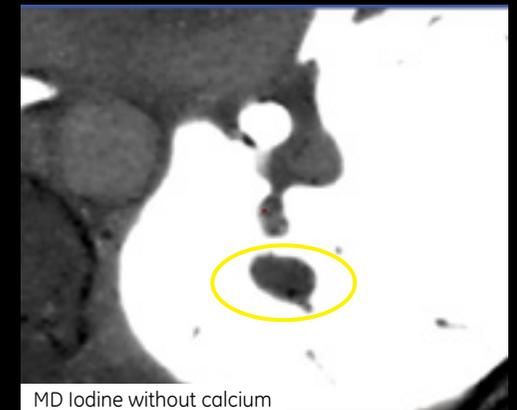


Standard image - 120kVp



MD Calcium without Iodine

The structure is visible



MD Iodine without calcium

The structure disappears, demonstrating that it is calcium



CASE STUDY

Evaluation of chest lesions

PATIENT HISTORY

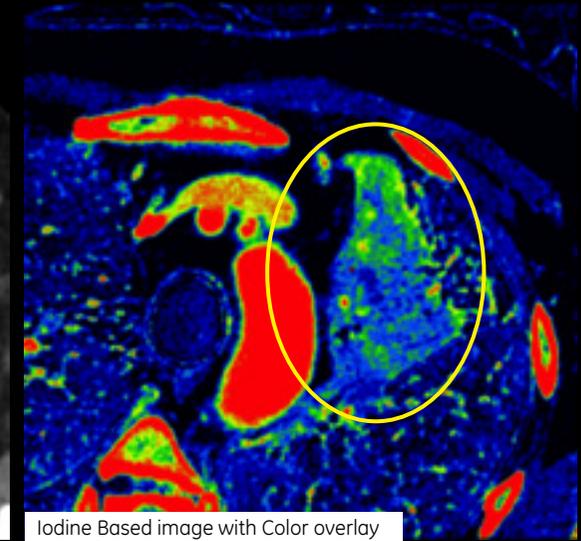
- ~50y male with Non Hodgkin's Lymphoma
- Chest CT for follow-up and evaluation of lesions

ACQUISITION

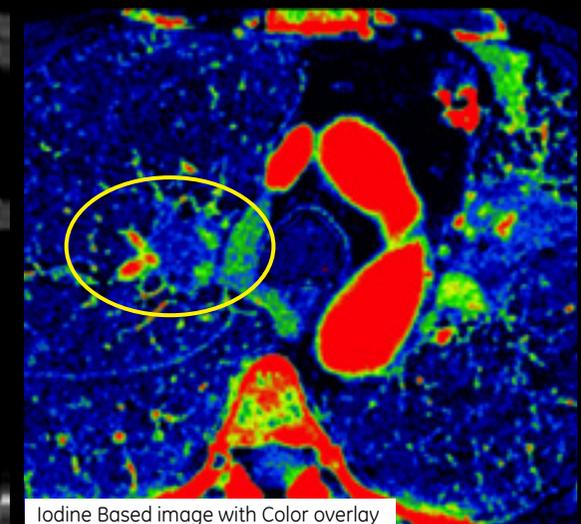
- GSI - 1
- 630 mA
- Rotation time: 0.5 sec - Pitch: 0.984:1
- Slice thickness : 0.625 mm
- Recon: STD

CONCLUSION

- Iodine Based images helped to classify the different tissues in the lesion
- More specifically, combined with clinical history, it aided to differentiate atelectasis from lymphomatous tissue
- It also helped to confirm that the second lesion was not enhancing



Second lesion



Second lesion



CASE STUDY

HCC characterization

PATIENT HISTORY

- M ~70y. Cirrhosis HCV related.
- MR Scan for follow up of regenerative/displastic nodules
- CT scan for characterization of regenerative/ displastic nodule vs HCC in segment VIII

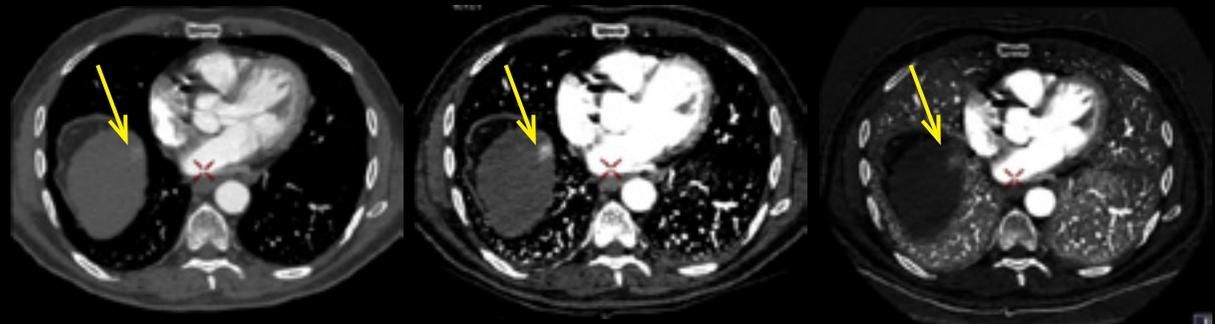
ACQUISITION

- GSI - 1
- 600 mA
- Rotation time: 0.5 sec – Pitch: 0.984:1 – Coverage: 220 mm
- Slice thickness: 1.25 mm
- CTDI: 17.77 mGy – DLP: 473.24 mGy.cm

CONCLUSION

- GSI images helped the radiologist in improving lesion conspicuity facilitating the characterization as HCC

CT IMAGES

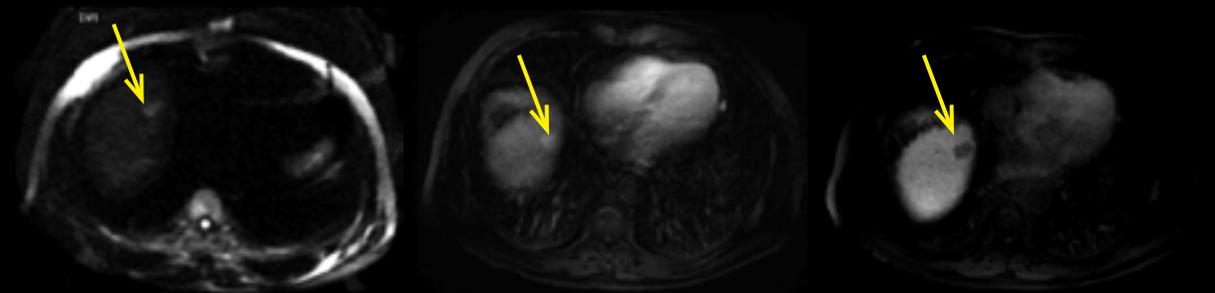


Conventional CT

GSI 40 Kev

GSI MD Iodine (Water)

MRI IMAGES



DWI

LAVA T1 FATSAT arterial phase

LAVA T1 FATSAT epato epatobiliary phase



CASE STUDY

Follow up in RF Ablated HCC

PATIENT HISTORY

- M ~70y. Alcohol induced cirrhosis
- HCC nodule in segment IV
- CT performed before and after RFA (1 month)

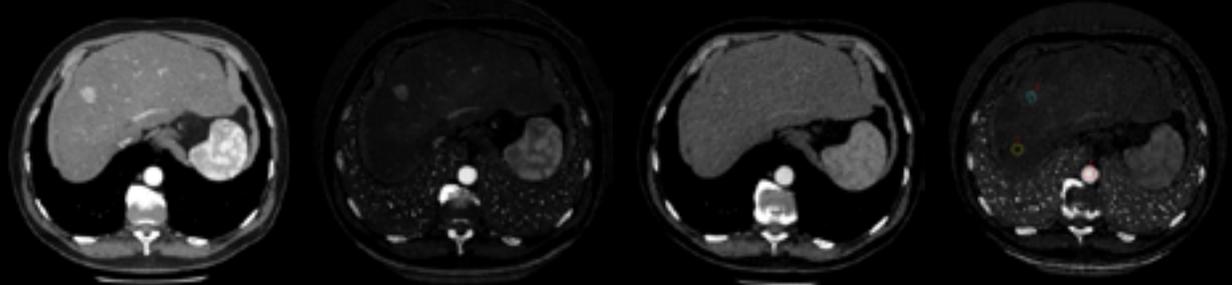
ACQUISITION

- GSI - 40
- 360 mA
- Rotation time: 0.6 sec - Pitch: 0.984:1 - Coverage: 220 mm
- Slice thickness: 1.25 mm
- CTDI: 12.28 mGy - DLP: 326.98 mGy.cm

CONCLUSION

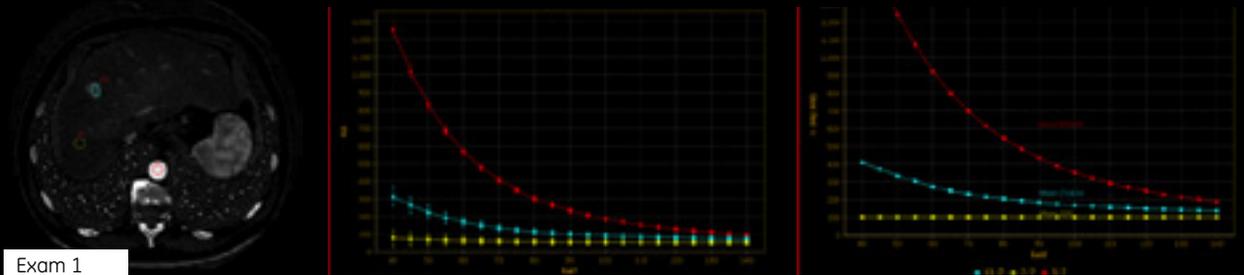
- Iodine (water) images increased the conspicuity of residual viable tumor and Spectral HU curves helped to provide quantitative assessment of tumor response
- With the help of GSI a quantitative assessment of treatment related devascularization enabled a reproducible assessment of tumor response

Follow up Conventional CT vs Iodine (Water) Iodine image increases the conspicuity of residual lesion

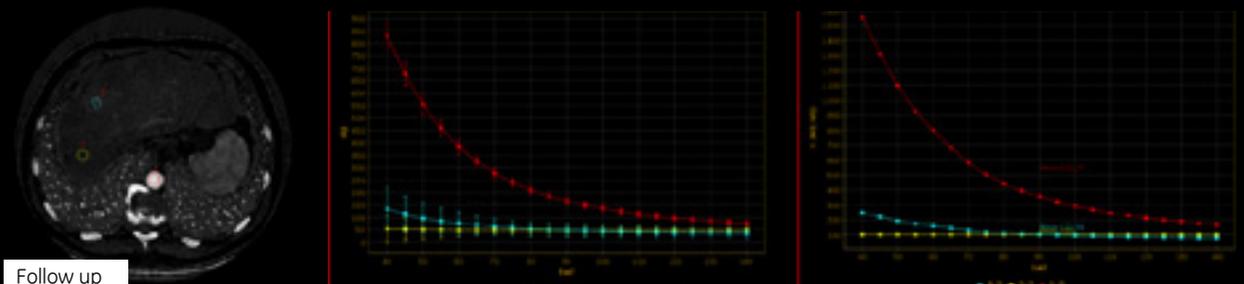


Ex 1 Conventional CT vs Iodine (Water)

Spectral HU and Normalization (normal parenchima) curves ROI 1 Aorta ROI 2 Parenchima ROI 3 Lesion



Exam 1



Follow up



CASE STUDY

Detection & follow-up of liver metastasis

PATIENT HISTORY

- ~60y female coming for follow-up of liver metastasis
- Both examinations were performed using GSI to monitor treatment response

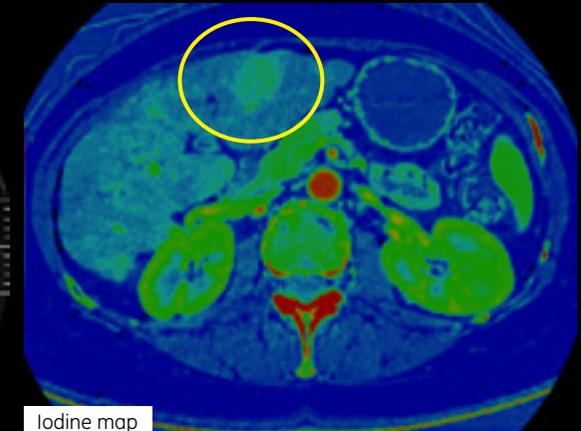
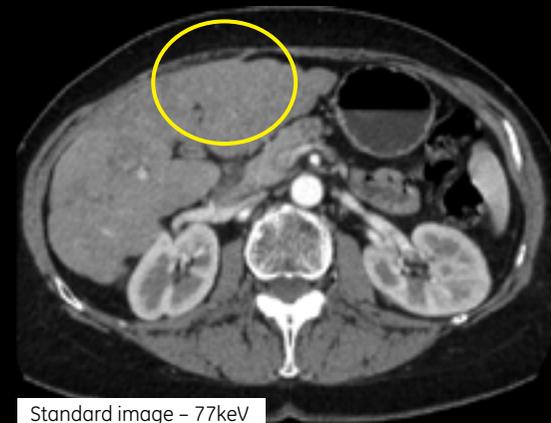
ACQUISITION

- GSI-1 Arterial time
- 630 mA
- Rotation 0.5 sec - Pitch 0.984:1

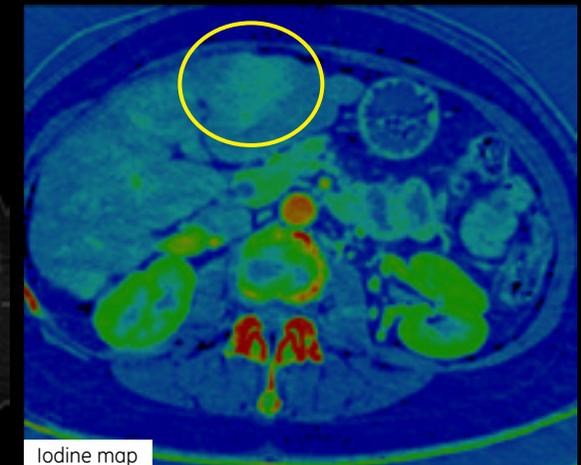
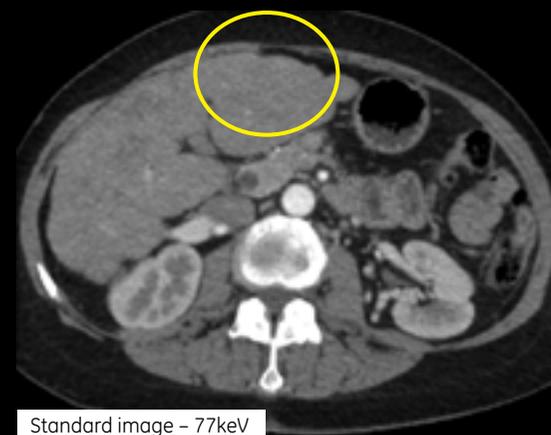
CONCLUSION

- GSI with iodine map (or at 45keV) helped to detect and measure the liver lesions
- It also allowed to follow-up the evolution of the lesions after treatment
- Physician concluded that the patient presented a mixed response to the treatment

FIRST EXAM



FOLLOW-UP EXAM- 3 MONTHS LATER



CASE STUDY

Liver lesion depiction

PATIENT HISTORY

- Patient with liver metastasis from stomach cancer
- Abdomen CT for surgery planning

ACQUISITION

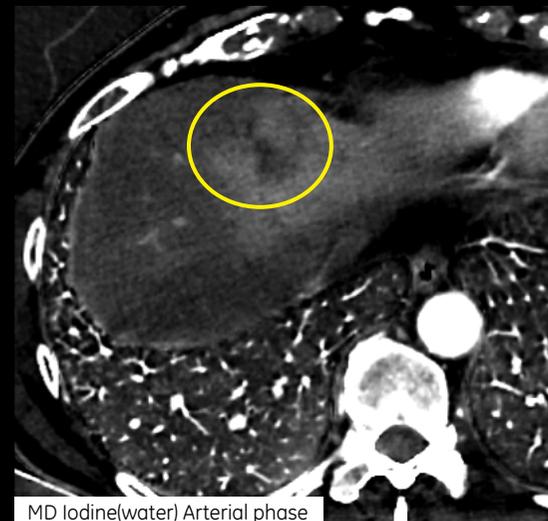
- GSI - 22
- 375 mA
- Rotation time: 0.7 sec - Pitch: 1.375:1
- Slice thickness; 1.25 mm
- CTDI 10.76 mGy - DLP 365 mGy.cm
- Recon: SOFT

CONCLUSION

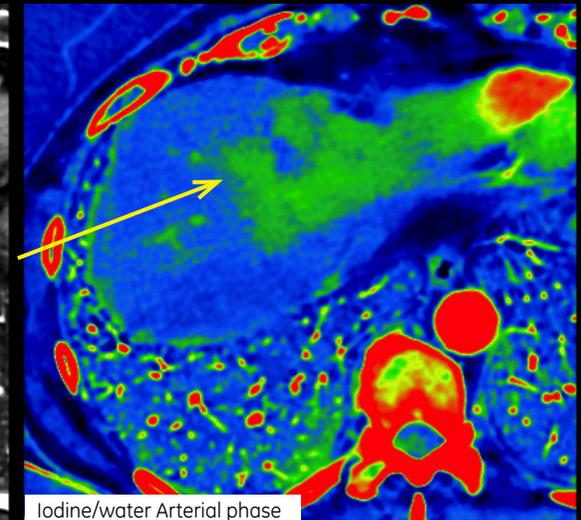
- Iodine map helped to depict and measure the liver metastasis, while its edges are difficult to visualize on the standard image
- MD Iodine arterial phase displayed the enhancement and edges of hepatic metastasis from stomach cancer aiding the physician in surgery planning



77Kev Arterial phase



MD Iodine(water) Arterial phase



Iodine/water Arterial phase



CASE STUDY

Liver lesion depiction

PATIENT HISTORY

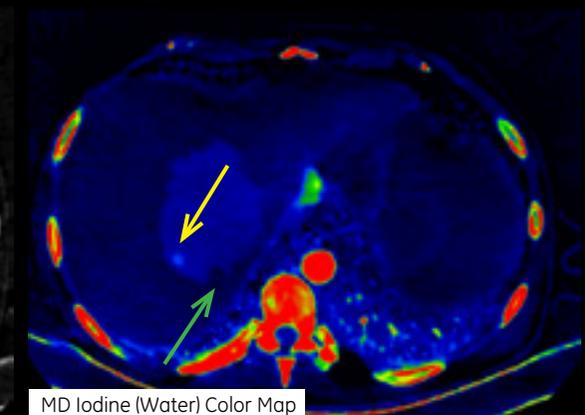
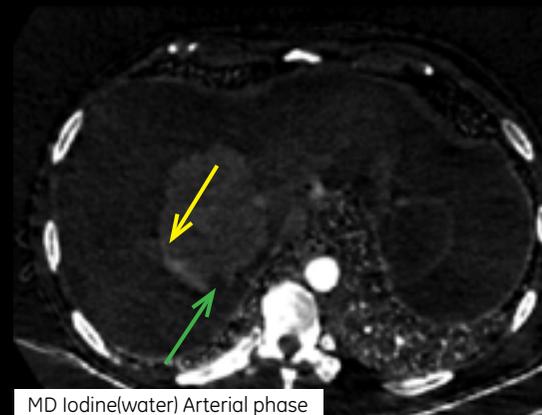
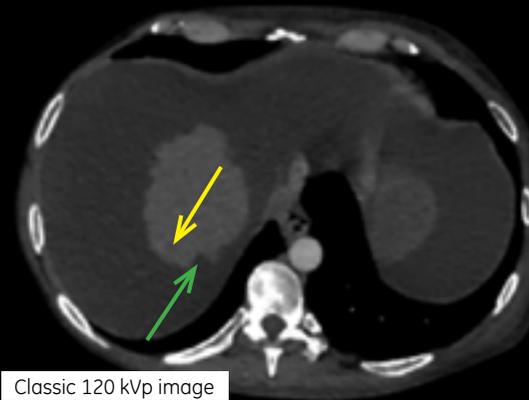
- ~60y male with cirrhosis
- Follow-up of hepatocellular carcinoma

