Easy Guide to Low Dose

Answers for life.

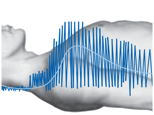
SIEMENS

II.A.
Dose Reduction Advances in Computed Tomography

In this chapter we discuss different technologies and algorithms that Siemens has implemented or developed to reduce the absorbed dose to a minimum.

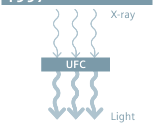
Siemens strives to implement all dose reduction methods available in the CT market today. As a leader in the dose reduction field, we also consistently develop our own solutions. Therefore, we were the first to implement many dose-saving features into clinical routine and for many critical features, we are still the only vendor offering these leading edge solutions.

1994



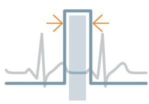
CARE Dose4D

1997



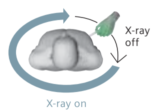
UFC

1999



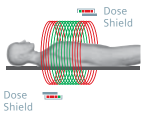
Adaptive ECG-Pulsing

1999



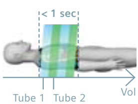
HandCARE

Adaptive Dose Shield



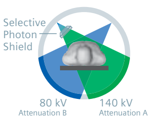
2007

Flash Spiral



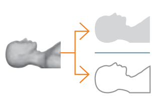
2008

Selective Photon Shield



2008

4D Noise Reduction



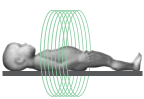
2008

To maintain our leading position and to improve health care for patients, we cooperate closely with experts from around the globe in universities, public clinics and private radiology centers to bring research developments into practical, everyday clinical routine.

In addition to the newest technology, dose reduction in CT requires training i.e. familiarity with dose reduction methods and factors. We therefore attempt to make our dose savings products as transparent as possible to reading physicians and technologists and also offer an on-going choice of seminars and resources relative to dose reduction.

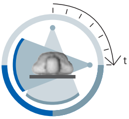
Below, you will find brief exposés of our dose-reduction products and algorithms (More detailed information can be found at www.siemens.com/low-dose):

2002



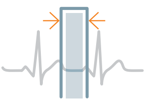
Pediatric 80 kV Protocols

2005



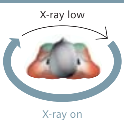
DSCT

2007



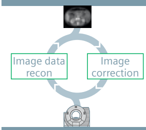
Adaptive Cardio Sequence

X-CARE



2008

IRIS



2009

1. **"CARE Dose4D" – Real-time Anatomic Exposure Control**
2. **"Adaptive ECG-Pulsing" – ECG-Controlled Dose Modulation for Cardiac Spiral CT**
3. **"Adaptive Cardio Sequence" – ECG-triggered Sequential CT**
4. **"Adaptive Dose Shield" – Asymmetric Collimator Control**
5. **"Flash Spiral" – ECG-Triggered Dual Source Spiral CT Using High Pitch Values**
6. **"X-CARE" – Organ Based Dose Modulation**
7. **"IRIS" – Iterative Reconstruction in Image Space**
8. **"CARE Dose kV" – Automated Dose-optimized Selection of the X-ray Tube Voltage (in development)**

1. "CARE Dose4D" – Real-time Anatomic Exposure Control

The most efficient way to reduce radiation dose in CT is an adaptation of the scan parameters to the anatomy of the patient. Centering the patient correctly, using the right protocols and adjusting the X-ray tube output to the patient's size and shape help to minimize radiation exposure. Many users, however, may not fully know how parameters should be modified to adjust radiation dose levels for different patients. As an example, they may not be aware that the tube output can be reduced by a factor of two while still maintaining adequate image quality if the patient's diameter decreases by only 4 cm. Hence, in all modern Siemens CT scanners, control mechanisms are available that automatically adjust the radiation dose level to the patient's anatomy – similar to a highly sophisticated camera's automatic exposure mode.

Siemens CARE Dose4D automatically adapts radiation dose to the size and shape of the patient, achieving optimal tube current modulation in two ways. First, tube current is varied on the basis of a topogram, by comparing the actual patient to a "standard-sized" patient. As might be expected, tube current is increased for larger patients and reduced for smaller patients. Differences in attenuation in distinct body regions are taken into account. For example, in an adult patient, 140 mAs might be needed in the shoulder region, whereas 55 mAs would be sufficient in the thorax, 110 mAs in the abdomen, and 130 mAs in the pelvis.

In addition, real-time angular dose modulation measures the actual attenuation in the patient during the scan and adjusts tube current accordingly – not only for different body regions, but also for different angles during rotation. This is particularly important in efficiently reducing dose in the shoulder and pelvic region, where the lateral attenuation is much higher than the anterior-posterior attenuation. Fig. 15 demonstrates the working principle of CARE Dose4D. Fig. 16 is a clinical example obtained with the use of CARE Dose4D.

