Dose Exposure Levels in 16-Row MSCT and 64-Row MSCT

R Irwan, H de Vries

Abstract

We evaluate the impact of scan length on the exposure levels at 16-row multislice computed tomography (MSCT) and 64-row MSCT. Dose length product (DLP) values were determined to compare exposure levels in 16- and 64-row MSCT. For scan slice thickness under 2 mm, the exposure levels of 64-row MSCT are lower than those of 16-row MSCT when scanning an object larger than 12.3 cm. At this value the plots of the 16- and 64-row DLP values versus scan length cross. The crossing of DLP curves obtained in MSCT at different numbers of detector rows has not been published before. Differences in object size may thus explain apparent discrepancies between previous studies reporting either higher or lower effective exposure levels at 64-row MSCT as compared with 16-row MSCT.

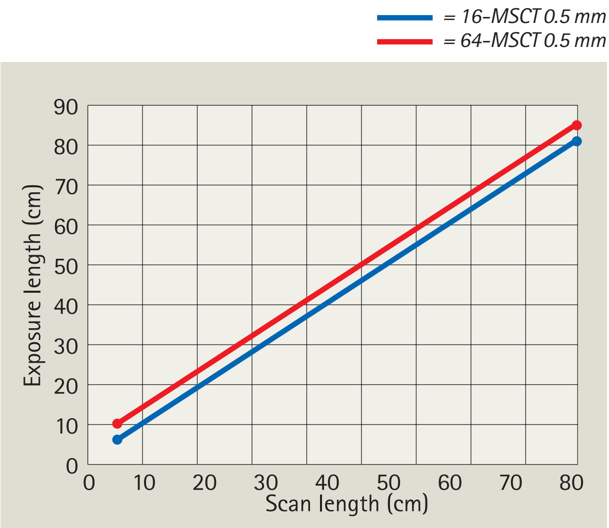


Fig 1: Exposure times versus scan lengths illustrating that the exposure times of 64-MSCT are higher than those of 16-MSCT

Introduction

Multislice computed tomography (MSCT) has become more and more important as a non-invasive imaging modality since its introduction in 1998[1]. Research of patient dosage, a major concern in MSCT examinations, has been ongoing for many years[2-4]. Particularly in young patients special attention to this matter is required. An accurate analysis of patient dose in MSCT as a function of beam widths is, nevertheless, still lacking.

CTDI (CT dose index) value is frequently used as reference for dose exposed under clinical conditions. CTDI can be measured inside a defined phantom ($CTDI_{weighted}$) in the air ($CTDI_{air}$) or in other ways. As CTDI measurements inside a phantom are linearly related to those in air, the analysis of exposure ratios can be done using $CTDI_{air}$. Furthermore, CTDI represents the output of tube/filter combination under specified conditions. Exposure to the patient, specified as DLP (dose length product), is used as measure of exposure in the scan procedure[3].

For a given slice thickness (0.5 mm in this study), the nominal beam width of 64-row MSCT is four times that of 16-row MSCT. A wider beam width comes with shorter scan times but increases overranging. When scanning continuously at the same position, we know that the exposure of 64-row MSCT is higher compared to that of 16-row MSCT (Fig. 1), creating a notion that the former produces more exposure than the latter.

Exposure length [cm]		Scan length* [cm]	DLP [mGy.cm]	
16-MSCT	64-MSCT		16-MSCT	64-MSCT
6.6	10.4	5	143.9	178.4
11.6	15.4	10	253.7	264.6
13.9	17.7	*12.3*	304.2	304.2
21.6	25.4	20	473.3	436.9
31.6	35.4	30	692.9	609.3
41.6	45.4	40	912.5	781.7
51.6	55.4	50	1132.1	954.0
61.6	65.4	60	1351.8	1126.4
71.6	75.4	70	1571.4	1298.7
81.6	85.4	80	1791.0	1471.1

Table 1: Comparison in DLP of 16- and 64-row MSCT with variable scan lengths. P = 15/16 for 16-MSCT and P = 53/64 for 64-MSCT. Separate experiments had established that $CTDI_{weighted}$ was 15.8 mGy for the 16-row MSCT and 12.4 mGy for the 64-row MSCT, both measured in the human body.