ACQUISITION

- GSI - 1
- 630 mA
- Rotation time: 0.5 sec - Pitch: 1.375:1
- Slice thickness: 1.25 mm
- Recon: STD

CONCLUSION

- Iodine Based images helped to classify the different tissues in the lesion
- More specifically, combined with clinical history, it helped to differentiate atelectasis from lymphomatous tissue
- It also aided to confirm that the second lesion was not enhancing



CASE STUDY

Renal lesion

PATIENT HISTORY

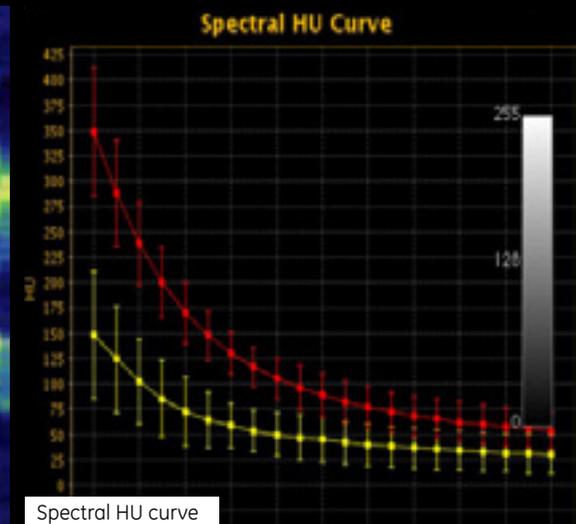
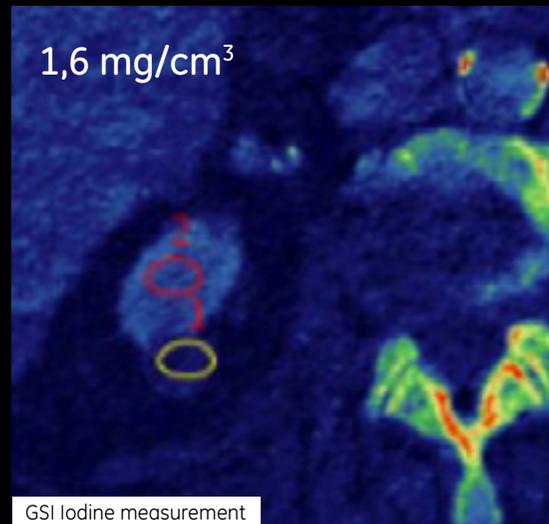
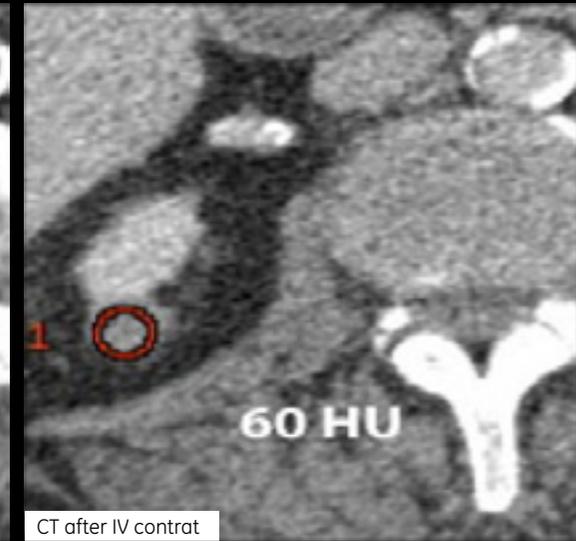
- Incidental finding of a small nodule in the upper pole of the right kidney
- No increase in density after IV contrast administration on conventional CT

ACQUISITION

- GSI

CONCLUSION

- Both qualitative and quantitative iodine uptake in a small renal lesion were visualized on GSI images, suggesting a Renal Cell Carcinoma to the physician
- Pathology after tumorectomy confirmed a papillary RCC
- With the help of GSI, iodine uptake in a small renal lesion was demonstrated and a RCC was resected



CASE STUDY

Characterization of renal cysts

PATIENT HISTORY

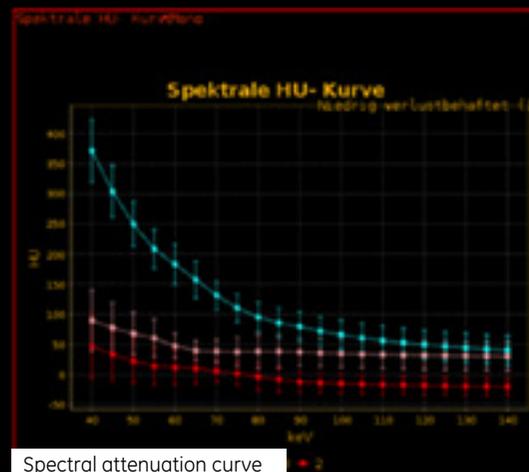
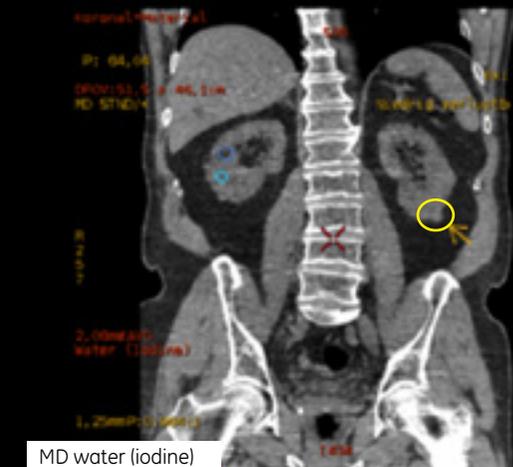
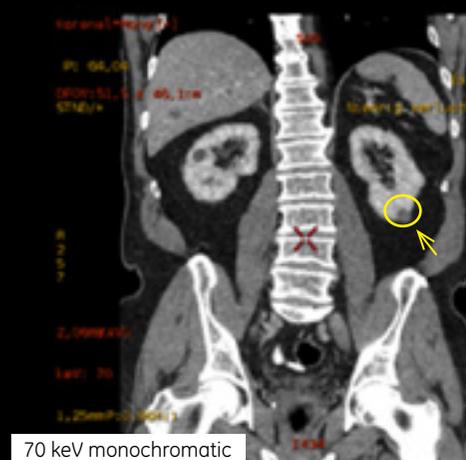
- ~65y male patient referred for evaluation of renal cysts
- Discovered on routine ultrasound by urologist
- BMI 30 kg/m²

ACQUISITION

- Biphasic abdominal scan
 - > arterial phase: 120 kVp, 70-400 mA (NI 18 @ 5 mm)
 - > GSI portal venous phase, : GSI – 22, 360 mA, 0.6 sec rotation
- Reconstruction of GSI: 70 keV monochromatic (50% ASIR), MD water/ iodine

CONCLUSION

- One cyst in lower pole of left kidney (12 mm) showed a CT number of 52 HU in arterial phase and 35 HU on 70 keV
 - > MD iodine image revealed no iodine content
 - > in MD water images, cyst appeared "hyperdense" (~ hemorrhagic/ proteinaceous)
- Based on the above findings, the cyst in the lower pole of the left kidney was classified by the physician as a minimally complex cyst (Bosniak class 2)
- Due to the generation of material decomposition images, no additional non-enhanced series needed to be acquired



CASE STUDY

Bladder tumor detection

PATIENT HISTORY

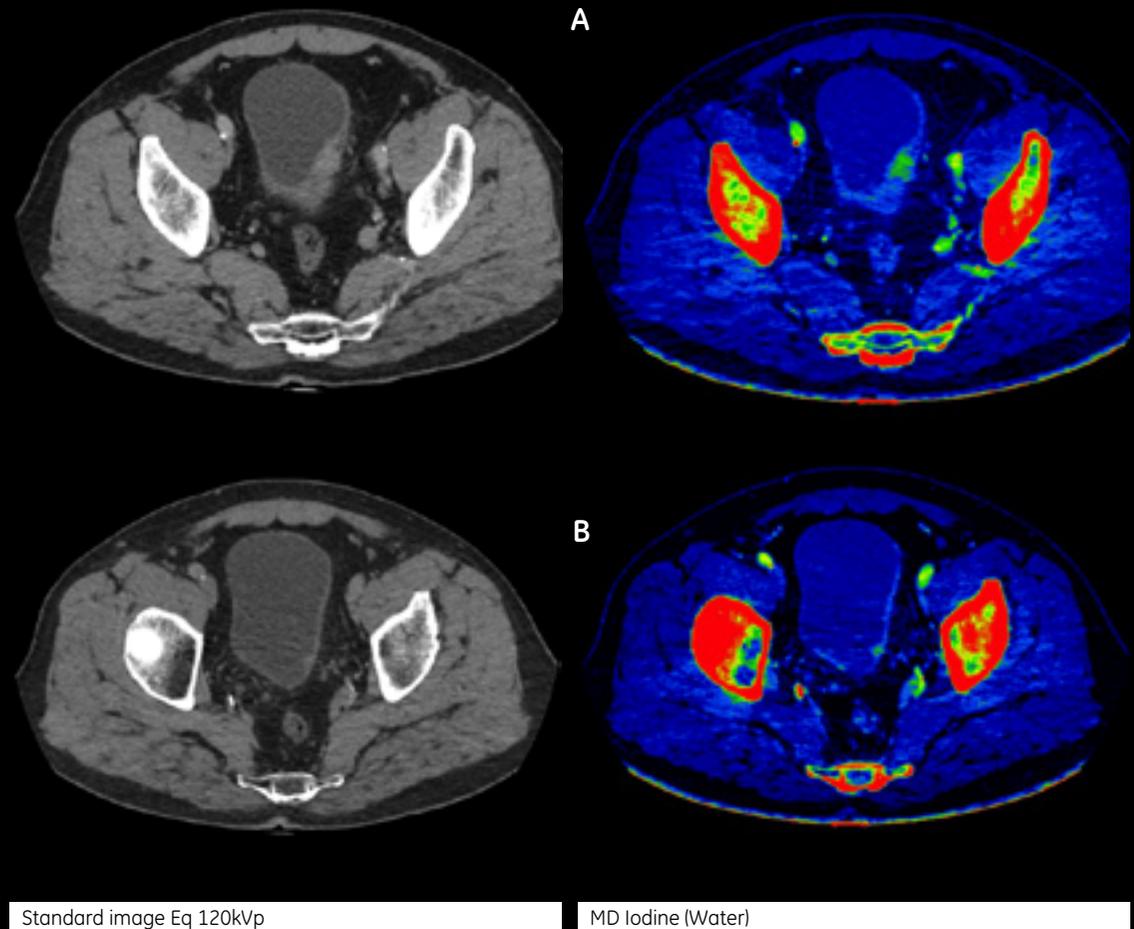
- Follow-up of bladder tumor
- Referred to Abdomen-Pelvis CT

ACQUISITION

- GSI - 10
- 600 mA
- Rotation time: 0.8 sec – Pitch: 1.375
- Slice thickness: 0.625 mm
- Recon: STD

CONCLUSION

- A) Iodine Based images helped to better visualize the tumor and to distinguish differently vascularized tissues
- B) It also assisted to detect a small hypervascular nodule



Standard image Eq 120kVp

MD Iodine (Water)



CASE STUDY

Inflammatory Bowel Diseases

PATIENT HISTORY

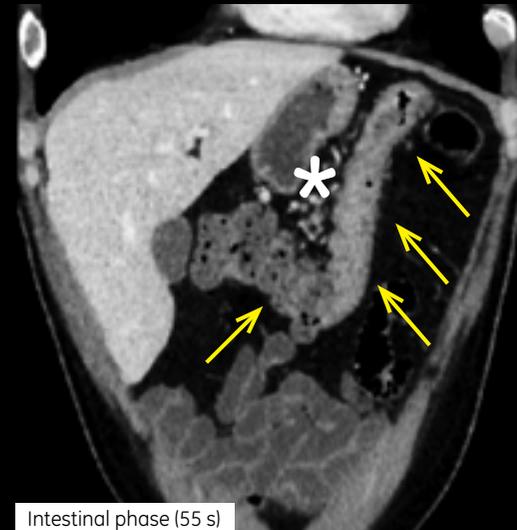
- Patient with weight loss (5 kg in 3 months), abdominal pain and diarrhea
- The goal was:
 - > to evaluate small bowel and colon morphology
 - > to exclude radiologic signs of IBD
 - > to stage inflammatory disease

ACQUISITION

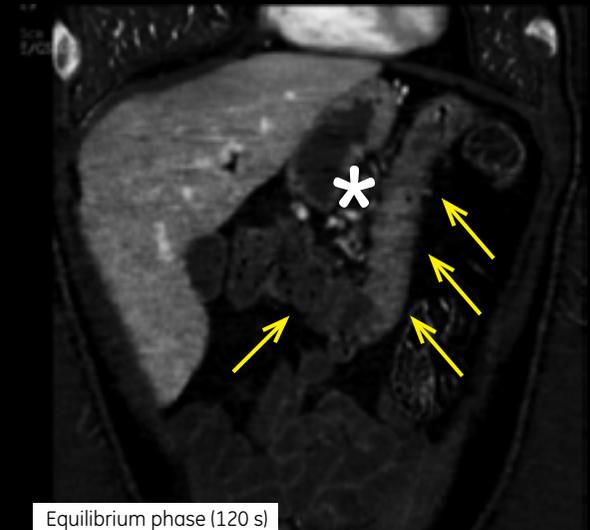
- GSI (intestinal and equilibrium phases)
- GSI-40
- 360 mA + ASIR 100%
- Rotation time: 0.6 sec – pitch 0.984:1
- 100 mL CM at 3 mL/s + 60 mL of saline flush
- Contrast media: 320 mgI/mL

CONCLUSION

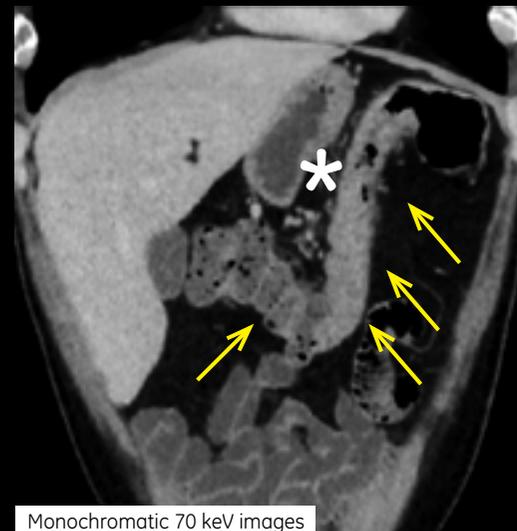
- Intestinal CT scan demonstrated parietal thickening of transverse and left colon with intense CM enhancement (short arrows)
- Evaluation of Iodine (Water) images helped physician to differentiate real parietal enhancement from pseudoenhancement, especially in equilibrium phase



Intestinal phase (55 s)



Equilibrium phase (120 s)



Monochromatic 70 keV images



Iodine (Water) images



Vascular imaging & contrast media optimization

Managing patients with impaired renal function is a challenge today in CT imaging due to the nephrotoxicity of iodine contrast media.

Often linked to chronic kidney disease—with arterial hypertension and diabetes as main contributing factors—kidney failure has a relatively high prevalence in the elderly population.

Additionally, due to an aging population, the number of patients affected by this medical condition has increased dramatically in the last 20 years.

GSI enables the generation of monochromatic energy images using a projection-space dual energy reconstruction algorithm. A benefit of monochromatic energy images is the ability to increase the contrast of higher attenuating materials, like bone or iodinated contrast, when lowering the energy levels (keV). With the aid of lower monochromatic energies it becomes possible to increase the visibility of enhancement in the body due to contrast material and may enable contrast optimization.

This ability to produce material decomposed images like MD Iodine(Water) is also very useful in CTPA indications as it allows to get an iodine map of the lung parenchyma, enabling to better assess the impact of the clots on the lung perfusion.



CASE STUDY

Pulmonary embolism

PATIENT HISTORY

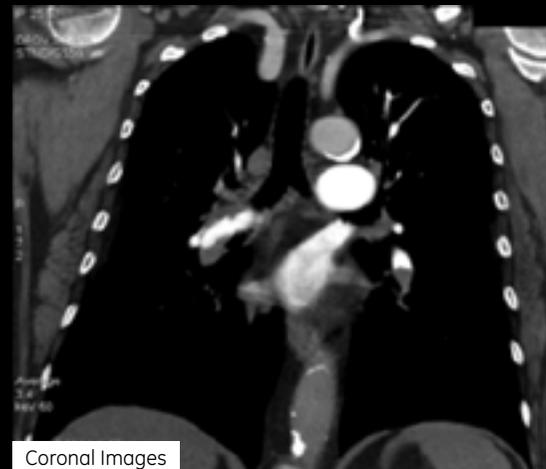
- ~75y female coming for dyspnea and chest pain
- Patient suffering from Wegener disease, with kidney involvement
- D-Dimer 3.4 mg/l
- The goal was:
 - > to determine if there is a pulmonary embolism
 - > to use as little contrast media as possible

ACQUISITION

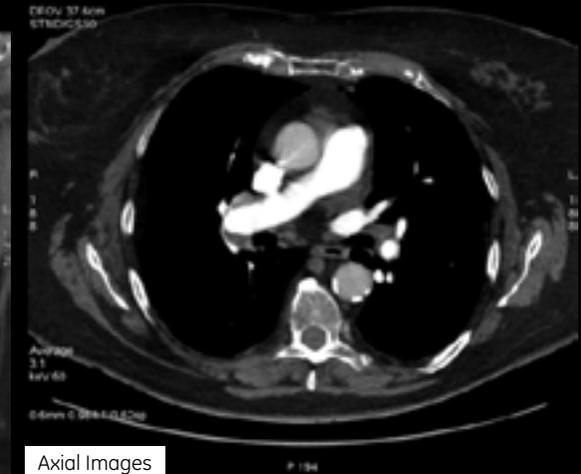
- GSI
- 300 mA + ASIR 80 %
- Rotation time: 0.5 sec – Pitch: 0.984:1
- Contrast media: 35 ml (370 mgI/mL), Flow 3ml/sec

CONCLUSION

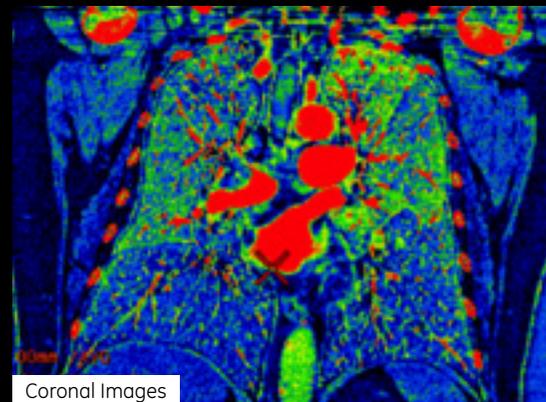
- With the help of Iodine overlay image, the radiologist concluded on bilateral pulmonary embolism, that would be difficult to see on conventional CT images with only 35 mL of contrast media