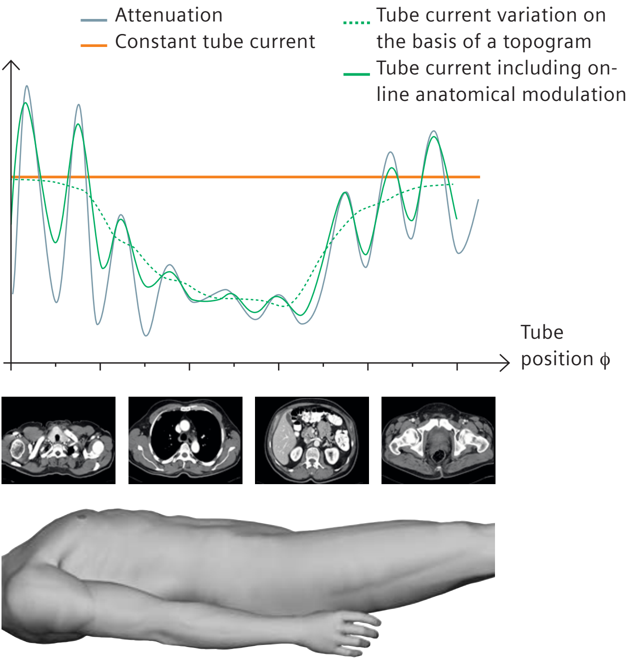


Fig. 15
Illustration of the working principle of CARE Dose4D. With constant tube current, regions in the shoulder and the pelvis would be under-dosed, while thorax and abdomen would be significantly over-dosed. On-line anatomical dose modulation efficiently adapts the tube current and hence the radiation dose to the patient’s attenuation.

140 mAs

55 mAs

110 mAs

130 mAs

Fig. 16
CARE Dose4D for a scan from the shoulders to the pelvis produces optimized radiation dose for all anatomic regions.

Clinical experience has shown that the relationship between optimal tube current and patient attenuation is not linear. Larger patients clearly need a higher dose than average-sized patients, but they also have more body fat, which increases tissue contrast. Smaller patients need a lower dose than average-sized patients, but they have less fat and less tissue contrast, which would result in noisy images if the dose were too low. Therefore, during real-time dose modulation, CARE Dose4D reduces radiation dose less than might be expected for smaller patients, while increasing the dose less than might be expected for larger patients. This maintains good diagnostic image quality while achieving an optimal radiation dose (Fig. 17).

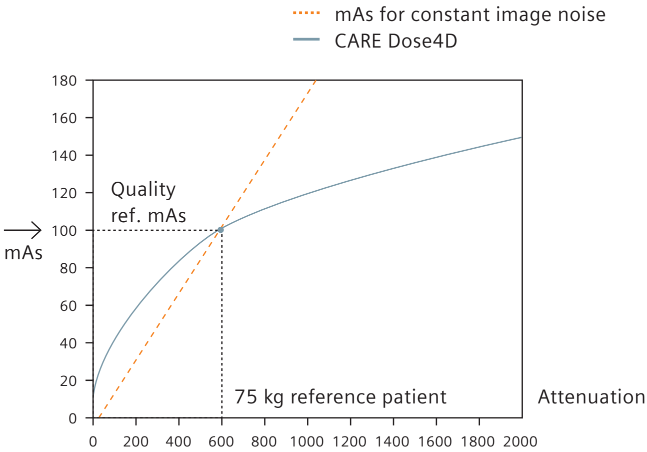


Fig. 17
Dose adaptation with CARE Dose 4D.

2. "Adaptive ECG-Pulsing" – ECG-Controlled Dose Modulation for Cardiac Spiral CT

With this method, the radiation dose is modulated during the complete spiral CT scan by using information from the patient's ECG. The tube current is maintained at 100 % of the desired level only during a predefined "phase of interest" of the patient's cardiac cycle. During the rest of the time the current can be reduced to as low as 4 %, thus reducing the mean radiation dose by up to 30–50 %[15] (Fig. 18).

ECG-controlled dose modulation is based on the continuous monitoring of the ECG and an algorithm that predicts when the desired ECG phase will start by calculating the mean durations of the preceding cardiac cycles. Older ECG-pulsing approaches reach their limitations with arrhythmia patient scans that cannot be predicted by simple averaging. Recently, more versatile ECG-pulsing algorithms have been introduced which react flexibly to arrhythmia and ectopic beats and have the potential to considerably enhance the clinical application spectrum of ECG-controlled dose modulation.

