The effect of pitch and collimation on radiation dose in spiral CT

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Abstract Measurements of radiation dose to patients in spiral computed tomography (CT) were completed for various collimations, table speeds and pitch. A standard CT head dosimetry phantom and thermoluminescent dosimeters (TLD) were used for the measurement. The effect of collimation and pitch on radiation dose was studied. The results indicated that the radiation dose at the given tube current, voltage and rotation speed was inversely proportional to pitch. And the increasing times of dose were as decreasing times of pitch. This regular pattern was tenable for radiation dose at both central holes and peripheral holes of the phantom at pitch = 1, >1 and <1. The collimation had no impact on the radiation dose. The results also indicated that radiation dose at central holes was nearly equal to that at peripheral holes. There was no significant difference between them statistically. The study demonstrates that the pitch in spiral CT scans is the primary parameter and has significant impact on radiation dose.

Key words Radiation dose, TLD, CT dosimetry head phantom, Pitch, Collimation

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1 Introduction

Spiral computed tomography (CT) was introduced in clinical practice in 1980s. Its distinctive characteristic is continuous data acquisition and continuous tube rotation with high speed while simultaneously translating the patient through the gantry.[1] Owing to these functions the spiral CT possesses the ability to scan an entire organ volume within a single breathhold. Thus, the anatomical section is contiguous and therefore the reliable demonstration of small lesions is possible. The high speed function is also applied in media contrast studies. It allows a reduction in administered media contrast and an improvement in contrast enhancement. Because of these outstanding advantages spiral CT has been widely used in clinical practice.

In conventional axial CT the CTDI and MSAD[2] are commonly used as descriptors of CT dose. However their definitions do not relate to patient motion, which is exactly the character of spiral CT. Thus, there has been an increasing concern about measuring radiation dose for patients during spiral CT scans. The motivation for this study was to find out the effect of pitch and collimation on the radiation dose and to summarize a regular pattern linking the radiation dose with these factors. This will provide radiologists with a practical method for assessment of patient dose in daily clinical practice.

2 Materials and methods

2.1 Standard CT head dosimetry phantom

The CT head dosimetry phantom used in this study is a right cylinder made up of polymethy1-methacrylate (PMMA). According to IEC recommendations,[3] the cylinder with 160mm diameter and 150mm long, was made in the National Institute of Metrology of China. Five holes were drilled through the cylinder, parallel to the axis of rotation, for placement of the monitor rods holding TLDs. The measuring positions were at the central hole and peripheral holes (10mm from the outer surface). TLDs were held in a custom-made monitor rod, the con-

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struction of which was described in Ref.[4].

2.2 CT machine and measuring equipment

A third-generation CT scanner (Somaton plus-4, Siemens) was used. The LiF (Mg, Cu, P) TLD chips, dimensions 3.2mm × 3.2mm × 0.89mm, were supplied by the Institute of Chemical Defense in Beijing. The TLD reader (Model RGD-3) was also supplied by the Institute of Chemical Defense in Beijing.

2.3 Methods for radiation dose measurement

2.3.1 Some parameters and concepts in spiral CT

There are three important parameters in spiral CT: table speed, i.e. the patient translation distance per gantry rotation;[5] pitch, i.e. the ratio of table speed to slice thickness (collimation); rotation speed, i.e. the time taken per gantry rotation. These parameters, especially the pitch, have significant impact on the radiation dose to patients. As described in Reference [6], under contiguous (pitch=1) CT scans the entrance radiation dose at both central hole and peripheral hole of the phantom is contiguous. However under noncontiguous (pitch>1) CT scans the radiation dose near or on the surface of the phantom is not contiguous . Some points are exposed to the entrance dose and scatter while others are exposed to scatter radiation. This means that the radiation dose received is dependent on the specific location and only the center of the phantom is exposed uniformly. McNitt-Gray et al.[6] have measured the radiation dose with TLDs placed in the center hole of the phantom for both pitch=1 and pitch>1. In this study the procedure is extended to peripheral holes.

2.3.2 Measuring conditions and sampling data

All data were acquired at 140 kVp. The time taken per rotation round the table was 1.5 s. The measurements were performed at 10, 8 and 5mm collimations for pitches of 0.5, 1, 1.5 and 2. The table speed was 5, 8, 10, 12, 15 and 16mm/1.5s. The details of the measuring conditions are listed in Table 1.