Coronal Images



Axial Images



Coronal Images



CASE STUDY

Hypoperfusion without PE

PATIENT HISTORY

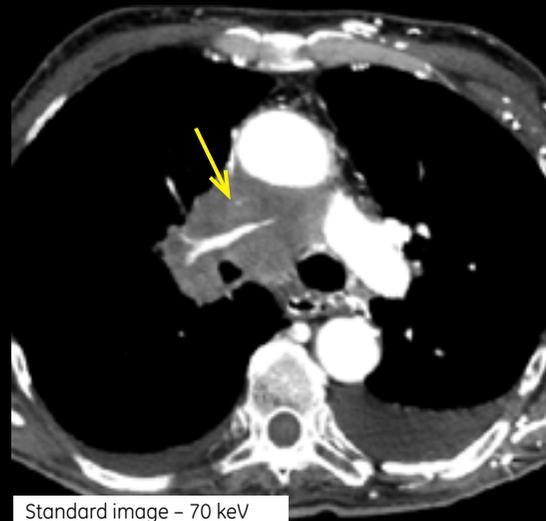
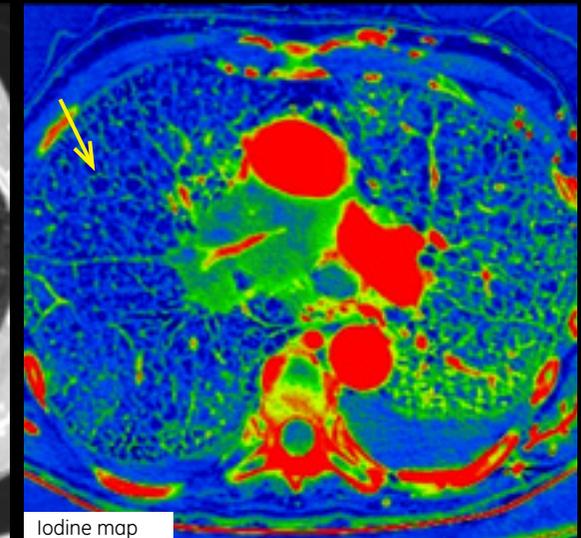
- ~75y male with lung cancer
- Referred for suspicion of pulmonary embolism

ACQUISITION

- GSI Acquisition
- Rotation 0.5 sec
- 375 mA
- Pitch 0.984:1

CONCLUSION

- The physician detected no contrast defect in pulmonary vasculature with monochromatic images and no pulmonary embolism
- With the help of GSI with iodine map, the physician concluded on hypoperfusion of the right lung due to tumor encasement



CASE STUDY

One-Stop-Shop Approach in Lung Diseases

PATIENT HISTORY

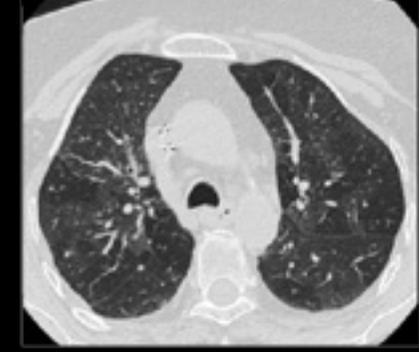
- 2 Patients coming with dyspnea. Both are affected by COPD and mild pulmonary hypertension. Case 2 has cardiac pacemaker
- The goal was:
 - > to investigate lung parenchyma
 - > to exclude vascular disease such as chronic pulmonary embolism

ACQUISITION

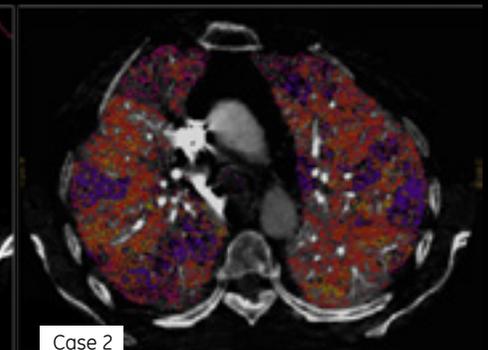
- HRCT inspiration + expiration
- GSI acquisition
 - > 100 kV, 300 mA + ASIR 50%
 - > Rotation time: 0.5 sec
 - > Recon: Bone PLUS
 - > GSI-1
 - > 6300 mA + ASIR 90%
 - > Rotation time: 0.5 sec – pitch 1.375:1
 - > 30 m 30 mL CM at 4 mL/s + 60 mL saline flush
 - > Contrast media: 320 mgI/mL

CONCLUSION

- In both cases, based on HRCT images, the physician detected a mosaic aspect of lung parenchyma (dark lung pattern) with diffuse expiratory air-trapping
- On the CT angiographic evaluation, no endovascular filling defect was shown
- With the help of GSI with iodine map, the physician noticed inhomogeneity in case 2, corresponding to air-trapping areas
- Based on the complementary information from the HRCT images and GSI images, the physician concluded:
 - > Case 1: bronchiolar disease
 - > Case 2: chronic thromboembolism



Case 1



Case 2



CASE STUDY

Superior Mesenteric Artery Thrombosis

PATIENT HISTORY

- ~80 year old woman with impaired renal function, hospitalized due to vascular troubles in the lower limbs
- One week after being admitted, the patient complained from severe abdominal pain, the radiologist decided to perform a GSI examination with low Iodine concentration and low volume

ACQUISITION

- 3 Phases acquisition
- GSI in arterial phase

INJECTION

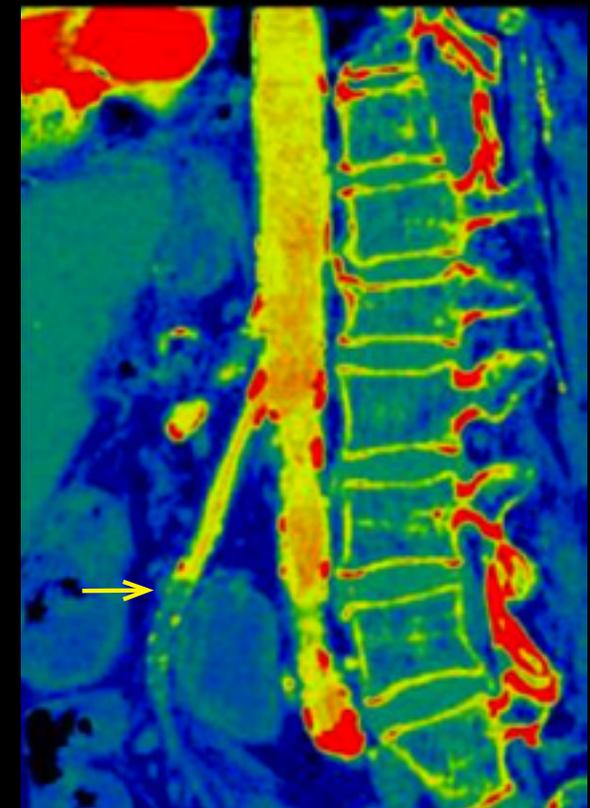
- 50 mL at 3.5 cc/s
- Contrast media: 270 mgI/mL

CONCLUSION

- With the help of GSI monochromatic capabilities, the physician detected a thrombosis of the superior mesenteric artery using low keV images to increase the conspicuity of Iodine



Curved view of the Superior Mesenteric Artery at low keV



Sagittal Plain on Arterial Phase at low keV



CASE STUDY

TAVI planning

PATIENT HISTORY

- ~80y male BMI 28
- Known for severe aortic stenosis under dialysis treatment
- CTA for TAVI planning

ACQUISITION

- 600 mA
- Rotation time: 0.5 sec – Pitch: 1.375:1
- Coverage: 680 mm
- Slice Thickness: 0,625 mm
- Total scan time: 6,77 sec
- CTDI: 12.72 mGy – DLP: 326.98 mGy.cm

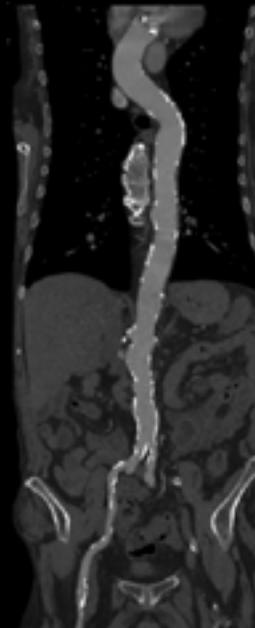
INJECTION

- 40 ml contrast + 50 ml saline at 3 cc/s
- Contrast media: 320 mgI/mL

CONCLUSION

- With the help of GSI monochromatic capabilities, using low keV images to increase the conspicuity of iodine, the radiologist achieved a very good contrast enhancement of the thoracic-abdominal aorta and its major branches for TAVI planning, despite a low amount of contrast media

CONVENTIONAL CT

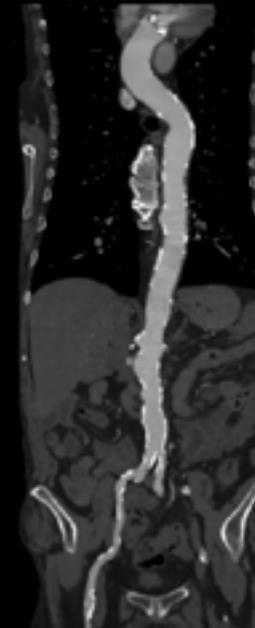


Curved MPR

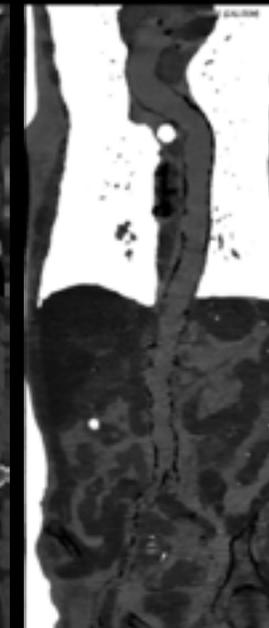


Average 247.9 HUStd
Deviation 15.1

GSI 60 KEV ASIR 40%



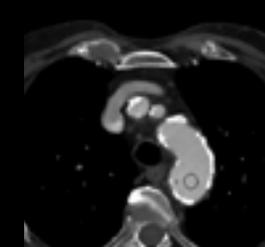
Curved MPR



Curved MPR Iodine (Calcium)



VR



Average 360.6 HU
Std Deviation 9.6
+ 32% CE
-37% Noise



CASE STUDY

TAVI planning

PATIENT HISTORY

- ~80 year old patient referred for an Abdominal Aorta CTA before TAVI procedure
- Patient with Hip Prosthesis that prevents the assessment of the femoral artery on conventional CT
- Patient suffering also from renal failure

ACQUISITION

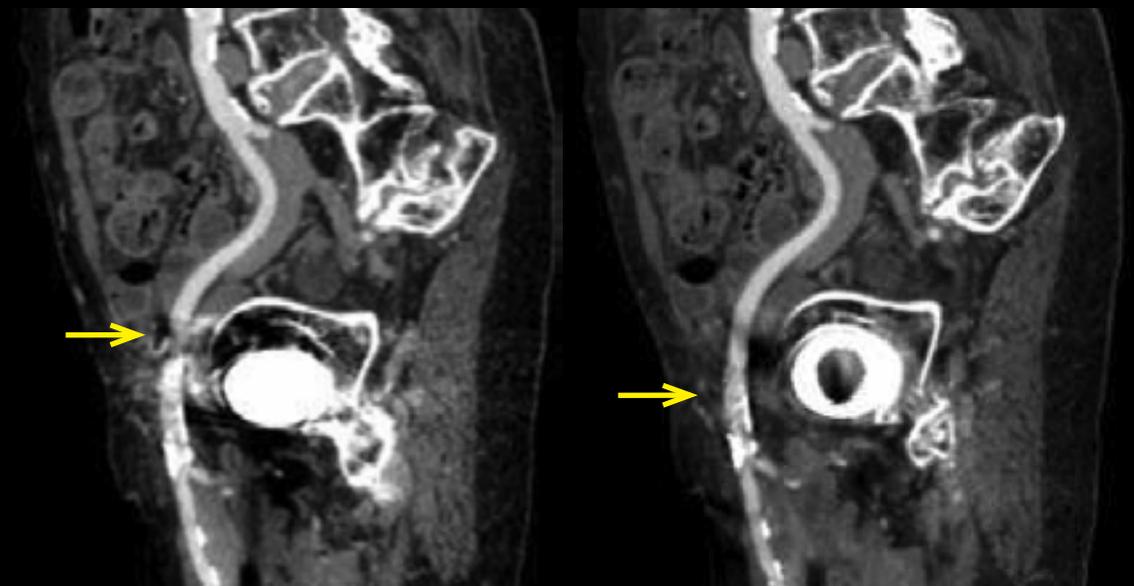
- Single phase acquisition
- GSI

INJECTION

- 30 mL
- Contrast media: 320 mgI/mL

CONCLUSION

- On conventional CT images, it is very difficult to accurately assess the patency of the femoral artery because of the hip prosthesis
- With the help of GSI with MARs, enabling metal artifact reduction, the physician was able to assess the patency of the femoral artery
- With the help of GSI monochromatic capabilities, using low keV images to increase the conspicuity of iodine, the radiologist achieved a very good contrast enhancement of the abdominal aorta and its major branches for TAVI planning, despite a low amount of contrast media



Conventional 100 kVp recon

65 keV recon with MARs



CASE STUDY

Carotids stenosis assessment

PATIENT HISTORY

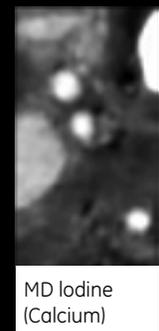
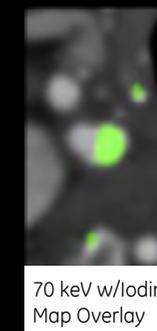
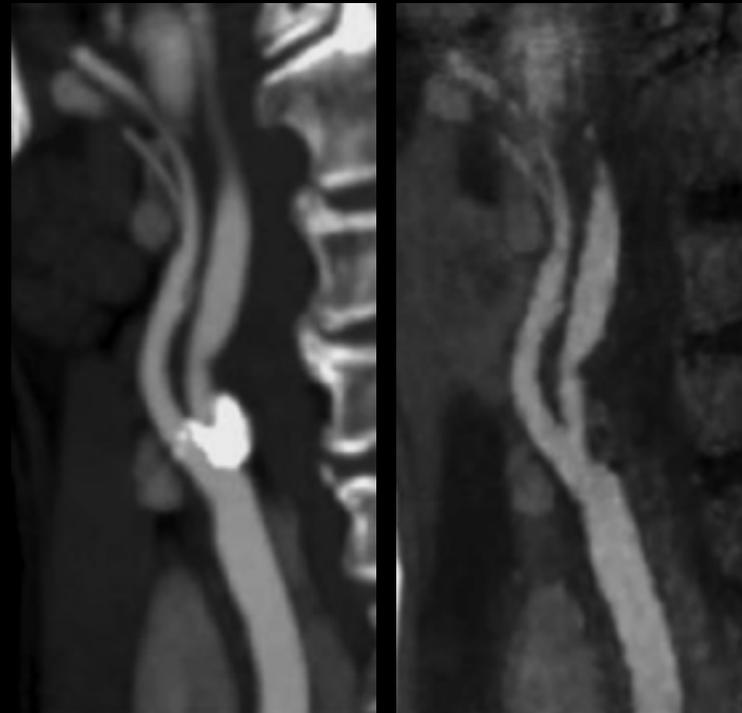
- ~65 year old patient referred for CTA of the supra aortic arch
- Lumen patency is not always accurately assessed with conventional CT imaging. Blooming artifact from dense calcium and poor iodine visualization are common challenges

ACQUISITION

- GSI
- 375 mA
- 0.625 mm slice thickness

CONCLUSION

- The GSI acquisition enables to reconstruct specific material decomposition images thus allowing in this case a better differentiation between iodine and calcium
- Material Decomposition images Iodine (Calcium) allowed to display the vessel lumen without calcium, helping the physician to assess the stenosis



CASE STUDY

Carotid Artery Plaque Characterization

PATIENT HISTORY

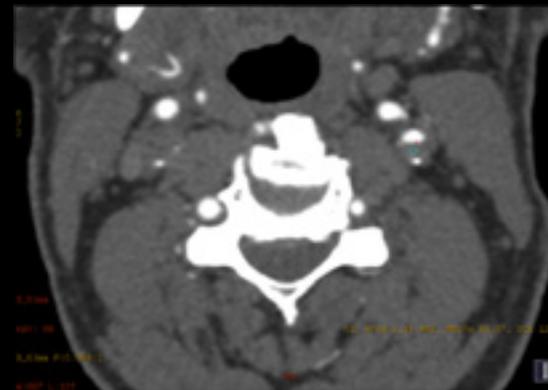
- M ~70 y old. Smoker. Some TIA episodes

ACQUISITION

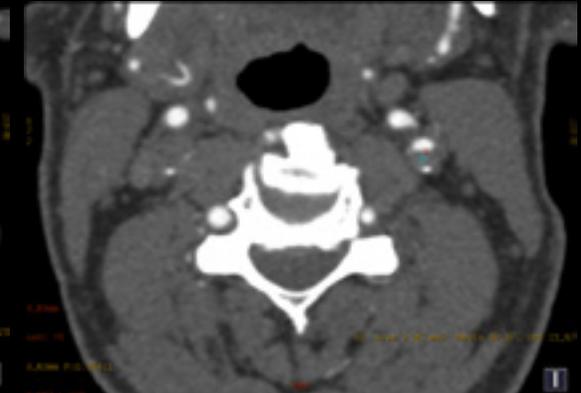
- GSI - 3
- 600 mA
- Rotation time: 0.5 sec - Pitch: 0.984:1
- Slice thickness: 0,625 mm
- Contrast media: 60 ml + 40 ml saline@ 5 ml/s after Bolus Test

CONCLUSION

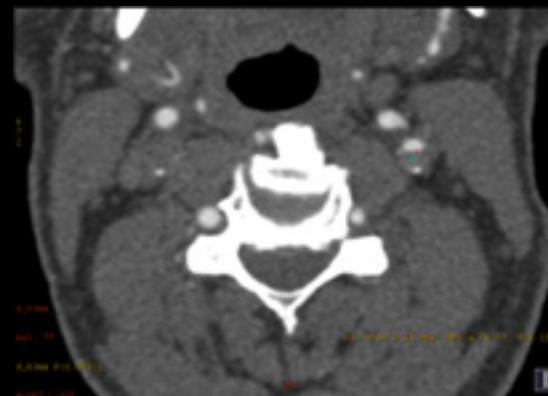
- The radiologist was able to observe that the HU value markedly changed when the keV changed, which helped in plaque characterization



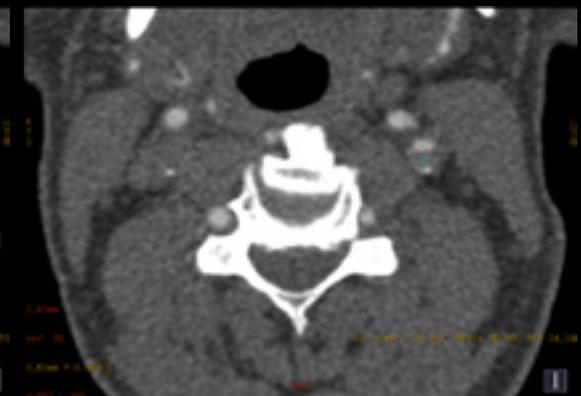
66 KeV Mean Value ROI: 89.07



70 KeV Mean Value ROI: 82.87



77 KeV Mean Value ROI: 74.73



86 KeV Mean Value ROI: 66.80



Metal artifact reduction with GSI and MARs

Imaging patients with metal implants has long been a challenge for all modalities. Artifacts in CT imaging are mainly due to the hardening of a polychromatic x-ray spectrum. By producing monochromatic images, GSI significantly reduces beam hardening artifacts. GSI Metal Artifact Reduction (MARs) provides outstanding diagnostic images by performing excellent projection measurements and reducing signal errors due to high density material.

HEAD IMAGING

Brain aneurysms are widely treated with coils, clips and stents. Thanks to its metal artifact reduction capability, GSI improves vessel visualization in proximity of these implants, enabling aneurysmal bleeding follow-up. In addition, GSI allows enhanced diagnostic imaging of patients with dental implants or TMJ prosthesis.

ABDOMINAL IMAGING

Metal implants, such as coils are also often used in the abdominal treatment like aneurysmal embolization. Thanks to its metal artifact reduction capability, GSI may help in the follow-up of these patients and the assessment of the success of the treatment.

MUSCULO-SKELETAL IMAGING

With aging, bone and joint disorders mainly caused by osteolysis and arthrosis become a major issue. Accidents may also lead to shoulder, hip or knee prosthesis implantation and fractures may be treated with screw, pin, rod and plate fixation. Post-operative scanning of these patients is essential for evaluation of bone resorption, aseptic loosening, implant failure or dislocation. Thanks to its metal artifact reduction capability, GSI helps to visualize the prosthesis and surrounding tissues.



