SPECIFIC APPLICATIONS AND PROTOCOLS FOR COMPUTED TOMOGRAPHY

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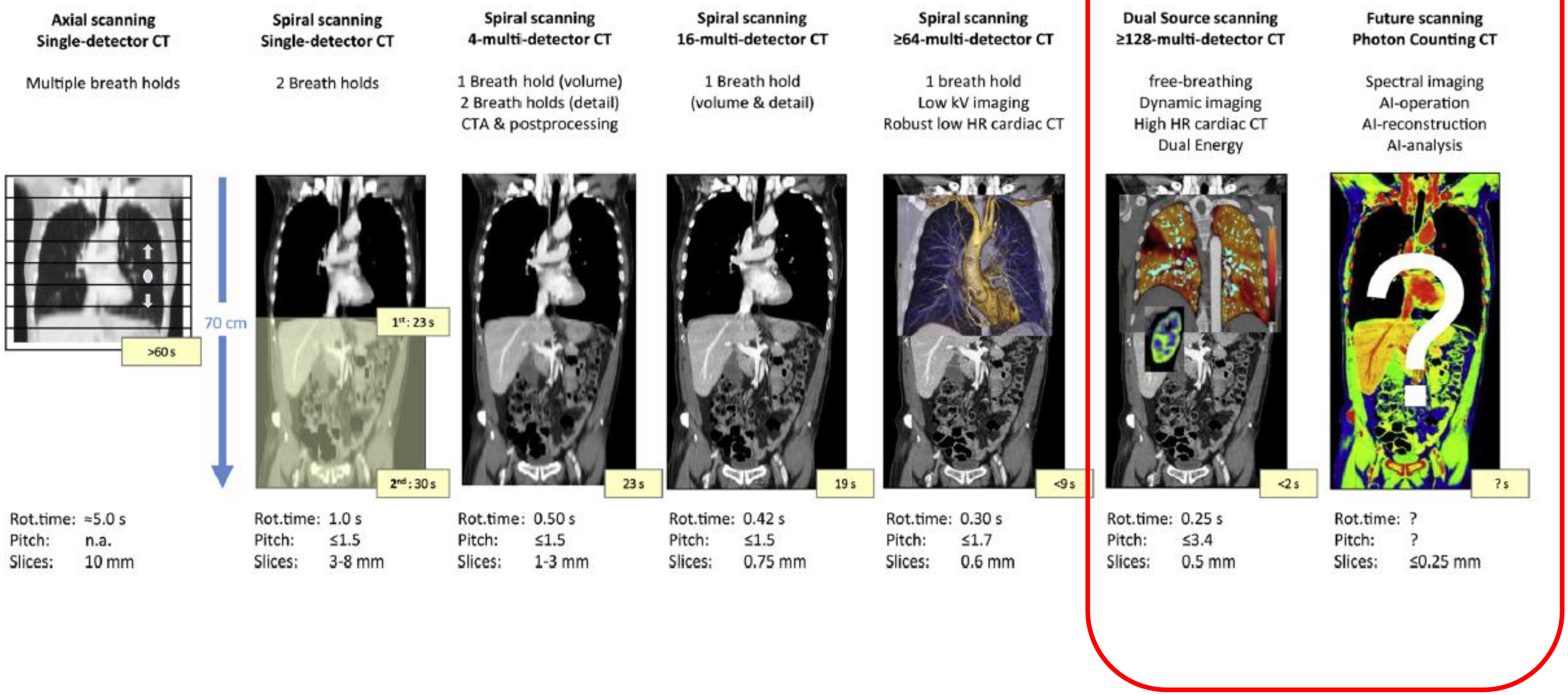
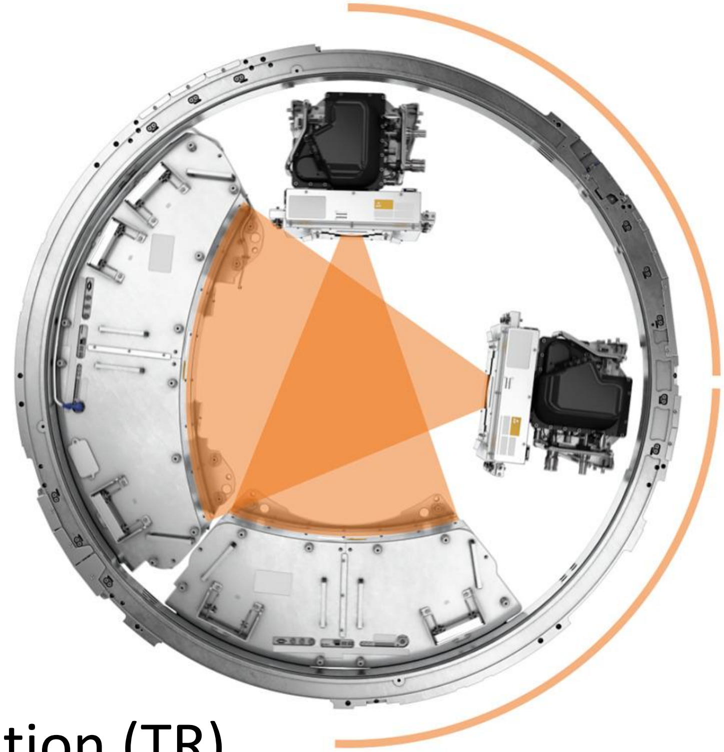
CT Scanner Evolution



Dual source CT (Siemens)

The Dual Source CT has two X-Ray tubes and two detectors (mounted on a CT gantry with a mechanical offset of 90°).



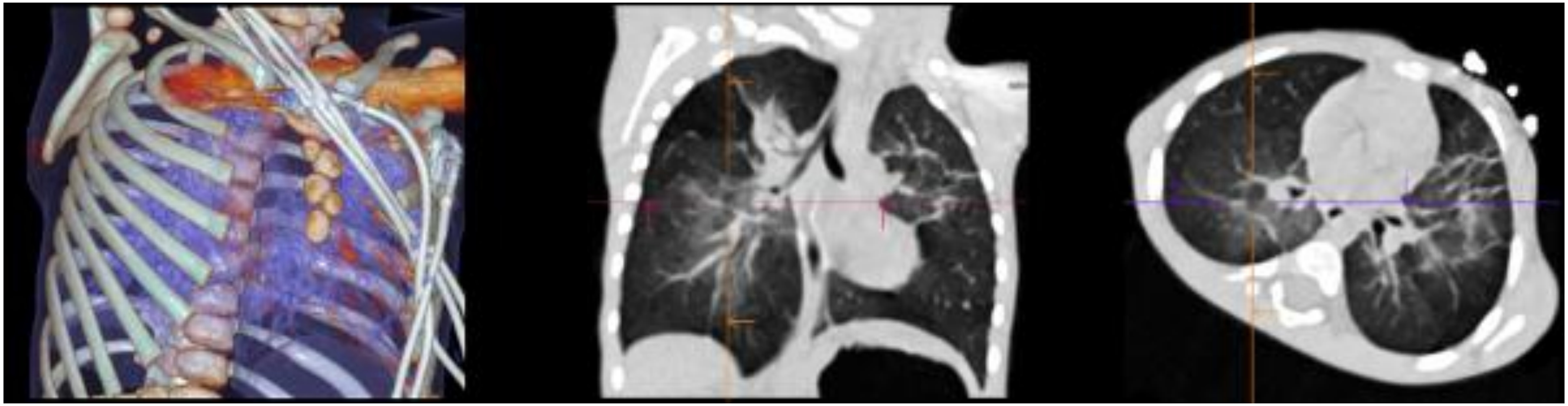
It can provide:

- fast imaging
- improved temporal resolution (TR)

Dual source CT

Temporal resolution can reach **66 milliseconds**

Motion Artifact-free images



Low-dose thorax for evaluation of pneumonia
22-month-old child, 8 kg (18 lbs), free breathing, no sedation, patient rolling at time of scan

Dual source CT

Fast imaging …

- improves productivity
- reduces the need for sedation in pediatric examinations and for the administration of beta-blockers in cardiac examinations
- reduces the movement artifacts

BUT

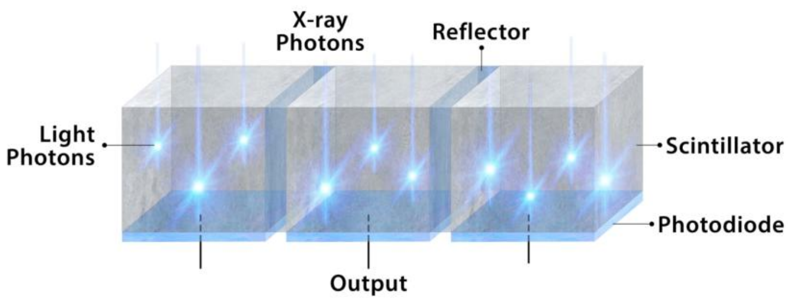
Fast imagine …

Improves the risk of overuse and inappropriate use

Photon Counting CT

- Photon-counting CT is an emerging technology with the potential to dramatically change clinical CT. Photon-counting CT uses new energy-resolving x-ray detectors which count the number of incoming photons and measure photon energy.