Table 1 Measurements of radiation dose under various scan conditions

Collimation (mm)	Table speed (mm/1.5s)	Pitch	Scan time(a) (s)	Scan length(b) (mm)	Tube current (mA)	mA•s (mA•s)	Location	Radiation dose (mGy)	Dose/100mA (mGy)
10	5	0.5	48(32)	150	129	6192	C(c)	44.40±6.84	34.45±5.24
							P(d)	44.31±10.83	34.36±8.44
	10	1	25.5(17)	150	206	5253	C	35.43±4.88	17.23±2.31
							P	34.99±5.41	17.05±3.11
	15	1.5	18(12)	150	206	3708	C	21.40±4.53	10.39±2.22
							P	21.31±6.48	10.30±3.11
8	8	1	31.5(21)	152	206	6489	C	32.94±6.39	15.98±3.11
							P	34.72±5.51	16.87±2.66
	12	1.5	22.5(15)	156	206	4635	C	22.64±2.58	11.01±1.24
							P	25.13±5.55	12.16±2.66
	16	2	18(12)	160	206	3708	C	17.49±3.20	8.44±1.51
							P	17.58±4.17	8.52±2.04
5	5	1	48(32)	150	129	6192	C	22.29±3.46	17.32±2.66
	10	2	25.5(17)	150	206	5253	C	17.14±4.88	8.35±2.40

Note: (a) The data in brackets are the number of scans. (b) Scan length = (number of scans –2) × table speed.[7] (c) C is the central hole. (d) P is the peripheral hole.

3 Results

All measurements were accomplished in various collimations, table speeds and pitches, with the tube current at 206 mA or 129 mA. The parameters are shown in Table 1. In general the radiation dose increases with the increase in the tube current. In order to determine the effects of collimation, table speed and pitch on the radiation dose, the tube current is normalized to 100mA. The data in the last column of

Table 1 express the radiation dose per 100mA. Table 1 shows that the radiation dose goes up as table speed goes down for fixed collimation. Obviously an increase in table speed leads to a reduction in radiation exposure time. Therefore the decrease in radiation dose is as expected. With the table speed fixed the radiation dose is increased with the collimation. This is because the exposed area of the phantom is decided by the collimation. It was found that the measured radiation dose increases with the decrease in pitch. And the increasing times of dose are as decreasing times of pitch. This conclusion not only relates to the central holes but also to the peripheral holes of the phantom.

The data in Table 2 show the radiation doses measured in various spiral CT scans relative to that in pitch 1 with the same collimation as well as the doses measured relative to that in pitch 1 with 10 mm collimation. All of the data indicate that the relative dose is inversely proportional to the pitch and is independent of collimation.

Table 2 The radiation dose values from different scans relative to that at pitch 1 with the same collimation and with 10 mm collimation

Collimation (mm)	Table speed (mm/1.5s)	Pitch	Values relative to that at pitch 1 with the same collimation		Values relative to that at pitch 1 with 10 mm collimation	
			C(a)	P(b)	C	P
10	5	0.5	2.00±0.51	2.02±0.61	2.00±0.41	2.02±0.62
	10	1	1.00±0.19	1.00±0.26	1.00±0.19	1.00±0.26
	15	1.5	0.60±0.18	0.60±0.21	0.60±0.15	0.60±0.21
8	8	1	1.00±0.28	1.00±0.22	0.93±0.24	0.99±0.24
	12	1.5	0.69±0.15	0.72±0.19	0.64±0.16	0.71±0.20
	16	2	0.53±0.14	0.51±0.15	0.49±0.11	0.50±0.15
5	5	1	1.00±0.22		1.01±0.22	
	10	2	0.48±0.16		0.48±0.15	

Note: (a) C is the central hole; (b) P is the peripheral hole.

4 Discussion

The data in Table 1 indicate that the radiation dose is inversely proportional to pitch. McNitt-Gray[6] reported that the radiation dose at the central hole is inversely related to pitch. The present study indicates that this conclusion is also tenable for the radiation dose in peripheral holes and for pitch = 1, pitch > 1 and pitch < 1. As pitch is the ratio of table speed to collimation, for a given collimation the pitch is proportional to table speed. The radiation dose increases with decrease in table speed. The decrease in table speed leads to increase in exposure time and to the value of mAs (for a given mA) as well. With the table speed given, the radiation dose increases with increase in collimation, while the pitch is inversely proportional to collimation. The radiation dose is, of course, increased with the decreasing of pitch.

The fact that radiation dose is inversely proportional to pitch is therefore a general law in spiral CT scans, disregarding pitch = 1, pitch > 1 and pitch < 1, either for central holes or peripheral holes in the phantom. The data in Table 1 also indicate that the radiation dose at central hole is nearly equal to that at peripheral holes.

The data in Table 2 show that the radiation dose from different scans relative to that at pitch 1 is inversely proportional to pitch, either with the same collimation or with 10mm collimation. This implies that the collimation makes no impact on radiation dose. Our study demonstrates that the pitch in spiral CT scans is the primary parameter, which has significant impact on radiation dose. Therefore under the condition of satisfying the diagnostic needs the pitch should be used as high as possible, so as to yield a lower radiation dose to patients.

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