CASE STUDY

Aneurysmal bleeding 1/2

PATIENT HISTORY

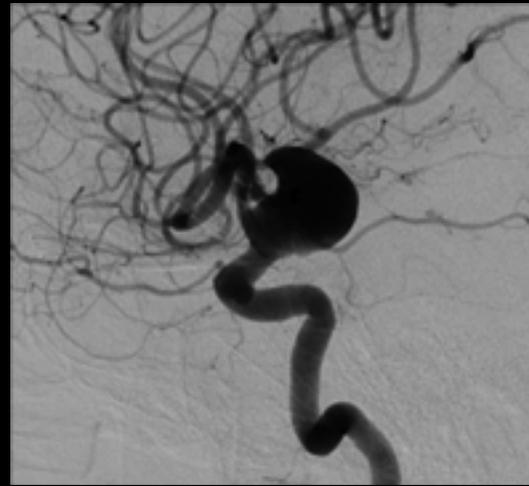
- F ~60 y old. Subarachnoid hemorrhage of the anterior segment treated with coil in 2009
- After one year follow up for aneurysm recanalization, aneurysmal rebleeding re-treated with coils
- Presence of vasospasm endovascularly treated

ACQUISITION

- GSI - 20
- 600 mA
- Rotation time: 0.5 sec - Pitch: 0.969:1 - Coverage: 200 mm
- Slice thickness : 0.625

CONCLUSION

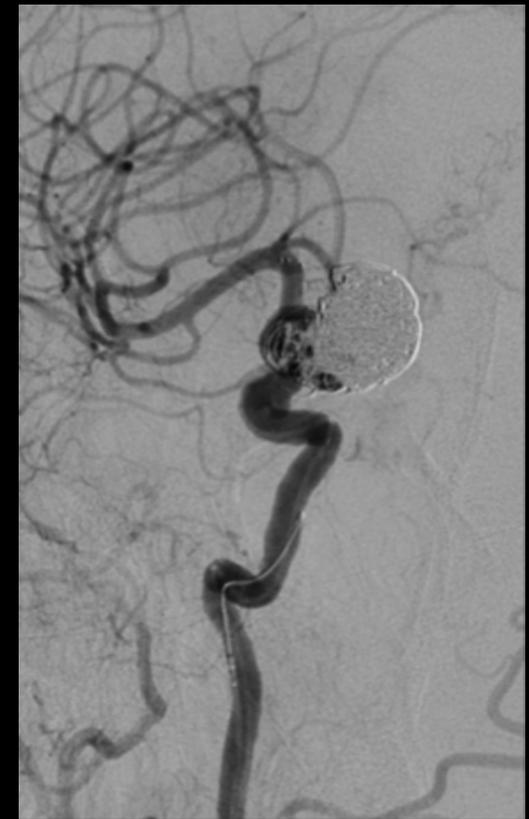
- With the help of GSI with MARs for metal artifact reduction, the radiologist was able to identify the vessels near the aneurysm and follow-up the vasospasm post treatment



Angiography- pre treatment



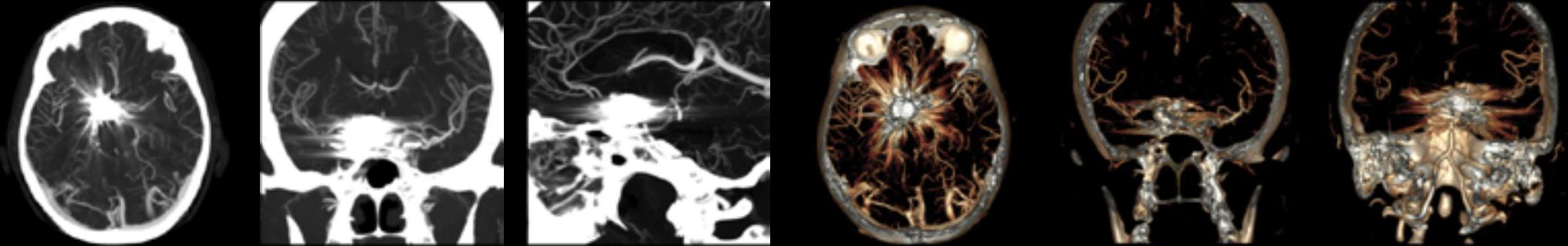
Angiography-post treatment A-P and L-L



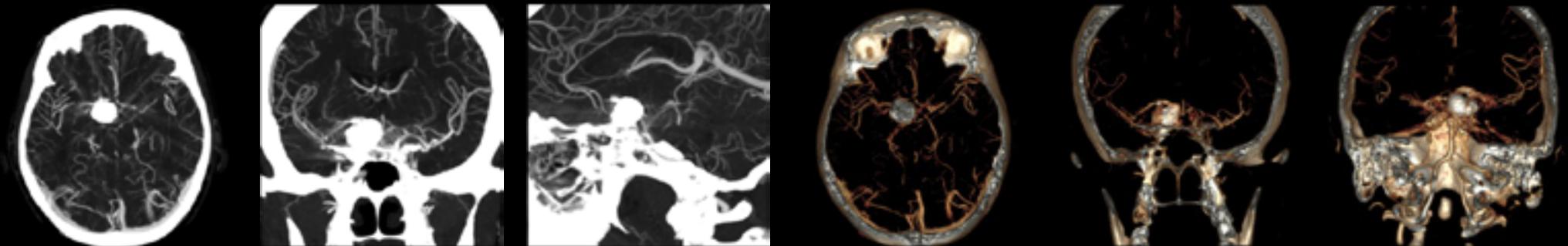
CASE STUDY

Aneurysmal bleeding 2/2

STANDARD ACQUISITION



GSI WITH MARS ACQUISITION



CASE STUDY

Stroke

PATIENT HISTORY

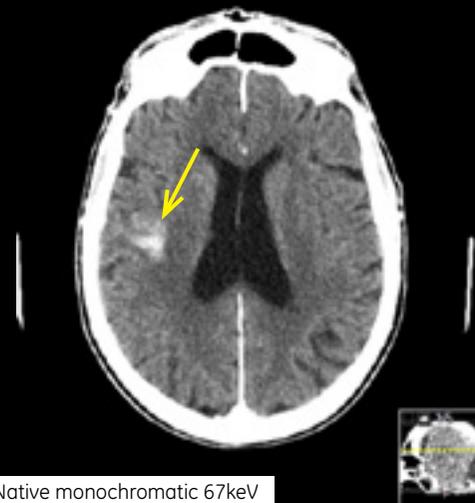
- ~75 year male, atrial fibrillation and aspirin. Acute stroke and mechanical thrombectomy. Due to abstinence of alcohol intubated - difficulties to follow in clinic evaluation
- One day follow-up

ACQUISITION

- GSI - 30
- 550 mA
- CTDI: 57.88 mGy

CONCLUSION

- The bright area represents iodinated contrast as a similar high intensity value is not observed in the Water image. This is not blood which would have altered the anticoagulation strategy



CASE STUDY

Temporomandibular joint prosthesis

PATIENT HISTORY

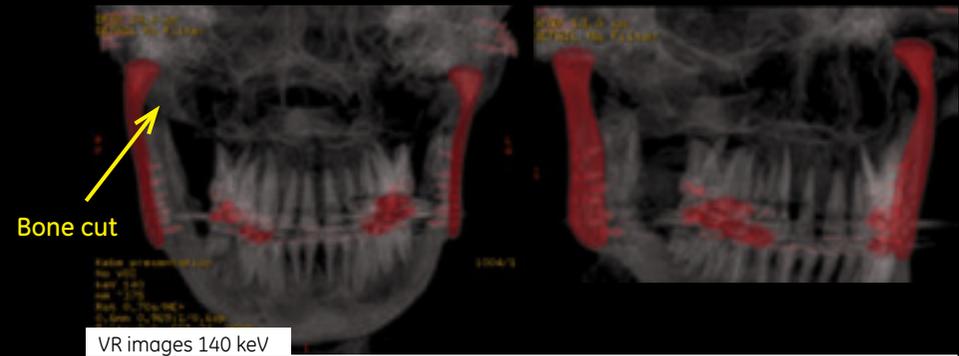
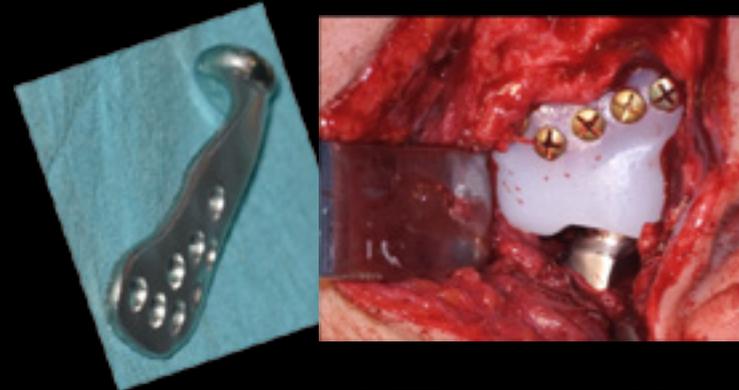
- Traffic injured face
- Double prosthesis operation
- Control of placement and bone structure status around the bone cuts
- Normal CT gave too much noise and artifacts from the titan prostheses

ACQUISITION

- GSI - 24
- 375 mA
- Rotation time: 0.7 sec

CONCLUSION

- With the help of GSI and its metal artifact reduction capabilities, images of titan operation gave good image quality in Volume Rendering
- The sagittal images showed the plastic cup and the titan prostheses with reduced artifact
- The physician was able to see for extra bone productivity in the cut lines of the mandible



VR images 140 keV



Sagittal images 140 keV 140 keV



CASE STUDY

Liver vascular mapping

PATIENT HISTORY

- M ~50y with Liver transplantation
- Biopsy to confirm recurrence of cirrhosis ~10 years earlier
- Development of portal hypertension
- Three previous embolyzations of post biopsy arteroportal fistula

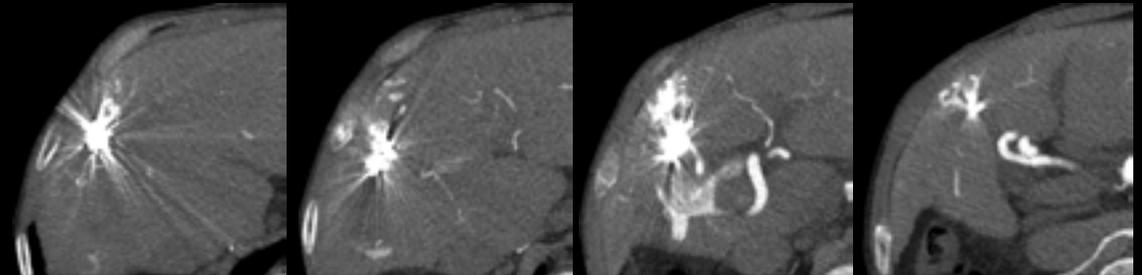
ACQUISITION

- GSI - 40
- 360 mA
- Rotation time: 0.6 sec - Pitch: 0.984:1 - Coverage: 220 mm
- Total scan time: 4.06 sec
- CTDI: 12.28 mGy - DLP: 326.98 mGy.cm

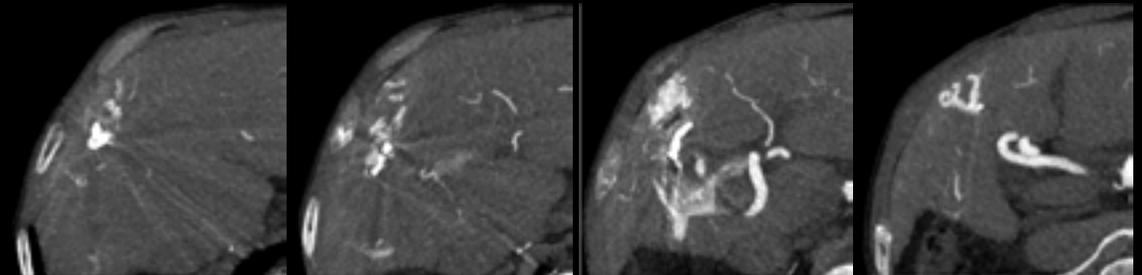
CONCLUSION

- With the help of GSI with MARs and monochromatic images, the radiologist was able to reduce metal artifacts helping in a vascular mapping for treatment planning

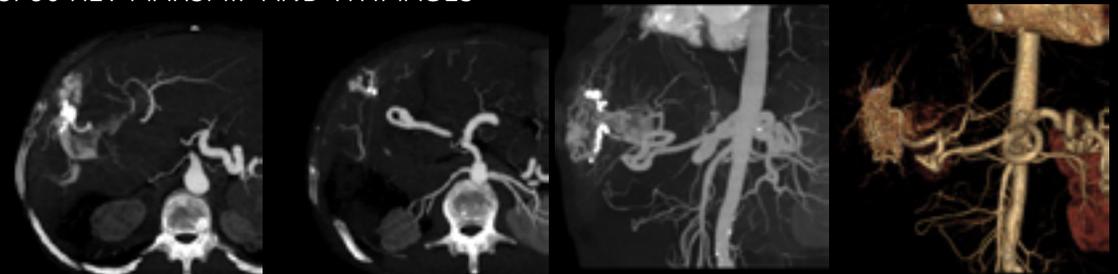
CONVENTIONAL CT



GSI 60 KEV MARS



GSI 60 KEV MARSMIP AND VR IMAGES



CASE STUDY

Arterial splenic aneurysm

PATIENT HISTORY

- Control CT in ~45y patient after arterial splenic aneurysm embolization with coils (2 packing : 1 before and one after the aneurysm)
- The goal was:
 - > to determine if aneurysm was excluded
 - > to assess the splenic parenchyma perfusion

ACQUISITION

- Conventional acquisition / GSI
- Rotation time: 0.5 sec
- Slice thickness: 1.25 mm every 0.9 mm

CONCLUSION

- With the aid of GSI Metal Artifact Reduction, the physician was able to confirm that there was no residual circulation post coiling



Without MARs



With MARs



Without MARs



With MARs



CASE STUDY

Shoulder Prosthesis 1/2

PATIENT HISTORY

- Patient coming for an inversed shoulder prosthesis control
- Implanted after a massive rupture of the rotator cuff
- The goal was :
 - > to determine if there was a lysis of the scapula linked to the frictionnal resistance with the prosthesis
 - > to assess the state of damage of the bone (scored from 1 to 4 according to the Nerot Classification)

ACQUISITION

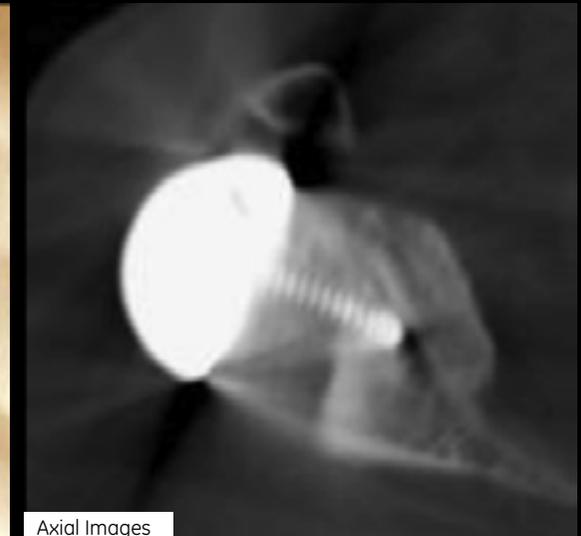
- Conventional acquisition
- 140 kV, 300 mA
- Rotation time: 1 sec

CONCLUSION

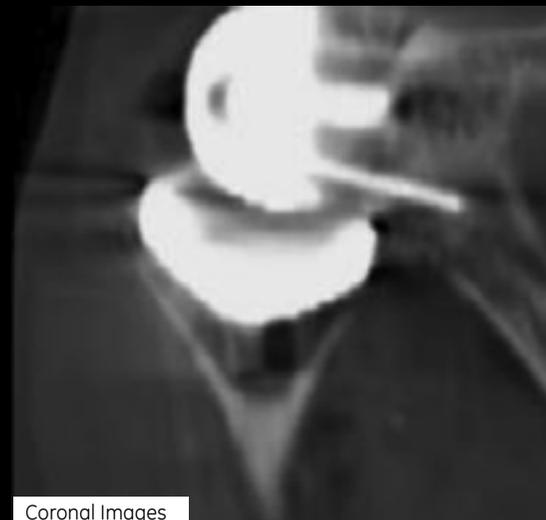
- The radiologist suspected a lysis of the scapula but cannot determine the state of damage due to metal artifacts



Nerot Classification



Axial Images



Coronal Images



Coronal Images



CASE STUDY

Shoulder Prosthesis 2/2

PATIENT HISTORY

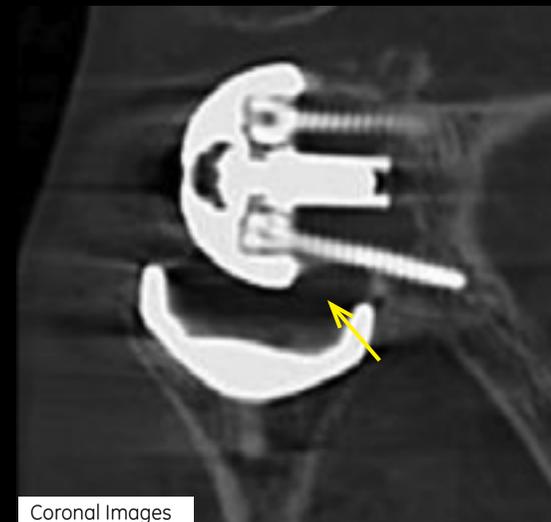
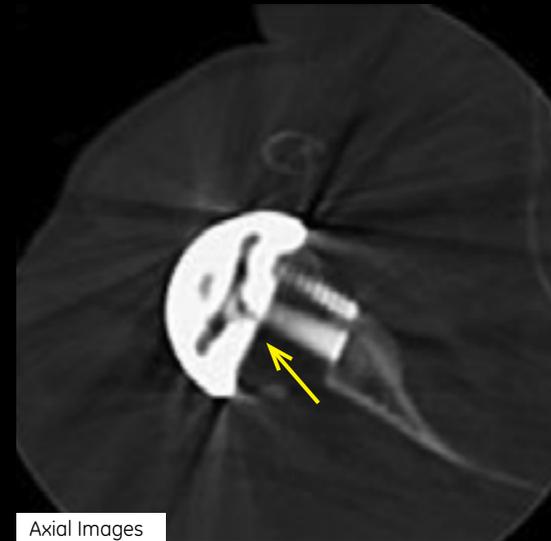
- The patient was referred for a CT scan using GSI with MARS in the hope to be able to reduce the metal artifacts

ACQUISITION

- GSI
- 375 mA
- Rotation time: 1 sec

CONCLUSION

- With the metal artifact reduction capabilities of the high keV images, the radiologist was able to diagnose an osteolysis of the scapula with damage state of 4 on the Nerot classification