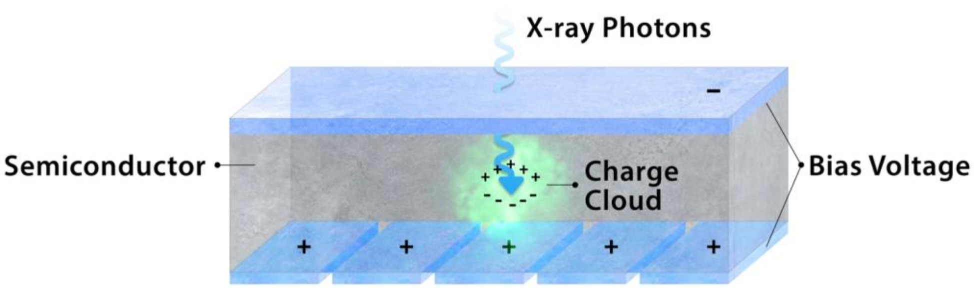
- This technique results in higher contrast-to-noise ratio, improved spatial resolution, and optimized spectral imaging and has the prospective to reduce radiation exposure.



Energy Integrating Detector

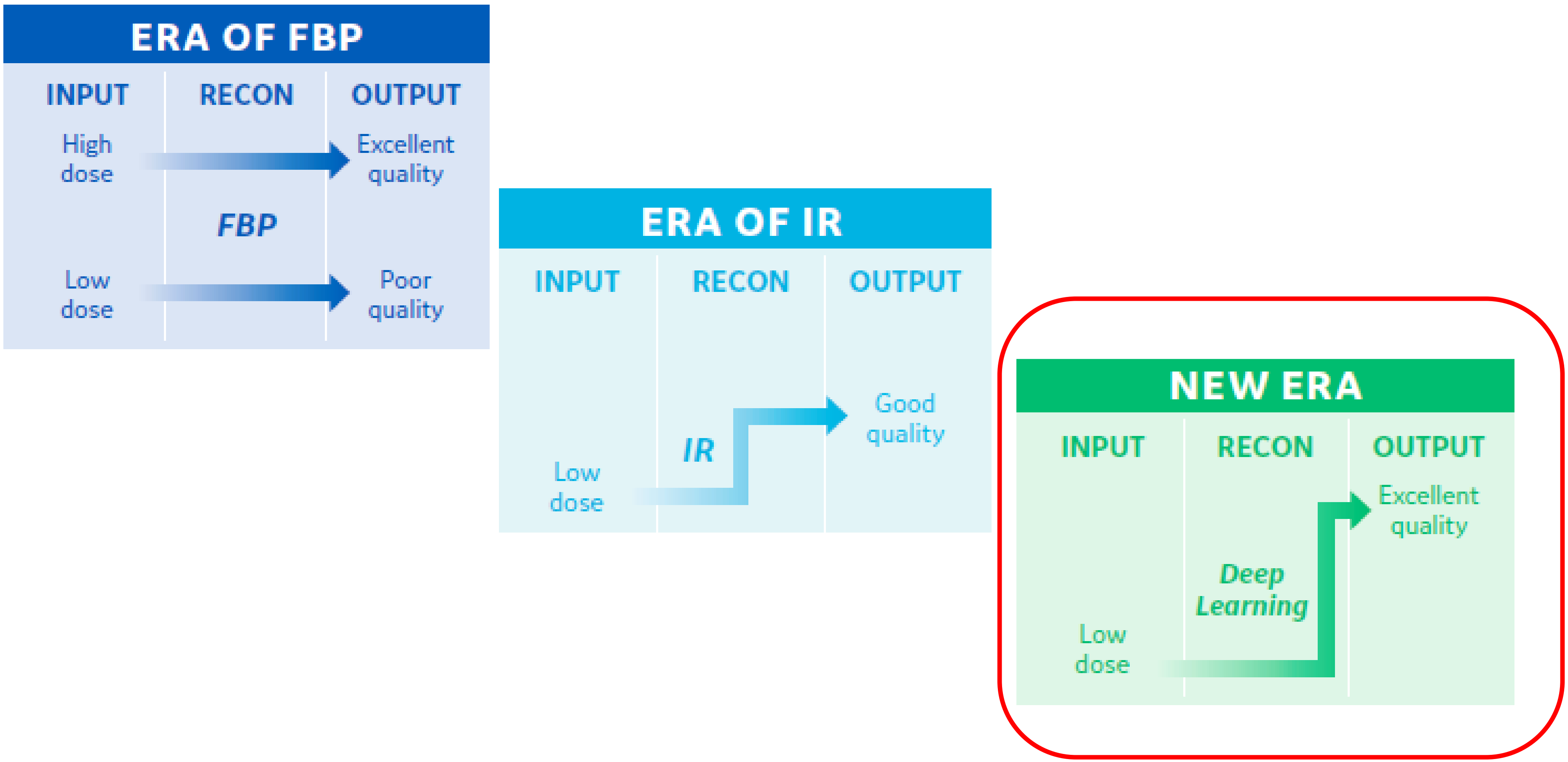
The x-ray photon hits a scintillator where it is turned into visible light. A photodiode collects this light to create an electrical charge (the CT signal). All the photons that hit the detector at the same time are added up to create the signals that are used to generate a CT image. This process provides no specific information about the energy level of each individual photon.

A photon counting detector is made from a semiconducting material that allows for the direct conversion of the x-ray photon to an electrical signal. In this case, the many photons hitting the detector can be counted individually, creating a more accurate signal to generate images. In addition, the energy level of each photon can be quantified, producing high quality spectral information



Photon counting detector

Post Processing



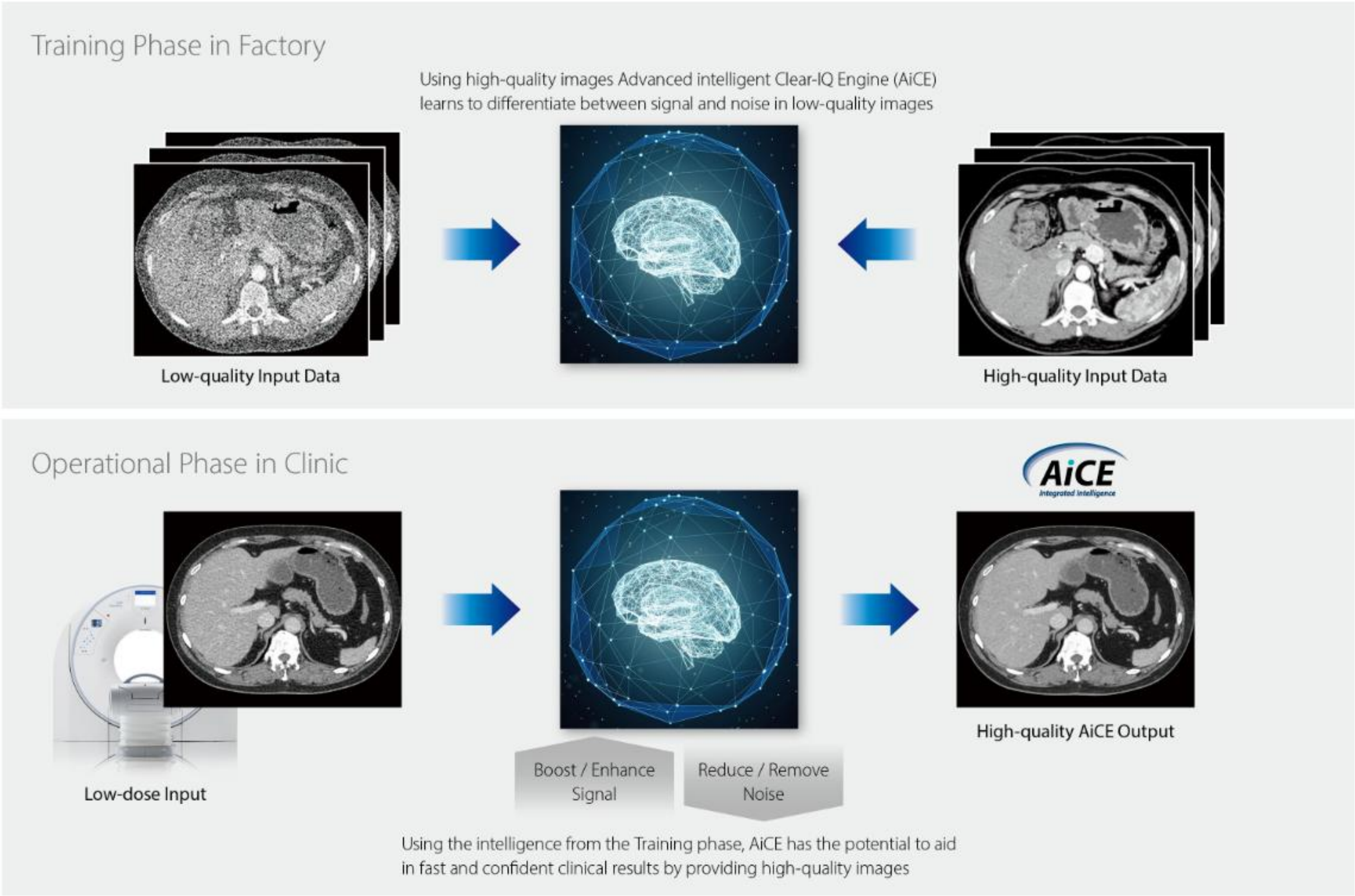
Deep Learning-based reconstruction

With better computational capabilities in both hardware and software domain, data availability for training, validation, and testing, **artificial intelligence-based reconstruction techniques** have emerged as viable options for CT image reconstruction

The state-of-the-art in the field of Artificial Intelligence (AI) is a subfield of machine learning known as **deep learning**.

