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ORIGINAL ARTICLE

Radiation Dose Survey: Comparison between New-generation Computed Tomography and 64-slice Multidetector Computed Tomography

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ABSTRACT

Objective: *To evaluate the radiation dose benefit of new-generation computed tomography compared with 64-slice multidetector computed tomography.*

Methods: *In this retrospective study, the radiation doses for patients undergoing new-generation computed tomography during a 9-month period were compared with those of patients undergoing multidetector computed tomography during a 12-month period. The scans included brain, thorax, abdomen biphasic, abdomen triphasic, and urogram examinations. Patient dose was estimated as the product of the measured dose-length product and the corresponding conversion coefficient for each type of scan. The average estimated patient dose was compared between the 2 scanners using Mann-Whitney* U *test.*

Results: *A significantly lower radiation dose was observed for all new-generation computed tomography examinations than for multidetector computed tomography ($p < 0.05$). The average dose was 1.9 ± 0.4 mSv for brain, 6.9 ± 2.3 mSv for thorax, 13.4 ± 9.1 mSv for abdomen biphasic, 20.9 ± 12.7 mSv for abdomen triphasic, and 9.3 ± 6.6 mSv for urogram scans. Compared with multidetector computed tomography, the radiation dose was lower for new-generation computed tomography by 44% for brain, 72% for thorax, 66% for abdomen biphasic, 61% for abdomen triphasic, and 49% for urogram examinations.*

Conclusion: *With the development of new-generation computed tomography, it is possible to deliver a significantly lower radiation dose to patients than with 64-slice multidetector computed tomography.*

Key Words: *Radiation dosage; Tomography, X-ray computed*

中文摘要

新一代電腦斷層造影與64排多切面電腦斷層造影的輻射劑量調查比較

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目標：評估新一代電腦斷層造影在放射劑量方面比64排多切面電腦斷層造影的優越之處。

方法：將九個月間接受新一代電腦斷層造影的病人的放射劑量與在12個月間接受64排多切面電腦斷層造影的病人的放射劑量比較。有關掃瞄包括腦掃瞄、胸腔掃瞄、雙相腹部掃瞄、三相腹部掃瞄及泌尿系掃瞄。病人在每種掃瞄中接受的劑量以劑量長度積及相關轉換系數計算。再用*Mann-Whitney* U統計比較兩組病人接受的放射劑量差別的顯著性。

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結果：新一代電腦斷層造影的放射劑量明顯比多切面電腦斷層造影為低(p < 0.05)。以平均劑量計，腦掃瞄為1.9 ± 0.4 mSv，胸腔掃瞄為6.9 ± 2.3 mSv，雙相腹部掃瞄為13.4 ± 9.1 mSv，三相腹部掃瞄為20.9 ± 12.7 mSv，而泌尿系掃瞄為9.3 ± 6.6 mSv。與多切面電腦斷層造影相比，新一代電腦斷層造影的放射劑量在腦掃瞄降低44%，胸腔掃瞄降低72%，雙相腹部掃瞄降低66%，三相腹部掃瞄降低61%，泌尿系掃瞄降低49%。

結論：隨著新一代電腦斷層造影的發展，可以為病人提供比64排多切面電腦斷層造影更低放射劑量的檢查服務。

INTRODUCTION

Computed tomography (CT) is a high–radiation dose imaging modality when compared with other diagnostic X-ray techniques. In the USA, approximately 60% of medical radiation exposure from imaging modalities is incurred during CT examinations.[1] With continued technological advancements and wider availability, the use of CT is likely to increase.[2,3]

There are many factors affecting the CT radiation dose.[4] The scanning parameters that affect CT radiation dose include tube current, tube voltage, helical pitch, slice thickness, scan time, scan mode, and scan length. The most commonly manipulated parameters are tube current and tube voltage. Radiation doses increase linearly with tube current and increase with the square of the tube voltage, if other parameters remain constant. Noise reduction filters are also commonly used to decrease noise so that low-radiation dose techniques can be used.[5]

The scanner design is also known to influence the radiation dose.[4] The design of the collimator, the distance from the X-ray tube to the isocenter, and the beam filtration/filtres all affect the radiation dose. Other design factors that may affect the radiation dose indirectly include the detector efficiency and geometric efficiency, since radiation dose may need to be changed to achieve a particular image quality.[6,7] However, there is limited information about the radiation dose performance with advanced multi-slice CT scanners, especially for body CT examinations.

In the past few years, several advanced CT scanners from different manufacturers have become available for clinical use. The manufacturers have different approaches for advancements in hardware and software designs to achieve different goals, such as better temporal resolution, larger volume coverage, and higher spatial resolution. However, the common goal is to reduce the radiation dose to patients. This study was performed to compare the radiation dose using the new-generation CT with that of the standard 64-slice multidetector CT (MDCT).