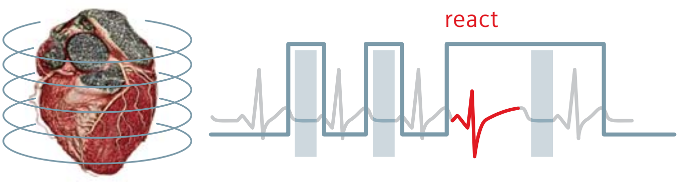


Fig. 18
The CT generates images only during a pre-defined phase of the heartbeat. During this phase, the tube current (blue line) is 100 % of the necessary level to achieve adequate image quality, but between these pre-defined phases, the current is reduced to 20 % or even 4 %. Recently introduced algorithms can react flexibly to arrhythmia.

[15] Jakobs T F et al. Multislice helical CT of the heart with retrospective ECG gating: reduction of radiation exposure by ECG-controlled tube current modulation, Eur. Radiol. 2002, 12: 1081-1086.

3. "Adaptive Cardio Sequence" – ECG-Triggered Sequential CT

Prospective ECG-triggering combined with "step-and-shoot" acquisition of axial slices is a very dose-efficient way of ECG-synchronized scanning because only the very minimum of scan data needed for image reconstruction is acquired during the previously selected heart phase. The patient's ECG-signal is monitored during examination, and axial scans are started with a pre-defined temporal offset relative to the R-waves. With conventional approaches, the method reaches its limitations with patients with severe arrhythmia, since ECG-triggered axial scanning depends on a reliable prediction of the patient's next cardiac cycle by using the mean length of the preceding cardiac cycles. With the adaptive cardio sequence, a more refined analysis of the patient's ECG is performed. Irregularities are reliably detected, and in case of an ectopic beat, the scan can be repeated at the same position. Hence, the application spectrum of ECG-triggered sequential scanning is extended to patients with high and irregular heart rates.

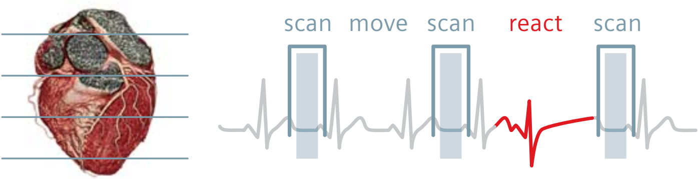


Fig. 19
Each slice of the heart is scanned during the same ECG phase.

Fig. 20
Using Adaptive ECG-Pulsing, an ECG-gated spiral scan of the heart (A) can be performed at 4–9 mSv dose[16]. With the Adaptive Cardio Sequence, an ECG-triggered sequential scan of the heart (B) requires only 1–3 mSv dose[17].

[16] Stolzmann P, Scheffel H, Schertler T, Frauenfelder T, Leschka S, Husmann L, Flohr TG, Marincek B, Kaufmann PA, Alkadhi H. Radiation dose estimates in dual-source computed tomography coronary angiography. Eur Radiol. 2008; 18(3):592-9.
Leschka S, Stolzmann P, Schmid FT, Scheffel H, Stinn B, Marincek B, Alkadhi H, Wildermuth S. Low kilovoltage cardiac dual-source CT: attenuation, noise, and radiation dose. Eur Radiol. 2008; 18(9): 1809-17.

[17] Stolzmann P, Leschka S, Scheffel H, Krauss T, Desbiolles L, Plass A, Genoni M, Flohr TG, Wildermuth S, Marincek B, Alkadhi H. Dual-source CT in step-and-shoot mode: noninvasive coronary angiography with low radiation dose. Radiology. 2008; 249(1):71-80.

4. "Adaptive Dose Shield" – Asymmetric Collimator Control

In spiral CT, it is routine to do an extra half-rotation of the gantry before and after each scan, fully irradiating the detector throughout, even though only part of the acquired data is necessary for image reconstruction. As a result, the wide cone beam exposes tissue that will never be part of reconstructed images (Fig. 21).

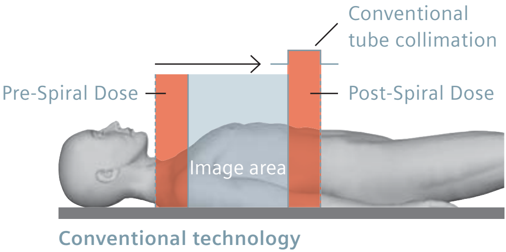


Fig. 21
Conventional pre-patient collimator. The areas marked in red are out of the necessary scan range but still irradiated with full power. This problem is typical for spiral CT and commonly referred to as "over-ranging".

The Adaptive Dose Shield, a technology based on precise, fast, and independent movement of both collimator blades, limits this over-ranging. The pre-patient collimator asymmetrically opens and closes at the beginning and end of each spiral scan, temporarily blocking those parts of the X-ray beam that are not used for image reconstruction. As a result, only the targeted tissue is irradiated (Fig. 22).

