AAPM 2019
Partners in Solutions Session

Single Source Dual Energy Computed Tomography (DECT) and Applications

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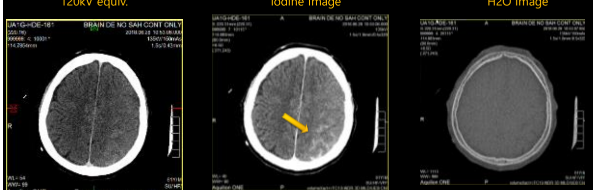
Medical Affairs Leader, CT

Neuro Case 1: Stroke patient 12-24 hrs after admission

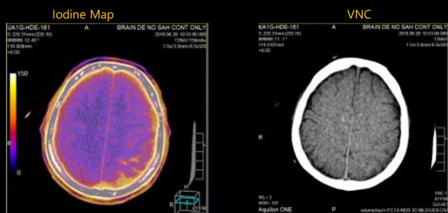
120kV equiv. | Iodine Image | H2O Image



Residual contrast from acute stroke CT (~12 hrs previous) visible in Iodine image.
No hemorrhage shown in H2O image.

Neuro Case 1: No Hemorrhagic Conversion

Iodine Map | VNC



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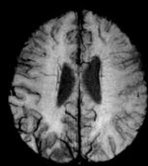
No hemorrhage shown in H2O image.

Neuro Case 1: No Hemorrhagic Conversion

MRI SWI MIP



MRI confirmed diagnosis

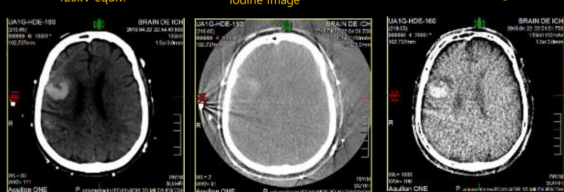
"The differentiation of contrast from blood permitted continuation of anticoagulation with the intent of preventing new clot formation or propagation of the infarction."

Canon

Courtesy of University of Florida Shands

Neuro Case 2: Stroke patient 12-24 hrs after admission

120kV equiv. | Iodine Image | H2O Image



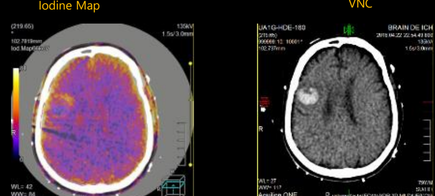
Residual contrast from acute stroke CT (~12 hrs previous) **not** visible in Iodine image. Some hyperdensity shown in H2O image – suggesting hemorrhage.

Canon

Courtesy of University of Florida Shands

Neuro Case 2: Hemorrhage

Iodine Map | VNC



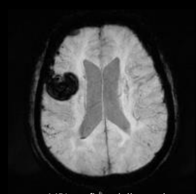
Residual contrast from acute stroke CT (~12 hrs previous) **not** visible in Iodine map. Hemorrhage clearly visible in VNC. This led to an immediate change in the patient's management.

Canon

Courtesy of University of Florida Shands

Neuro Case 2: Hemorrhage

MRI SWI MIP



MRI confirmed diagnosis

"This led to an immediate change in the patient's management."

Courtesy of University of Florida Shands

Hounsfield, G.N. (1973) Computerized transverse axial scanning (tomography): I. Description of systems. *British Journal of Radiology*, 46, 1016 - 1022

material which is to be viewed. A more convenient scale used on the print-outs (of absorption values) is given on the right where air is shown as −500, water as 0, and bone as approximately +500; this scale is used on the machine.

The pictures shown in Fig. 10 illustrate in practice how the picture changes, similar to a television "contrast" control, when the "window level" control is raised from −20%(−100 units) to +70% (+350 units).

As this scale uses water as a reference (*i.e.* water =0), to obtain the absorption coefficient of any material for the 120 kV X-ray beam, 500 must be added to the readings and multiplied by a factor of 0·19/500, the absorption coefficient of water for this beam being 0·19 cm^{-1}.

