CARE Dose4D
New Techniques for Radiatioon Dose Reduction

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CARE Dose4D
New Technique for Radiation Dose Reduction

Discussion of fundamental basis, clinical applications and advantages of automatic exposure control techniques, with particular emphasis on the CARE Dose4D™ technique

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The need to reduce radiation dose and optimize image quality have spurred vendors to develop novel techniques[1]. In this respect, automatic exposure control techniques represent the most important and efficient method for reducing radiation dose while maintaining desired image quality[2]. The present article discusses fundamental basis, clinical applications and advantages of automatic exposure control techniques, with particular emphasis on Siemens' *syngo* CARE Dose4D technique.

What are the Limitations of Manually Selected Fixed Tube Current?

Manual selection of a fixed tube current remains the most commonly used way of performing CT scanning[1]. With this technique, the technologist prescribes a tube current value for CT scanning and the entire scanning is done at the specified fixed tube current. The scanner does not change the tube current based on patient size and/or attenuation. Although radiation dose reduction can be achieved with such fixed tube current technique, there are some limitations of this technique that can be addressed with use of automatic exposure control technique. For example, surveys suggest that many centers do not change the tube current based on patient size[1]. As a consequence, patients might be overdosed or image quality might not meet the clinical needs. Rapid development in CT technology and newer clinical applications makes it difficult to adapt scanning protocols with fixed tube current for different size patients and clinical indications.

Moreover, unlike automatic exposure control techniques, the fixed tube current technique cannot modulate tube current in response to rapidly changing patient size or attenuation within a slice position or from one slice position to the next.

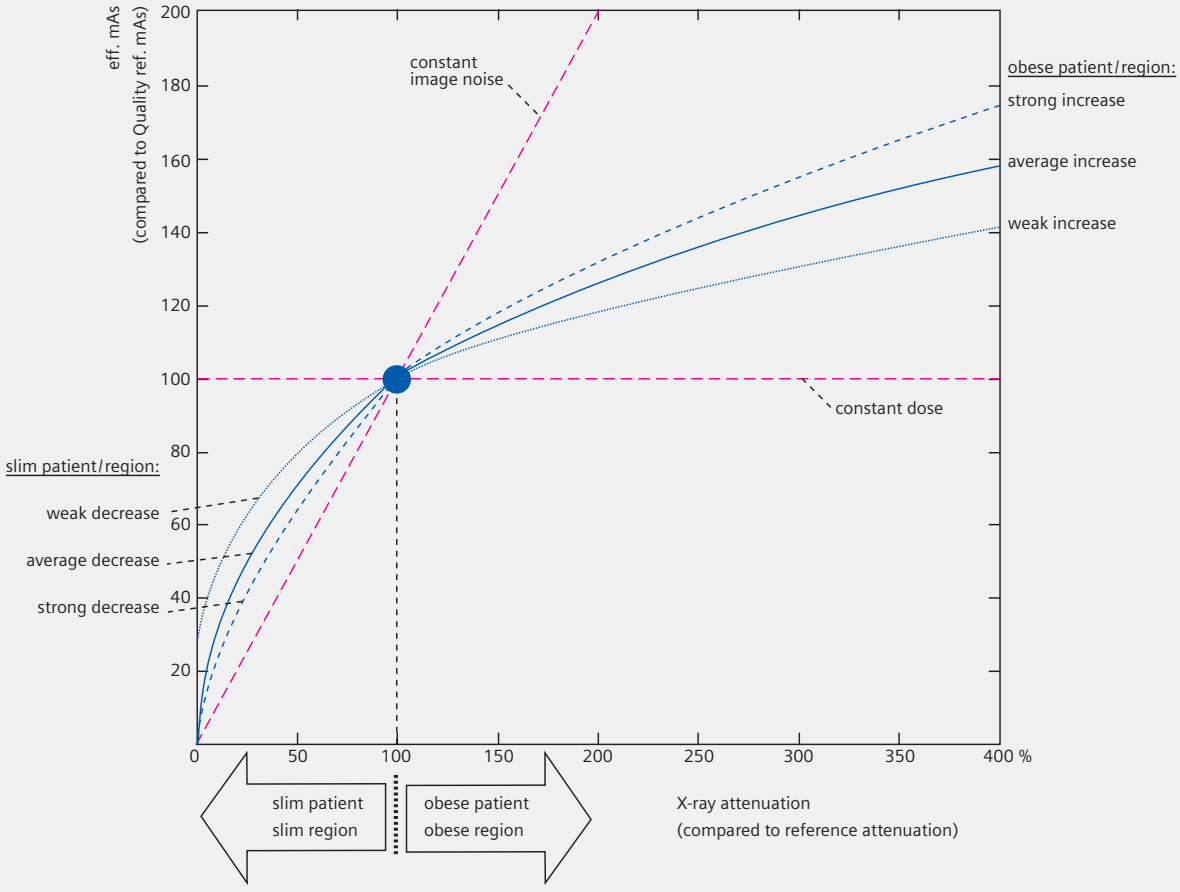
What is Automatic Exposure Control?