CASE STUDY

Instrumented Spine Control

PATIENT HISTORY

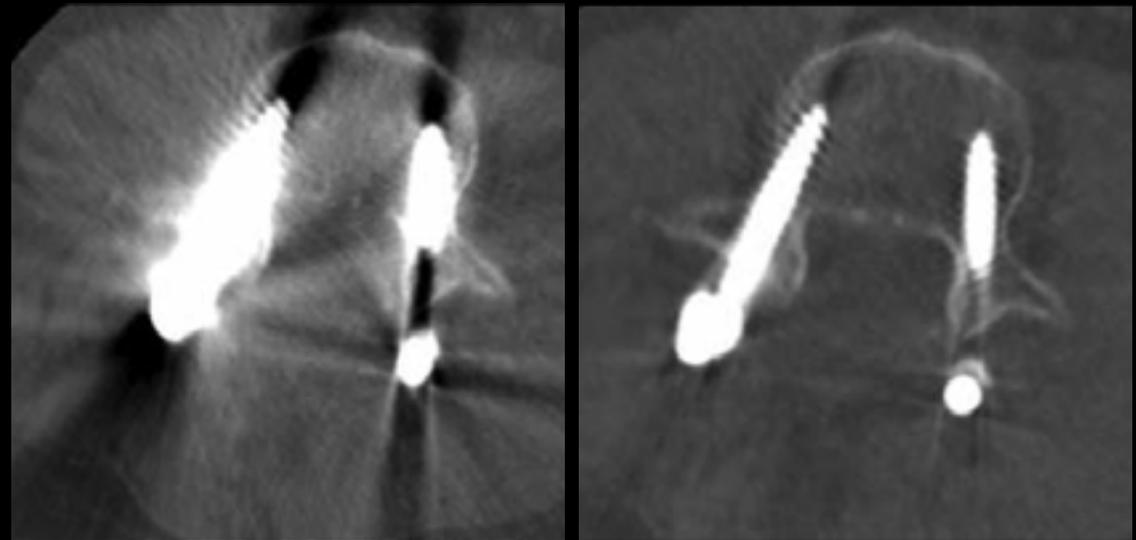
- ~60 year old patient referred for an instrumented spine control after surgery

ACQUISITION

- GSI

CONCLUSION

- On conventional CT images it was very difficult to accurately assess the surrounding structures and the interface between the screws and the bone
- GSI with its monochromatic energy capabilities enabled a significant metal artifact reduction thus improving the assessment of the structures surrounding the metallic implants



Conventional 120 kVp polychromatic images

110 keV monochromatic images



CASE STUDY

Bone metastasis in a hip prosthesis corner 1/2

PATIENT HISTORY

- ~50y patient with medical history of thyroid carcinoma with bone metastasis on the right hemipelvis
- Search for metastatic recurrence

ACQUISITION

- GSI
- 600 mA
- Rotation time: 0.8 sec – Pitch: 0.516:1

CONCLUSION

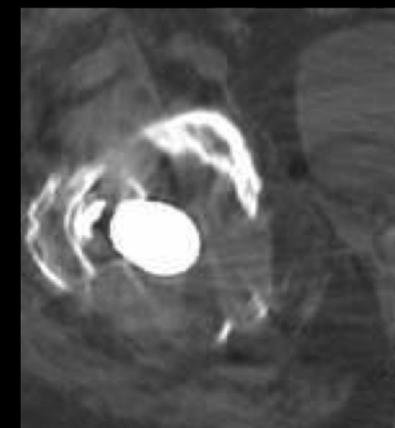
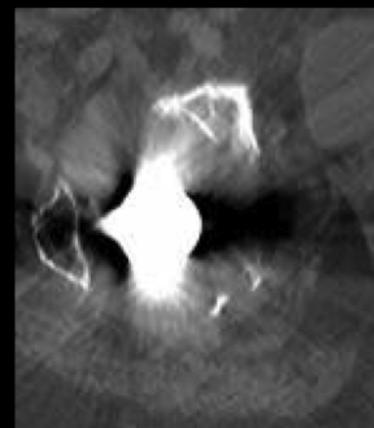
- GSI with monochromatic and MARs capabilities helped the radiologist to visualize the metastasis in the corner of the hip prosthesis with reduced artifacts



Standard polychromatic image



Monochromatic with MARS



CASE STUDY

Bone metastasis in a hip prosthesis corner 2/2

PATIENT HISTORY

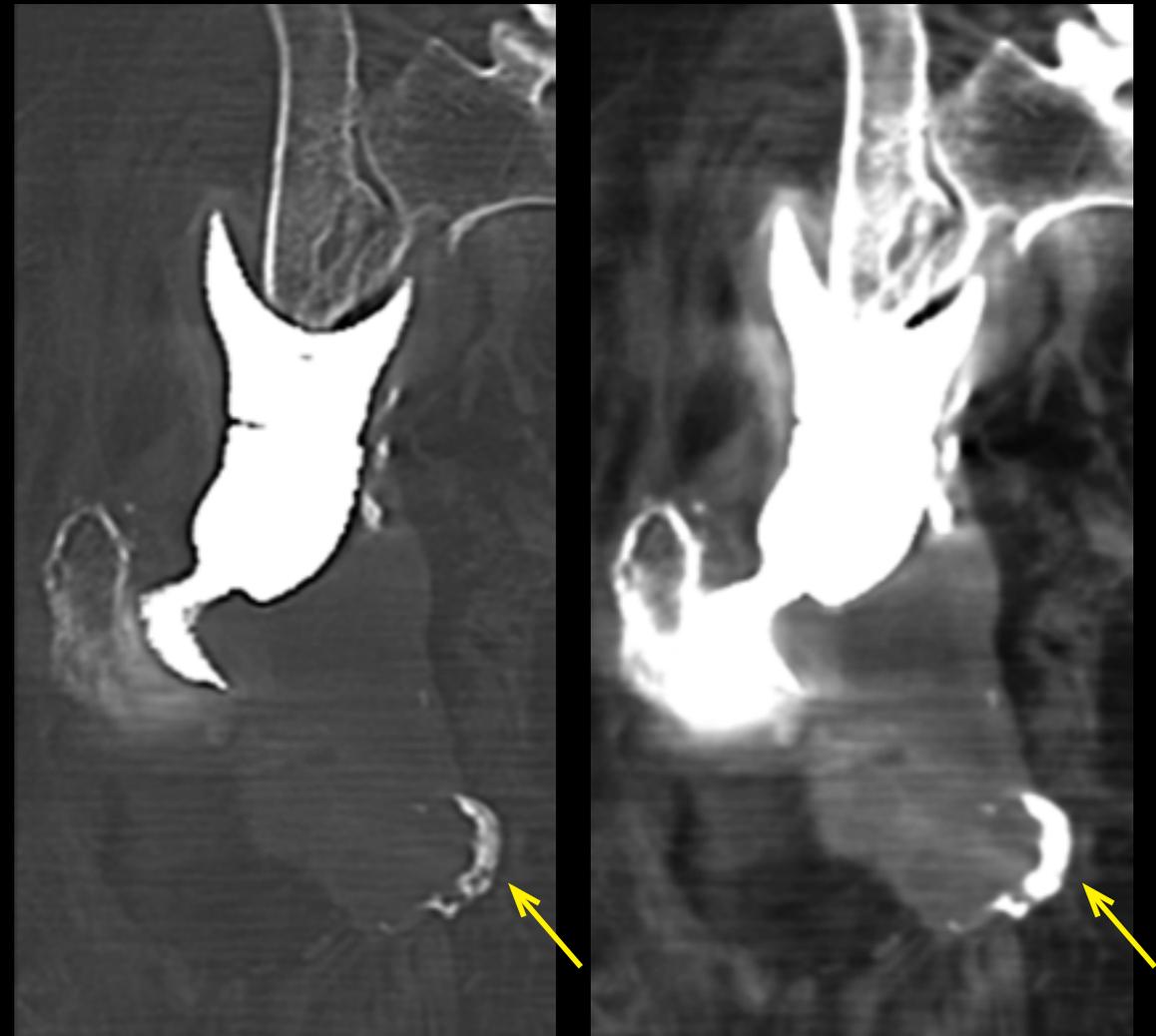
- ~50y patient with medical history of thyroid carcinoma with bone metastasis on the right hemipelvis
- Search for metastatic recurrence after 6 months

ACQUISITION

- GSI
- 600 mA
- Rotation time: 0.8 sec – Pitch: 0.516:1

CONCLUSION

- GSI with monochromatic images and MARs capabilities helped the physician to visualize a bone metastasis recurrence through a reduction in artifacts



Monochromatic with MARs

Bone window

Soft tissue window



CASE STUDY

Hip Prosthesis

PATIENT HISTORY

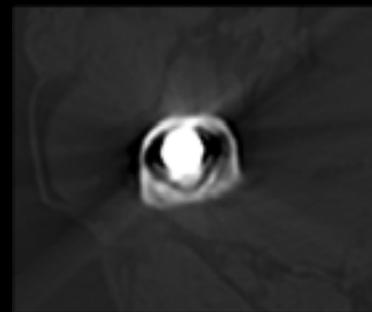
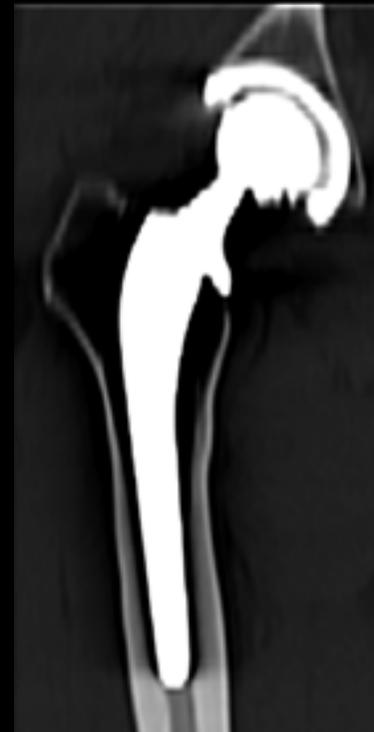
- Patient with hip prosthesis
- Suspicion of aseptic loosening of the prosthesis

ACQUISITION

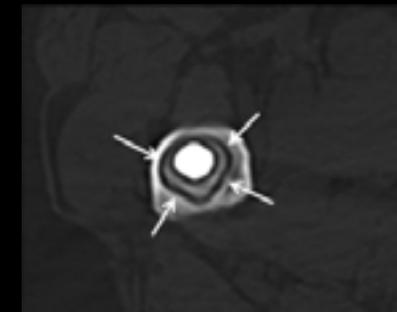
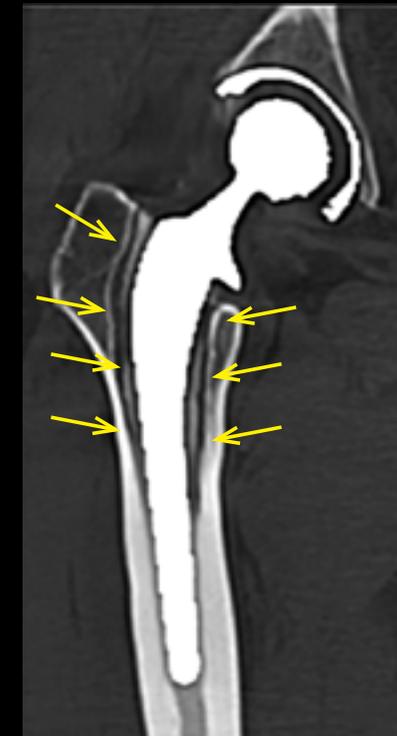
- GSI
- 600 mA
- Rotation time: 0.8 sec – Pitch: 0.516:1

CONCLUSION

- GSI with monochromatic images and MARs capabilities helped the physician to visualize a hypodense border at the interface of cement and bone that showed an aseptic loosening of the femoral component



Polychromatic



Monochromatic 140keV with MARS



CASE STUDY

Intra-articular mass in presence of knee prosthesis

PATIENT HISTORY

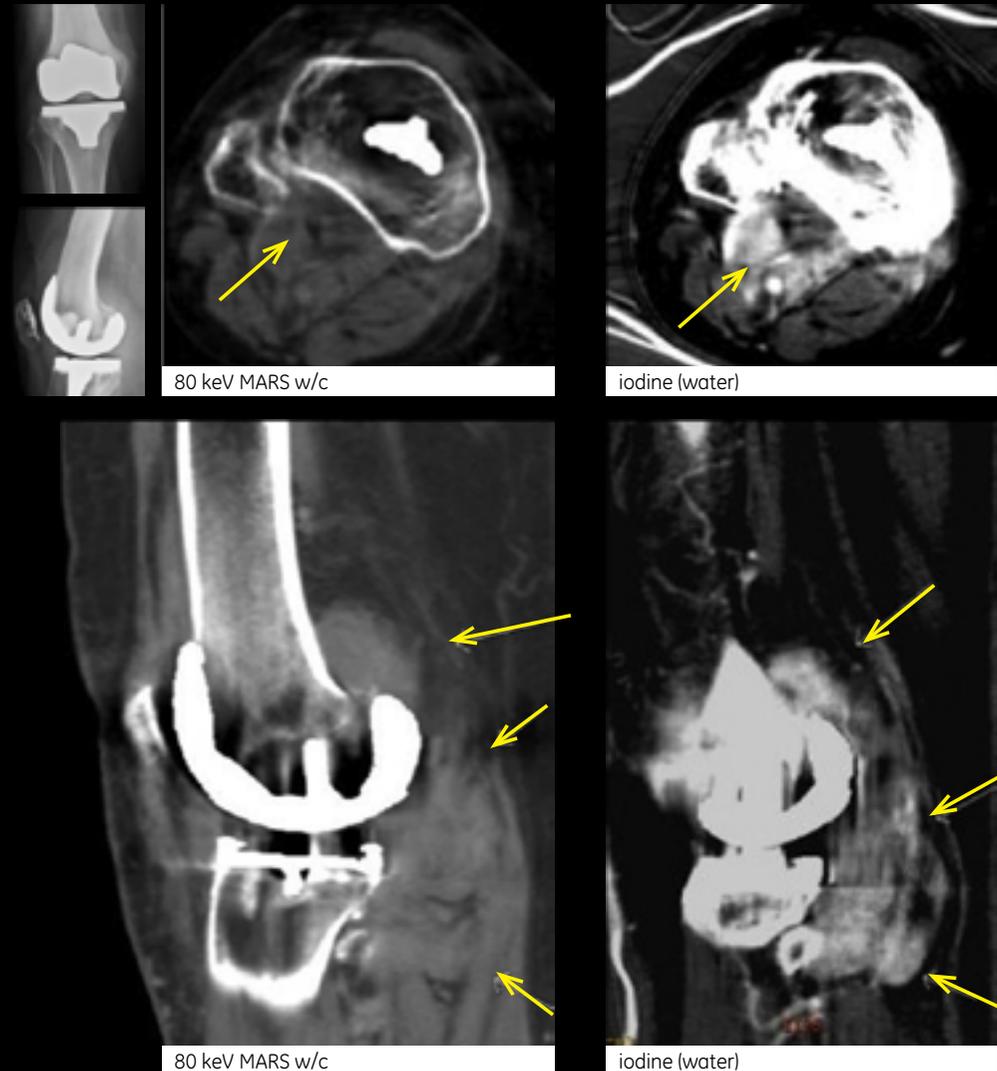
- ~65y female with history of pigmented villonodular synovitis (PVNS) of the knee ten years earlier. The knee had been asymptomatic since then, but a total joint replacement had been performed because of advanced arthrosis
- A year after this operation, the patient presented symptoms suggesting a recurrence of PVNS
- Due to prostheses, GSI with contrast was performed to verify or exclude the presence of intra-articular mass

ACQUISITION

- GSI acquisition with contrast
- 630 mA
- Rotation time: 0.5 sec

CONCLUSION

- The iodine distribution on the iodine-based material decomposition images was used to improve the detection, conspicuity and enhancement of the soft-tissue mass, indicating a possible recurrence of disease, around the knee joint despite the metal artifacts due to prostheses



Cardiac Imaging

The use of CT in cardiac imaging has demonstrated high sensitivity in ruling out Coronary Artery Disease. However, CT imaging for Cardiac has a reported low specificity in part due over estimating stenosis in the presence of calcification. This may be caused by the beam hardening and blooming effect observed in the CT images. Besides, whereas CT helps identifying coronary stenosis, the information regarding its hemodynamic significance remain limited. Recent studies have shown the interest for Myocardial Perfusion Imaging with CT to provide comprehensive assessment of the coronary artery stenosis and its hemodynamic significance. Nevertheless they also highlighted that beam hardening (BH) is an obstacle for perfusion.

Indeed beam hardening in CT arises from high density iodinated contrast into the heart chambers and may result in dark bands that could mimic defects of perfusion. This artifact is directly linked to the polychromatic nature of X-Ray used in CT.

By providing access to monochromatic and material decomposition images, GSI cardiac is designed to reduce blooming effect and reduce myocardial beam hardening, therefore enabling enhanced visualization of coronary artery in presence of calcium and more accurate myocardial perfusion.



CASE STUDY

Coronary Artery Assessment

PATIENT HISTORY

- M ~60y. Known for hypertension and hypercholesterolemia
- Previous invasive coronary angiography showed absence of significant coronary stenosis
- Because of new onset chest pain patient underwent CTA

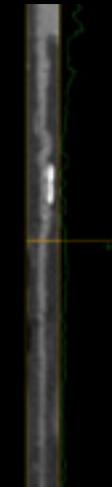
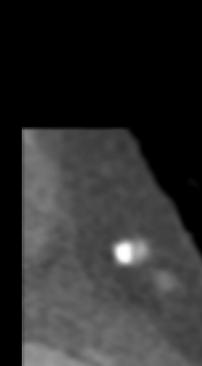
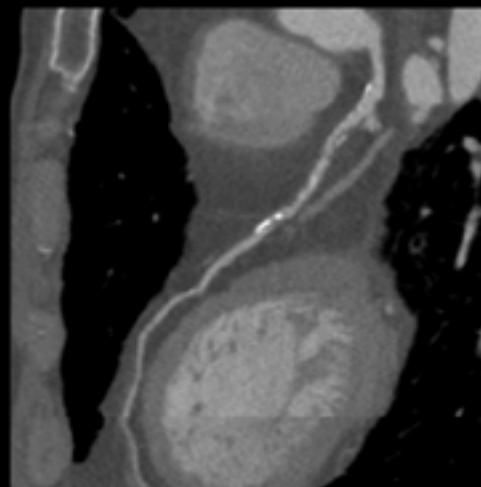
ACQUISITION

- GSI - 60
- 600 mA
- Rotation time: 0.35 sec - Coverage: 140 mm
- Slice thickness: 0.625 mm
- Total scan time: 0.96 sec
- CTDI: 11.39 mGy – DLP: 159.41 mGy.cm

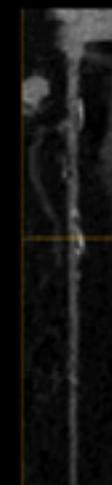
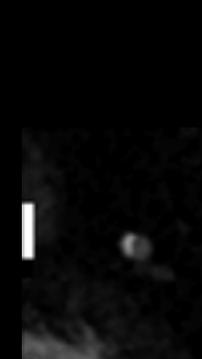
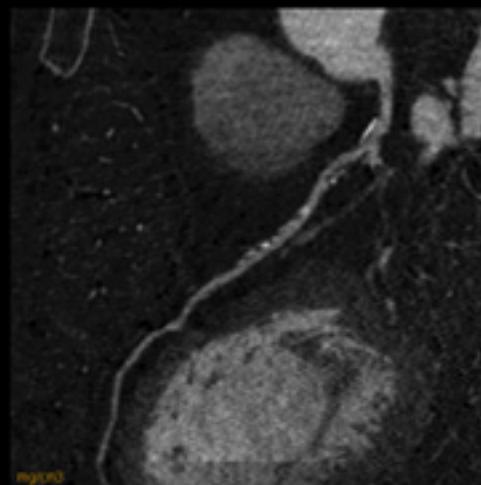
CONCLUSION

- With the help of MD Iodine (HAP) images that reduced the blooming effect of calcification, the radiologist was able to identify a moderate stenosis with the presence of mixed plaque in the middle LAD that was classified as significant in the non-GSI evaluation

CONVENTIONAL CT



GSI MD (IODINE-HAP)



CASE STUDY

Myocardial Perfusion Rest & Stress 1/4

PATIENT HISTORY

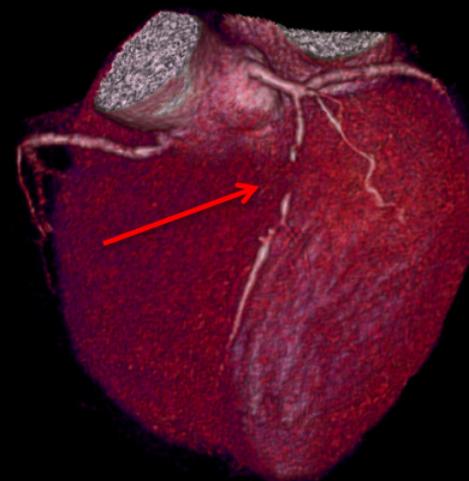
- ~60 year old man
- Hypertension and hypercholesterolemia
- Evaluation of suspected CAD
- Normal ECG and absence of wall kinesis abnormalities with normal ejection fraction