DETERMINATION OF ATOMIC NUMBER OF MATERIAL

It is possible to use the machine for determining approximately the atomic number of the material within the slice. Two pictures are taken of the same slice, one at 100 kV and the other at 140 kV. If the scale of one picture is adjusted so that the values of normal tissue are the same on both pictures, then the picture containing material with a high atomic number will have higher values at the corresponding place on the 100 kV picture. One picture can then be subtracted from the other by the computer so that areas containing high atomic numbers can be enhanced. (In practice a contrast medium, sodium iothalamate containing 420 mg of atomic iodine per millilitre (Conray 420) can be readily detected at a concentration of one part in 1,000 by the machine.) For example, tests carried out to date have shown that iodine (Z=53) can be readily distinguished from calcium (Z=20). The scope of this technique is under further investigation at present.

RADIATION DOSE

The skin area irradiated is confined to a narrow band around the edge of each slice and provided the slices do not overlap the skin dose will not increase with the number of slices taken (although the area irradiated will increase). The exposure at the patient's skin is 1·9 R for an examination which provides six tomographic slices covering the whole of the head. This exposure is approximately equivalent to a conventional skull X-ray examination. Two pic-

1020

ALVAREZ and MACOVSKI (1976) Energy-selective Reconstructions in X-ray Computerized Tomography. *Phys. Med. Biology*, 21:5, 733- 744

Energy-selective Reconstructions in X-ray Computerized Tomography

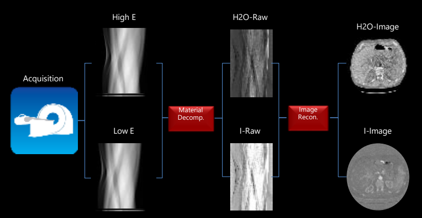
ROBERT E. ALVAREZ and ALBERT MACOVSKI

Department of Electrical Engineering, Stanford University, Stanford, CA 94305, U.S.A.

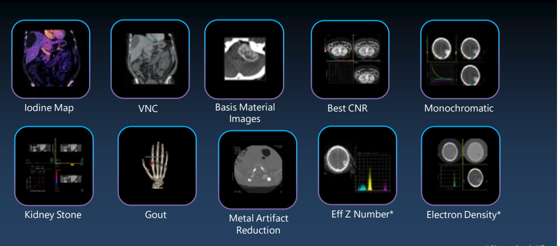
Received 11 *September* 1975, *in final form* 17 *February* 1976

ABSTRACT. All X-ray computerized tomography systems that are available or proposed base their reconstructions on measurements that integrate over energy. X-ray tubes produce a broad spectrum of photon energies and a great deal of information can be derived by measuring changes in the transmitted spectrum. We show that for any material, complete energy spectral information may be summarized by a few constants which are independent of energy. A technique is presented which uses simple, low-resolution, energy spectrum measurements and conventional computerized tomography techniques to calculate these constants at every point within a cross-section of an object. For comparable accuracy, patient dose is shown to be approximately the same as that produced by conventional systems. Possible uses of energy spectral information for diagnosis are presented.

Raw data based Dual Energy

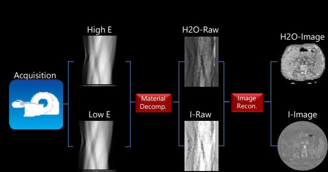


Dual Energy Output



Key Features for Accuracy

- Monochromatic images and basis materials processed from raw data
- High and Low energy projections must travel the same path
- Good energy separation



Dual Energy Scan Modes

Volume Scan Mode

Helical Scan Mode

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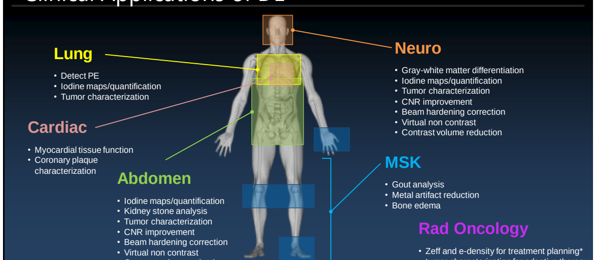
Clinical Applications of DE



