

128-slice Dual Source CT: How Does it Work and What Can it Do?

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Introduction

Overview

A 128-slice dual source CT scanner (Fig. 1) is equipped with two x-ray tubes and two corresponding detectors, mounted onto the rotating gantry with an angular offset of 94°. One detector (A) covers the entire scan FOV (50 cm), while the other detector (B) is restricted to a smaller, central FOV (33 cm) due to space limitations on the gantry (Fig. 2). Each detector contains 64 detector rows, each of which is 0.6 mm wide. Using the z-flying focal spot technique, two 64-channel 0.6 mm measurements are combined to create 128 "slices" of projection data along the z axis. The shortest gantry rotation time is 0.28 s. Two on-board generators provide up to 100 kW peak power to each of the two rotating envelope (Straton) X-ray tubes.



Figure 1
SOMATOM Definition Flash (Siemens Healthcare)

Operating modes

The scanner can be operated in one of several different modes:

Single-source

Functions as a conventional single-source 128-slice CT scanner for head or body imaging.

Single-source 4D spiral

Patient is moved smoothly in and out of the gantry to provide 14-cm z-axis coverage for perfusion imaging

Dual-source cardiac

Both sources operate at the same energy to provide high temporal resolution (85 msec)

Dual-source Flash

Both sources operating at the same energy at pitch values up to 3.4 and provide 85 msec temporal resolution

Dual-source dual-energy

The two sources operate at different energies to characterize or classify materials

Dual-source obese

The two sources operate at the same energy to maximize scanner output (2x100kW)

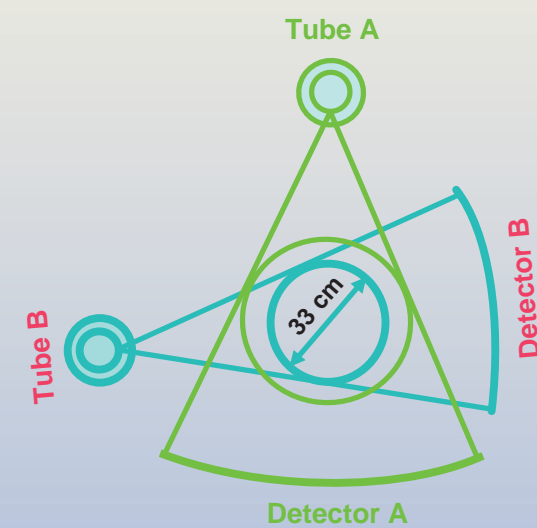


Figure 2
Diagram of tube configuration

Cardiac CT

What is new

The Flash scanner has the following major improvements over the first generation 64-slice dual-source scanner (Definition DS, Siemens Healthcare):

- Better temporal resolution: 75 ms vs. 83 ms
- Wider collimation: 38.4 mm vs. 19.2 mm – reduces scan time from about 10 sec to about 5 sec
- More tube power: 2x100 kW vs. 2x80 kW – beneficial for larger patients
- Flash scan mode – allows coverage of the whole heart within one heart beat

Three cardiac scanning modes

a. Retrospectively gated spiral (Figure 3a)

Retrospectively gated spiral scanning is the most commonly used technique in cardiac CT. The x-ray beam is continuously on and the patient is translated through the gantry at a very slow speed (pitch ~ 0.2-0.3, depending on heart rate). The images are reconstructed by retrospectively using projection data from the desired phase of the cardiac cycle.

b. Prospectively triggered sequential (Figure 3b)

Prospective ECG-triggered sequential (or step-and-shoot) scanning is a more dose-efficient technique for cardiac CT, particularly for studies where only a single cardiac phase is of interest. The x-ray beam is turned on only at pre-selected phases during the cardiac cycle and therefore the dose can be significantly reduced relative to the retrospectively ECG-gated scan mode.

c. Prospectively triggered Flash (Figure 3c)

In this mode, a very fast spiral scan is triggered by the ECG signal. With the detector coverage of 38.4 mm and pitch of 3.4, a 12-cm heart can be scanned within 270 ms, which can be fit into one cardiac cycle when the heart rate is low.