Unlike conventional algorithms that are constrained by pre-programmed rules for performing a complex task, deep learning occurs when a neural network learns from its own intensive training process and develops its own logic structure

AiCE (CANON)


Training Phase in Factory
Using high-quality images Advanced intelligent Clear-IQ Engine (AiCE)
learns to differentiate between signal and noise in low-quality images
Low-quality Input Data
High-quality Input Data
Operational Phase in Clinic
AiCE
Low-dose Input
Boost / Enhance Signal
Reduce / Remove Noise
High-quality AiCE Output
Using the intelligence from the Training phase, AiCE has the potential to aid
in fast and confident clinical results by providing high-quality images

Special techniques

- Cardio CT
- Dynamic Imaging
- Dual energy / Spectral Imaging

Heart imaging: a demanding procedure

Requirements on temporal, spatial and contrast resolution are greater than for any other organ system in the body:

- Excellent **spatial resolution** is necessary to evaluate the fine anatomic detail of the coronary arteries, which may harbor plaque that is clinically significant at a submillimeter level.

- Sufficient **temporal resolution** is also necessary to evaluate coronary arteries without motion artifacts.

- **Contrast resolution** is critical for determining coronary plaque composition, which may greatly influence patient prognosis and management

Cardiac CT

Organ continuously in movement.

Different heart rate (depending on the patient)

- Low or moderate heart beat

  (60 – 75 beats per minute [bpm])
- High heart beat
- arythmia

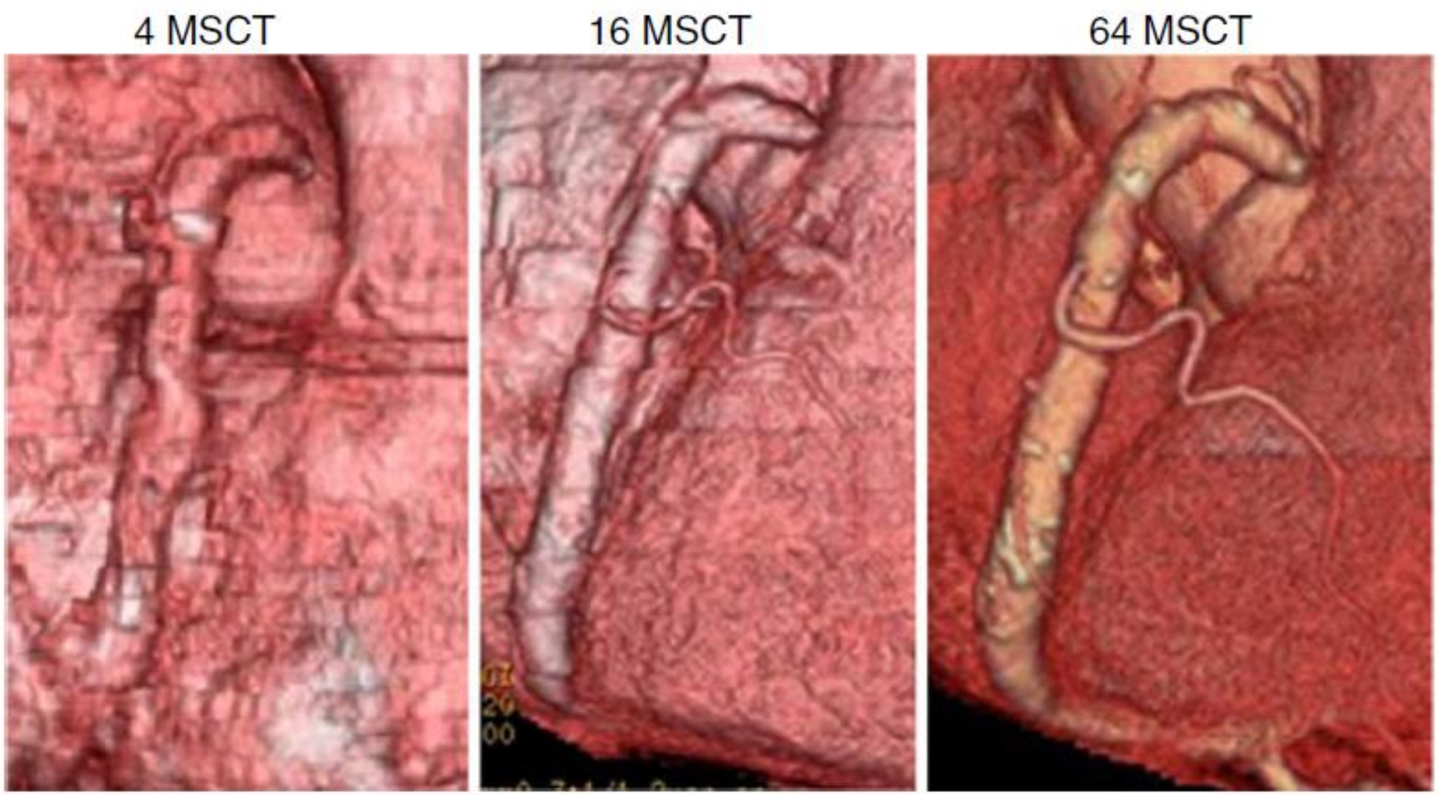
Coronary angiography

Coronary angiography is a procedure that uses a special dye (contrast material) and x-rays to see how blood flows through the arteries in the heart.

AN INVASIVE TECHNIQUE

Cardiac CT (4, 16 and 64 detector row)

CCT has introduced in clinical use since the advent, in the early 2000s, of multidetector CT (MDCT) scanners with submillimeter resolution that allow evaluation of the coronary anatomy.



2002 2003 2005

Cardiac CT

With the avaibility of the 64-row MDCT, robust **low** heart rate (HR) cardiac CT was possible. In case of medium or high heart rate, beta-blockers were adopted to reduce the rate

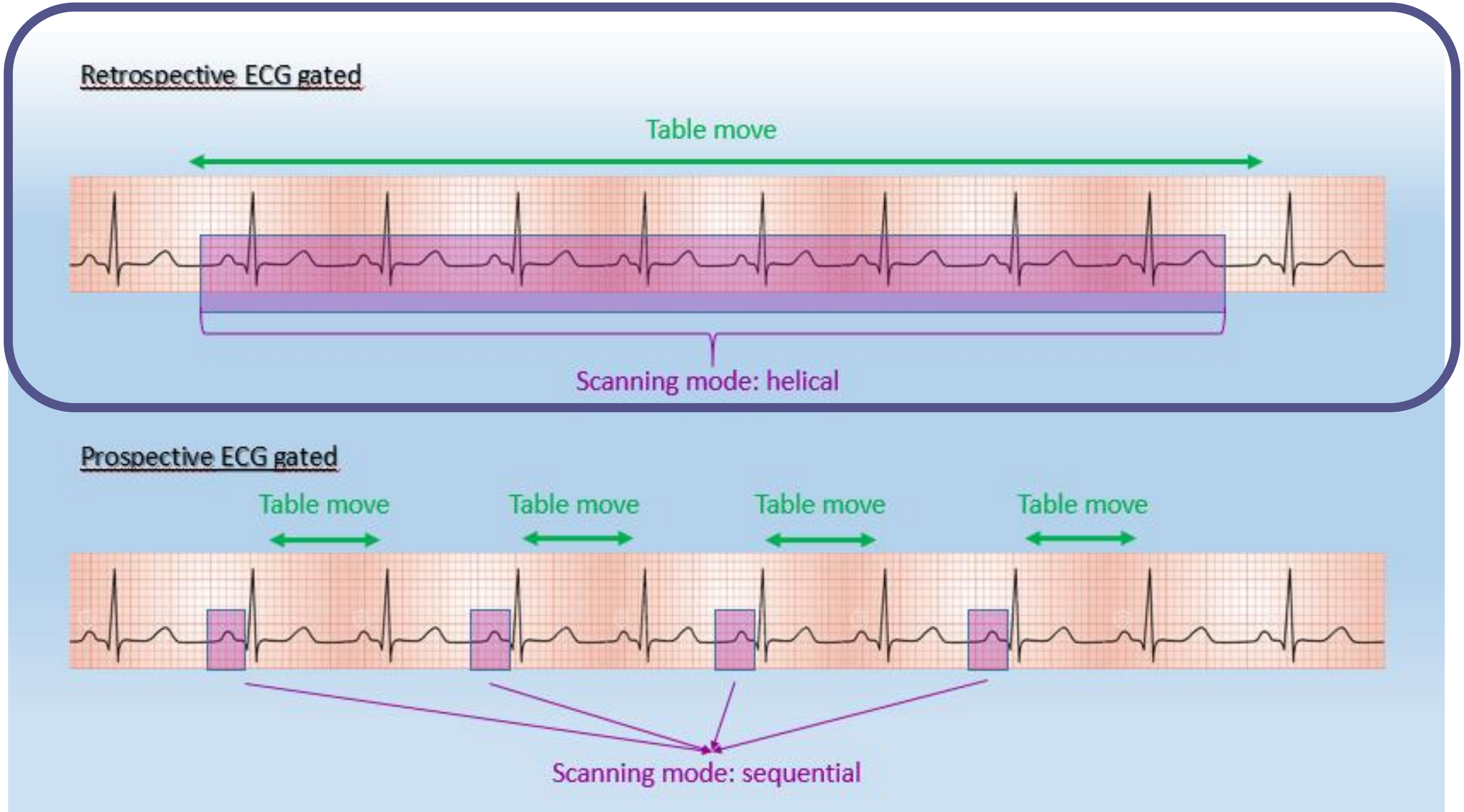
The maximum coverage along Z-axis with a single rotation was around 4 cm.