Automatic exposure control techniques used in CT are analogous to photo timing in digital radiography. The latter technique terminates the exposure once a pre-specified radiographic density is obtained, which implies that exposure is terminated earlier (lower radiation dose) for smaller patients and longer exposure time (higher dose) is allowed for larger patients[2]. In this way, photo timing technique allows optimization of radiation exposure while maintaining desired or specified image quality. Likewise, automatic exposure techniques used in CT scanning adapt tube current in the x-y plane (angular) or along the scanning direction in z-axis or both (combined modulation) based on size and attenu-ation of the body region (attenuation profile) being scanned to obtain specified image quality or noise with lowest possible radiation dose. The image noise, an important determinant of image quality, is determined by x-ray beam attenuation as it traverses through the patient.

Angular Modulation

During CT scanning, the x-ray tube continuously emits x-rays from 360 degrees (projection angles) around the patient over the entire scan length. Since image noise is dominated by those projections, which have the highest attenuation, tube current – and with it also dose – can be reduced for those projections which have a low attenuation without increasing overall image noise. Therefore, in asymmetric or non-circular body parts, such as the shoulders, there is less x-ray beam attenuation in the anteroposterior direction compared to the lateral direction. Thus, within each slice position, less photons or lower tube current would be necessary in anteroposterior direction than in the lateral direction. Tube current modulation minimizes unnecessary x-rays in

Effect of Modulation Strengths on Radiation Dose for Slim and Obese Patients



[1] *The sophisticated algorithm provides desired image quality for all patients, slim to obese. Individual preferences on tube current increase and decrease can be realized by choosing strong, moderate or weak.*

the anteroposterior projection without any substantial effect on image quality.