Limitations of the gated Flash mode:

- The heart rate must be regular. To scan using a high pitch, the table requires about 1 sec to be accelerated. The scanner must accurately predict the timing of future R-waves in order to synchronize the x-ray-on time with the diastolic phase.
- The heart rate must be low since the scan will require about 270 ms to cover the heart. If the heart rate is high, the x-ray-on time may exceed the diastolic phase and lead to motion artifacts.
- Reconstruction of multiple cardiac phases is not possible.
- The scan range cannot be too long. For triple rule out and other protocols that need to cover longer scan ranges, it is important to scan the heart during the diastole phase.
- Lateral width of the patient across top of the liver should be less than 45 cm.

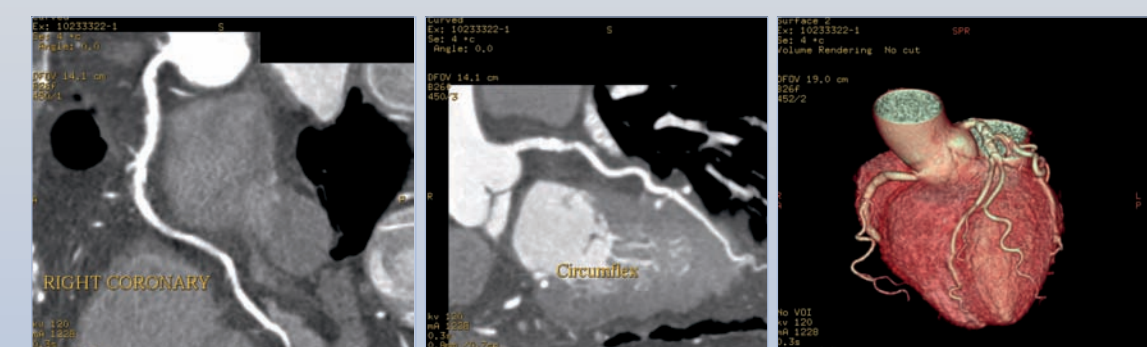
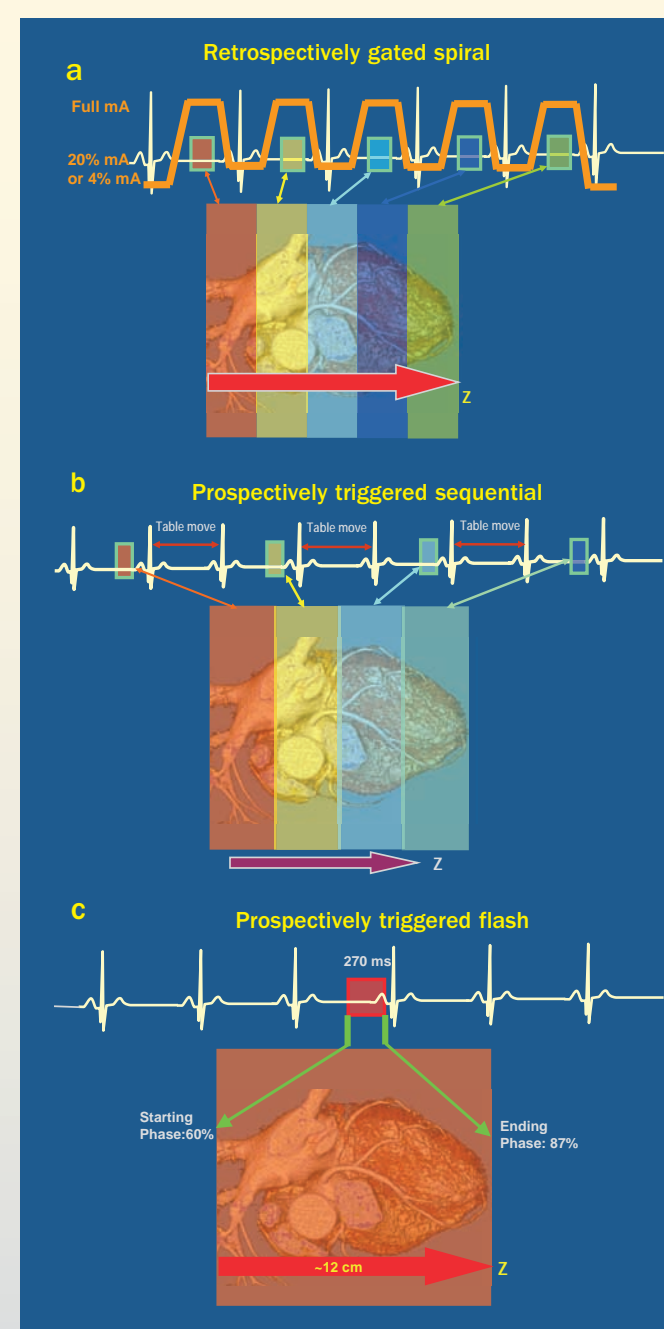