At first, only a **retrospective spiral scan mode.**

X-Ray beam was turned on during the entire cardiac cycle (whole R-R interval) without adjusting the tube current, allowing for acquisition of volume data. Low pitch values were selected, to ensure enough data for reconstruction (also in case of arythmia)

The effective dose for a cardiac CT was very high (10 – 20 mSv)

Acquisition ECG gated



Cardiac CT

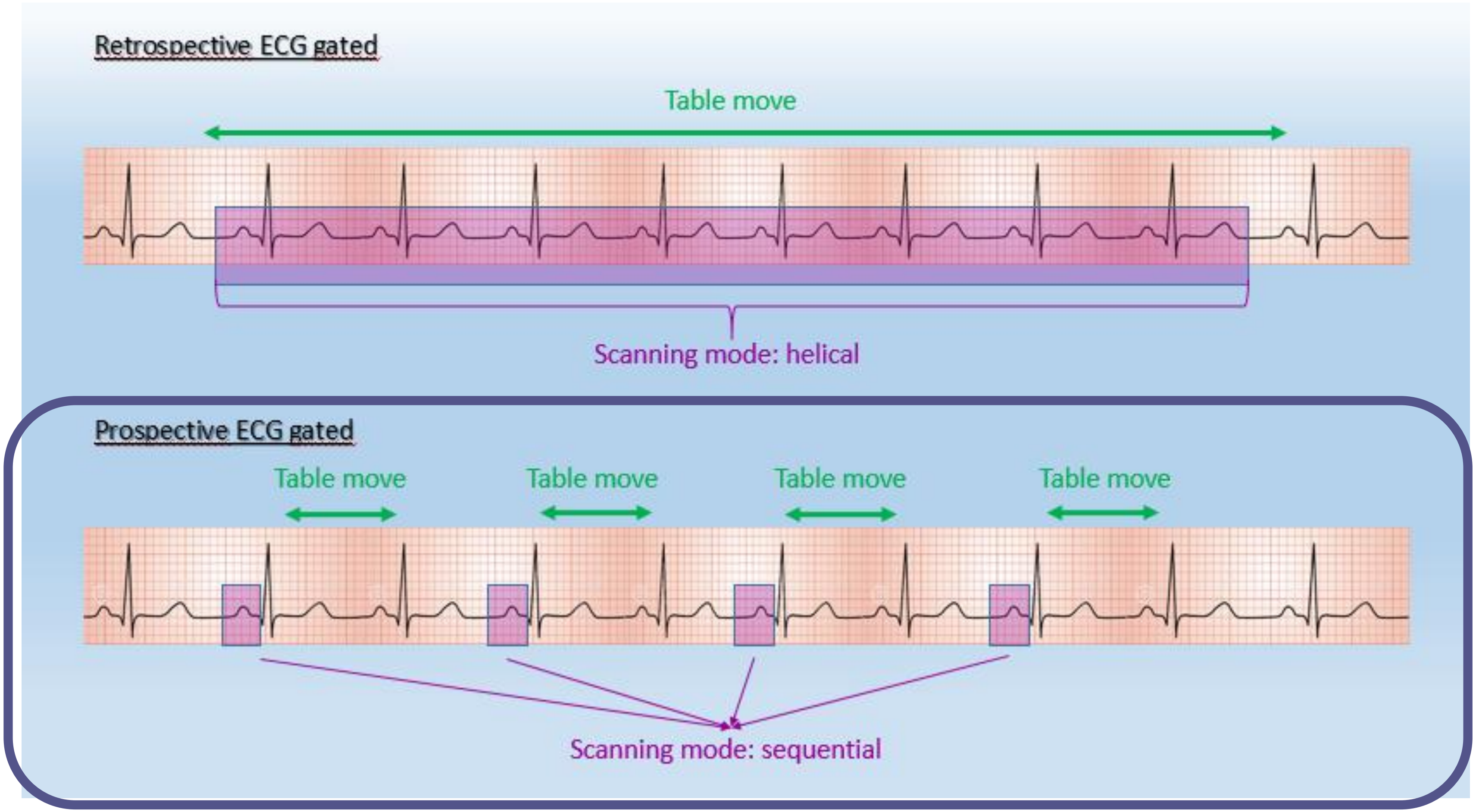
Prospective ECG-triggered coronary CT angiography uses the partial-scan technique to the motion of the heart, which is defined as the step-and-shoot method so that scan is triggered by ECG signal instead of spiral CT acquisition.

This technique allows data to be acquired in a certain phase of cardiac cycle, preferably in the mid-diastolic phase, when cardiac motion is minimal.

Unusable in case of irregular heart rate

Radiation dose of prospective ECG-triggered coronary CT angiography is significantly lower than that of retrospective gating protocol (< 10 mSv)

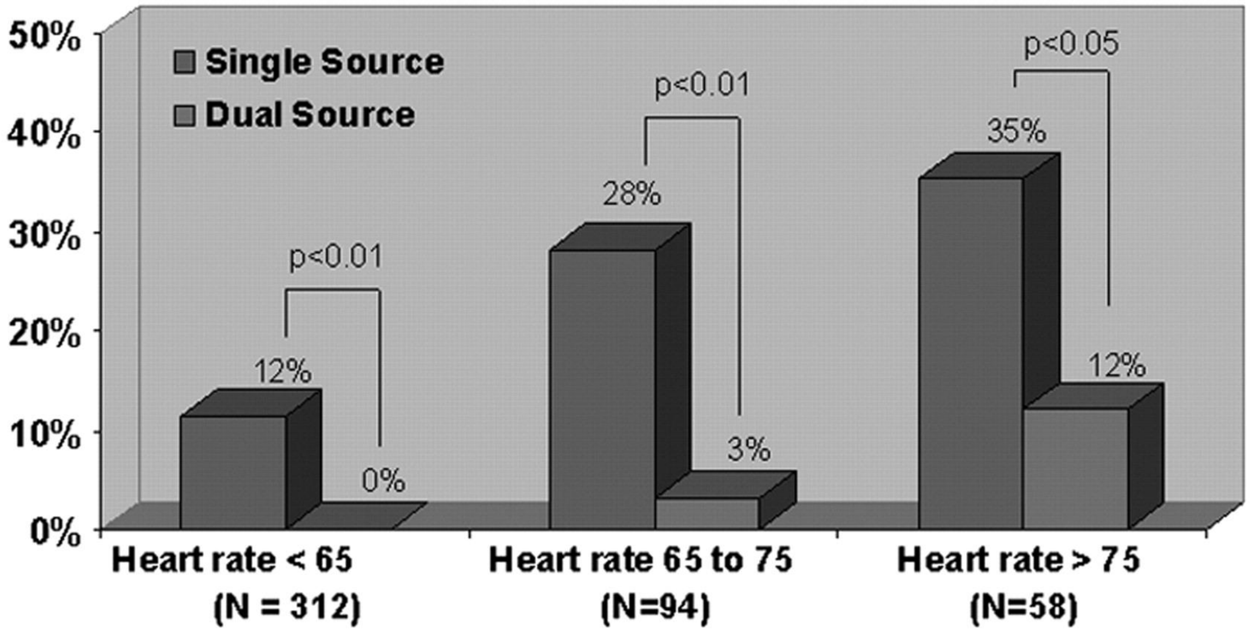
Acquisition ECG gated



Cardiac CT with Dual source CT

The key benefit of Dual Source CT (DSCT) is the improved temporal resolution. DSCT offers very robust diagnostic image quality in **a wide range of heart rates.**

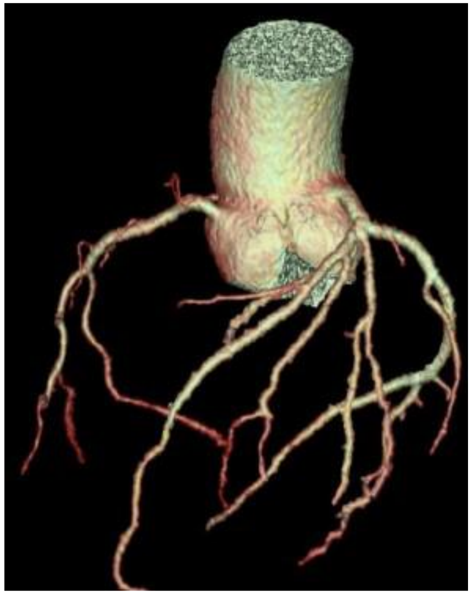
Percentage of examinations with any degree of motion artifact