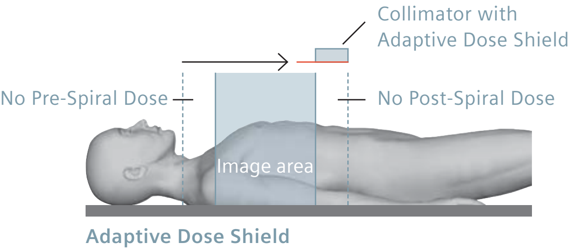


Fig. 22
Adaptive Dose Shield. When the CT scan starts, the collimator opens asymmetrically. In the center of the scan range, the collimator is fully open according to the selected beam width. At the end of the scan range the collimator closes asymmetrically.

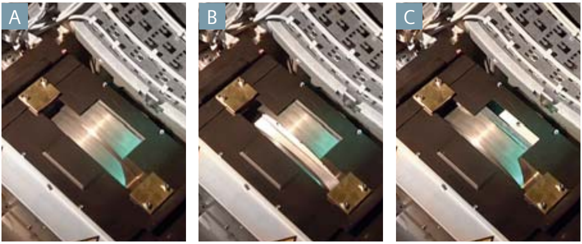


Fig. 23
The two collimators of the Adaptive Dose Shield.
A: Closed
B: Open left
C: Open right

Measurements at the Institute of Medical Physics, University Erlangen-Nürnberg, Germany, and at the Clinical Innovation Center, Mayo Clinic, Rochester, Minnesota, USA, have demonstrated significant dose reductions, depending on the scanned range, without affecting image quality (Fig. 24).

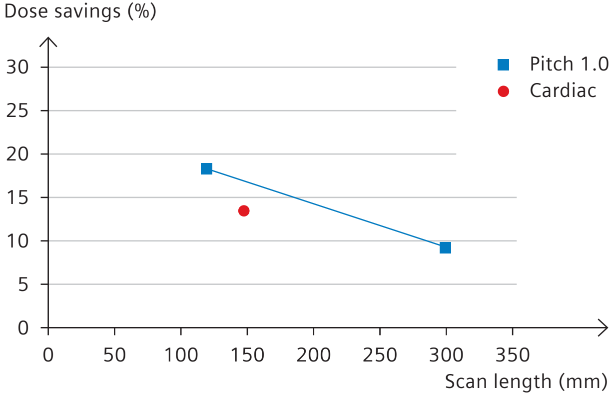


Fig. 24
Dose savings with Adaptive Dose Shield for different CT scan lengths.

5. "Flash Spiral" – ECG-Triggered Dual Source Spiral CT Using High Pitch Values

Dual Source CT (DSCT) offers a way to scan the heart within one heartbeat without using an area detector that covers the entire heart volume. With a single source CT, the spiral pitch is limited to values below 1.5 to ensure gapless volume coverage along the z-axis. If the pitch is increased, sampling gaps occur (see Fig. 25) that hamper the reconstruction of images with well-defined narrow slice sensitivity profiles and without excessive image artifacts.

With DSCT systems, however, data acquired with the second measurement system a quarter rotation later can be used to fill these gaps (see Fig. 25). In this way, the pitch can be increased up to 3.4 in a SFOV that is covered by both detectors. Since no redundant data are acquired due to the high pitch, a quarter rotation of data per measurement system is used for image reconstruction, and each of the individual axial images has a temporal resolution of a quarter of the rotation time.

The SOMATOM Definition Flash offers 38.4 mm detector z-coverage and 0.28 s gantry rotation time. At a pitch of 3.4, the table feed is 450 mm/s, which is sufficient to cover the heart (12 cm) in about 0.27 s. The scan is triggered and starts at a user-selectable phase of the patient's cardiac cycle. Each of the images has a temporal resolution of 75 ms, the phase of images adjacent in the z-direction is slightly shifted (Fig. 26). Since no overlapping data are acquired, the radiation dose of this new mode is very low and even below the dose values of ECG-triggered sequential scanning. First publications have demonstrated that reliable coronary CTA is feasible at radiation dose values below 1 mSv.[19/20]

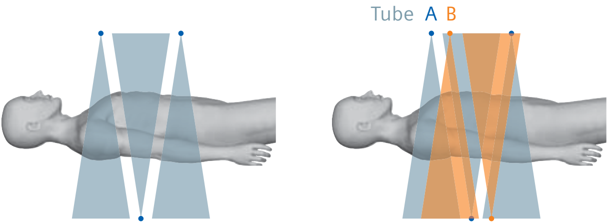


Fig. 25
Sampling scheme along the z-axis for a single source CT operating above the pitch limit of 1.5 (left), and for a dual source CT (right). Here, the sampling gaps are filled with data acquired by the second measurement system, such that considerably increased pitch values are feasible.