** The number in italics represents the intersection point of the two curves.*

This paper has partly been published in Academic Radiology, Vol. 15, No. 9, Sept. 2008

Higher patient exposure levels have been reported for 64-row MSCT as compared with 16-row MSCT[5,6]. The purpose of this study is to make a thorough comparison by determining the DLP exposure values in 64-row MSCT and 16-row MSCT as a function of scan length.

Methods

System parameters

Experiments were performed with a Toshiba MSCT Aquilion 64 system (Toshiba Medical Systems, Otawara, Japan). Collimations were 16 x 0.5 mm and 64 x 0.5 mm, respectively, and rotation time was set to 500 ms. Control of effective mAs is necessary to keep constant image quality. Tube current and voltage were therefore kept the same, that is 139 mAs and 120 kV, respectively. Data sampling rate was 900 views/s, and the dynamic range of the A/D converter was 16 bits.

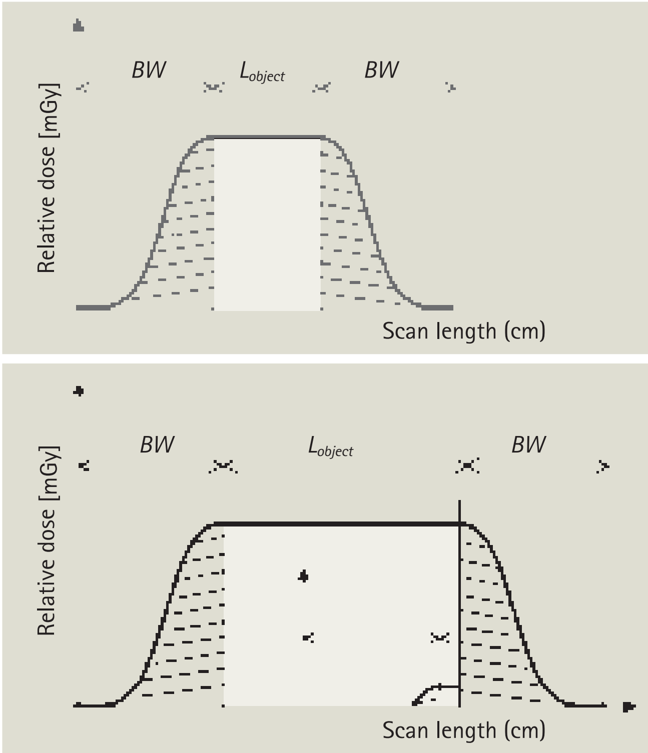
Effective exposure analyses

Nowadays, all CT scanners provide the user with the indication of exposure in the form of the $CTDI_{weighted}$ or $CTDI_{vol}$, and dose-length product (DLP). Exposure can be derived from the following quantities.

$CTDI_{air}$ is given as[3]:

$$CTDI_{air} = \frac{1}{NT}\int_{-50mm}^{50mm} d(z)dz \ [\text{mGy}]$$

Fig 2: Top: Typical relative dose profile as a function of scan length. The overranging is illustrated in the hatched area. Bottom: the relative contribution of overranging to total patient exposure becomes less relevant with increasing scan lengths.