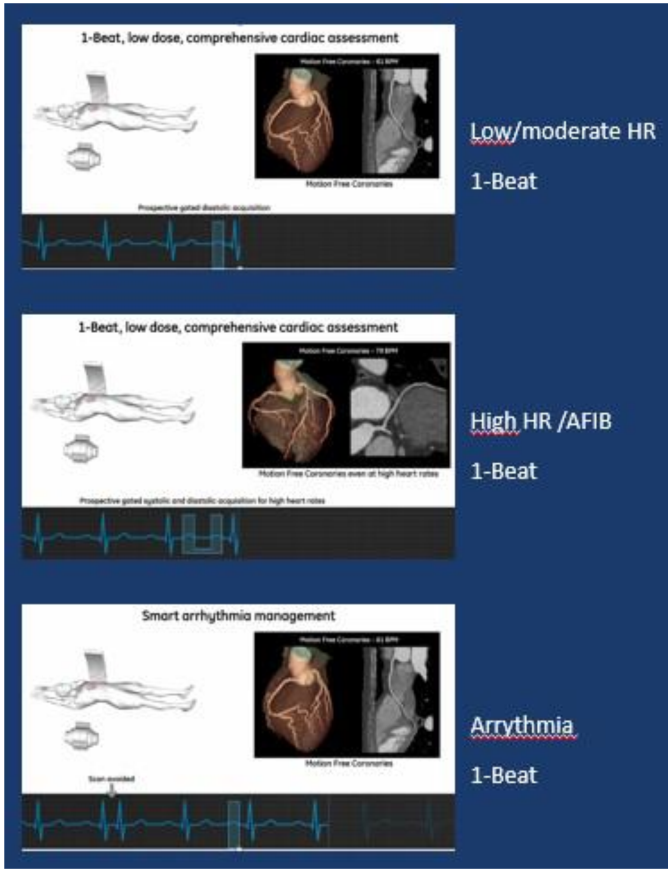


Donnino et al. «Dual-Source Versus Single-Source Cardiac CT Angiography: Comparison of Diagnostic Image Quality» Cardiopulmonary Imaging. April 2009, Volume 192, Number 4

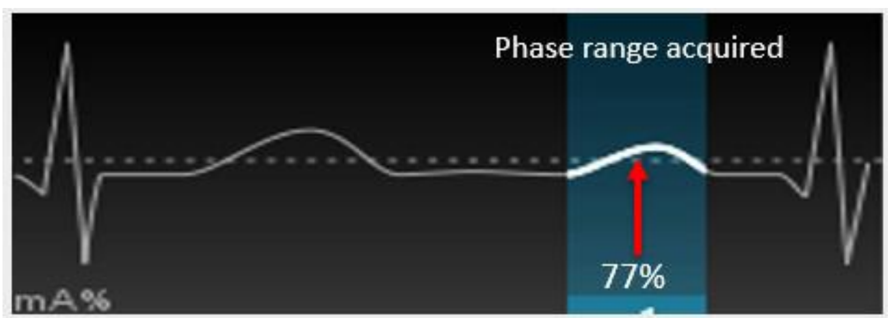
Cardiac CT - state of the art

256-slice systems and 320-slice systems with 16 cm of coverage are able to capture the entire heart in one heartbeat and rotation.





High quality images, without any movement artifact regardless of HR (also using automatic phase selection)



Automatic Phase Selection

Perfusion imaging methodology

Perfusion is the passage of fluid through the lymphatic system or blood vessels to an organ or a tissue.

CT perfusion is a dynamic, contrast-enhanced study of a region of the body (head, liver, heart..).

The purpose of this scan is to measure/observe contrast enhancement as it makes its way through the arterial and venous system, making this a 'functional scan'.

Several images are acquired without moving the table.

A software performs the analysis of plain and contrast-enhanced images obtained at different times.

CT brain perfusion

CT brain perfusion is a dynamic, contrast-enhanced study utilized in patients with suspected stroke to differentiate salvageable ischemic brain tissue (i.e. penumbra) from damaged infarcted brain.

The parameters chosen for evaluating cerebral perfusion are:

- time to peak (**TTP**)

  The time at which contrast concentration reaches its maximum

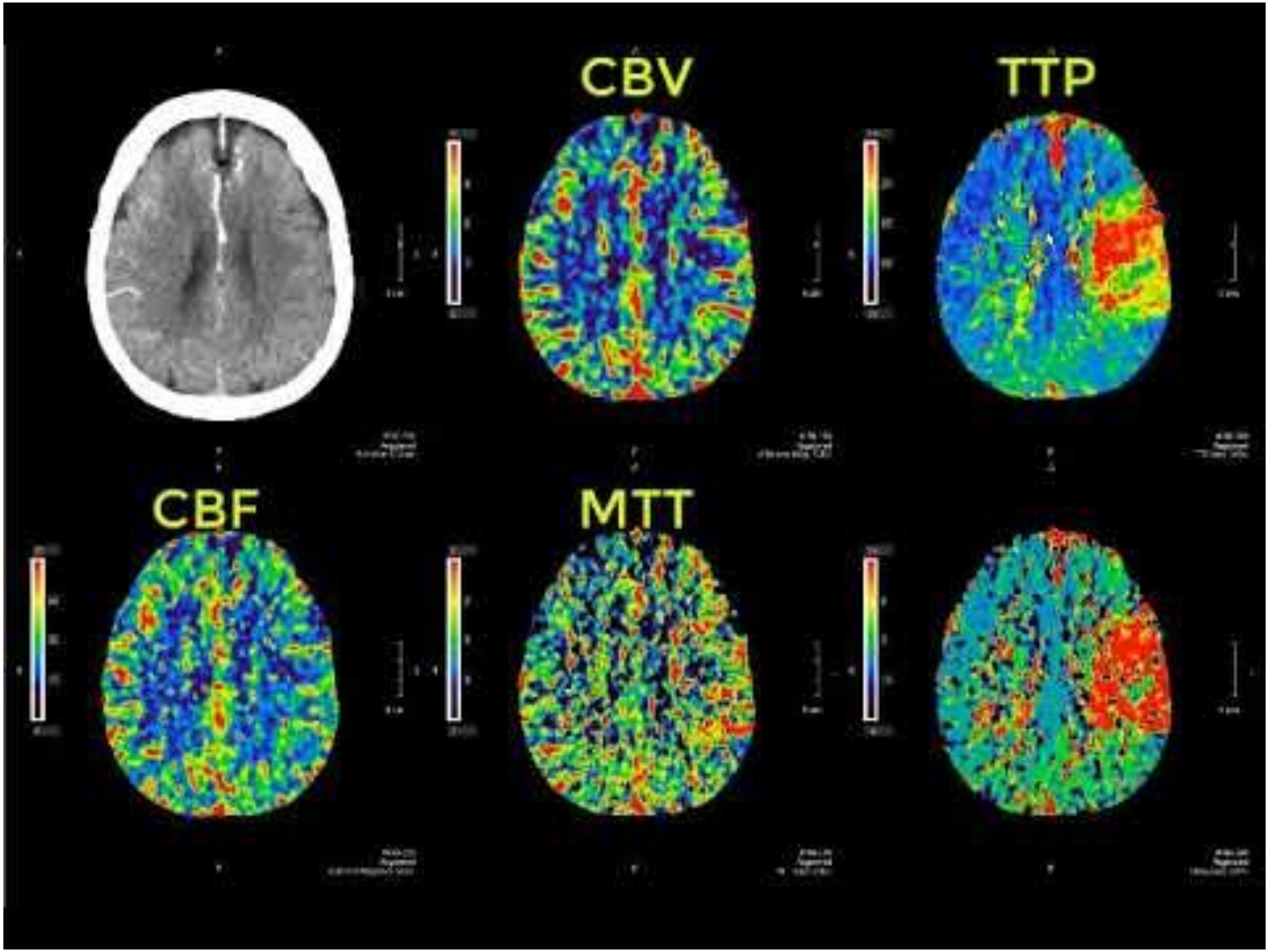
- cerebral blood flow (**CBF**)

  The volume of blood passing through a given amount of brain tissue per unit of time

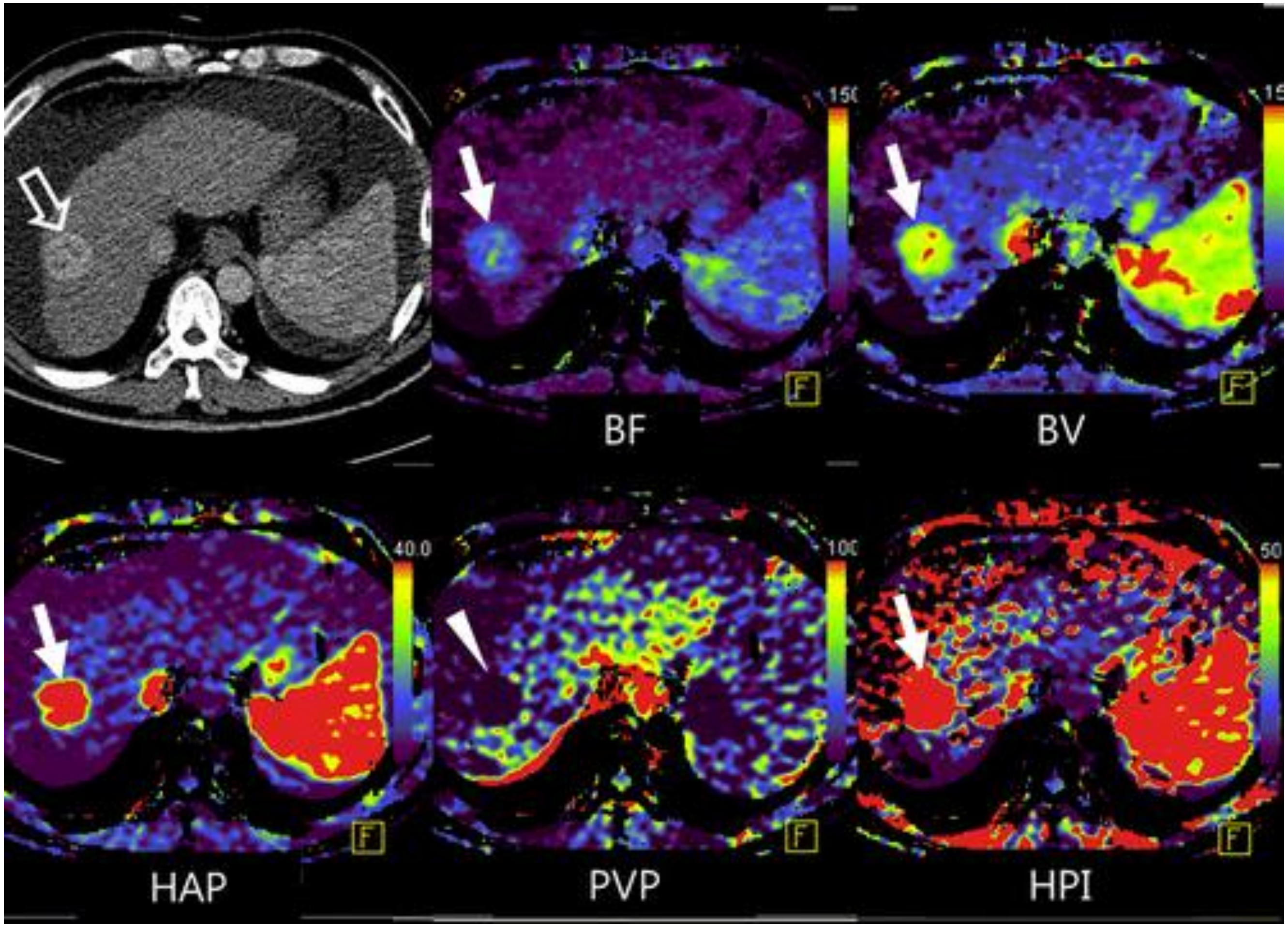
- cerebral blood volume (**CBV**)

