# Survey of patients' CT radiation dose in Jiangsu Province

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**Background:** Through investigating 245 adult patients' CT scanning conditions and the radiation dose, to analysis the patients' radiation dose level of CT examination in Jiangsu Province.

**Methods:** We investigated 245 patients' CT scanning parameters from eight different hospitals of five cities in Jiangsu Province, collected and measured the CT dose index (CTDI), weighted CT dose index (CTDIw) and dose-length-product (DLP) by using standard adult dose model under the same scanning conditions, then estimated the effective doses(E) with transformation coefficient.

**Results:** The CTDIw values of patients' head, chest and abdomen scanning were lower than the national reference level. The third quartile (75%) DLP of 245 patients' head and chest scanning were close to IAEA's reference level, and the abdomen scanning value was lower than IAEA and other foreign research data.

**Conclusions:** At present the CT scanning doses level of Jiangsu Province is lower than the national standard. It is conducive to the realization of the optimization of medical radiation protection with reasonable optimization of CT scanning parameters and improving the level of medical radiation dose reference.

**Keywords:** Computed tomography (CT); CT dose index (CTDI); dose length product (DLP); effective dose; reference level of the medical radiation

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## Introduction

Computed tomography (CT) is an important diagnostic imaging modality that plays a key role in medical diagnosis. With increasingly widespread clinical application of CT imaging technology, the patient exposures of CT examinations has shown a steady increase (1). According to the UNSCEAR, CT contribution to collective effective dose was estimated to account for 34% of the total (2). Therefore, it is useful for researching the CT examinations of dose distribution caused and there have been many related investigations and reports about analyzing the radiation dose levels of different types scanning in the worldwide (3,4).

The Chinese national technical standard file called GBZ165-2012 (5) has released in 2012, it provides a diagnostics reference level of CT examination on radiological protection requirements with different types of patients and patient's different parts. This study through the investigation and analyzing 245 cases of adult patients with CT examination of radiation dose in Jiangsu province, and to compare it with diagnostic reference level (DRL) provided by the newly national standard.

## Methods

### *Object*

For this CT dose survey, samples were selected by the multi-stage cluster sampling method. First, five cities (Nanjing, Zhenjiang, Xuzhou, Suzhou and Yancheng) were selected randomly according to the economic situation in Jiangsu Province, then choosing eight hospitals with different sizes in those cities and considering different types of CT equipment in proportion. Finally a total of 245 cases of adult patients with CT scan parameters as the research object in those hospitals, at the same time the patients' sex, weight and age, CT equipment type, scanning area and scanning mode will be recorded .

### *Equipment*

The equipment consists of the following models, Philips offerings six row helical CT, Philips offerings 128 row helical CT, GE Lightspeed 16 row helical CT, GE Lightspeed 16 row helical CT Pro, GE CT325 spiral CT, GE Hispeed spiral CT, Siemens Somatom Definition since 16 row helical CT , Siemens Somatom Definition since 64 row helical CT , Siemens Somatom Definition since 128 row helical CT, Siemens Somatom Definition—as spiral CT, Siemens Somatom Definition. And testing instruments such as Swedish Barracuda X-ray, CT quality control detector, TM160 and TM164 CT dose phantom are also be needed. Testing instruments are in the calibration period of validity.

### *Parameter measurement*

Putting the dose model on the scanning field center, the cylindrical phantom axis and the vertical scanning level, respectively, placing CT dose probe in the center of the dose model and 1 cm from the surface 3, 6, 9, 12 points in the direction of the hole. The effective sensitive center of probe is located in the middle of the scanning plane position, and the rest of the hole filled with organic glass rod. Choose the actual examination of scanning sequence, and at the same working voltage kVp, current mAs parameters such as scanning, then measure and record the CT dose index, according to the following formula to calculate respectively CTDIw and DLP. CTDIw =1/3 $CTDI_{100\ (center)}$ + 2/3 $CTDI_{l00\ (peripheral)}$, $CTDI_{100\ (center)}$ is a position in the center of the die body measurement $CTDI_{100}$; $CTDI_{100\ (peripheral)}$ for the die bodies around four different positions (10 mm) under the surface of the body measurement of average.