METHODS

In this retrospective study, the radiation doses for patients undergoing new-generation CT from December 2008 to August 2009 were compared with those of patients undergoing standard 64-slice MDCT from July 2007 to June 2008. Since the radiation dose may differ with different scanners, centres, operators, and protocols,[8] the comparison was made using the same manufacturer's machines operated by the same group of radiographers to the requirements of the same group of radiologists. The machines used were the Discovery™ CT750 HD (GE Healthcare Technologies, Chalfont St Giles, UK) for new-generation CT and the LightSpeed VCT XT™ (GE Healthcare Technologies) for 64-slice MDCT. The scanning protocols for the 2 scanners followed the manufacturer's recommendations, and are listed in Table 1. The scans included brain, thorax, abdomen biphasic, abdomen triphasic, and urogram examinations. The radiation dose for each scan was estimated by the measured dose-length product and the corresponding conversion coefficient for that type of scan.[9] The estimated dose for new-generation CT and MDCT was compared using the Mann-Whitney *U* test.

RESULTS

645 patients underwent new-generation CT and 1184 patients underwent MDCT (Table 2). The radiation doses for all 5 types of CT scan were significantly lower for new-generation CT than for MDCT ($p < 0.05$) [Table 2]. The average doses were 44% lower for brain scans, 72% lower for thorax scans, 66% lower for abdomen biphasic scans, 61% lower for abdomen triphasic scans, and 49% lower for urogram scans.

DISCUSSION

According to the UK National Radiological Protection Board, CT accounted for approximately 40% of the medical exposure to radiation in the early 1990s.[10] Since then, there has been a rapid increase in the use of CT and a substantial increase in the radiation dose received by patients.[11,12] A similar situation has been found in the

Table 1. Manufacturer's recommended scanning protocols for new-generation computed tomography and 64-slice multidetector computed tomography.

Site	kV	mA	Rotation time (seconds)	Slice thickness (mm)	Noise index
New-generation computed tomography*					
Brain	120	280	1.0	5.00	
Thorax non-contrast	100	Auto	0.4	1.25	26
Thorax contrast	100	Auto	0.4	1.25	26
Abdomen biphasic non-contrast	100	Auto	0.8	1.25	28
Abdomen biphasic arterial	100	Auto	0.8	1.25	26
Abdomen biphasic venous	100	Auto	0.8	1.25	26
Abdomen biphasic delay	100	Auto	0.8	1.25	28
Abdomen triphasic non-contrast	100	Auto	0.8	1.25	28
Abdomen triphasic early arterial	100	Auto	0.8	1.25	24
Abdomen triphasic late arterial	100	Auto	0.8	1.25	24
Abdomen triphasic venous	100	Auto	0.8	1.25	24
Abdomen triphasic delay	100	Auto	0.8	1.25	26
Urogram non-contrast	100	Auto	0.8	1.25	25
64-slice multidetector computed tomography†					
Brain	120	360	0.8	5.00	
Thorax non-contrast	120	240	0.5	5.00	
Thorax contrast	120	300	0.5	5.00	
Abdomen biphasic non-contrast	120	240	0.5	5.00	
Abdomen biphasic arterial	120	300	0.5	5.00	
Abdomen biphasic venous	120	300	0.5	5.00	
Abdomen biphasic delay	120	300	0.5	5.00	
Abdomen triphasic non-contrast	120	240	0.5	5.00	
Abdomen triphasic early arterial	120	540	0.5	2.50	
Abdomen triphasic late arterial	120	360	0.5	5.00	
Abdomen triphasic venous	120	360	0.5	5.00	
Abdomen triphasic delay	120	360	0.5	5.00	
Urogram non-contrast	120	180	0.5	5.00	

* The detector coverage was 20 mm for brain scans and 40 mm for other scans. All the scans were in helical mode with a pitch value of 1.375 except for the brain scans, which were performed in axial mode. An adaptive statistical iterative reconstruction algorithm setting of 30% was applied to all scans.

† The detector coverage was 20 mm for brain scans and 40 mm for other scans. All the scans were in helical mode with a pitch value of 0.984 except for the brain scans, which were performed in axial mode.

Table 2. Radiation dose for new-generation computed tomography and 64-slice multidetector computed tomography.