Figure 4
Coronary CTA scanned with prospectively-triggered flash mode. Scanning technique: 120 kV, 350 mAs/rot, CTDIvol 5.7 mGy, DLP 101.6 mGycm, phase 65%.

Dose comparison among the three cardiac modes

Radiation doses were measured for the three cardiac modes (Figure 5)

Flash scanning mode reduced dose by:
 89% vs. Cardiac Spiral (no modulation)
 60% vs. Cardiac Spiral (4%)
 25% vs. Cardiac Sequential

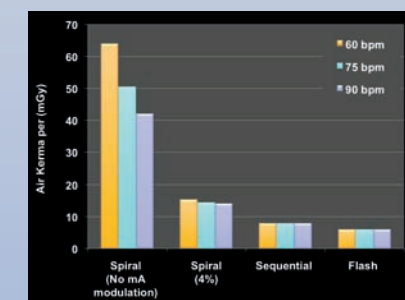


Figure 5
Radiation dose comparison among three cardiac scanning modes: retrospectively-gated spiral mode (without ECG controlled mA pulsing and with 4% pulsing), prospectively-triggered sequential mode, and prospectively-triggered flash mode, for three different heart rates.

Flash Scan Mode

Image quality

Image quality of the Flash scan mode was evaluated and compared to a regular single-source acquisition at a pitch of 1.0. No significant differences in quantitative measures of image quality were found for spatial and low-contrast resolution, CT number accuracy and linearity, slice sensitivity profiles, image uniformity, and noise (Figure 6). The pitch value (ranging from 1.6 - 3.2) had only minor impact on radiation dose and image noise when the effective tube current time product (mAs/pitch) was kept constant. However, while not severe, artifacts were found to be more prevalent for the dual-source pitch = 3.2 scan when structures varied markedly along the z axis, particularly for head scans.

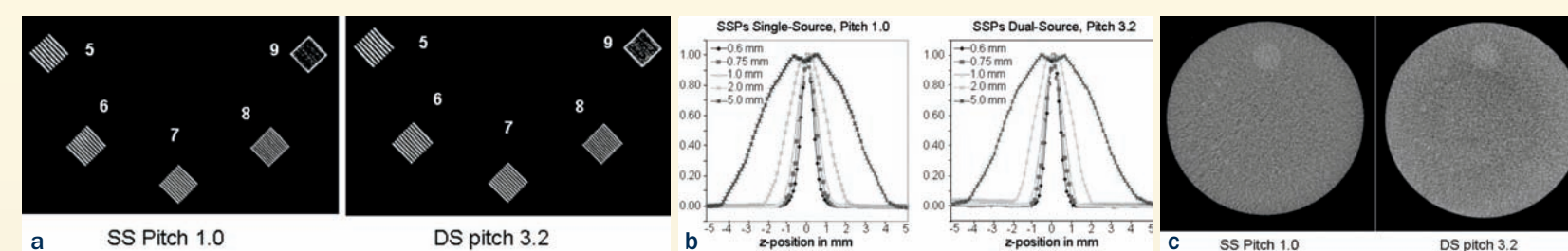


Figure 6
Image quality of Flash scan (dual source, pitch 3.2) and regular single source (pitch 1.0). (a) High-contrast spatial resolution; (b) Slice sensitivity profile; (c) Low-contrast resolution