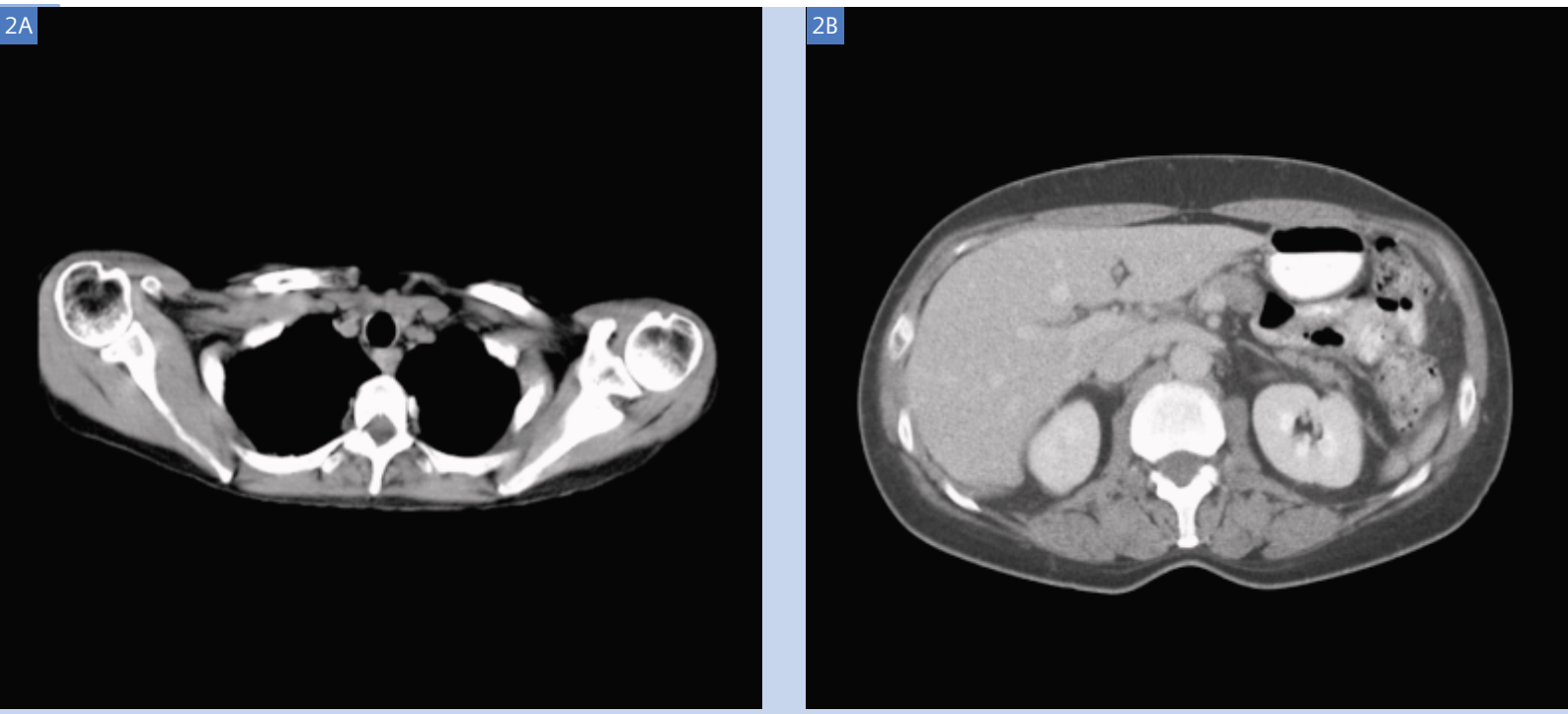
The technical implementation of angular modulation differs from vendor to vendor. Some only offer sinusoidal modulation, others are limited in the modulation range (min. to max ratio). Siemens' CARE Dose4D modulates the tube at all rotation times without compromising the modulation range, comparable to an organ specific dose reduction.[3]

z-Axis Adaptation

With z-axis adaptation, the tube current changes from one slice position to the other without optimization in the x-y axis. The technique automatically selects higher tube current for larger patients and anatomical regions with higher attenuation and lower tube current for smaller patients and anatomical regions with low attenuation in order to maintain desired image quality at optimum radiation dose[2]. Lastly, combined modulation technique (CARE Dose4D), discussed in the following section, combines benefits of angular and z-axis modulation techniques.

How does CARE Dose4D technique work?

From a single topogram, the CARE Dose4D technique measures attenuation profile in the z-axis in the direction of projection and also in the perpendicular direction with a sophisticated algorithm[4]. Tube current values are calculated and adapted to the patient size and attenuation changes based on these attenuation profiles. Tube current adjustment



[2] *CT image acquired with CARE Dose4D techniques reveal excellent image quality with substantial dose reduction. [Fig. 2A] Chest-CT with 20% mean dose reduction and [Fig. 2B] abdomen-liver with 38% mean dose reduction*[5].

depends on a user defined so-called "image quality reference mAs" (z-axis modulation). Based on these tube current levels, real-time tube current modulation during each tube rotation according to patient's angular attenuation profile (angular modulation) is then performed.

The challenging part of automatic exposure techniques is how to adapt the tube current to the different sizes of patients and how to compensate for changes along the patient's length. The first and simplest approach would be a modulation which keeps the noise constant from patient to patient and over the whole scan. However, this approach has two limitations: Firstly, this is not possible from a technical perspective since the range of attenuation changes from patient to patient and also during a single scan (for example shoulder to neck) is much larger than any tube can provide. Secondly, studies have shown that, from a clinical perspektive, needs are different. In smaller patients, lower noise levels are desired, whereas in obese patients more noise is often acceptable due to higher contrast . This indicates different requirements for automatic exposure techniques.

With CARE Dose4D, tube current is modulated so that both limitations are overcome. The user selects a "quality reference mAs" according to the diagnostic requirements and the individual preference of the user. For a given protocol, this value reflects the effective mAs used in a certain body region for a "reference patient" defined as a "typical adult," weighing 70 kg to 80 kg (for adult protocols) or as a "typical child" having the age of 6 years (for pediatric protocols).