Continuous table feed, pitch 3.4

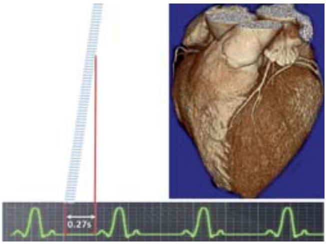


Fig. 26
Principle of ECG-triggered DSCT spiral scan data acquisition and image reconstruction at very high pitch. The patient table reaches a pre-selected z-position (e.g. the apex of the heart) at a pre-selected cardiac phase after acceleration to maximum table speed. At this pre-selected z-position data acquisition is started. Due to the fast table movement, the entire heart can be scanned in a fraction of a heartbeat. The total scan time is typically 0.25–0.27 s. The scan data for images at adjacent z-positions (indicated by short horizontal lines) are acquired at slightly different phases of the cardiac cycle. Each of the images is reconstructed using data of a quarter rotation per X-ray tube, resulting in a temporal resolution of 75 ms per image.

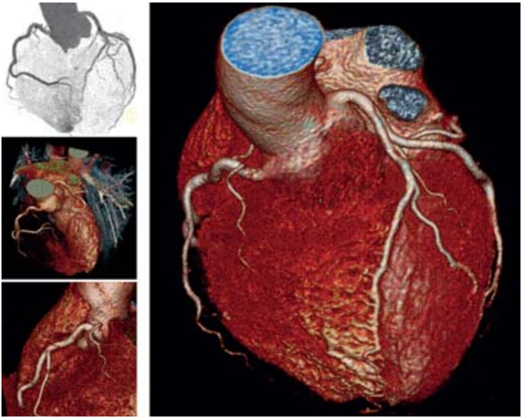


Fig. 27
CT angiography of the coronary arteries acquired with the high pitch DSCT spiral mode ("Flash Spiral").[18]

Fig. 27 shows images reconstructed in this modus with an acquisition time of 250 ms, a temporal resolution of 75 ms, 100 kV and 0.8 mSv.

First scientific papers[19, 20] on the SOMATOM Definition Flash, confirm effective radiation doses of 0.88–0.9 mSv for routine coronary CTA. Please feel free to visit the worldwide, low-dose counter at **www.siemens.com/low-dose** that displays real-time average dose values of Flash Spiral Cardio scanning though out our installed base.

[18] Courtesy of Prof. S. Achenbach, Erlangen, Germany.
[19] Achenbach S, Marwan M, Ropers D, Schepis T, Pflederer T, Anders K, Kuettner A, Daniel WG, Uder M, Lell MM. Coronary computed tomography angiography with a consistent dose below 1 mSv using prospectively electrocardiogram-triggered high-pitch spiral acquisition. Eur Heart J. 2010;31(3):340-6.
[20] Leschka S, Stolzmann P, Desbiolles L, Baumueller S, Goetti R, Schertler T, Scheffel H, Plass A, Falk V, Feuchtner G, Marincek B, Alkadhi H. Diagnostic accuracy of high-pitch dual-source CT for the assessment of coronary stenoses: first experience. Eur Radiol. 2009;19(12):2896-903.

6. "X-CARE" – Organ Based Dose Modulation

According to recently modified tissue weighting factors (recommendations of the International Commission on Radiological Protection of 2007, ICRP103), the female breast is more radiosensitive than previously assumed. In any CT examination of the thorax, the breast, without being the object of interest, is irradiated and should therefore be especially protected. Siemens X-CARE, the organ-based dose modulation, can selectively limit the radiation exposure of sensitive organs. When using this mode, radiation intensity is reduced when the patient is irradiated from the front as shown in Fig. 28.

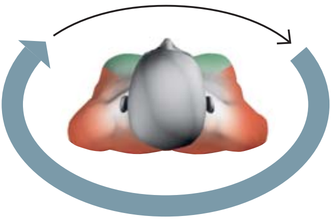


Fig. 28
Illustration of the X-CARE principle.

With this method, the radiation exposure of the breast or the eyes is reduced by 30–40 %, while image noise and detail visualization remain unaffected, as shown in Fig. 29:

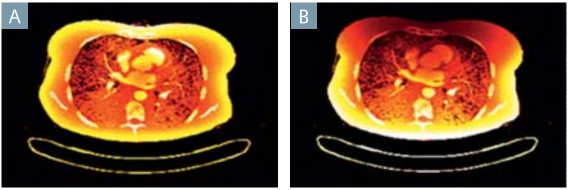


Fig. 29
A: Radiation doses without X-CARE and **B:** with X-CARE. Darker areas indicate lower absorbed dose.

7. "IRIS" – Iterative Reconstruction in Image Space

IRIS is a unique, Siemens-only method that reduces image noise without loss of image quality or detail visualization. The significant image noise reduction provided by IRIS allows for up to 60 % radiation dose reduction in routine clinical use.

Today, CT scanners use standard filtered back-projection methods in which improved spatial resolution can only be achieved at the cost of increased image noise. In contrast to filtered back-projection, iterative reconstruction enables a decoupling of spatial resolution and image noise. It enhances spatial resolution in areas with higher contrast and reduces image noise in low contrast areas, enabling the user to perform CT scans with lower radiation dose.