Pediatric imaging

Due to the high scanning speed (up to 41 cm per second), the Flash scan mode is ideal for pediatric patients. The benefit of the Flash scan mode in pediatric CT is demonstrated in Figure 7. A baby doll was used to mimic an infant. It was rocked from side to side using a motion device (Figure 7a). The first scan was a single-source helical scan with a pitch of 0.9 (Figure 7b). The second scan was a dual-source Flash scan with a pitch of 3.2 (Figure 7c). The single-source 0.9 pitch data showed very strong motion artifacts. The surface of a volume rendered image showed the spiral scanning pattern and severe misalignment, up to 3cm, between contiguous locations. Motion artifacts prevented accurate visualization of the three embedded items. Conversely, the 3.2 pitch data showed minimal motion artifact. The doll surface and all embedded structures were clearly delineated. Two coronal images from a flash scan on a 3-year-old pediatric patient are shown in Figure 8.

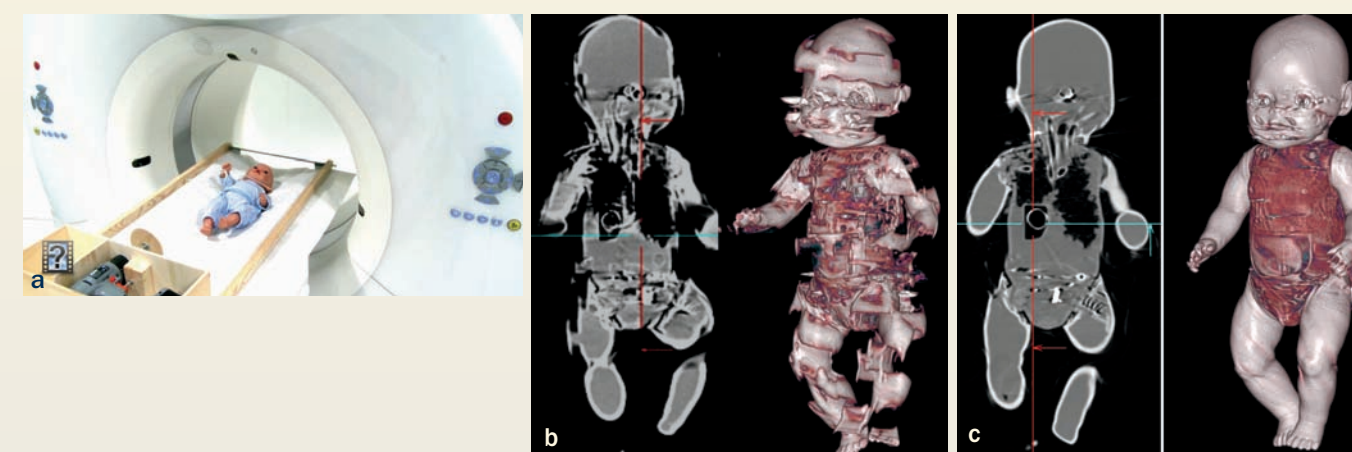


Figure 7
Demonstration of the ability of Flash scanning to image moving patients. (a) A doll was used to mimic an infant. It was rocked from side to side using a motion device. (b) A regular single-source helical scan with a pitch of 0.9 and (c) a dual-source Flash scan with a pitch of 3.2 were acquired. Coronal and 3D images demonstrate the difference in motion artifact.

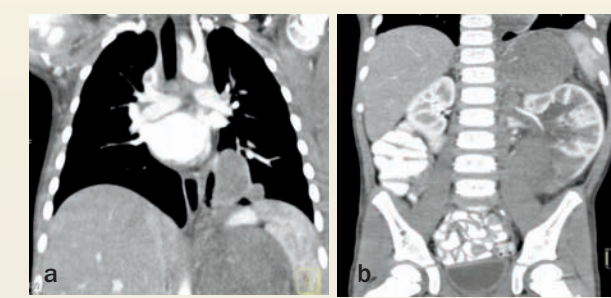


Figure 8
A chest/abdomen/pelvis exam for a 3-year-old patient acquired with the Flash mode. Scanning techniques: 100 kV, quality reference mAs 90, CTDIvol 4 mGy, total scan time 0.9 sec. (a) coronal image of the chest; (b) coronal image of the abdomen.

Pulmonary Embolism (PE) imaging

Main benefit:

Coverage of the lung in about 1 second, no breath hold is necessary.