* Not product in US

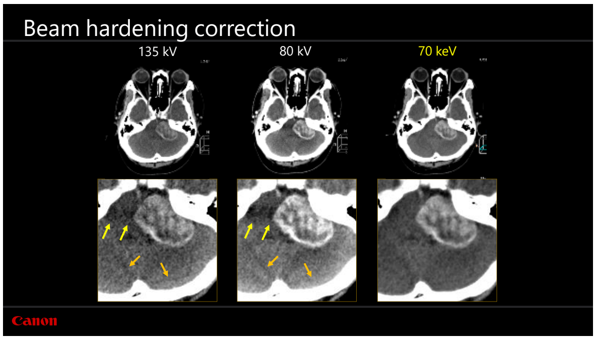
Canon

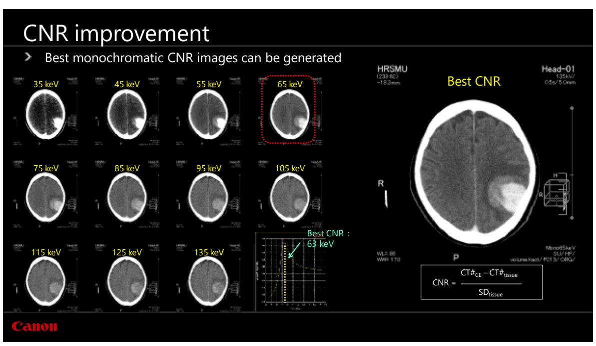
Beam hardening correction

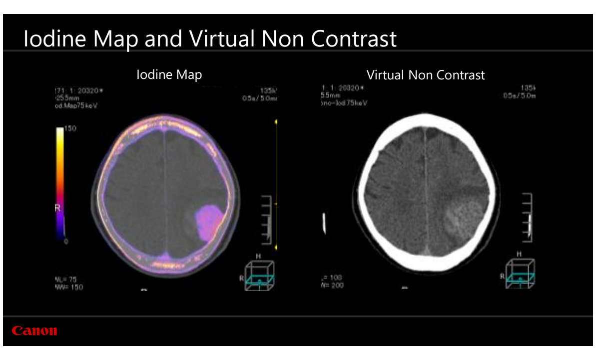
- Monochromatic Imaging's ability to reduce beam hardening artifact due to dense bone in the posterior fossa is demonstrated in the 70keV monochromatic image

Low kV High kV 70 keV

Canon

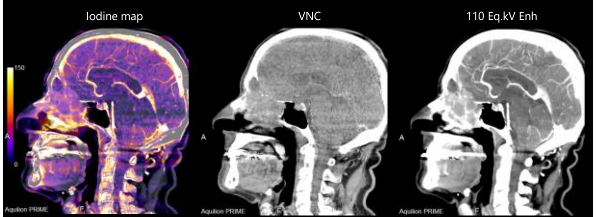

Beam hardening correction
135 kV
80 kV
70 keV


CNR improvement
Best monochromatic CNR images can be generated
35 keV
45 keV
55 keV
65 keV
75 keV
85 keV
95 keV
105 keV
115 keV
125 keV
135 keV
Best CNR : 63 keV
HRSMU
Best CNR
Head-01
R
P
CNR = (CT#CE − CT#tissue) / SDtissue


Iodine Map and Virtual Non Contrast
Iodine Map
Virtual Non Contrast

Iodine Map and Virtual Non Contrast

- PNS adenocarcinoma
- Tumor expansion into the anterior fossa



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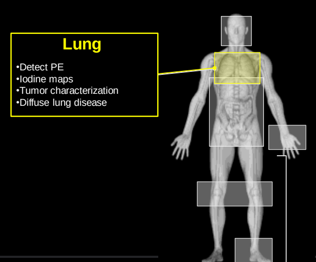
Do Not Distribute

Courtesy of Prof. Varoquaux
University Hospital Marseille

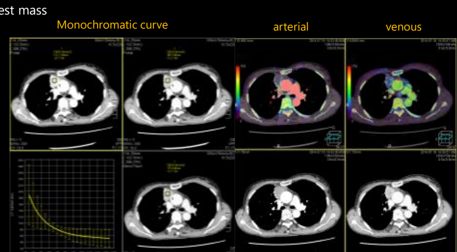
How is DE being used clinically?