In an iterative reconstruction, a correction loop is introduced into the image reconstruction process. Once an image has been reconstructed from the measured projections, a ray-tracing in the image is performed to calculate new projections that exactly represent the reconstructed image. This step, called re-projection, simulates the CT measurement process, but with the image as the "measured object." If the original image reconstruction were perfect, measured and calculated projections would be identical. In reality they are not, and the deviation is used to reconstruct a corrected image and to update the original image.

Then the loop starts again. The images are improved step by step, and a significant noise reduction can be obtained by carefully modeling the data acquisition system of the CT scanner and its physical properties in the re-projection algorithm. This method is called "theoretical iterative reconstruction". The drawback of this approach is that the exact modeling of the scanner during re-projection requires high computer processing power, therefore significant hardware capacity is needed to avoid long image reconstruction times that is not available in the near future (Fig. 30).

Simplified approaches with less computer complexity and faster reconstruction are possible, but with significantly less accurate re-projection and calculation of the correction image. This may result in strange, unfamiliar noise textures and a plastic-like look of the images.

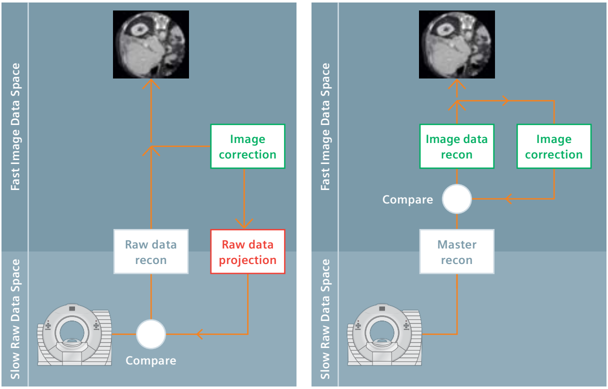


Fig. 30
Comparison of different approaches to iterative reconstruction.

Siemens has developed IRIS (Iterative Reconstruction in Image Space), a unique method that translates the iterative reconstruction loop into the image domain, hence avoiding the time consuming traditional re-projection. IRIS offers both a significant image noise reduction and a fast reconstruction for routine clinical use. In addition, the noise texture of the images is similar to standard well-established convolution kernels. Starting point of the IRIS method is a master volume reconstruction that optimally utilizes all measured data and provides all available detail information but at the expense of significantly increased image noise.

This master volume is then "cleaned up" step by step in an iterative loop using 3 to 5 iterations, enhancing object contrasts and reducing image noise with each iteration. IRIS is more advanced than simplified iterative reconstruction attempts, due to the special master reconstruction that is used to start IRIS and the special iterative structure of the image enhancement steps (Fig. 30 and Fig. 31).

Filtered Back Projection

40 % less noise with IRIS

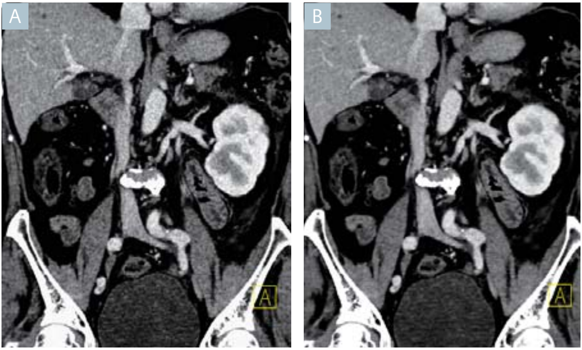


Fig. 31
Contrast-enhanced CT scan of the abdomen.
A: Standard Filtered Back Projection Reconstruction, kernel B31.
B: Iterative Reconstruction. Note the significantly decreased image noise without loss of resolution.

8. "CARE Dose kV" – Automated Dose-optimized Selection of the X-Ray Tube Voltage (in development)

Conventional dose modulation approaches control only the X-ray tube current, while the X-ray tube voltage (the kV-setting) is left untouched. Yet, there is a big potential for dose reduction by adapting the kV setting and thus the radiation energy to the diagnostic task, such that an optimized contrast to noise ratio is achieved.

The quality of CT images is characterized by three parameters: contrast, noise, and sharpness (spatial resolution).

Improving all or any of these parameters will render a better image and enable the reading physician to make a more precise diagnosis. For example, if the contrast is high and the noise is low, the image quality improves.

Additionally, an iodine contrast agent is often administered to improve contrast and thus the visibility of organ structures in CT images (particularly in CT angiographies). The contrast is best with lowered X-ray tube voltage, since the low energy X-rays are better absorbed by the dense iodine than by the surrounding tissue. However, in order to maintain low noise levels, the tube current usually requires an adjustment. Nevertheless, for a constant contrast-to-noise ratio in CT angiographic studies, the radiation dose can be significantly reduced by choosing 80 kV or 100 kV tube voltages instead of 120 kV (Fig. 32).