Site	Average radiation dose (mSv)	
	New-generation computed tomography	64-slice multidetector computed tomography
Brain	1.9 ± 0.4 (n = 125)	3.4 ± 0.8 (n = 344)
Thorax	6.9 ± 2.3 (n = 135)	24.7 ± 5.7 (n = 221)
Abdomen biphasic	13.4 ± 9.1 (n = 103)	38.9 ± 9.7 (n = 163)
Abdomen triphasic	20.9 ± 12.7 (n = 170)	53.9 ± 10.1 (n = 267)
Urogram	9.3 ± 6.6 (n = 112)	18.3 ± 4.3 (n = 189)

USA, in that CT has been estimated to account for approximately two-thirds of the overall radiation dose to patients from imaging modalities.[1]

The issue of radiation dose reduction has received much attention. Several measures have been proposed to reduce the radiation dose,[13,14] including optimisation of protection through improvements in CT technology and practice.[11,15,16] One of the most effective ways of achieving substantial dose reduction is by modification of the hardware design of the CT scanner. In cardiac CT angiography, a significant dose reduction can be achieved by using electrocardiogram dose modulation (30% to 50%) or prospectively gated techniques (up to 80%).[17-20] Automatic exposure control techniques have been shown to be effective for radiation dose reduction,[21-26] such that a 22% radiation dose reduction has been reported for angular modulation[23] and a 26% radiation dose reduction has been reported for z-axis modulation[26] in patients undergoing chest CT.

Recently, newly designed CT scanners have become available for clinical use. These machines have many fundamental refinements of CT imaging technology,

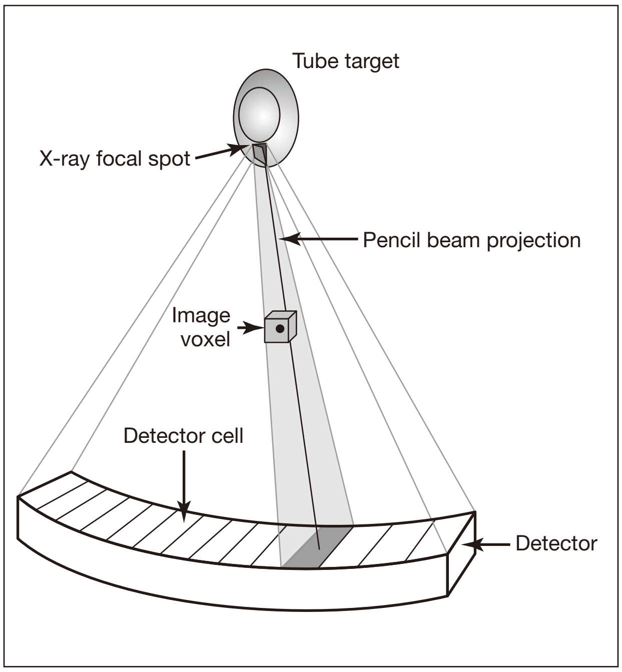

Figure 1. Schematic diagram of a computed tomography system and sampling geometry.

and some have led to radiation dose reduction. For example, new garnet-based gemstone detector couples with a new ultra-fast data acquisition system and new high-power dynamic focusing X-ray tube to offer high signal-to-noise ratio and 2.5-fold more angular-sampled data for image reconstruction. These improvements in spatial resolution and image noise provide reconstructed images of the same quality with a lower radiation dose.

Another technological breakthrough is the new reconstruction algorithm using the iterative approach. All the reconstruction algorithms currently used in conventional CT scanners are based on filtered backprojection (FBP). The FBP algorithms are fast and robust, but the drawbacks are that the CT system model that is developed by the FBP algorithms does not represent reality. As shown in Figure 1, the X-ray focal spot is assumed to be infinitely small and can be approximated by a point. All X-ray photon interactions are assumed to take place at a point located at the geometric centre of the detector cell, not across the entire area of the detector cell. The shape and size of the