DLP (cm), mGy = $CTDI_{vol}$ (mGy) × scanning length (cm); $CTDI_{vol}$ = CTDIw/pitch type, $CTDI_{vol}$ was volumetric CT dose index, for a particular scan scheme under the radiation dose. DLP reflects a specific scan of the total absorbed dose.

### *Effective dose estimation*

Using the conversion factor (6) by the DLP estimating effective dose based on the report ICRP102, then through the following formula for estimating effective dose (E) of the different parts of the scanning. E = K*DLP, and K is a type of experience weighted factor with the units $mSv{\cdot}cm^{-1}{\cdot}mGy^{-1}$, related to the parts of the body.

### *Statistical processing*

In this article, the relevant data are written in the form of $\bar{x}{\pm}s$, data analysis by SPSS 13.0.

## Results

### *Main CT scanning parameters used in adult patients in Jiangsu Province*

*Table 1* summarizes the four types of inspection of Jiangsu Province, a total of 245 cases of adult patients with main parameters used in the CT scanning. As can be seen from *Table 1*, the change of the tube voltage range is small between different kinds of examination and scanning way, average about 120 kV, the range in kV [110–140], the head and spine scanning time is 1.3 times longer than that of the chest and abdomen. The chest average scanning length has a maximum value (220.78 mm), is nearly 2.8 times that of the lumbar spine (79.98 mm), but between the chest and abdomen scanning pitch have no obvious difference.

### *Adult patients with weighted CTDIw CT dose index value of CT examination in Jiangsu Province*

Weighted CT dose index called CTDIw is an important characterization of dose in patients with CT examination. *Table 2* summarizes the adult patients with weighted CT dose index value of CT examination in Jiangsu Province. As can be seen from *Table 2*, different type checking CTDIw mean have obvious difference, the head scan has a maximum average scanning length value of 44.54 mGy, which is 2.6 times than the chest scan value (17.31 mGy). When checking with the same scanning type, CTDIw value range also have bigger difference, the lumbar CTDIw minimum value range, the ratio of the maximum and minimum value is 3.25, and the chest check CTDIw value range is the largest, the ratio of the maximum and the minimum of 12.6 times. *Table 3* shows the national standards in the diagnosis of the reference level with CT examination, so

 

**Table 1** Main CT scanning parameters used in adult patients in Jiangsu Province

| Examination type | Scanning way | Cases | Tube voltage (kV) | | Current time product (mAs) | | Scan length (mm) | | Pitch | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Range | Mean ± SD | Range | Mean ± SD | Range | Mean ± SD | Range | Mean ± SD |
| Head | Axis | 70 | 110–140 | 120.57±6.99 | 150–435 | 256.43±94.43 | 48–140 | 110.8±25.59 | – | – |
| Abdomen | Spiral | 69 | 110–140 | 119.85±6.06 | 82–270 | 186.20±65.88 | 90–700 | 114.29±205.72 | 0.75-1.38 | 1.08±0.28 |
| Chest | Axis | 46 | 110–120 | 118.70±3.41 | 43–270 | 191.91±62.86 | 108–320 | 220.78±59.31 | 1-1.75 | 1.43±0.22 |
| Spine | Spiral | 60 | 120–140 | 124.31±8.31 | 100–400 | 245.83±74.84 | 30–136.8 | 79.98±27.15 | – | – |

SD, standard deviation.

**Table 2** Adult patients with weighted CTDIw of CT examination in Jiangsu Province

| Examination type | Scanning way | Cases | Range | CTDIw (mGy) |
|---|---|---|---|---|
| Head | Axis | 70 | 19.36–66.9 | 44.54±12.78 |
| Abdomen | Spiral | 69 | 4.15–35.13 | 21.90±8.36 |
| Chest | Spiral | 46 | 2.4–30.34 | 17.31±8.16 |
| Spine | Axis | 60 | 16.48–53.71 | 31.75±10.34 |

CT, computed tomography; CTDIw, CT dose index.