ACQUISITION

- GSI Cardiac at rest
- DLP: 159 mGy-cm (2.2 mSv[†])
- 60 ml CM + 40 ml saline @ 5 ml/sec

CONCLUSION

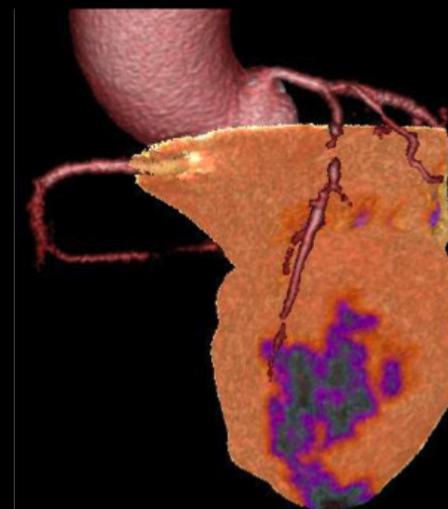
- GSI Cardiac CT imaging at rest helped the physician to see an LAD occlusion with a corresponding perfusion defect. Patient was scheduled to have a stress GSI Cardiac CT exam



Volume rendering showing LAD occlusion



LAD occlusion



Iodine Based image with Color overlay demonstrating perfusion defect

[†] Obtained by ICRP using a chest factor of 0.014DLP



CASE STUDY

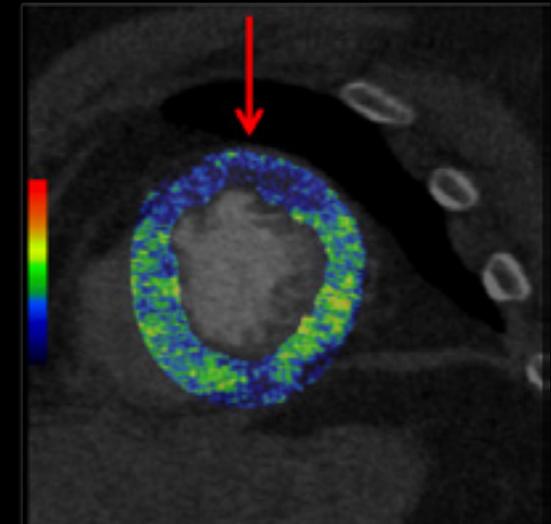
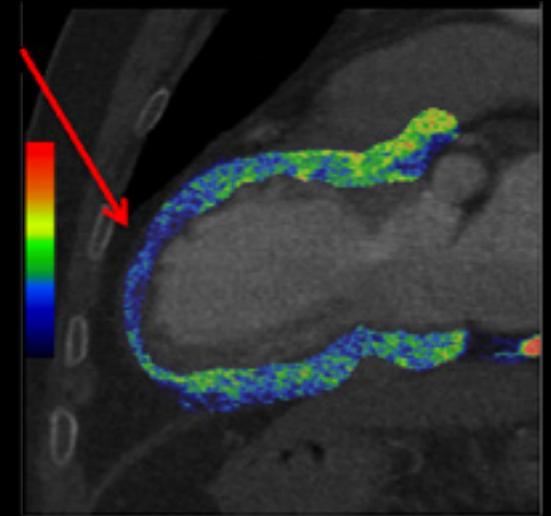
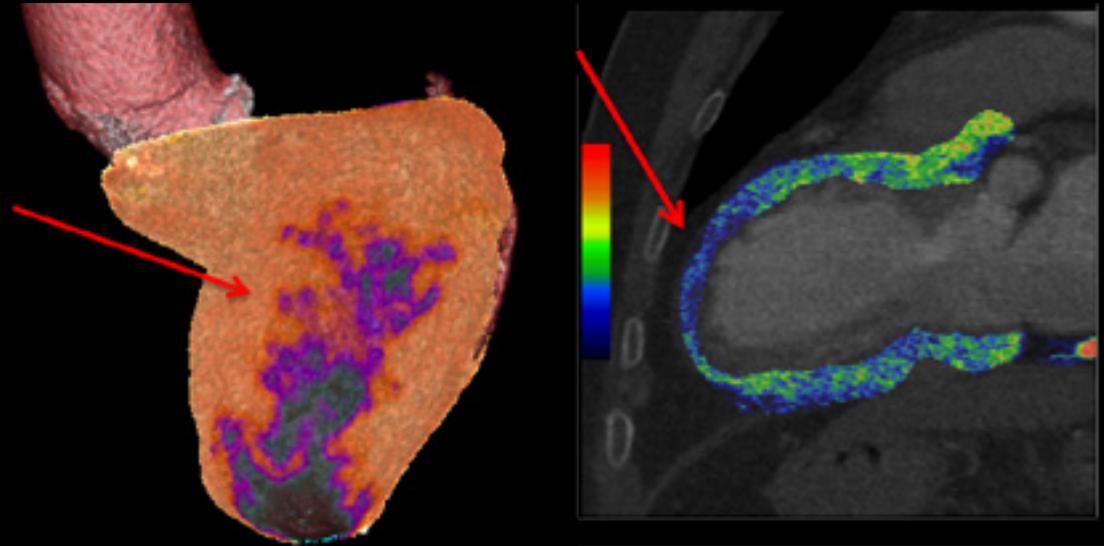
Myocardial Perfusion Rest & Stress 2/4

ACQUISITION

- GSI Cardiac at Stress (Adenosine)
- DLP: 159 mGy-cm (2.2 mSv[†])
- 60 ml CM + 40 ml saline @ 5 ml/sec

CONCLUSION

- GSI Cardiac monochromatic imaging with reduced beam hardening artifacts showed an increased area of perfusion deficit at chemically induced stress compared to rest



Iodine Based image with Color overlay demonstrating perfusion defect

[†] Obtained by ICRP using a chest factor of 0.014DLP

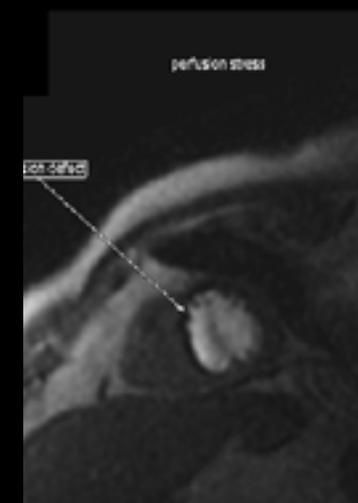
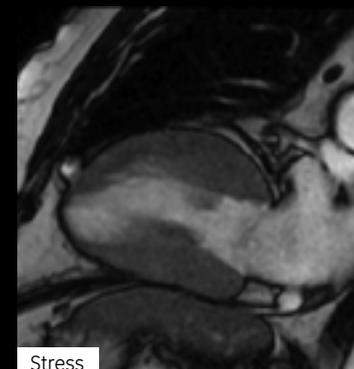
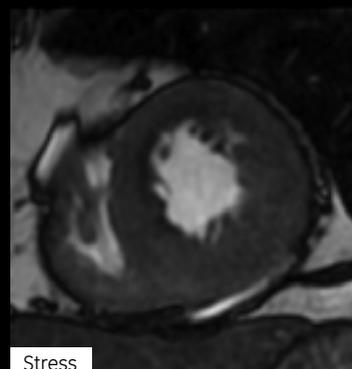
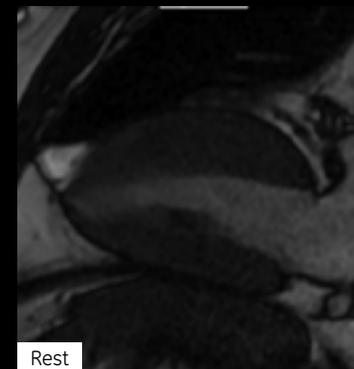
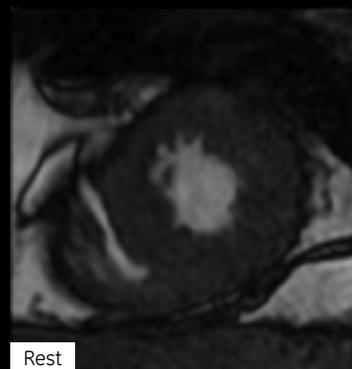


CASE STUDY

Myocardial Perfusion Rest & Stress 3/4

CONCLUSION

- The perfusion defect demonstrated on GSI Cardiac was confirmed using MR for perfusion and viability
- Patient was addressed to invasive coronary angiography that confirmed the CTO of LAD that was treated by coronary angioplasty and stent implantation



CASE STUDY

Myocardial Perfusion Rest & Stress 4/4

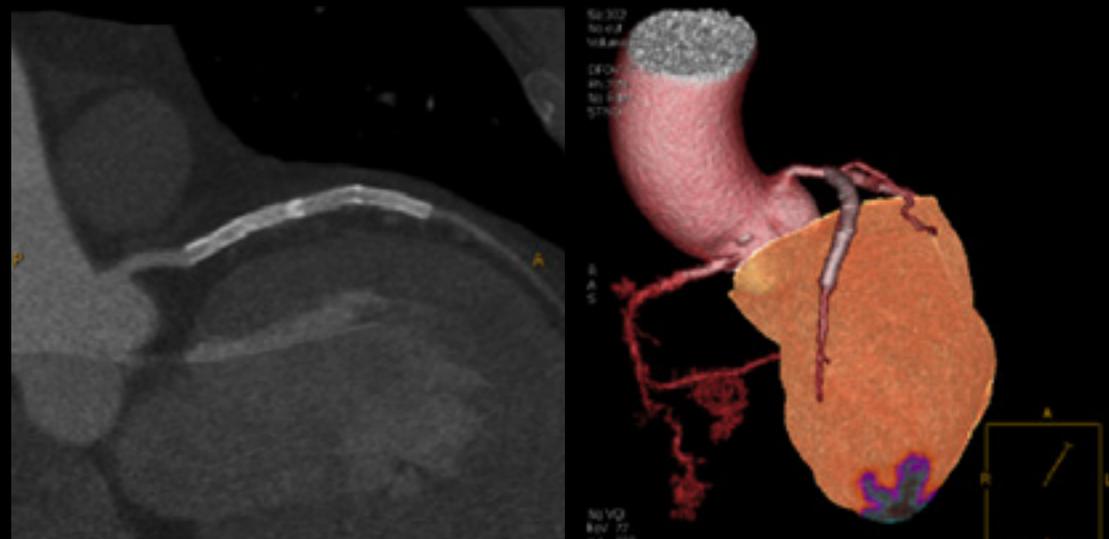
ACQUISITION

CT Acquisition – Stent follow-up

- GSI Cardiac at rest
- DLP: 159 mGy-cm (2.2 mSv[†])
- 60 ml CM + 40 ml saline @ 5 ml/sec

CONCLUSION

- A GSI Cardiac CT exam was performed 3 days after stenting. The physician concluded on the stent patency and on a significant reduction of perfusion defect



LAD and myocardial perfusion after stenting

[†] Obtained by ICRP using a chest factor of 0.014DLP



CASE STUDY

Myocardial Perfusion 1/2

PATIENT HISTORY

- Male ~60y with hypertension, diabetes mellitus, dyslipidemia, inferior myocardial infarction and three vessel coronary artery disease

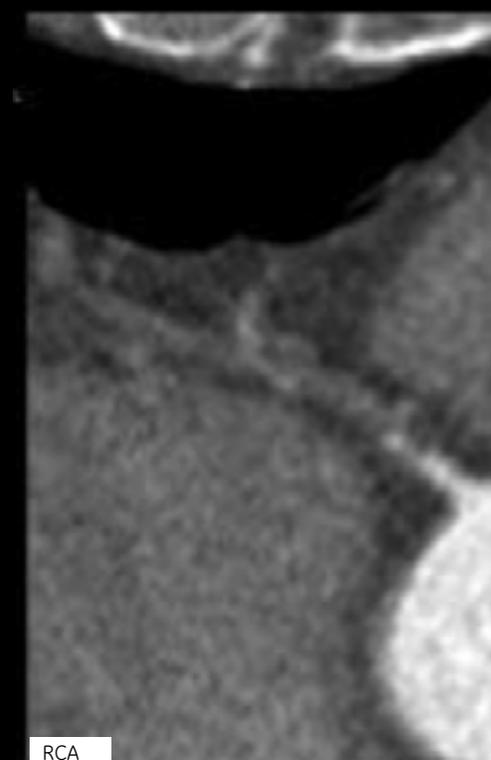
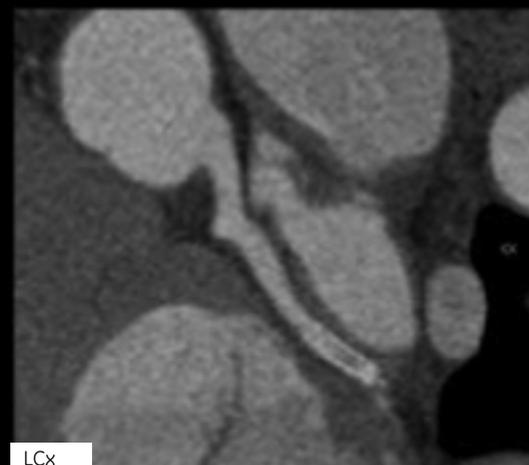
ACQUISITION

- GSI - 60
- 600 mA
- Rotation time: 0.35 sec - Coverage: 140 mm
- Slice thickness: 0.625 mm
- Total scan time: 0.96 sec
- CTDI: 11.39 mGy – DLP: 159.41 mGy.cm

CONCLUSION

Based on GSI Cardiac images, the physician made the following conclusions:

- LAD: proximal portion mixed arteriosclerotic pathology with 70% stenosis
- CX: medial portion stent with severe intimal hyperplasia
- RCA: proximal portion occlusion



CASE STUDY

Myocardial Perfusion 2/2

CONCLUSION: REST

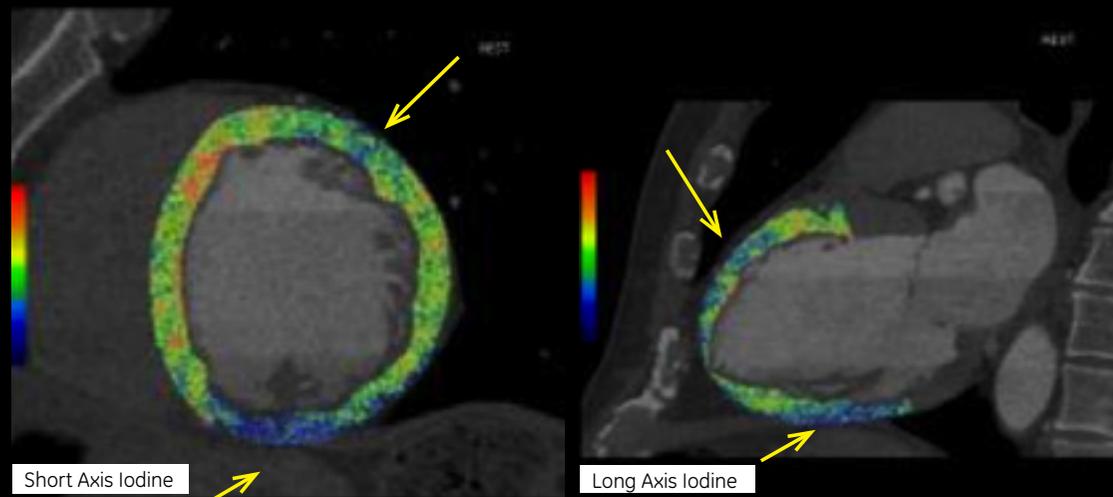
Based on GSI Cardiac Iodine overlay images, the physician concluded on:

- Inferior and inferior-posterolateral medium-basal wall segmental deficit perfusion
- Little anterior-medium wall segmental deficit perfusion

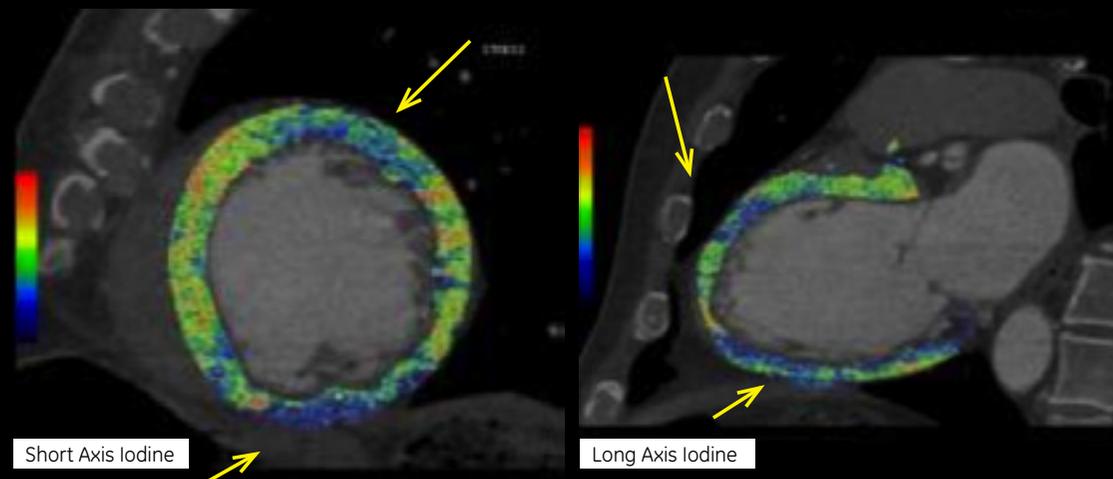
CONCLUSION: STRESS

Based on GSI Cardiac Iodine overlay images, the physician concluded on a Inferior-posterolateral medium-basal wall segmental deficit perfusion increase

REST



STRESS



CASE STUDY

Myocardial Perfusion

PATIENT HISTORY

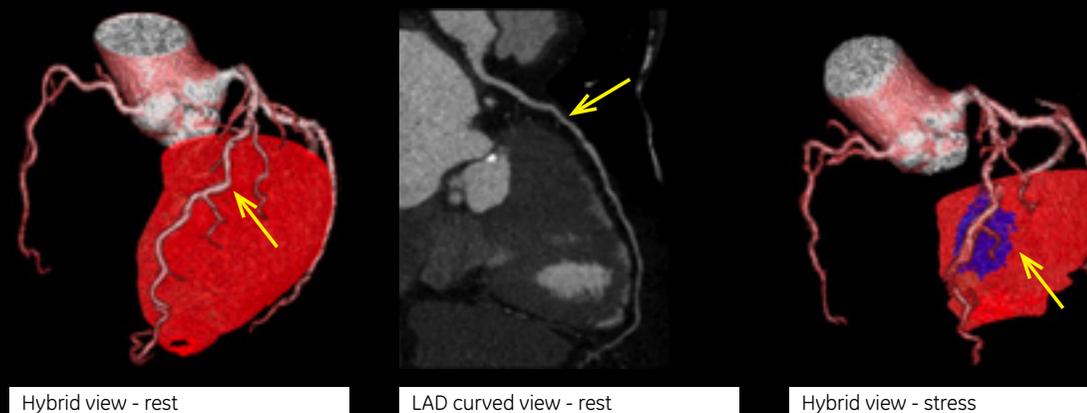
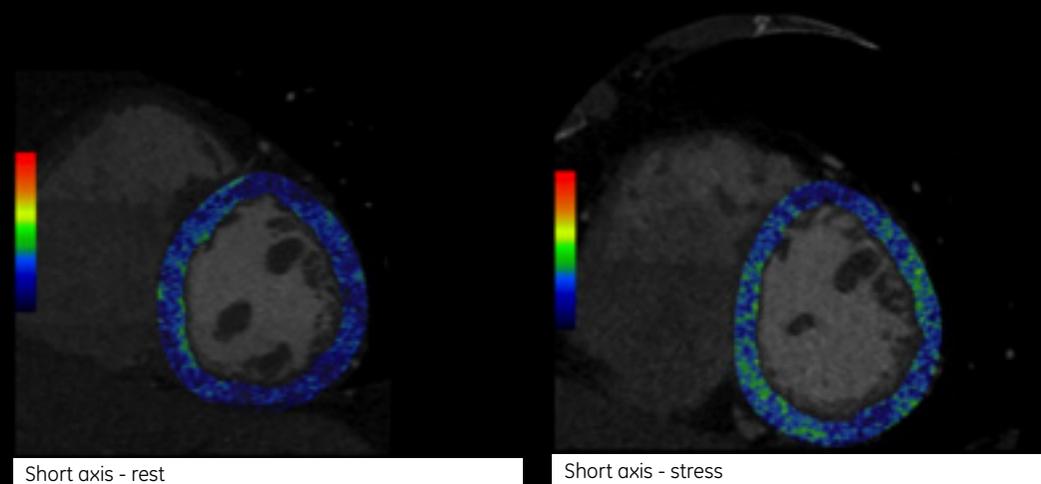
- ~80 years old male patient, suspicion of coronary disease
- Occasionally undefined chest pain
- CTA requested by cardiologist