Each image has the same temporal resolution as a cardiac image (75 ms).

Iodinated contrast volume can be reduced.

Main Limitations:

Limited FOV – less than 33 cm, but still can cover the lung region for the majority of patients.

Limited dose capacity – maximum CTDIvol is 7.85 mGy at 120 kV and 3.2 pitch.

Because of these two limits, this mode is only recommended for patients with a lateral width across the top of the liver no bigger than 43 cm.

Figure 9 compares two PE studies for the same patient, one scanned with a Flash technique and one with a regular spiral technique. There was no breath hold using the Flash technique. (scan time 1 second).



Figure 9
Two PE exams for the same patient scanned using (a) Flash technique (1 sec scan) and (b) regular spiral technique (12 sec scan).

CT Angiography

Main benefit:

Similar to PE, very useful for reducing motion artifacts

Main limitation:

Similar to PE, avoid scanning very large patients

Figure 10 shows a comparison of a Flash CTA and a regular spiral CTA and Figure 11 shows a Chest/Abdomen/Pelvis CTA using the Flash mode.

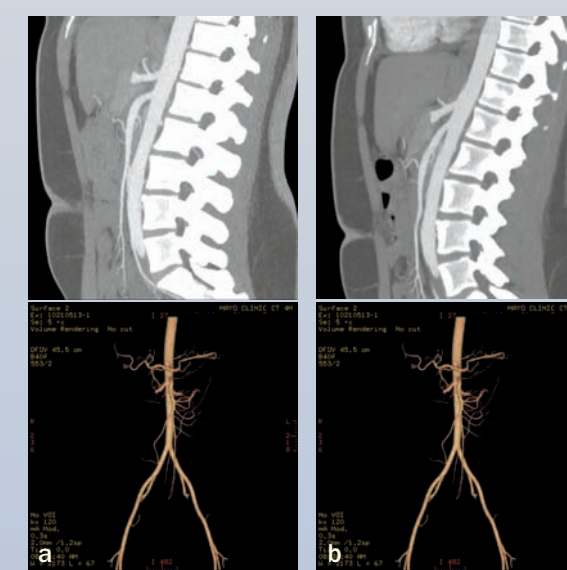


Figure 10
Two abdominal CTA exams for the same patient. (a) Flash technique and (b) regular spiral technique.

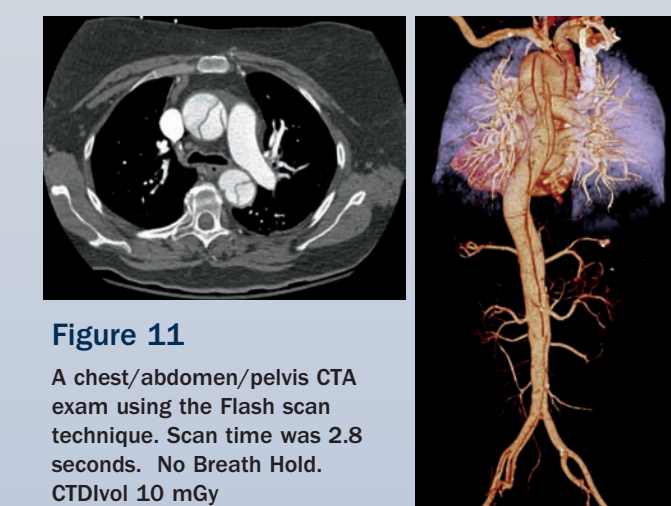


Figure 11
A chest/abdomen/pelvis CTA exam using the Flash scan technique. Scan time was 2.8 seconds. No Breath Hold. CTDIvol 10 mGy

Does the Flash scan mode reduce radiation dose?

The Flash scan mode reduces dose only for cardiac applications, as demonstrated in Figure 5.

For other exams, the dose efficiency in the Flash scan mode is the same as for a single-source spiral scan, i.e., the same CTDIvol would yield approximately the same noise. Flash scanning can generate more helical artifacts than regular spiral scanning in the presence of highly attenuating structures. The Flash mode is not recommended for routine body scans for solid organ evaluation unless it is essential to reduce motion artifacts.

Dual-energy Scan Mode

What is dual-energy CT?