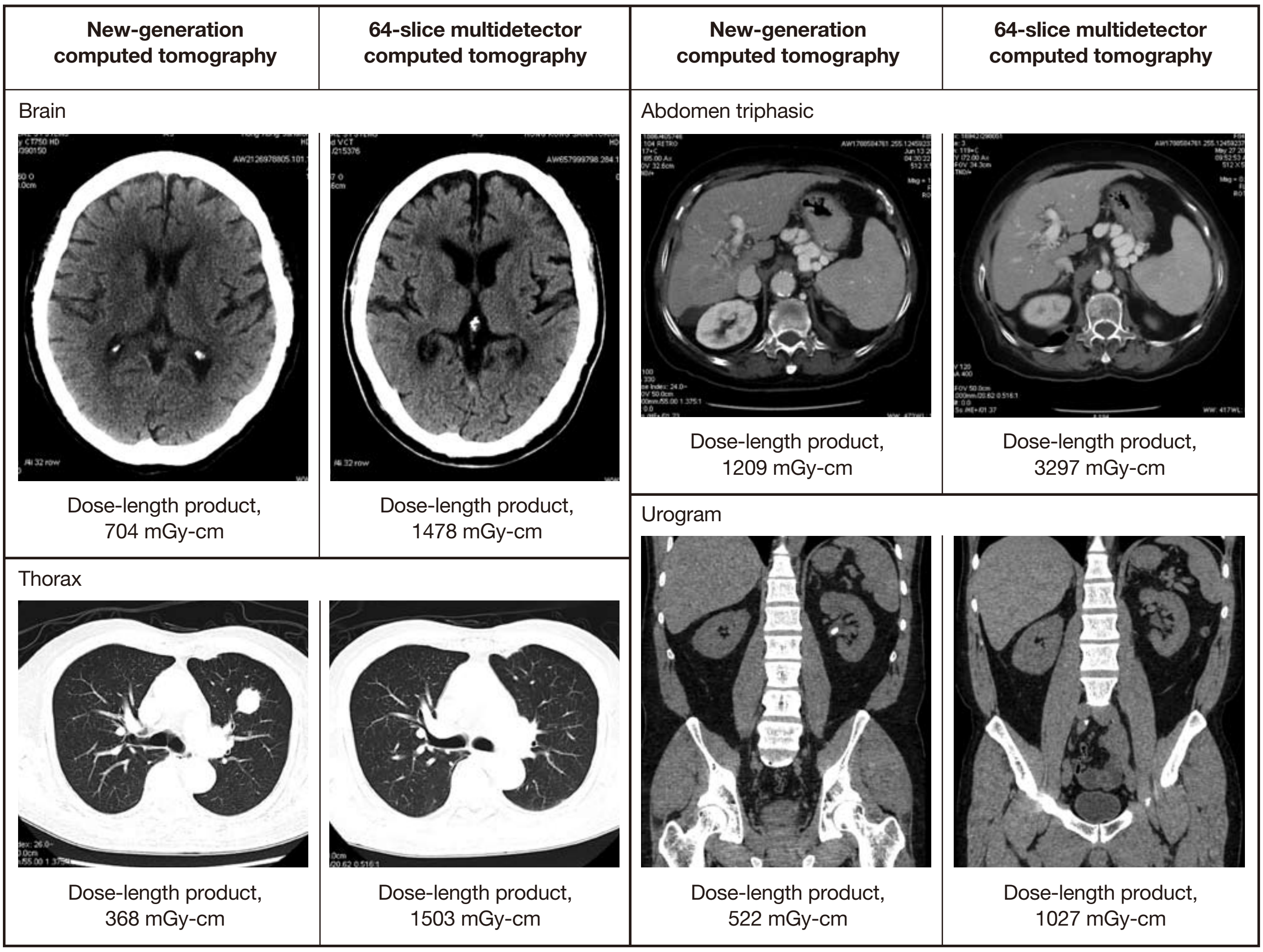

Figure 2. Example images of scans from new-generation computed tomography and 64-slice multidetector computed tomography.

reconstruction image pixels are also ignored by simply assuming them to be infinitely small points located on a square grid. Importantly, each of the measurements is treated as an accurate quantity and is not influenced by the statistical fluctuation. One way of overcoming these over-simplified assumptions is to apply the statistical iterative reconstruction technique.[27] The approach to the statistical iterative reconstruction technique is as follows. Attenuation along each projection view is estimated by forward projection using the actual focal spot size and detector area. During the modelling of X-ray interaction with the object, the actual size and shape of the image voxel is considered by calculating the different path lengths for X-rays entering the voxel at slightly different orientations and locations. In a similar fashion, the detector shape and size is considered through modelling of the detector response function. The result is then compared with the actual measurement, and the difference between the 2 shows the amount of adjustment needed. Photon statistics of each individual measurement are estimated and are used in the reconstruction update process. After the reconstructed image has been updated, it is fed through the entire process again to obtain a newly updated image. The process continues for several iterations so that the difference between the projection of the updated image and the actual measurement is minimised. This technique has the potential to provide significant dose benefit by lowering the noise in the reconstructed images, so that the scanning technique can be reduced with equivalent noise.

Another newly available dose-reduction feature in new generation CT scanners is organ-sensitive dose protection for breast dose reduction (http://health.siemens.com/ct%5Fapplications/healthier%5Fct/). This is accomplished by turning off the X-ray tube during those parts of the rotation that would result in the most direct exposure for these areas. Another new dose reduction technique is dynamic blockage of clinically irrelevant pre- and post-spiral dose using an adaptive dose shield.

In this study, the radiation doses for a new-generation CT and an ordinary 64-slice MDCT were compared for 5 types of scan. The manufacturer's recommendations for the imaging protocols of the 2 scanners were followed, and the image quality of the 2 scanners were assessed and ensured to comply with the standard by the same group of radiologists. As shown in Figure 2, the image quality was acceptable for both new-generation CT and MDCT. Thus, the radiation dose can be significantly reduced using new-generation CT with new hardware and software designs, when compared with standard 64-slice MDCT.

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