  The volume of blood in a given amount of brain tissue

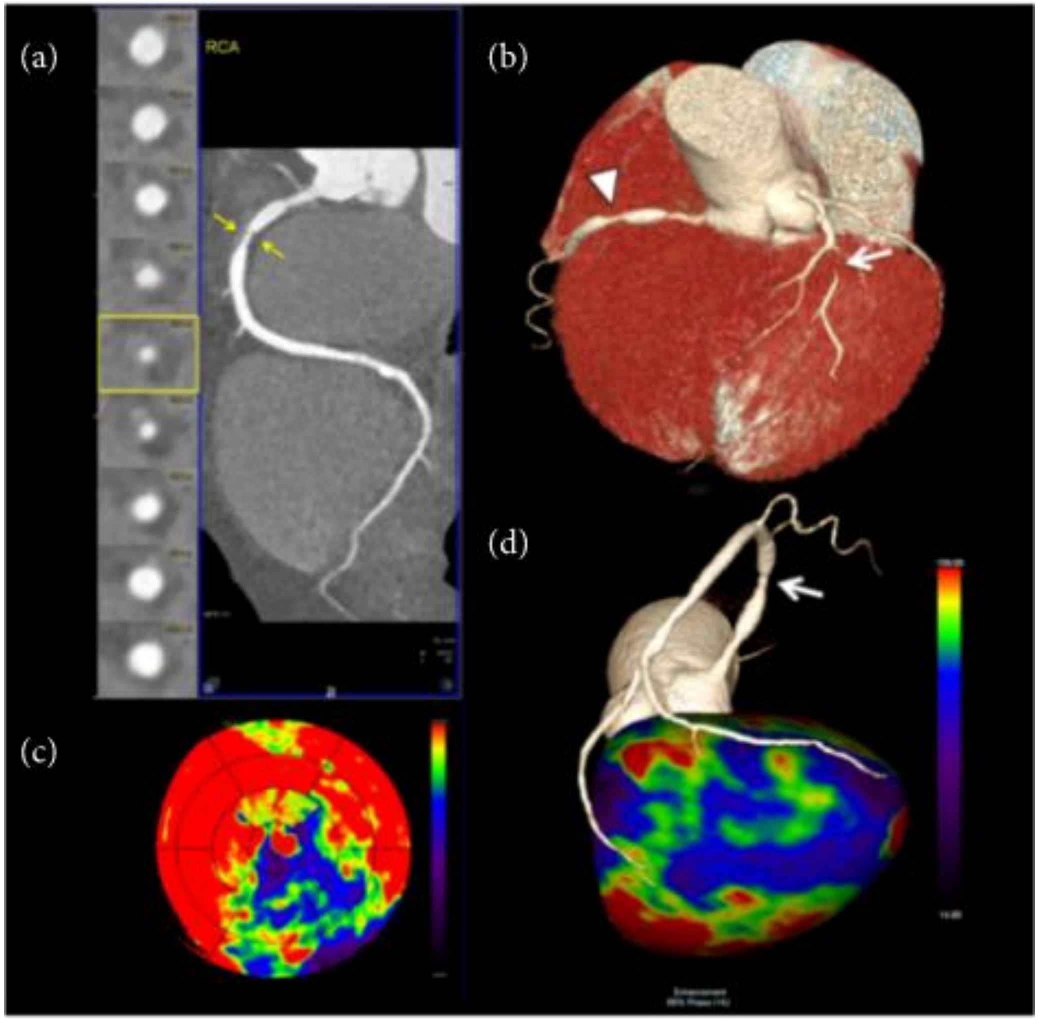
CT brain perfusion



CT perfusion of the liver



CT myocardial perfusion imaging

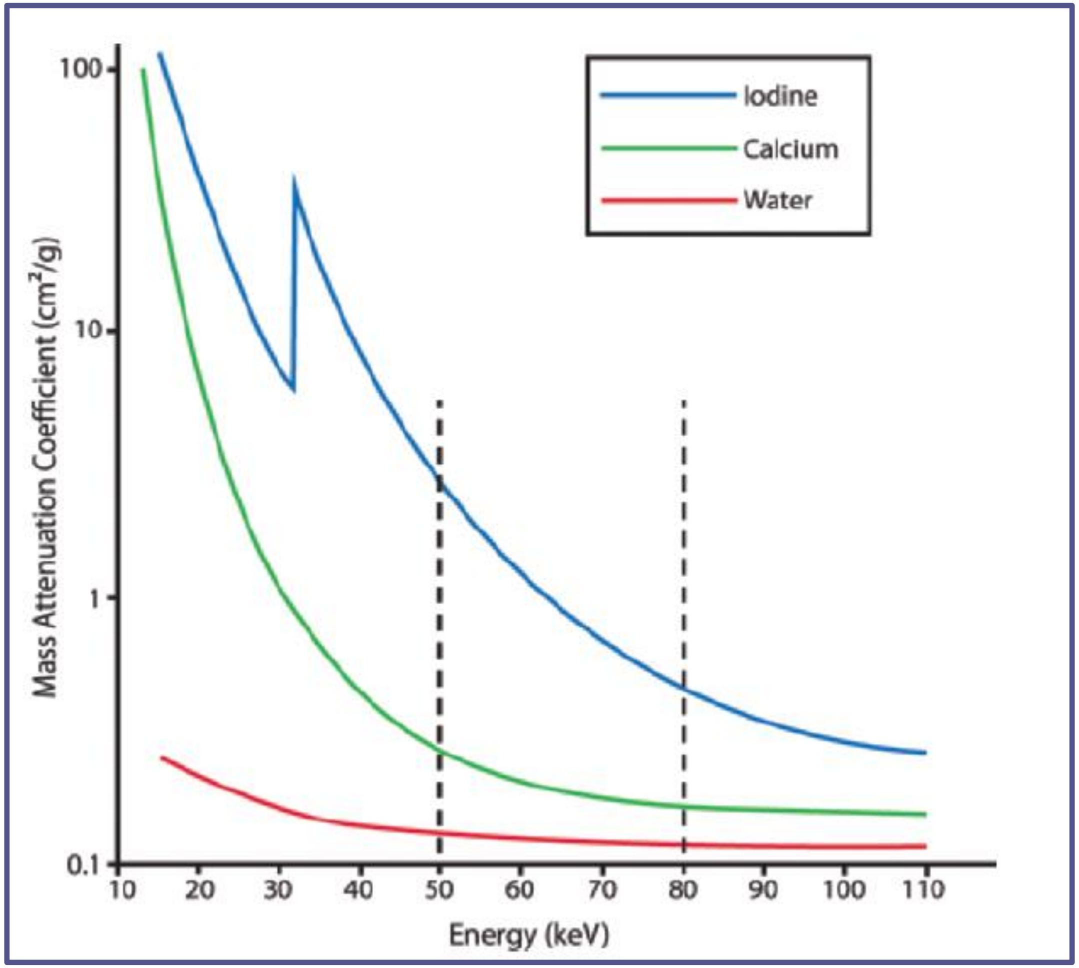


Dual Energy CT

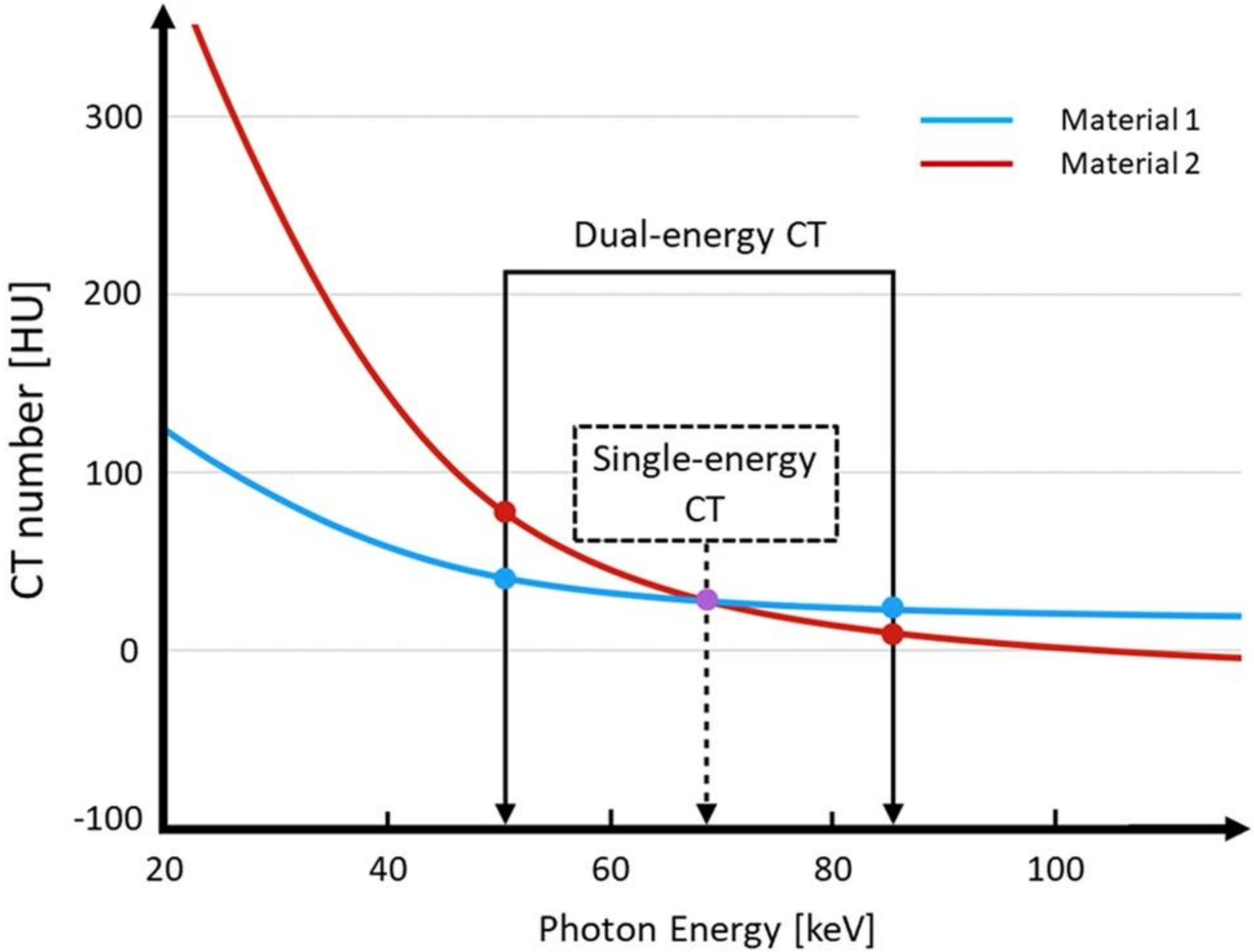
Conventional CT is performed at a fixed tube potential.

With dual-energy CT, two image datasets are acquired in the same anatomic location with two different x-ray spectra.

Two different materials that show similar attenuation on images acquired with one of the two energy spectra are often more easily differentiated on images acquired with the other spectrum because of substantial differences in their attenuation to allow the analysis of energy-dependent changes in the attenuation of different materials



Iodine and calcium may demonstrate similar attenuation on conventional CT images, the attenuation of iodine increases more markedly than that of calcium on dual-energy CT images obtained with low energy when compared with images obtained with high energy and this attenuation difference facilitates differentiation of the two materials.