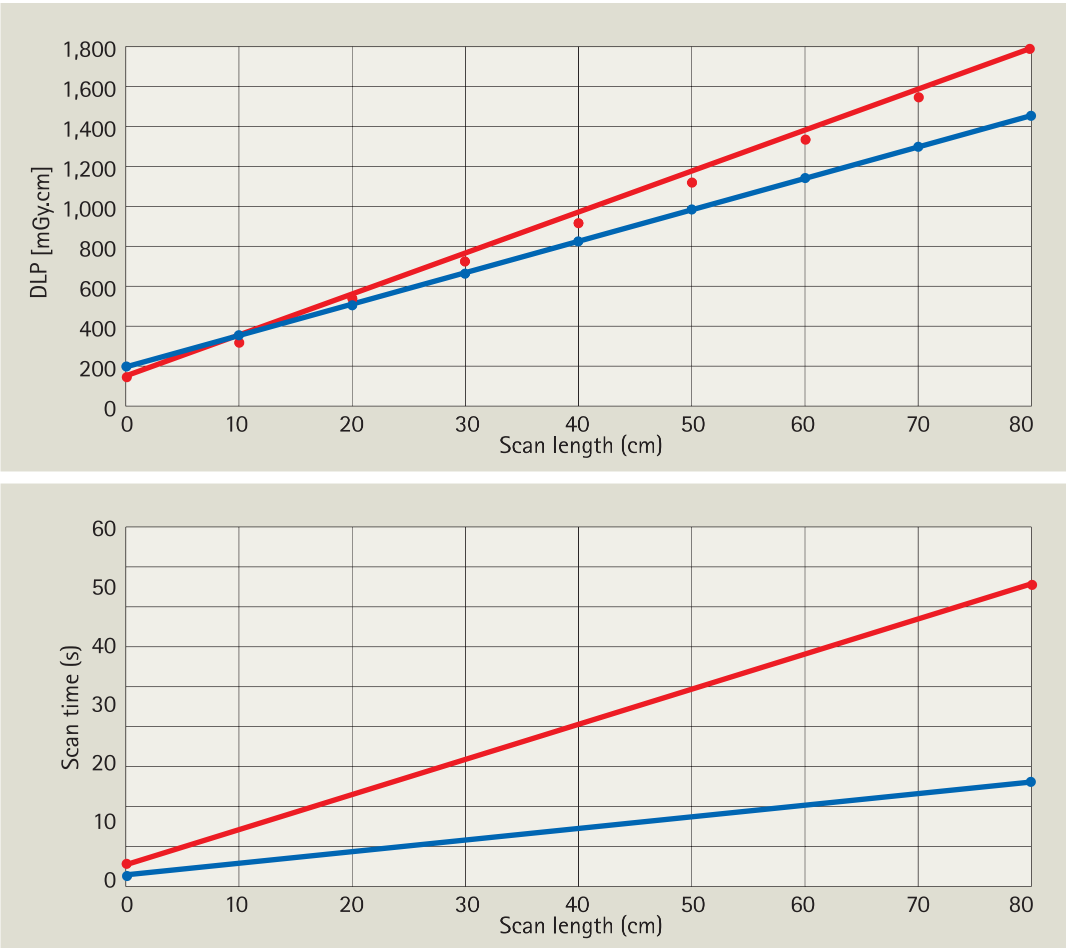


Fig 3: Top: DLP curves using 16- and 64-MSCT. The intersection point was found at around 12.3 cm which indicates that nominal beam-width does not play an important role in exposure levels at this length. Bottom: Total scan times of both systems demonstrating that 64-MSCT takes much less time than 16-MSCT as the scan length increases.

= 64-MSCT simulated 0.5 mm
= 64-MSCT measured 0.5 mm
= 16-MSCT simulated 1 mm
= 16-MSCT measured 1mm