Canon

Tumor Characterization

- Chest mass



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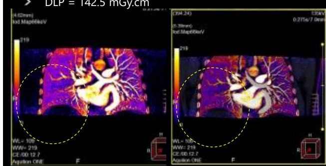
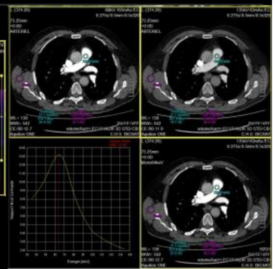
Courtesy of HMU Hospital, Harbin China.

Detect PE

- pulmonary embolization
- DLP = 142.5 mGy.cm





2.EMBOLIE PUL DOUBLE ENERGI+AP POR

No.	Protocol	Bdy scan(s)	kVp	CTDIvol (mGy)	DLP (mGy.cm)
1	S&V	1	100	5.30 (Body)	1.10 (Body)
2	Start	1	135	65.20 (Body)	26.10 (Body)
3	DE-Vol	1	135	7.20 (Body)	115.30 (Body)

Canon

Courtesy University Hospital of Paris

How is DE being used clinically?

Abdomen

- Iodine maps/quantification
- Kidney stone analysis
- Tumor conspicuity
- Tumor characterization
- Iodine maps
- CNR improvement
- Beam hardening correction
- Virtual non contrast
- Contrast volume reduction

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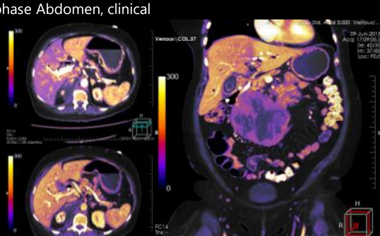
Iodine Map