**Table 3** Reference level with CT examination in adult patients

| Examination type | CTDIw (mGy) |
|---|---|
| Brain | 50 |
| Lumbar | 35 |
| Abdomen | 25 |

The value is measured by the value of the rotation axis of a water phantom deduced, the length of phantom is 15 cm, the diameter is 16 cm (head) and 30 cm (lumbar spine and abdomen). CT, computed tomography; CTDIw, CT dose index.

it is obvious the dose level of adult patients with different types of CT scan in Jiangsu are lower than the national standard.

### *The DLP values of adult patients CT examination in Jiangsu Province*

The DLP value is derived from the product of the scanning length is a representational characteristic parameter which can appear the CT examination's diagnostic radiology reference (guidance) levels currently. *Table 4* summarizes the adult patients the DLP values of four types CT examination in Jiangsu Province. As you can see in *Table 4*, there were significant differences in values of DLP from different kinds of examination, and the head scan average DLP is nearly 2 times than the chest and lumbar spine. Even if the same types of inspection, different client to scan the DLP value also have obvious difference, the head scanning maximum DLP value is times 4.2 larger than the minimum value, and abdominal scan DLP ratio as high as 17.5 times the maximum and the minimum. With the IAEA's reference level in *Table 5*, compared to the corresponding diagnostic reference levels in Jiangsu's adult patients with head scan , DLP's third quartile (75%) value was slightly higher than the IAEA data, and the scan of the chest and abdomen third quartile (75%) values are lower than the IAEA's; Compared to the research, the third quartile (75%) value of the head of Jiangsu's patients scanning was a value of 65% of the patients in UK, chest check for 39% of the UK, but abdominal examination's values of the two countries are basically equal. Compared with Europe, the head DLP's third quartile (75%) value of Jiangsu inspection is 1.8 times that of Europe, chest is 1.4 times as much, and the abdomen to check for 74% of European research data. *Figure 1* shows intuitive adult patients DLP values of different types of CT scan in Jiangsu and the comparison of different studies of diagnostic reference levels DRL results.

 

**Table 4** DLP values of adult patients CT examination in Jiangsu Province

| Examination type | Scanning way | Cases | DLP (mGy·cm) | Range | The third quartile (75%) value of DLP (mGy·cm) |
|---|---|---|---|---|---|
| Brain | Axis | 70 | 493.16±198.65 | 222.62–936.63 | 601.52 |
| Abdomen | Spiral | 69 | 408.96±250.44 | 82.9–1,452.23 | 536.51 |
| Chest | Spiral | 46 | 256.93±127.92 | 67.86–511.38 | 365.25 |
| Lumbar | Axis | 60 | 253.25±134.71 | 98.96–580.05 | 290.89 |

DLP, dose-length-product; CT, computed tomography.

**Table 5** Adult patients' diagnostic reference levels in different studies DRL (mGy·cm)

| Examination type | IAEA reach data (Tsapaki etc., 2006) | UK's DRL of MDCT (Shrimpton etc., 2005) | Europe's DRL of MDCT (Bongartz etc., 2004) | Jiangsu's third quartile (75%) value of DLP (mGy·cm) |
|---|---|---|---|---|
| Brain | 527 | 930 | 337 | 601.52 |
| Chest | 447 | 940 | 267 | 365.25 |
| Abdomen | 696 | 560 | 724 | 536.51 |

These data was from ten representative research centers of six countries, DLP (mGy·cm) was considered as a dose parameter in this table, and the listed data was the third quartile (75%) value of the average. DRL, diagnostic reference level; MDCT, multi-detector computed tomography; DLP, dose-length-product.