Dual-energy CT uses data acquired at two tube potentials and special dual-energy processing techniques to provide material-specific information. Several applications, such as bone removal, iodine quantification, kidney stone characterization, and gout diagnosis, have been implemented clinically.

What is new on the Flash scanner?

Detector B has a larger scanning field of view (33 cm) than first generation of dual-source CT (26cm), which allows bigger patients to be imaged in dual-energy mode.

A retractable tin filter is used on tube B to improve the spectral separation between the two tubes (figure 12). This improves the image quality of dual-energy material specific images. In the first generation dual-source CT system, identical filtration for both tubes results in considerable spectral overlap.

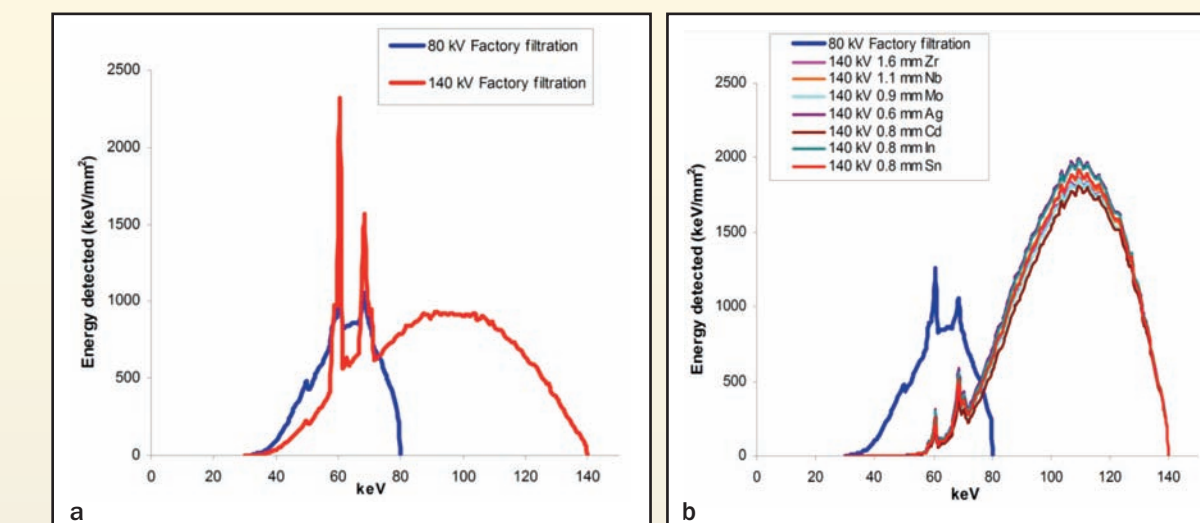


Figure 12
Added filtration improves spectral separation and dual-energy contrast. (a) spectra without added filter (b) spectra with added filter

Clinical examples

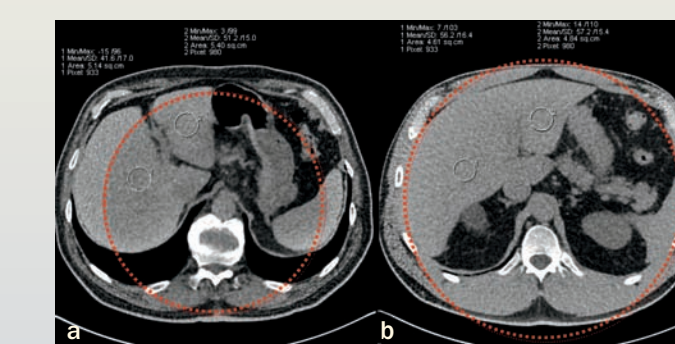


Figure 13
Improved virtual non-contrast (VNC) image quality on Flash scanner. (a) VNC image from 1st generation dual-source scanner (140/80 kV). The patient had a 34 cm lateral width. (b) VNC image from Flash scanner with an added tin filter (100/Sn140 kV). The patient had a 36 cm lateral width.



Figure 14
Automatic bone removal from a dual-energy COW/Carotid CTA scan.