The technique adapts the tube current to the individual patient size based on the quality reference mAs value. It determines whether the patient is "slim" or "obese" from the topogram and adapts the tube current based on the preselected adaptation strengths (weak, average or strong). As illustrated in Fig. 1 the system uses an advanced algorithm to adapt tube current so that the user gets the desired image quality. This means that for example for slim patients tube current is reduced less than constant image noise would require. For obese patients to get the desired image quality tube current is increased less than constant image noise would require.

The adaptation strengths are prospectively set for these patient types and determine the extent of change in effective mAs. Thus, image quality and radiation dose can be controlled by selecting an appropriate modulation strength and/or quality reference mAs value.

Where Can CARE Dose4D Technique be Applied?

CARE Dose4D technique can be used for CT scanning of neck, chest, abdomen, and pelvis [Fig. 2]. The technique is commercially available on Siemens MSCT scanners with 1 to 64 detector configurations. It is also available on the Dual Source CT, the SOMATOM Definition. CARE Dose4D can be used in scans for all patients, including pediatric and obese patients. It also can be used for patients with metal prostheses without causing unnecessary increase in the radiation dose[7]. This is due to the fact that a special detection algorithm is implemented into CARE Dose4D[8] [Fig. 3].

What is the Evidence Supporting CARE Dose4D?

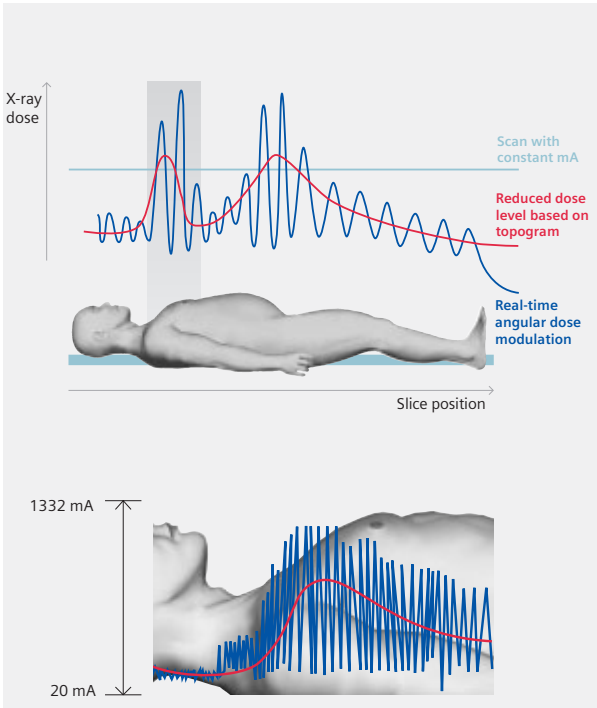
Several large studies have evaluated CARE Dose4D technique its effect on image quality and radiation dose in clinical routine[4-6].

For instance Dr. Rizzo and colleagues[4] have reported that, "compared with constant tube current technique, there was a 19% (15.4/19.0) reduction in radiation dose for angular modulation, a 42% (11.0/19.0) reduction with 'weak decrease (slim) – strong increase (obese)' type of combined modulation and a 44% (10.6/19.0) reduction with 'average decrease (slim) – average increase (obese)' type of combined modulation."

Mulkens et al[5] have also found that, "mean dose reduction for combined angular and z-axis modulation technique and for the angular modulation technique alone was as follows: thorax, 20% and 14%, respectively; abdomen-liver, 38% and 18%, respectively; abdomen-pelvis, 32% and 26%, respectively; lumbar spine, 37% and 10%, respectively; and cervical spine, 68% and 16%, respectively."

For CT colonography, Graser et al[6] have reported 33% (prone) to 35% (supine) dose reduction with CARE Dose4D compared to CARE Dose technique.

CT-Scan With CARE Dose4D



[3] *Instead of just taking into account the patient's external dimensions and apparent size, CARE Dose4D analyzes the cross-secional anatomy in real-time and adjust the emitted X-ray dose accordingly – providing excellent image quality with minimized exposure.*

References

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