Material 1
Material 2
Dual-energy CT
Single-energy CT
CT number [HU]
300
200
100
0
-100
20
40
60
80
100
Photon Energy [keV]

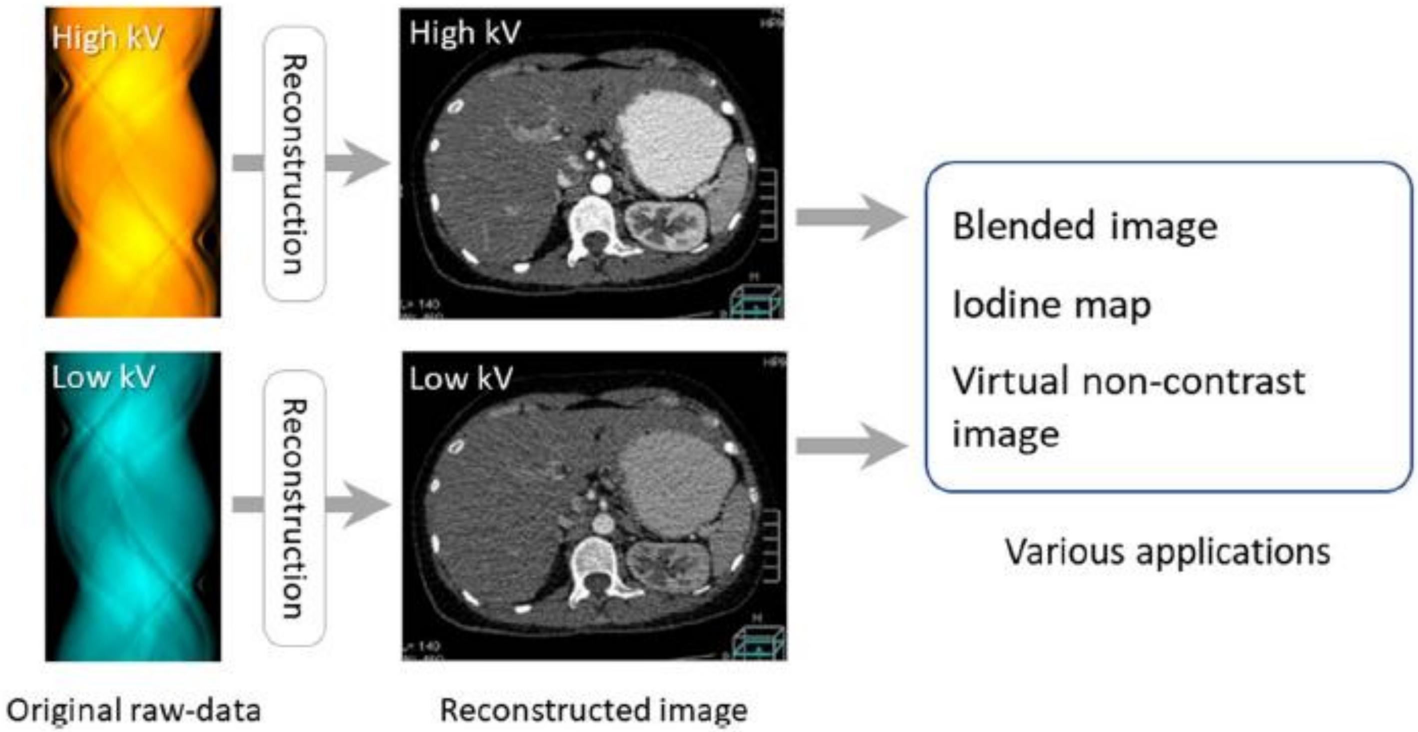
Dual Energy CT

Dual-energy CT data can be obtained and viewed using various hardware and software applications capable of material-specific classification and image display.

Al leats three types of dual-energy CT scanners are available to acquire high- and low-energy CT datasets:

- a dual-source CT
- a single-source scanner with fast kilovoltage switching (ie,rapid alternation between high and low kilovoltage settings)
- a single-source scanner with dual detector layers.

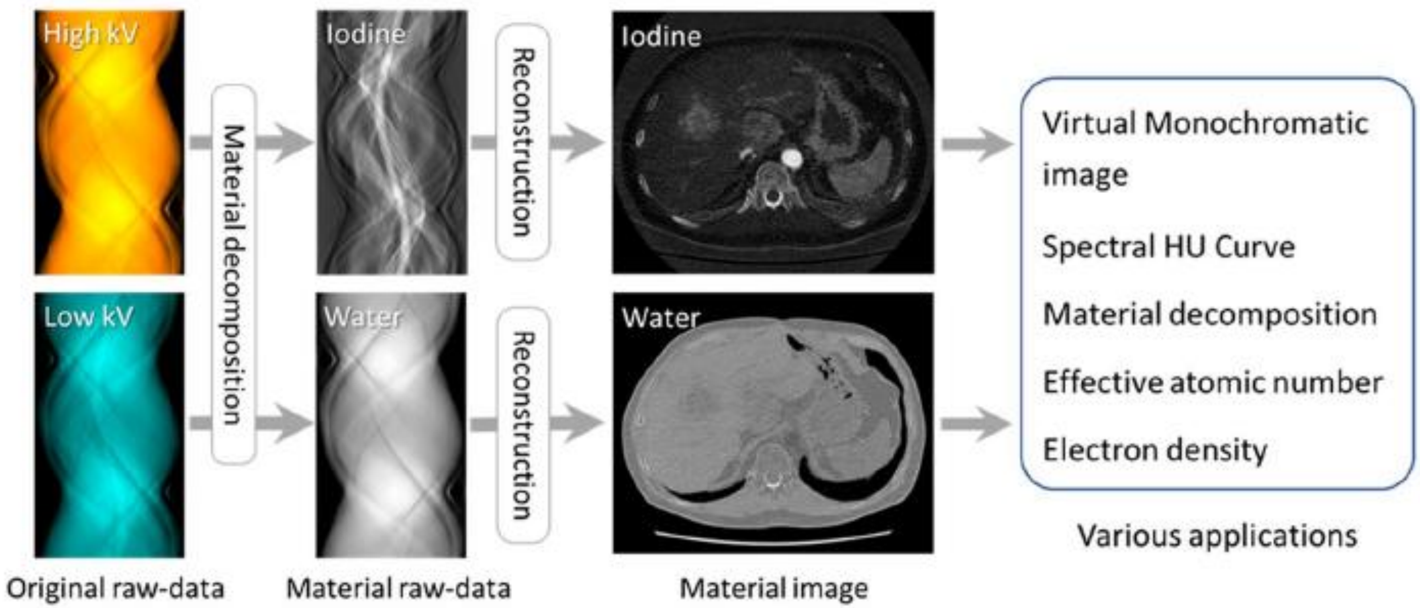
Image-based approach for dual energy CT analysis



F. Tatsugami et al. «Dual-energy CT: minimal essentials for radiologists», Japanese Journal of Radiology (2022) 40:547–559

Dual-energy data are processed after the reconstruction of high-energy and low-energy images, then various applications are created.