ACQUISITION

- GSI cardiac acquisition at rest and at stress (chemically induced stress 400 μ g)
- DLP: 85.7 mGy.cm - 1.2 mSv[†] each

CONCLUSION

- GSI Cardiac helped visualizing a subtle LAD stenosis, GSI Cardiac myocardial perfusion using iodine overlay showed a perfusion deficit at stress



[†] Obtained by ICRP using a chest factor of 0.014DLP



CASE STUDY

Late enhancement

PATIENT HISTORY

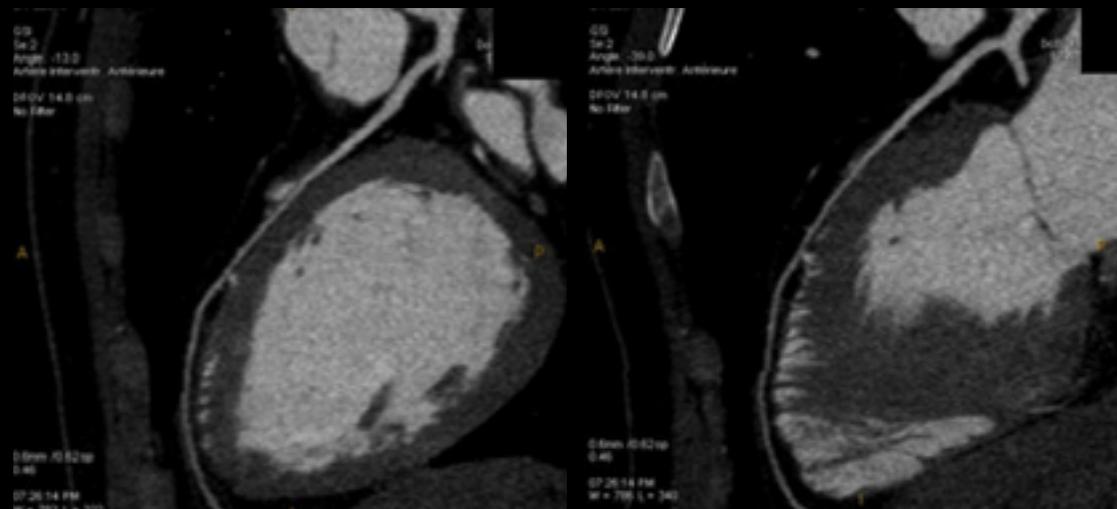
- ~20 year-old Male with Chest Pain
- Moderately elevated troponine; no ST elevation; no cardiovascular risks
- Suspicion of Myocardial infarction/coronary disease/myocarditis?

ACQUISITION

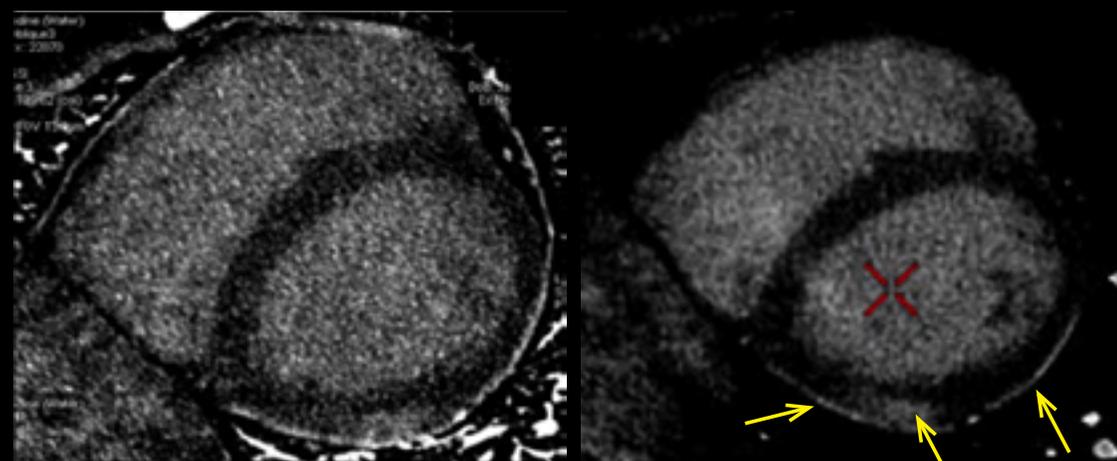
- GSI Cardiac - 2 acquisitions (arterial phase and delayed 7 min)

CONCLUSION

- GSI Cardiac MD iodine and low keV imaging at a delayed phase helped the physician to visualize the subtle nodular enhancement indicative of a typical myocarditis



1st acquisition: coronary study



2nd acquisition - Delayed enhancement 7mn

Iodine Image

Monochromatic 40keV



CASE STUDY

Delayed enhancement with GSI Cardiac

PATIENT HISTORY

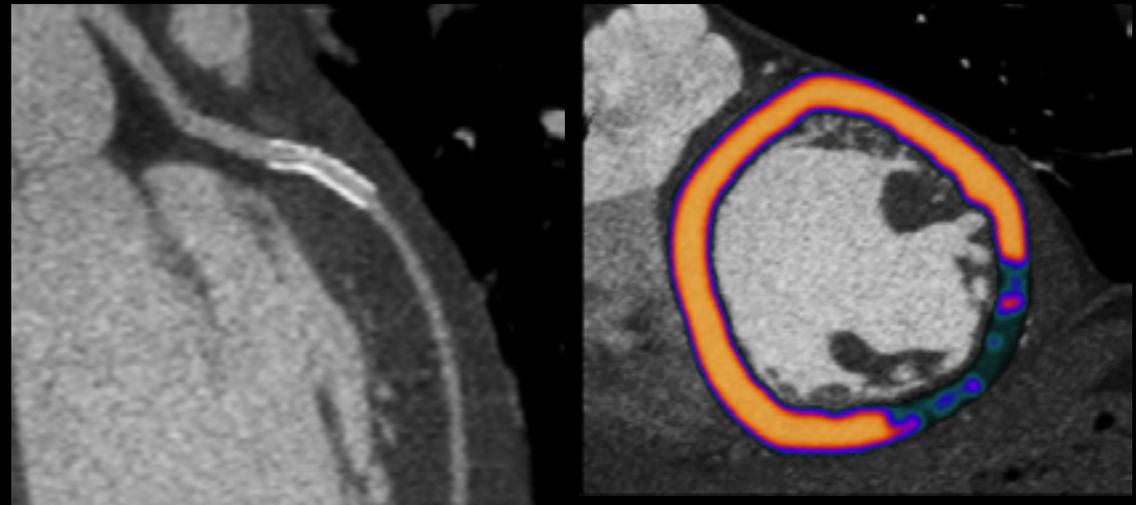
- ~40 year-old man
- Hypertension and hypercholesterolemia
- Stent follow-up

ACQUISITION

- GSI Cardiac delayed enhancement acquisition

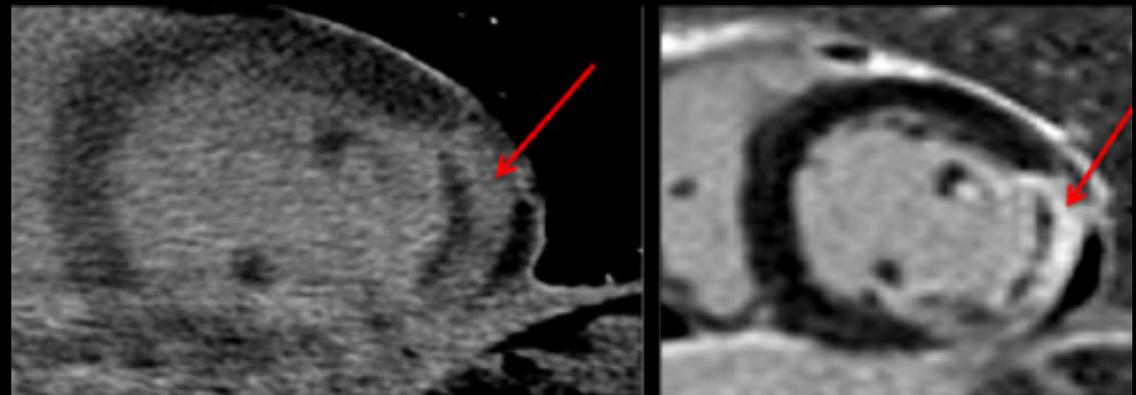
CONCLUSION

- GSI Cardiac 60keV imaging at a delayed phase helped visualization of enhancement in myocardium which is well correlated with MRI
- Helped assess absence of myocardial viability post- stent placement



LAD Curved view

Myocardial Perfusion Iodine Overlay



Delayed Enhancement with GSI Cardiac

MRI Delayed Enhancement sequence



Material Decomposition

GSI Fast kVp switching technology consists of the near simultaneous acquisition of 80 and 140 kVp projection images enabling a projection based reconstruction that allows for material decomposition. This allows for material separation that can enable new clinical applications.

As an example, the data extracted from the GSI acquisition enable separation of materials with close HU values like calcium and Uric Acid using effective atomic values, thus helping to characterize gout and renal stone composition.



CASE STUDY

Renal Stone characterization

PATIENT HISTORY

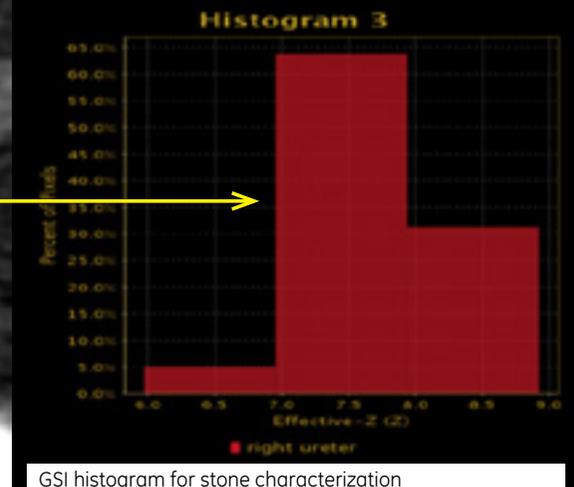
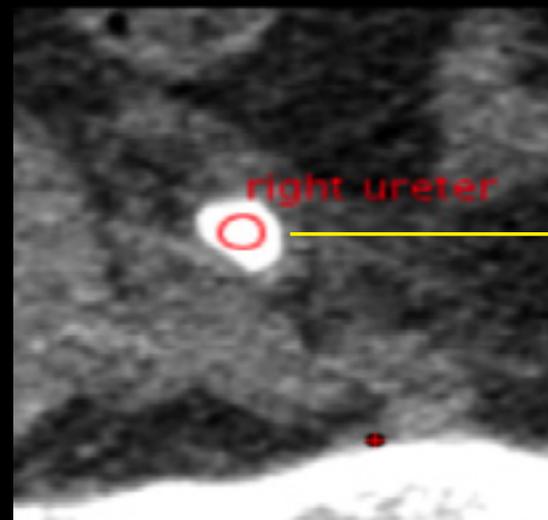
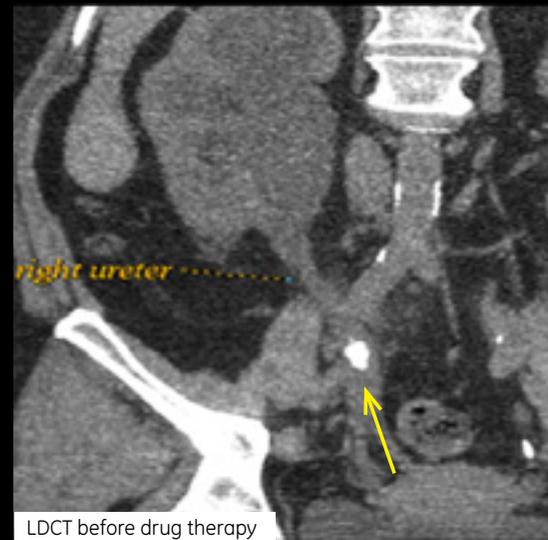
- ~65 y patient with blunt right lumbar pain
- On low-dose CT (LDCT) stones of 2 cm were shown at iliac artery and ureter crossing
- GSI acquisition was performed to characterize the stone composition

ACQUISITION

1. LDCT of abdomen and pelvis
2. Targeted GSI of stone
 - > Pitch: 0.9:1
 - > FOV: 10 cm

CONCLUSION

- GSI images of stones suggested an uric acid stone. The patient was directed to conservative treatment with oral *Uralyt-U*. After 6 months ureterohydronephrosis disappeared
- Follow up LDCT confirmed stone-free status



CASE STUDY

Renal Stone characterization

PATIENT HISTORY

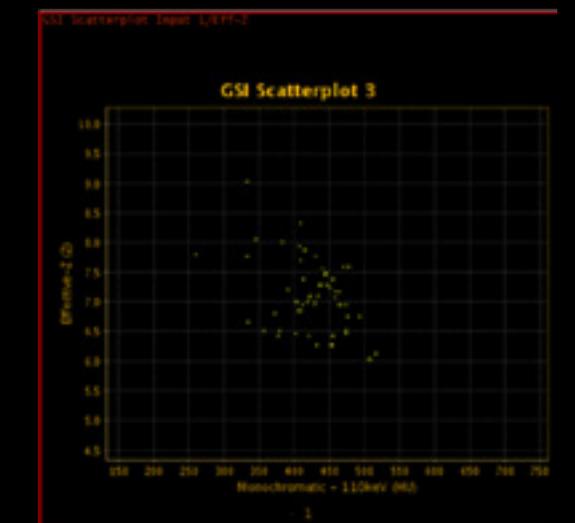
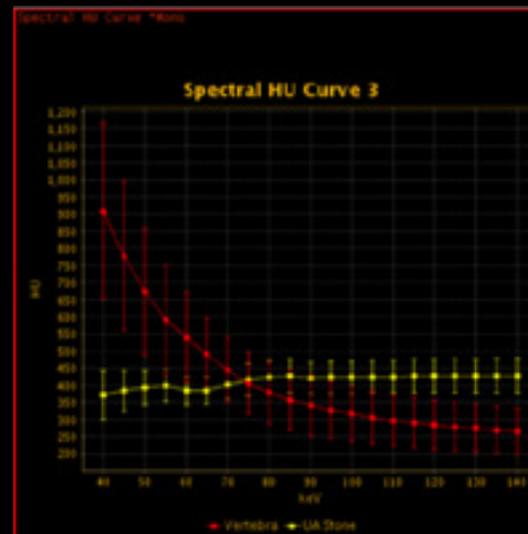
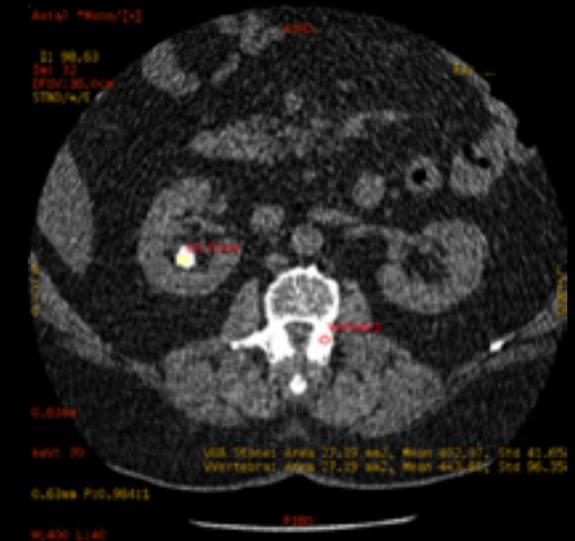
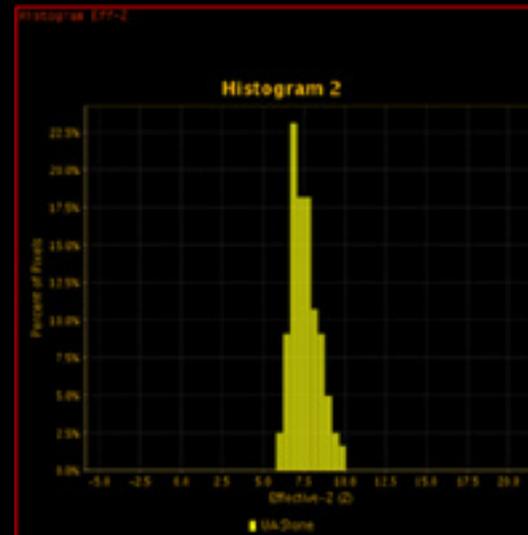
- Pain in the right side. No hematuria. No fever

ACQUISITION

- GSI - 32
- ~375 mA
- Rotation time: 0.6 sec – Pitch: 0.984:1

CONCLUSION

- Uric acid stone has a typical spectral curve (yellow) compared with the spectral curve of the pedicle of the vertebral body (red)
- Uric Acid stone has an effective-Z value around 7
- GSI acquisition helped the separation of materials with close HU values like calcium and Uric Acid, thus allowing for a better assessment of renal stone composition



CASE STUDY

Renal Stone detection 1/2

PATIENT HISTORY

- Right sided Renal Calculi with dilation of Right Renal Pelvis and upper right ureter
- Peri Renal stranding and small urinoma

ACQUISITION

- NON GSI – Pre contrast + 10 mins delayed with contrast - split bolus
- 120kV, 135-190mA NI: 45
- Rotation time: 0.5 sec – Pitch: 0.9

CONCLUSION

- Renal stones can be seen on Non contrast scan
- Stones are obscured by contrast on post contrast scan (prone)



Non Contrast Supine Study – DLP 276



CASE STUDY

Renal Stone detection 2/2

PATIENT HISTORY

- GSI VUE produces virtual unenhanced images from a contrast-enhanced CT. These images have CT numbers similar to those of a conventional 120kVp- non contrast acquisition

ACQUISITION

- GSI - 54
- 275 mA
- Rotation speed: 0.6 sec - Pitch: 0.984
- IV contrast - 65mls 3ml/s 10 mins prior + 40mls at 2ml/s 65 second prep delay - Patient prone
- DLP: 381.16 mGy.cm

CONCLUSION

- Renal stones seen on the non contrast scan were also visible on the VUE image after suppression of iodine



Monochromatic images: 75 keV VUE image



Post contrast prone



Pre contrast Supine



CASE STUDY

Tophus/Urate Detection in Gout

PATIENT HISTORY

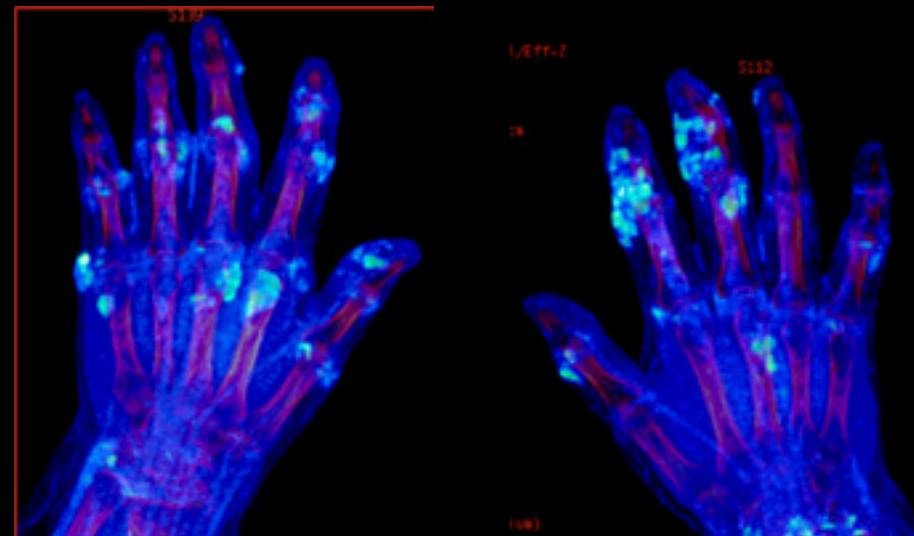
- Does GSI reliably visualize urate deposits in tophaceous gout and its extent in peripheral joints?
- Are further subclinical affected joints detected?