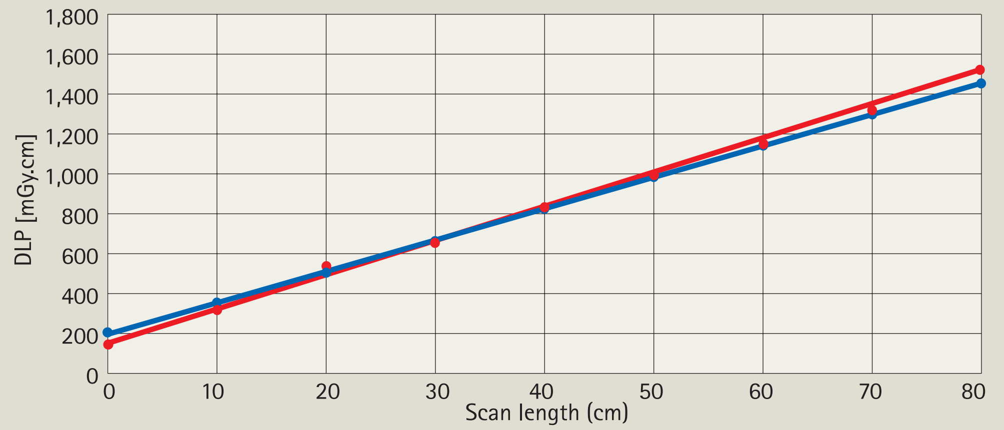
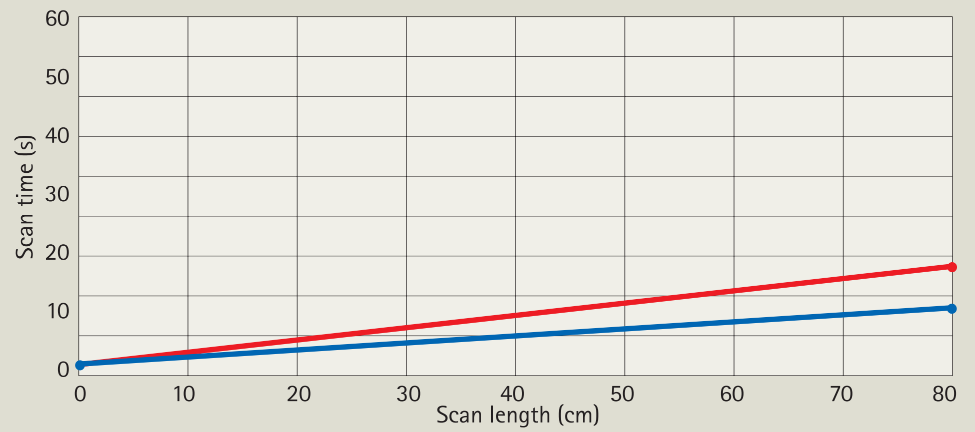


Fig 4: Top: DLP curves using 16 x 1 mm and 64 x 0.5 mm. Bottom: Total scan times of both systems demonstrating that 64-MSCT takes less time than 16-MSCT as the scan length increases.



= 16-MSCT 0.5 mm
= 64-MSCT 1 mm

where *N* is the number of slices, *T* (mm) is the nominal slice thickness, and *d(z)* is the dose profile for an axial scan, and the integral is taken over the interval of 100 mm scan length.
Dose-length product per rotation (dlp_{air}) is given as[3]:

$$dlp_{air} = CTDI_{air} \times N \times h \text{ [mGy.cm]}$$

where *h* is the nominal slice thickness in cm. The dose-length product for the total scan is then defined as:

$$DLP_{air} = dlp_{air} \times R \text{ [mGy.cm]}$$

where *R* is the total number of rotations which includes the overranging (the hatched areas in Fig. 1). Mathematically, *R* can be expressed as:

$$R = \frac{L + overranging}{BW_{nom} \times P}$$

where *L* is the scan length, BW_{nom} is the nominal beam-width, and *P* is the CT-pitch which is determined by the couch-top movement and the number of slices[7]. Overranging, the difference between exposure length and scan length, depends on the nominal beam width and is independent of scan length (Fig. 2).