Figure 15
Dual-energy scan to differentiate uric acid and calcium crystal deposition. The patient had demonstrated very impressive images of a large plantar tophus. The patient was initially seen at another facility for his plantar soft tissue mass and told that he would need a forefoot amputation for "some type of tumor".

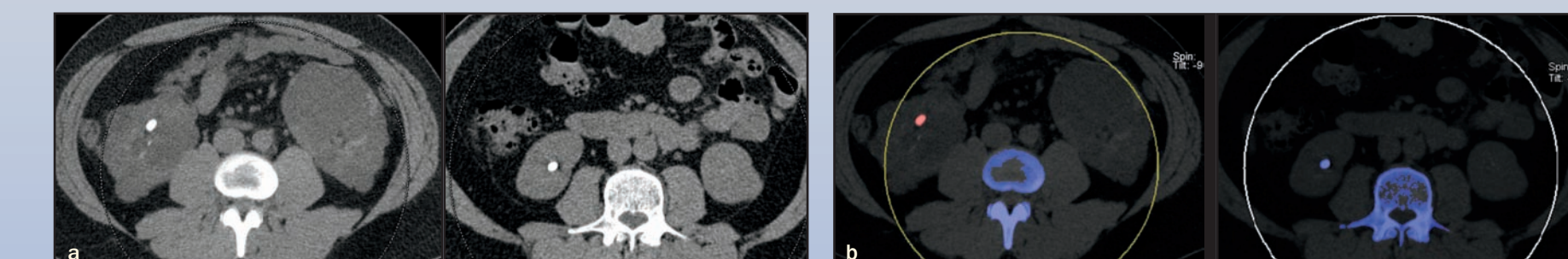


Figure 16 (a) All stones are white in single energy CT giving little information regarding stone composition. (b) In dual energy CT, the stone composition has been characterized as red (uric acid stone) or blue (non uric acid stone).

Adaptive 4D Spiral for Perfusion Scan

CT perfusion is increasingly used for evaluation of blood flow, blood volume, and vascular permeability in brain, liver, heart, and kidney. It involves repeated scans over the same anatomy for an extended time (e.g., ~40 seconds for brain perfusion) to track the flow of contrast through the organ.

Due to the limited detector collimation, traditional sequential mode can only cover very limited anatomy range along z-direction. Adaptive 4D spiral mode is a new scanning mode where the patient couch continuously moves in and out of x-ray beam field while gantry rotates, thus allowing a coverage of up 14 cm perfusion volume along z-direction.

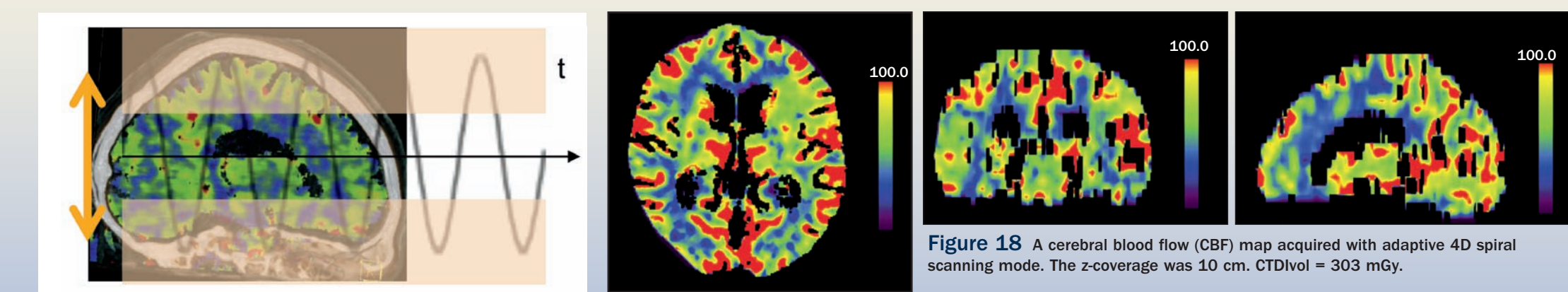


Figure 17
Adaptive 4D spiral scanning mode

Figure 18
A cerebral blood flow (CBF) map acquired with adaptive 4D spiral scanning mode. The z-coverage was 10 cm. CTDIvol = 303 mGy.

References

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