For larger patients, though, who have a higher X-ray attenuation, the output of the X-ray tube at lower kV settings may not be sufficient to produce the required contrast to noise ratios.
For these patients, higher X-ray tube voltages will have to be selected, despite reduced iodine contrasts.

In a busy environment, the technicians and reading physicians often have insufficient time to measure the attenuation of each patient. Automatic tools that define the optimal combination of voltage and current for each patient according to the patient's topogram and the selected examination protocol are necessary and will be implemented in the near future.

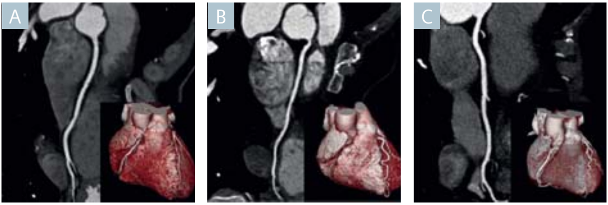


Fig. 32
Three CT angiographies with 3 different current and voltage settings. Note that the mean contrast in the aorta is higher with 100 kV.

A: 120 kV 330 mAs, CTDIvol=43.1 mGy,
Mean contrast aorta: 322 HU

B: 100 kV 330 mAs, CTDIvol=31.8 mGy,
Mean contrast aorta: 561 HU

C: 100 kV 230 mAs, CTDIvol=21.2 mGy,
Mean contrast aorta: 559 HU

II.B.
Pediatric Computed Tomography

Radiographic examinations are used much less frequently for children than for adults, because their organism is still developing and because children seldom understand the cooperation (such as breath-holds, etc.) required of them. Furthermore, the smaller the cross section of the patient, the larger the actually absorbed radiation dose. Nevertheless, computed tomography is of great importance for the treatment of pediatric patients, especially for complex lung imaging, for the treatment of congenital malformations, and in intensive care. As a consequence, the ALARA principle (As Low As Reasonably Achievable) is of particular importance in pediatrics. It calls for always selecting the dose that is as low as possible, yet sufficient for a reliable diagnosis.

The Siemens Dual Source CT SOMATOM Definition Flash system offers effective doses below 0.5 mSv in pediatric applications, with full diagnostic image quality. Due to the fast scan speed using very high pitch values ("Flash Spiral"), even uncooperative children can be examined without sedation, saving time and money and reducing stress for the patient.

A Final Word

We want to thank you very much for reading and familiarizing yourself with Siemens low-dose efforts and progress. Should you have any questions or need support or information of any kind, rest assured that the entire Siemens organization stands ready to serve you.

For further information: www.siemens.com/low-dose

The Siemens Healthcare Sector is one of the world's largest suppliers to the healthcare industry and a trendsetter in medical imaging, laboratory diagnostics, medical information technology and hearing aids. Siemens is presently the only company to offer products and solutions for the entire range of patient care from a single source – from prevention and early detection to diagnosis and on to treatment and aftercare. By optimizing clinical workflows for the most common diseases, Siemens also makes healthcare faster, better and more cost-effective. Siemens Healthcare employs some 49,000 employees worldwide and operates in over 130 countries. In fiscal year 2008 (to September 30), the Sector posted revenue of 11.2 billion Euros and profit of 1.2 billion Euros.

III. Glossary

A

Absorbed dose	The absorbed dose is the amount of energy deposited in matter after being exposed to a certain amount of radiation
Acute radiation syndrome (ARS)	The acute radiation syndrome (ARS) is the death of large number of cells in the organs impairing their function after exposure to radiation
Adaptive Cardio Sequence	Modus in which the CT scanner registers in real time the ECG, analyses if the heart beats are normal and triggers the scan during a predefined phase of the ECG
Adaptive Dose Shield	Pre-patient collimator in which both collimator blades move asynchronously, thus reducing the radiation dose at the beginning and end of the scan range
Adaptive ECG-Pulsing	CT scan modus in which the current intensity is modulated such that the radiation is maximal during the prescribed phase of the ECG and the radiation is reduced to a minimum during the rest of the ECG
Alpha particles	Alpha (α) particles are fast moving Helium-4 (^{4}He) nuclei
Angiography	Radiographic visualization of the blood vessels after injection of a radio opaque substance (contrast agent). In CT, iodine is frequently used as a contrast agent.
Anode	The electron-collecting electrode of the X-ray tube
Apoptosis	A genetically determined process of cell self-destruction that is marked by the fragmentation of nuclear DNA, it can be activated by radiation

Attenuation	Reduction of the amount force or value of a parameter, in this context, reduction of the intensity of the radiation beam