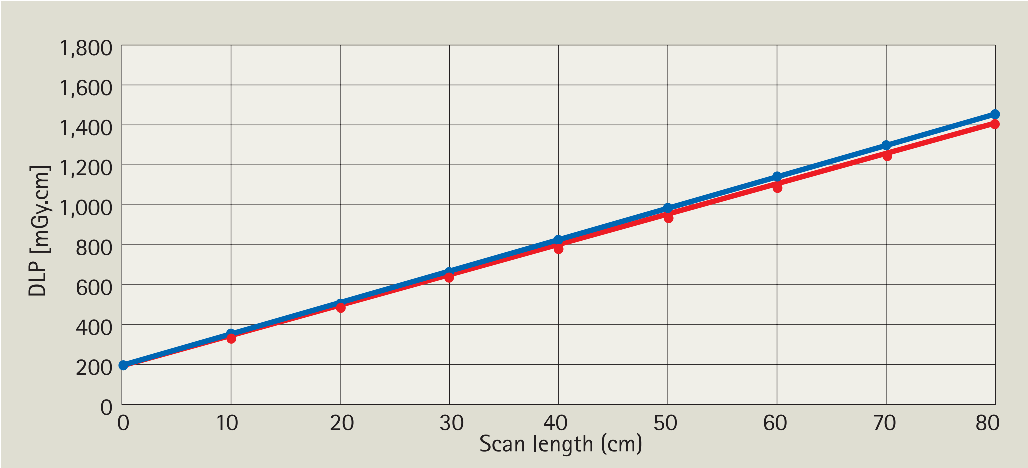
For air dose measurements we used a calibrated pencil dosimeter (Unfors Mult-O-Meter 601, Unfors Instruments, Sweden, http:/www.unfors.com) that is put exactly in the isocenter of the gantry. As these were point measurements, the number of rotations represented the object length.

Results

The exposure levels measured in DLP for 16-row MSCT (*P* = 15/16) and 64-row MSCT (*P* = 53/64) are summarized in Table 1. For a scan length of 5 cm, the DLP of 16-row MSCT is approximately 19% lower (144 mGy.cm) than that of the 64-row MSCT (178 mGy.cm). In contrast, for a larger scan length of 80 cm the DLP of 16-MSCT is 21% *higher* (1791 mGy.cm) than that of 64-MSCT (1471 mGy.cm).

It can be seen from Table 1 that overranging (exposure length – scan length) of both 16-row MSCT and 64-row MSCT are the same for the whole range, i.e. 1.6 cm and 5.4 cm, respectively. Figure 3 (top) demonstrates the calculated DLP values ranging from 5 to 80 cm for both 16- and 64-MSCT. It can be seen that there is an intersection point at approximately 12.3 cm scan length, below which the 16-row MSCT yields the lowest DLP and beyond which 64-row MSCT produces a lower exposure level than 16-row MSCT. The measured DLPs of both systems, shown in asterisks (*), closely resemble the simulated values.

Scan times were smaller in 64-row MSCT as compared with 16-row MSCT, especially so at the greater scan lengths (Fig. 3 bottom). For a comparison, we followed the same measurement and calculation procedure for 16-row MSCT with slice thickness of 1mm (Fig. 4) and 2 mm (Fig. 5), respectively. At increased slice thickness the results obtained with 16-row MSCT, closely resemble the DLP and scan times obtained 64-row MSCT with 0.5 mm slice thickness



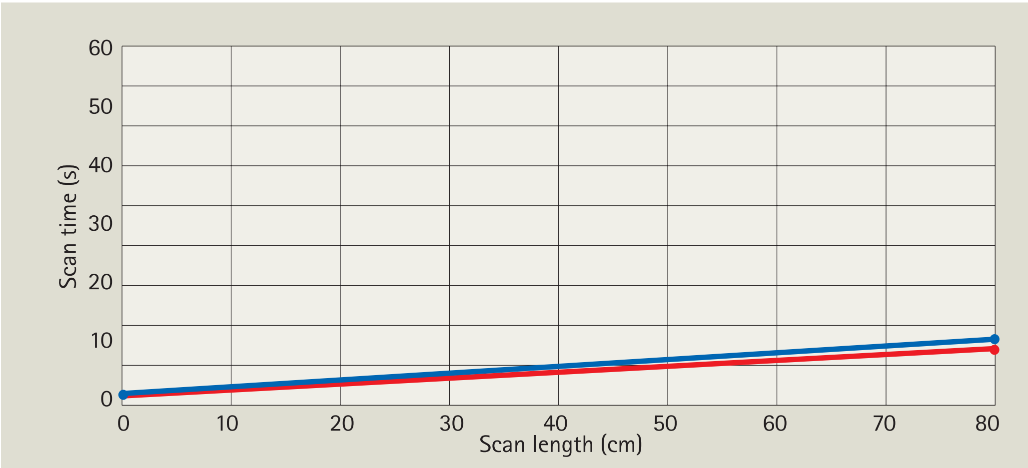


Fig 5: Top: DLP curves using 16 x 2mm and 64 x 0.5mm. Bottom: Total scan times of both systems demonstrating that 64-MSCT takes approximately the same as 16-MSCT for all scan lengths.