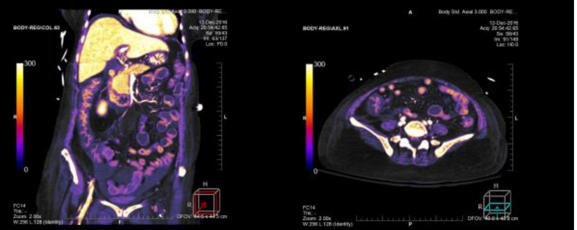
- Multi-phase Abdomen, clinical



Canon

Courtesy of UHN, Professor Rogalla

Iodine Map

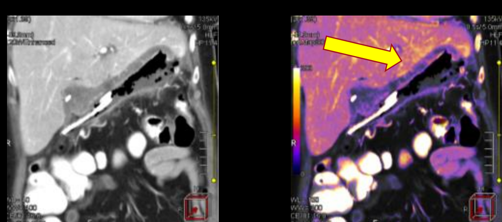


Canon

Courtesy of UHN, Professor Rogalla

Iodine Map

Ischemic Bowel, clinical

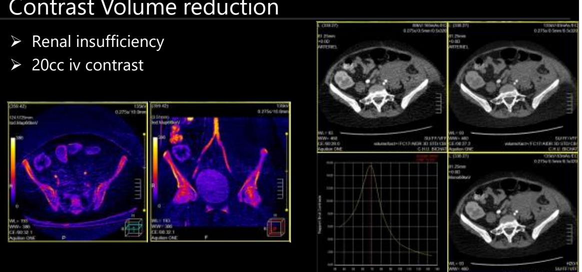


Canon

Courtesy of UHN, Professor Rogalla

Contrast Volume reduction

- Renal insufficiency
- 20cc iv contrast

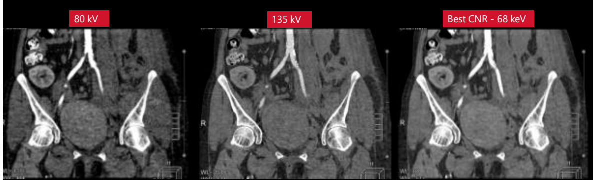


Canon

Courtesy University Hospital of Paris

Contrast Volume reduction

- 20cc iv contrast
- Monochromatic image increase contrast enhance



Canon

Courtesy University Hospital of Paris

Contrast Volume reduction

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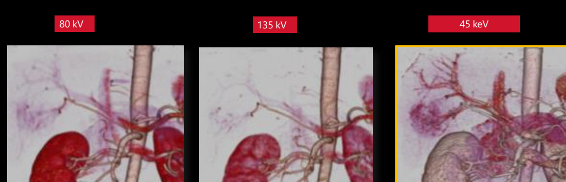

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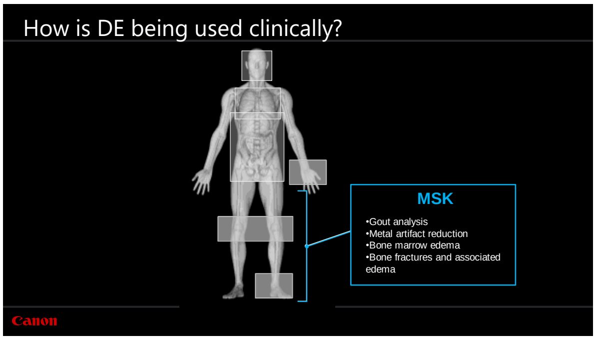
Courtesy The Fourth Hospital of Harbin Medical University

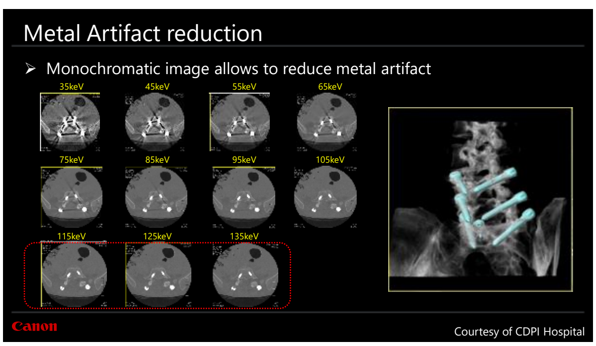
Kidney Stone Analysis

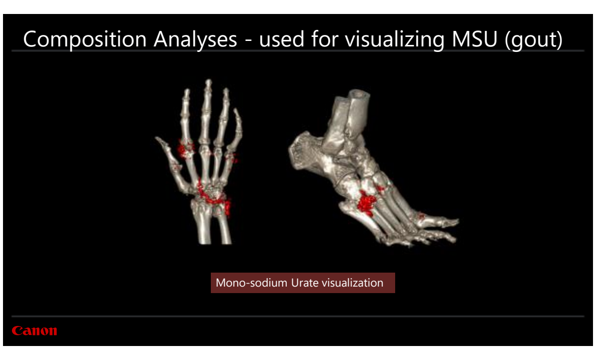
- To characterize urinary stones – uric acid content

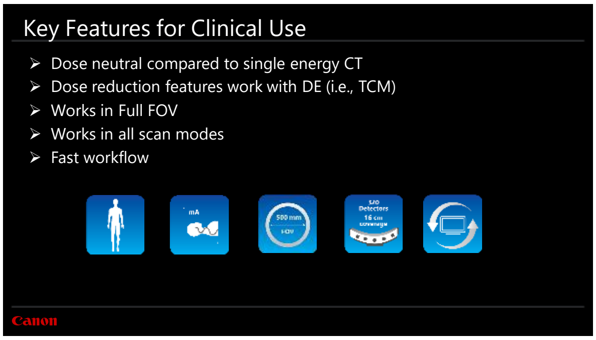
Canon

Courtesy Kitasaito Hospital, Japan.