Raw data-based approach for dual-energy CT analysis



Material raw data are processed directly by material decomposition, then image reconstruction is performed.

Virtual monochromatich images

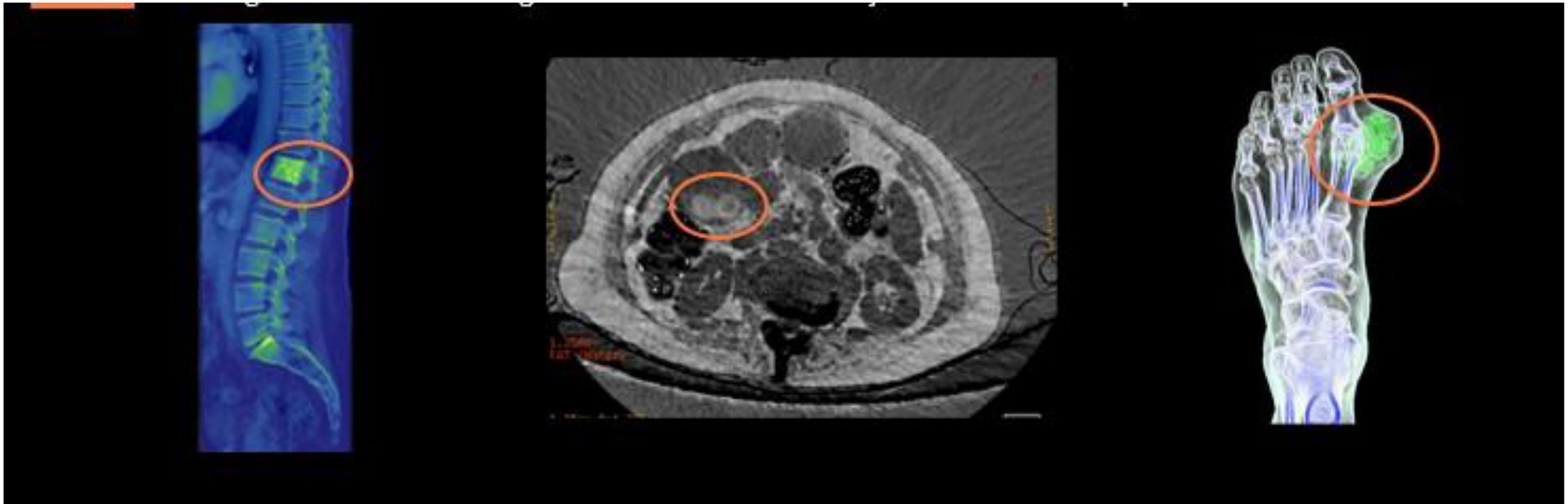
40 keV 70 keV 140 keV

F. Tatsugami et al. «Dual-energy CT: minimal essentials for radiologists», Japanese Journal of Radiology (2022) 40:547–559

Virtual monochromatich images simulate CT images obtained with monochromatic x-rays of arbitrary energy.
Images obtained at low keV show an improvement of CNR and a better visibility of the lesions

Material decomposition images

Material decomposition images contain qualitative and quantitative information about the tissue composition

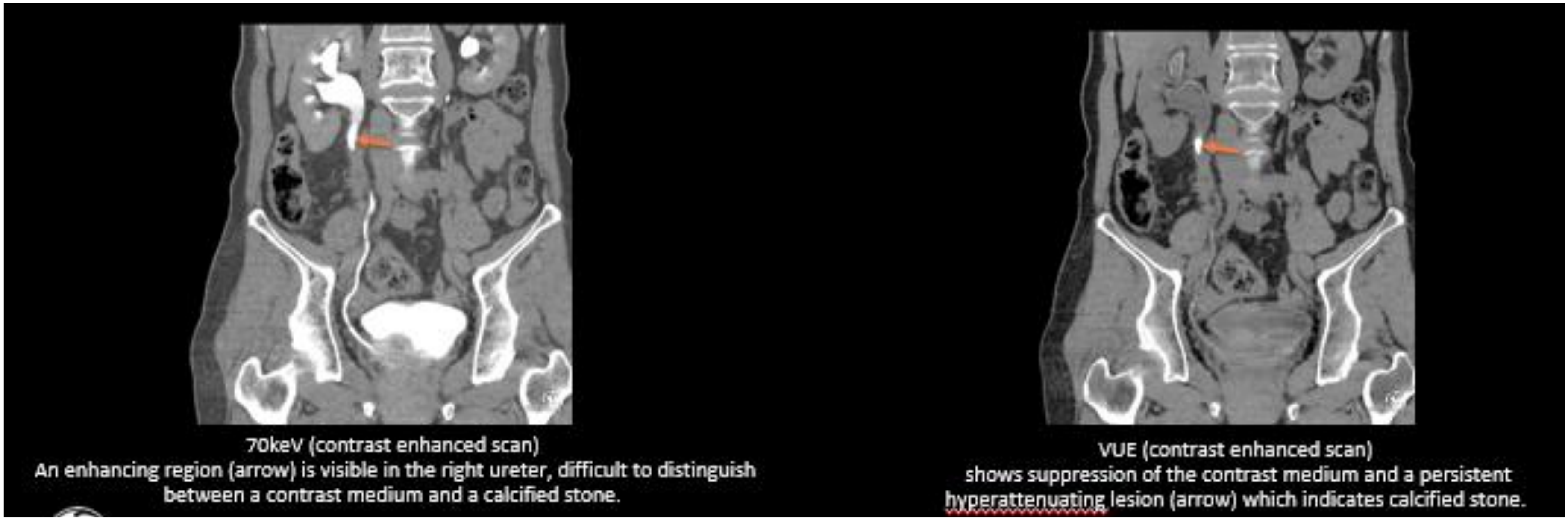


Iodine image
to show cancer metastasis lesions in spine

Fat image
to show cholesterol stone in gall bladder

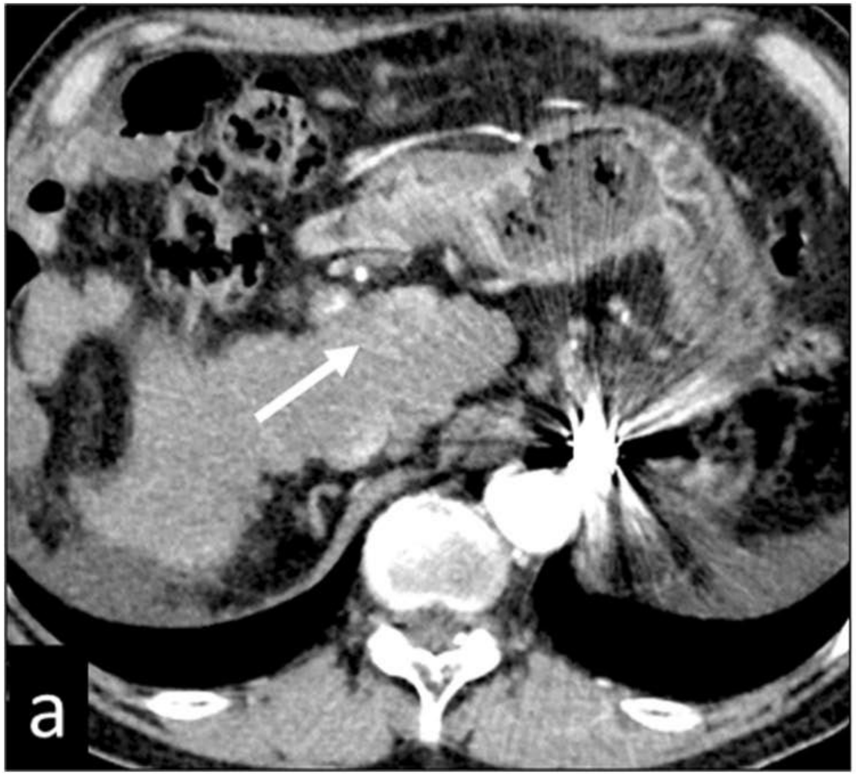
Uric Acid image
to show gout lesion in left foot

Virtual un-enhanced images (VUE),



VNC images facilitate the differentiation of calcifications or high-attenuation materials from iodine-enhanced tissues

Metal Artifact Reduction



a) 70 keV virtual monochromatic image
Metal artifacts (metallic coil implanted in the left inferior phrenic vein) affect tumor detection.

b) iodine map applied with metal artifact reduction software
Artifacts are reduced and the visibility of the tumor is considerably improved