(compare Figs 4 and 5 with Fig. 3). Again, the measured DLP values closely match the simulated values.

Discussion

We have demonstrated that, in addition to beam width, scan length also is an important factor in the comparison of different MCST systems. The approach was to compare exposure levels in the 64-row and 16-row MSCT in terms of DLP by characterizing the integral dose for a complete CT scan series over an axial length instead of using CTDI. This is legitimate because CTDI represents the exposed dose under standardized condition while DLP values reflect the exposed patient dose necessary for clinical imaging. In addition to CTDI, five other scan protocol specific parameters (kV, mAs, CT-pitch, slice thickness, and the number of slices) are incorporated in the calculation of DLP.

The results presented imply that the 64-row MSCT does not necessarily produce higher DLP than 16-row MSCT. In contrast, radiation protection of patients should rather be based on scan range optimisation. Optimisation of scan range implies that the benefit for the patient outweighs the risk of radiation exposure.

This work has not dealt with comparison of image quality between the two scanners, which however can be found in many papers[5,6,8]. The objective assessments presented here indicate that the patient dose using 64-row MSCT is *not higher but lower* than that of 16-row MSCT, provided that the object length is larger than approximately 12.3 cm.

In conclusion, exposed dose measurement should be based on DLP that includes CTDI and other scan protocol parameters. In spite of previously published findings[5,6], in 64-row MSCT patient exposure is not necessarily higher than in 16-row MSCT. This partly counteracts the established opinion that the dose increases in proportion to the nominal beam width, and should reopen the discussion around exposure levels in CT technology.

References
1 Kalender WA, Seissler W, Klotz E, Vock O, Spiral volumetric CT with single-breath-hold technique, continuous transport, and scanner rotation. Radiology 1998;176:181-183.
2 Aoki C, Nishizawa K, Tonari A, Hachiya J. Effective dosing for multi-detector CT scanning. Jpn J Med Imaging 2001;20:101-9.
3 Nagel HS, Galanski M, Hidajat N, Maier W, Schmidt T. Radiation exposure in computed tomography-fundamentals, influencing parameters, dose assessment, optimisation, scanner data, terminology. Hamburg: CTB Publications, 2001.
4 Thomas LT, Neil BB, Tin-Su P, et al. A dose reduction X-ray beam positioning system for high-speed multislice CT scanners. Med Phys 2000;27:2659-68.
5 Deetjen A, Möllmann S, Conradi G, Rolf A, Schmermund A, Hamm CW, Dill T. Use of automatic exposure control in multislice computed tomography of the coronaries: comparison of 16-slice and 64-slice scanner data with conventional coronary angiography. Heart 2007;93:1040-3.
6 Mori S, Endo M, Nishizawa K, Murase K, Fujiwara H, Tanada S. Comparison of patient doses in 256-slice CT and 16-slice CT scanners. Br J Radiol 2006;79:56-61.
7 International Electrotechnical Commission. Evaluation and routine testing in medical imaging departments constancy tests – X-ray equipment for computed tomography. Publication IEC 1994:1223-1226.
8 Dewey M, Hoffmann H, Hamm B, CT coronary angiography using 16 and 64 simultaneous detector rows: intraindividual comparison, Rofo. 2007;179:581-6.

Roy Irwan, PhD
Henk de Vries
TOSHIBA Medical Systems Europe BV
CT Systems Division
Zilverstraat 1
2718 RP Zoetermeer
The Netherlands