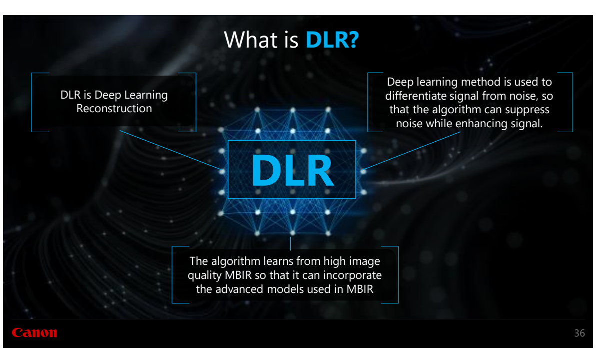

How is DE being used clinically?
MSK
•Gout analysis
•Metal artifact reduction
•Bone marrow edema
•Bone fractures and associated edema
Canon


Metal Artifact reduction
➢ Monochromatic image allows to reduce metal artifact
35keV
45keV
55keV
65keV
75keV
85keV
95keV
105keV
115keV
125keV
135keV
Canon
Courtesy of CDPI Hospital


Composition Analyses - used for visualizing MSU (gout)
Mono-sodium Urate visualization
Canon


Key Features for Clinical Use
Dose neutral compared to single energy CT
Dose reduction features work with DE (i.e., TCM)
Works in Full FOV
Works in all scan modes
Fast workflow
Canon


A new era of AI in medical imaging
AiCE
Deep Learning-based Reconstruction
DCNN
Deep Convolutional Neural Network
Canon
35


What is DLR?
DLR is Deep Learning Reconstruction
Deep learning method is used to differentiate signal from noise, so that the algorithm can suppress noise while enhancing signal.
DLR
The algorithm learns from high image quality MBIR so that it can incorporate the advanced models used in MBIR
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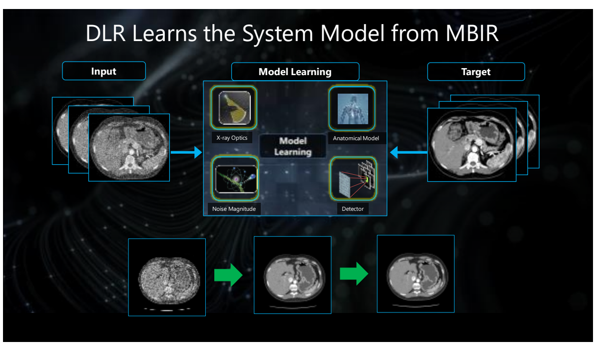
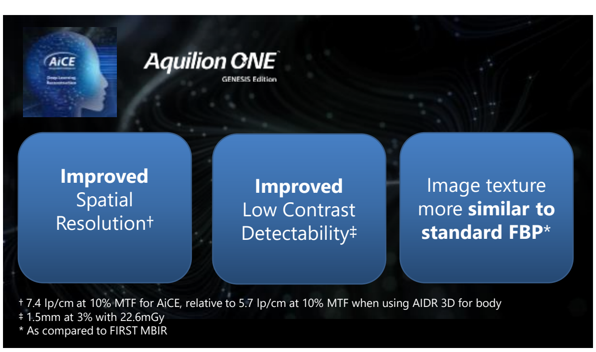
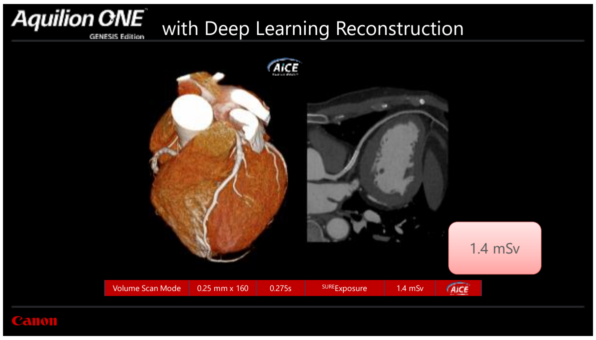
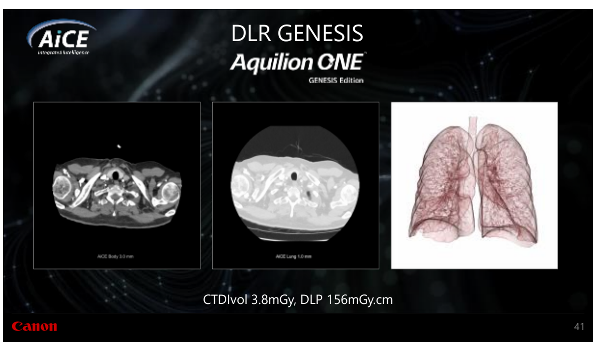
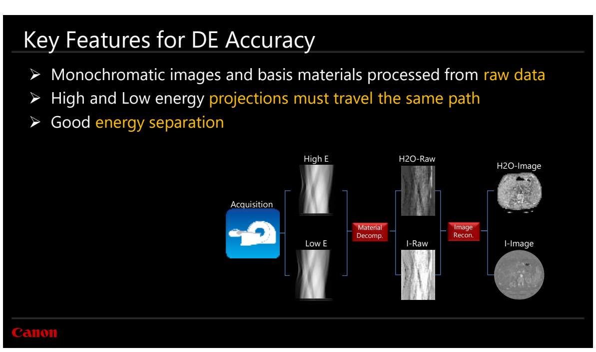
Training Process