ACQUISITION

- GSI - 38
- 260 mA
- Rotation time: 0.8 sec
- CTDI: 12.07 mGy (each hand)

CONCLUSION

- GSI enabled a detailed color coding of tophous gout and helped visualize subclinical urate deposits



CASE STUDY

Chondrocalcinosis characterization

PATIENT HISTORY

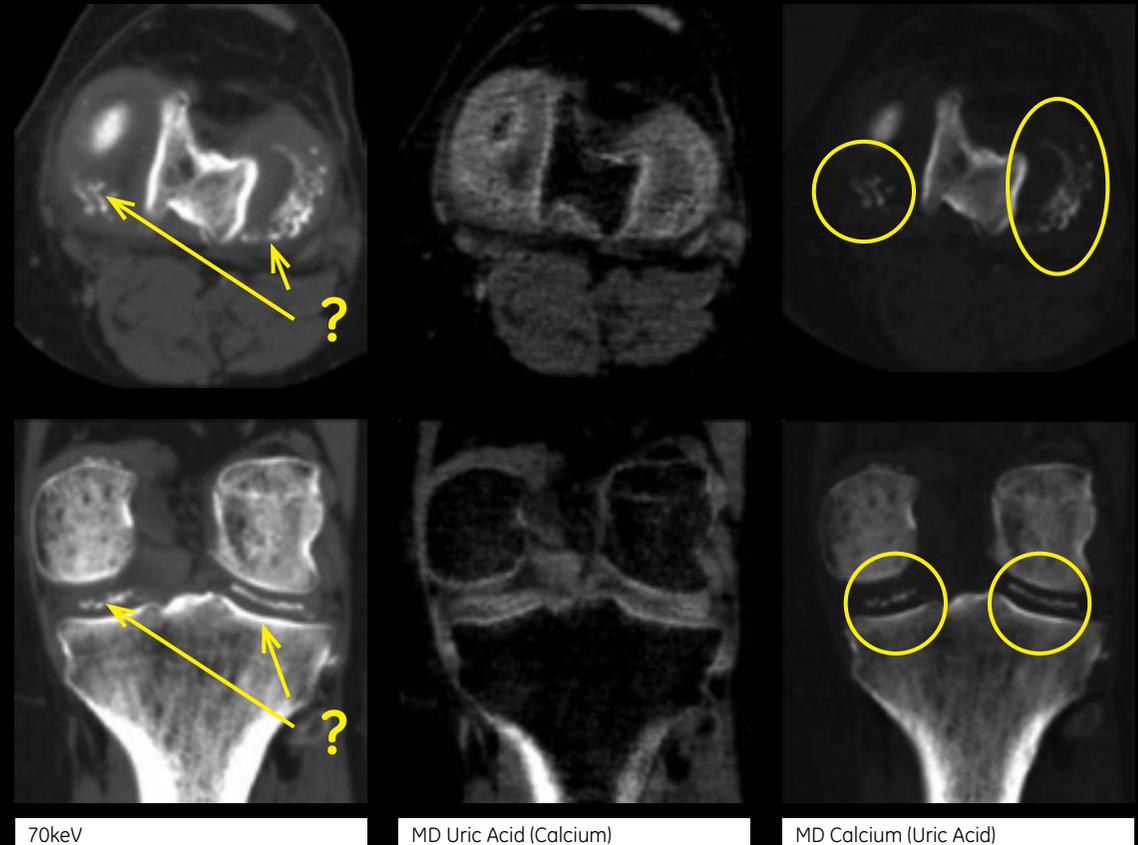
- ~ 70 year old patient with high density deposits in the knee
- Radiologist wanted to know whether the high density deposits are Uric Acid (Gout) or Calcium Pyrophosphate (chondrocalcinosis)

ACQUISITION

- GSI
- 375mA
- 0.625 mm slice thickness

CONCLUSION

- GSI Viewer allowed the user to load additional materials providing new tools for the assessment of uric acid deposits. After loading uric acid the physicians were able to differentiate uric acid from calcium
- In MD Uric Acid (Calcium), the high density deposits disappeared whereas they were visible in the MD Calcium (Uric Acid)
- GSI helped the physician differentiate Gout vs Pseudogout non-invasively after loading additional materials



CASE STUDY

Silicone Prosthesis Tissue Decomposition

PATIENT HISTORY

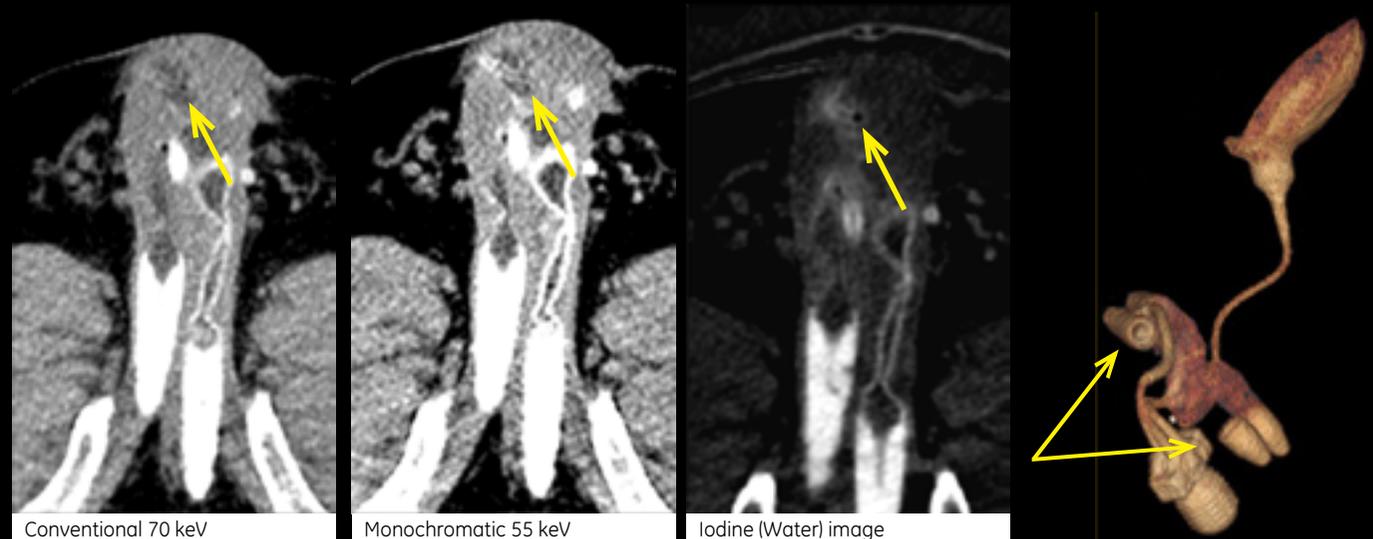
- Patient with non working penile prosthesis implanted 5 years ago after retropubic prostatectomy
- The goal was:
 - > to evaluate prosthesis morphology
 - > to evaluate prosthesis tank
 - > to confirm rupture prosthesis

ACQUISITION

- GSI-12
- 600 mA + ASIR 100%
- Rotation time: 0.8 sec – pitch 0.984:1

CONCLUSION

- Conventional 70 keV images (~120kVp) showed altered density of right cavernous body
- Monochromatic 55 keV images showed silicone prosthesis residues in right cavernous body
- GSI helped in the evaluation of the rupture of silicone implants



CASE STUDY

Cocaine and Heroin differentiation in a bodypacker

PATIENT HISTORY

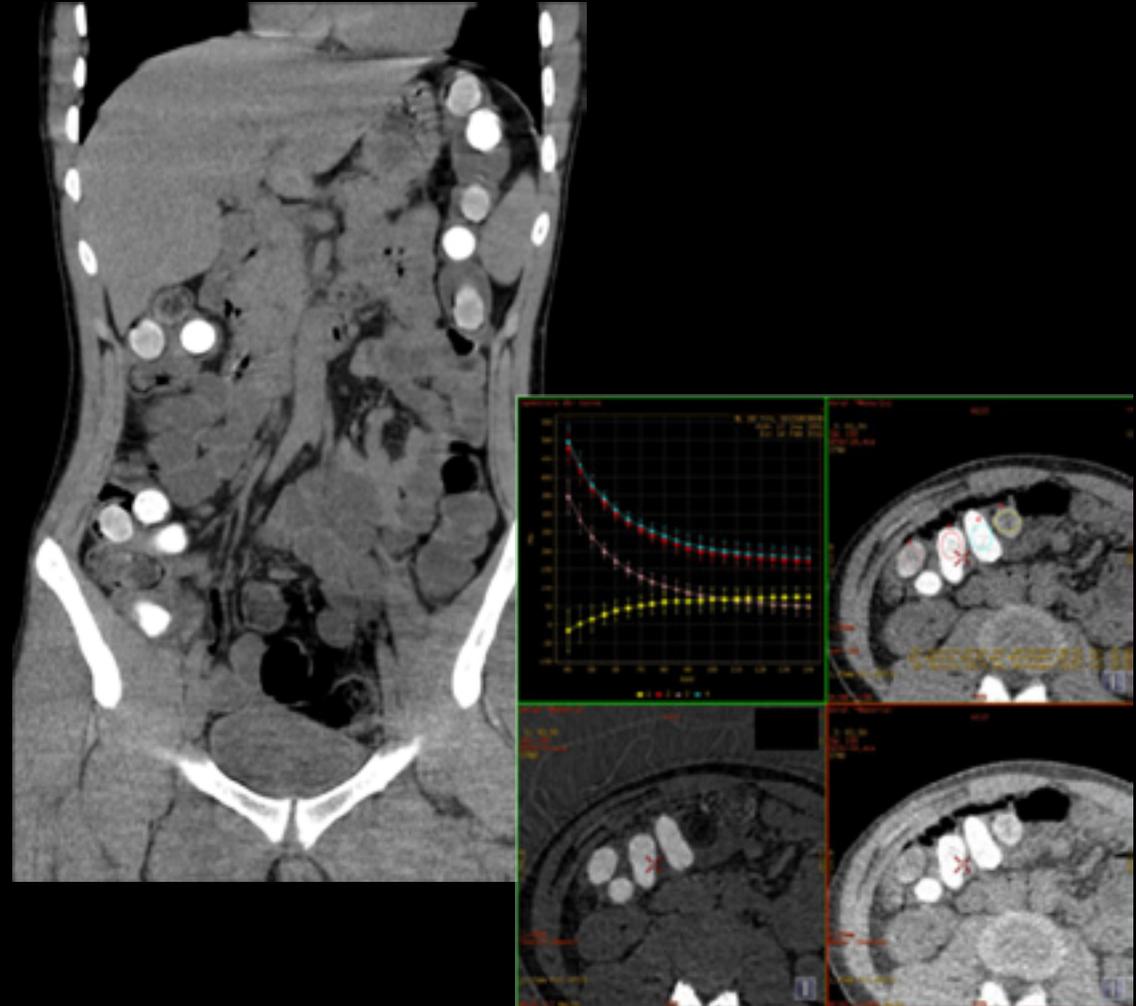
- Bodypacker
- Does GSI differentiate ingested illegal drugs in bodypacking, e.g. cocaine and heroin?
- Is there a difference between properly closed and leaking packages in a severely intoxicated patient?

ACQUISITION

- GSI - 33
- 375 mA
- Rotation time: 0.6 sec

CONCLUSION

- With the help of GSI spectral curves the physician was able to differentiate drug compounds in a bodypacker
- Wet/leaking packages resulting in intoxication were differentiated from dry ones by water subtraction



Recent GSI publications



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Recent GSI publications

ONCOLOGY IMAGING

General Oncology	<ul style="list-style-type: none"> • MDCT: Impact of new technologies on oncologic imaging—practical considerations, Tamm <i>et al.</i>, AJR 2013
Thyroid	<ul style="list-style-type: none"> • Dual-Energy Computed Tomography Imaging of Thyroid Nodule Specimens, Li <i>et al.</i>, Investigative Radiology 2012
Pancreas	<ul style="list-style-type: none"> • Single-source dual-energy spectral multidetector CT of pancreatic adenocarcinoma: Optimization of energy level viewing significantly increases lesion contrast, Morgan <i>et al.</i>, Clinical Radiology 2013
Liver	<ul style="list-style-type: none"> • Spectral CT in patients with small HCC: investigation of image quality and diagnostic accuracy, Lv <i>et al.</i>, Eur Radiol 2011 • Spectral CT: Preliminary Studies in the Liver Cirrhosis, Lv <i>et al.</i>, KJR 2012 • Differentiation of Small Hepatic Hemangioma from Small Hepatocellular Carcinoma: Recently Introduced Spectral CT Method, Lv <i>et al.</i>, Radiology 2011 • Virtual Monochromatic Spectral Imaging for the Evaluation of Hypovascular Hepatic Metastases, Yamada <i>et al.</i>, Investigative Radiology 2012
Renal	<ul style="list-style-type: none"> • Usefulness of the Virtual Monochromatic Image in Dual-Energy Spectral CT for Decreasing Renal Cyst Pseudoenhancement: A Phantom Study, Jung <i>et al.</i>, ARRS 2012 • Distinguishing Enhancing From Nonenhancing Renal Lesions With Fast Kilovoltage-Switching Dual-Energy CT, Kasa <i>et al.</i>, AJR 2011
Radiation Oncology	<ul style="list-style-type: none"> • Feasibility and accuracy of relative electron density determined by virtual monochromatic CT value subtraction at two different energies using the gemstone spectral imaging, Ogata <i>et al.</i>, Radiation Oncology 2013
Gastro-intestinal	<ul style="list-style-type: none"> • Gastric Cancer Staging with Dual Energy Spectral CT Imaging, Pan <i>et al.</i>, PLOS ONE 2013 • <i>In Vivo</i> Differentiation of Complementary Contrast Media at Dual-Energy CT1, Yeh <i>et al.</i>, Radiology 2012

VASCULAR IMAGING

Pulmonary angiography	<ul style="list-style-type: none"> • Imaging of acute pulmonary embolism using a dual energy CT system with rapid kVp switching: Initial results, Geyer <i>et al.</i>, European Journal of Radiology 2011 • Pulmonary Embolism Detection and Characterization Through Quantitative Iodine-Based Material Decomposition Images With Spectral Computed Tomography Imaging, Wu <i>et al.</i>, Investigative Radiology 2012 • Reduced Iodine Load at CT Pulmonary Angiography with Dual-Energy Monochromatic Imaging: Comparison with Standard CT Pulmonary Angiography—A Prospective Randomized Trial, Yuan <i>et al.</i>, Radiology 2012 • Differentiation of neoplastic from bland macroscopic portal vein thrombi using dual-energy spectral CT imaging: a pilot study, Qian <i>et al.</i>, Eur Radiol 2012
Venography	<ul style="list-style-type: none"> • Indirect Computed Tomography Venography of the Lower Extremities Using Single-Source Dual-Energy Computed Tomography: Advantage of Low-Kiloelectron Volt Monochromatic Images, Kulkarni <i>et al.</i>, J. Vasc Interv Radiology 2012 • Improving image quality in portal venography with spectral CT imaging, Zhao <i>et al.</i>, EJIR 2011
Abdominal Aorta angiography	<ul style="list-style-type: none"> • “Sweet spot” for endoleak detection: Optimizing contrast to noise using low keV reconstructions from fast-switch kVp dual energy CT, Maturen <i>et al.</i>, JCAT 2012 • “Sweet Spot” for Endoleak Detection: Optimizing Contrast to Noise Using Low keV Reconstructions From Fast-Switch kVp Dual-Energy CT, Maturen <i>et al.</i>, J Comput Assist Tomogr 2011
Carotid angiography	<ul style="list-style-type: none"> • Changes in measured size of atherosclerotic plaque calcifications in dual-energy CT of ex vivo carotid endarterectomy specimens: effect of monochromatic keV image reconstructions, Mannelli <i>et al.</i>, European Radiology 2013

Recent GSI publications

METAL ARTIFACT REDUCTION

Brain	<ul style="list-style-type: none">• High-Definition CT Gemstone Spectral Imaging of the Brain: Initial Results of Selecting Optimal Monochromatic Image for Beam-Hardening Artifacts and Image Noise Reduction, Lin <i>et al</i>, JCAT 2011• High-Definition CT Gemstone Spectral Imaging of the Brain: Initial Results of Selecting Optimal Monochromatic Image for Beam-Hardening Artifacts and Image Noise Reduction, Lin <i>et al</i>, J Comput Assist Tomogr 2011
MSK	<ul style="list-style-type: none">• Virtual Monochromatic Spectral Imaging with Fast Kilovoltage Switching: Reduction of Metal Artifacts at CT , Pessis <i>et al</i>, Radiographics 2013• Metal artifacts reduction using monochromatic images from spectral CT: Evaluation of pedicle screws in patients with scoliosis ,Wang <i>et al</i>, EJR 2013• Metal artefact reduction in gemstone spectral imaging dual-energy CT with and without metal artefact reduction software, Lee <i>et al</i>, Eur Radiol 2012• The pilot study of dual-energy CT gemstone spectral imaging on the image quality of hand tendons, Keng <i>et al</i>, Clin Imaging 2013• Preliminary application of high-definition CT Gemstone Spectral Imaging in hand and foot tendons, Deng <i>et al</i>, Korean J Radiol 2012
Radiation Oncology	<ul style="list-style-type: none">• Spectral CT with Metal Artifacts Reduction Software for Improvement of Tumor Visibility in the Vicinity of Gold Fiducial Markers, Brook <i>et al</i>, Radiology 2012
General imaging	<ul style="list-style-type: none">• Virtual Monochromatic Spectral Imaging with Fast Kilovoltage Switching: Improved Image Quality as Compared with That Obtained with Conventional 120-kVp CT, Matsumoto <i>et al</i>, Radiolgy 2011

CARDIAC IMAGING

Coronary angiography	<ul style="list-style-type: none">• First experience with monochromatic coronary computed tomography angiography from a 64-slice CT scanner with Gemstone Spectral Imaging (GSI), Kaufmann <i>et. al</i>, JCCT. 2013• Coronary Artery Imaging with Single-Source Rapid Kilovolt Peak-Switching Dual-Energy CT, Scheske <i>et al</i>, Radiology 2013• Evaluation of Severely Calcified Coronary Artery Using Fast-Switching Dual-kVp 64-Slice Computed Tomography, Yamada <i>et al</i>,Circulation Journal 2011
Myocardial Perfusion	<ul style="list-style-type: none">• Myocardial perfusion imaging using dual-energy computed tomography: a clinical case, Pontone <i>et al</i>, EHJC 2013• Dual-energy CT and its potential use for quantitative myocardial CT perfusion, So <i>et al</i>, JCCT 2012

MATERIAL DECOMPOSITION

Kidney Stone	<ul style="list-style-type: none">• Gemstone Spectral Imaging Dual-energy Computed Tomography: A Novel Technique to Determine Urinary Stone Composition, Li <i>et al</i>, Urology 2013• Determination of Renal Stone Composition in Phantom and Patients Using Single-Source Dual-Energy Computed Tomography, Sahani <i>et al</i>, J Comput Assist Tomogr 2013
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