B

Bone marrow	Soft highly vascular modified connective tissue that occupies the cavities of most bones and occurs in two forms: a: a yellowish bone marrow consisting chiefly of fat cells and predominating in the cavities of the long bones – called also yellow marrow b: a reddish bone marrow containing little fat, being the chief seat of red blood cell and blood granulocyte formation, and occurring in the normal adult only in cancellous tissue especially in certain flat bones – called also red marrow

C

CARE Dose4D	System that not only modulates the radiation intensity according to the size of the patient but also to the anatomic region which is being irradiated as the CT scan progresses
Cathode	The electron-emitting electrode of the X-ray tube
Collimator	Device (shield) for obtaining a beam of radiation (as X-rays) of limited cross section
Computed Tomography Dose Index – $CTDI_w$	Computed Tomography Dose Index (CTDI) is the sum of the absorbed dose in the slice and outside the slice (due to scattering outside the slice)
CT slice	Each transversal image generated by a CT scan
$CTDI_{vol}$	$CTDI_w$ divided by the pitch

D

Detector	Device for detecting the presence of electromagnetic waves or of radioactivity
Deterministic damage	Damage of organic tissue that will occur for sure due to the exposition to a high amount of ionizing radiation
Dose Length Product (DLP)	Dose Length Product or DLP is the product of $CTDI_{vol}$ and the length of the examination range

E

Ectopic beat	A heartbeat that is spurious and is not synchronized as normal heart beats
Effective dose E	The effective dose reflects the sensitivity of each organ and is a weighted average of the equivalent dose received by the organs
Electromagnetic radiation	Radiation that has the properties of particles and waves (photons)
Electrons	An elementary particle consisting of a charge of negative electricity and spinning around the atom nuclei
Equivalent dose	The equivalent dose for any type of radiation is defined as the absorbed dose multiplied by a factor (w_f) that weights the radiation-specific damage caused to biological tissue. In the case of X-rays used in CTs the weighting factor is 1, therefore the equivalent dose is the same as the absorbed dose
Examination range	Part of the body to be scanned along the longitudinal axis (z-axis)

F

Flash Spiral	This is a new ECG-triggered technique that is based on a dual source spiral scan at very high pitch. Enables scanning the heart in only one heart beat

Fluorescence	Luminescence that is caused by the absorption of radiation at one wavelength followed by nearly immediate re-radiation usually at a different wavelength and that ceases almost at once when the incident radiation stops
Free radicals	Atoms, molecules, or ions with unpaired electrons. These unpaired electrons are usually highly reactive, so radicals are likely to take part in chemical reactions that eventually change or harm the DNA of the cells

G

Gamma rays	(γ-rays) Radiation consisting of photons with a wave length of less than 1 pm

I

Ionization	The process by which atoms are converted into ions (electrically charged atoms)
Ionizing radiation	Radiation that can ionize matter
Irradiation	Radiation emitted with a specific, in this case, medical purpose

K

Kinetic energy	Energy stored in a moving object

M

Modulation	Adjustment of a parameter to keep it in the desired range

N

Neutrons	Uncharged elementary particle that has a mass nearly equal to that of the proton and is present in all known atomic nuclei except the hydrogen nucleus
Noise	In this context the grainy structure of a CT image.

P

Photon	A quantum of electromagnetic radiation Longitudinal distance in mm that the table
Pitch	Table feed during one revolution of the X-ray tube divided by the nominal scan width in mm
Plexiglas phantoms	Dummies of plexiglass used to measure the radiation doses on different parts of the body
Positron	Positively charged particle with the same mass as the electron

R

Radiation	The process of emitting radiant energy in form of waves or particles
Radioactive substances	Substances that emit radiation of different types
Radioactivity	The property possessed by some elements (as uranium) or isotopes (as carbon 14) of spontaneously emitting energetic particles (as electrons or alpha particles) by the disintegration of their atomic nuclei
Radionecrosis	Destruction of the organic tissue by radiation
Radon	Heavy radioactive gaseous element formed by the decay of radium
Resolution	A measure of the sharpness of an image or of the fineness with which a device (as a video display, printer, or scanner) can produce or record such an image

S

Sharpness	Clearness in outline or detail of an image, ability to resolve small details
Spiral CT	CT scan during which the table and the X-ray tube move continuously
Stochastic damage	Damage that might happen; involves a chance or probability

T

to trigger	To initiate, actuate, or set off by a certain event or signal
Topogram	Contour of the human body
Tube current	Current applied to the cathode of the X-ray tube
Tube voltage	Voltage between the anode and the cathode of the tube

X

X-CARE	Organ based dose modulation. In this modus the radiation intensity is reduce when the patient is irradiated from the front
X-rays	Electromagnetic radiations that has an extremely short wavelength of less than 100 angstroms and has the property of penetrating various thicknesses of all solids

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