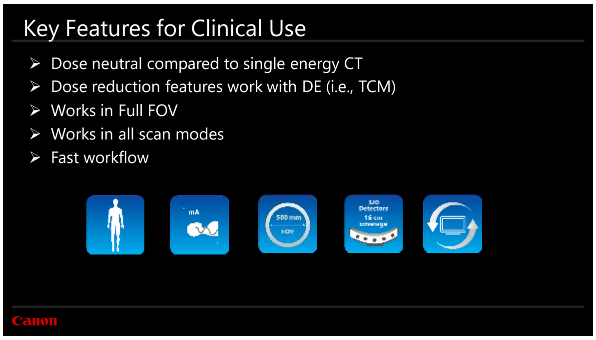

DLR Learns the System Model from MBIR
Input
Model Learning
Target
X-ray Optics
Anatomical Model
Model Learning
Noise Magnitude
Detector


AiCE
Aquilion ONE
GENESIS Edition
Improved Spatial Resolution†
Improved Low Contrast Detectability‡
Image texture more similar to standard FBP*
† 7.4 lp/cm at 10% MTF for AiCE, relative to 5.7 lp/cm at 10% MTF when using AIDR 3D for body
‡ 1.5mm at 3% with 22.6mGy
* As compared to FIRST MBIR


Aquilion ONE
GENESIS Edition
with Deep Learning Reconstruction
AiCE
1.4 mSv
Volume Scan Mode
0.25 mm x 160
0.275s
SUREExposure
1.4 mSv
AiCE
Canon


AiCE
DLR GENESIS
Aquilion ONE
GENESIS Edition
CTDIvol 3.8mGy, DLP 156mGy.cm
Canon
41


Key Features for DE Accuracy
➢ Monochromatic images and basis materials processed from raw data
➢ High and Low energy projections must travel the same path
➢ Good energy separation
Acquisition
High E
Low E
Material Decomp.
H2O-Raw
I-Raw
Image Recon.
H2O-Image
I-Image
Canon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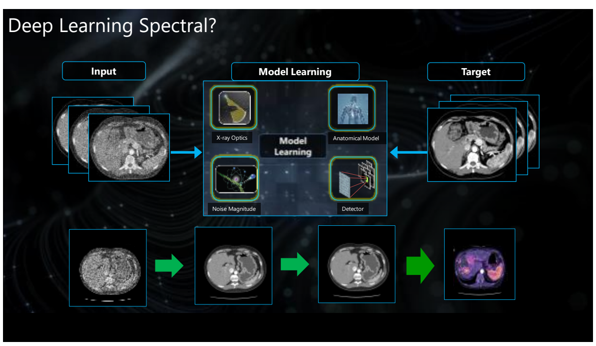
Deep Learning Spectral?
Input
Model Learning
Target
X-ray Optics
Anatomical Model
Model Learning
Noise Magnitude
Detector