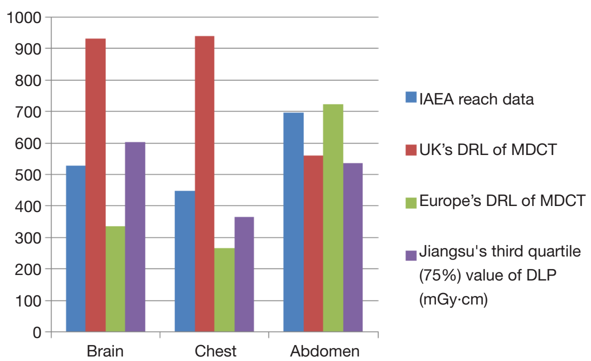


**Figure 1** The comparison of different studies of diagnostic reference levels DRL results. DRL, diagnostic reference level; MDCT, multi-detector computed tomography.

### *Adult patients' effective dose of CT examination in Jiangsu Province*

*Table 6* lists the adult patients with effective dose of CT examination in Jiangsu province (mSv), and the comparative analysis with the relevant study in the UK, as you can see from the *Table 6*, adult patients with different types of effective dose of CT examination in our province values were much lower than the UK and the United States related research data.

## Results

### *Reasonable optimization of CT scan parameters is the key to reduce the patient radiation dose*

Radiation dose of CT examination subjects mainly depends on the scanning parameters, such as tube voltage, tube current and so on. So without affecting the quality of CT images, the reasonable optimization of CT scanning parameters, as far as possible to make the client doses of radiation can be reasonably reach the lowest level is the direction (9). Scanning parameters, such as in the previous summary analysis, when the average tube voltage is 120 kV, scanning the mean length of 110 mm, the head scanning tube current time product 256 mAs and abdominal tube current product 186 mAs differences, cause head scan's CTDIw value is 2 times of the abdomen's. When the pipe average voltage set at 120 kV, and current product of time average 190 mAs, it is found that because of the abdominal scan length is 114 mm and chest scan length is 220 mm in length of different, then the abdominal dose product of DLP is 1.6 times of the chest.

These gaps of CTDIw or DLP values in patients not only depends on the individual differences and diagnosis of actual need, has also been different hospitals, different radiation workers by reason of personal habits and the

**Table 6** The comparison of CT examination effective dose in Jiangsu province (mSv) with the UK and the United States

| Examination type | Scanning way | Conversion factor (7) (mSv·mGy$^{-1}$·cm$^{-1}$) | Range | Effective dose | UK (6) | United States (8) |
|---|---|---|---|---|---|---|
| Brain | Axis | 0.0021 | 0.46–1.97 | 1.04±0.42 | 2 | 2 |
| Abdomen | Spiral | 0.015 | 1.24–21.78 | 6.13±3.76 | 10 | 10 |
| Chest | Spiral | 0.014 | 0.95–7.15 | 3.59±1.79 | 8 | 7 |

CT, computed tomography.

technical problems in the choice in a CT scan parameters (tube voltage, tube current, pitch and scanning length, etc.) effects. All in all, there are many influence factors in client dose, we should keep in does not affect the diagnosis quality conditions, select individual scan scheme to achieve the effect of the patients with lower dose.

### *Constantly update perfect reference level dose of CT examination in order to reduce patient doses to achieve protection optimization*

This study through the investigation of 245 cases of CT scan parameters Jiangsu Province, using the standardization of the CT die body and long ionization chamber to measure the CT dose index CTDIw and DLP values which from CTDI again obtained at various points. Through comparative analysis of adult patients head weighted with CT examination in Jiangsu, lumbar and abdominal CT dose index CTDIw is lower than the national standard. Compared with foreign research data, the head CT scan DLP's third quartile (75%) value in Jiangsu was less than in Britain, higher than that of the IAEA and the European research data, the chest CT scan DLP's third quartile (75%) value was higher than that of Europe, below the IAEA and the UK, and the abdominal CT scan DLP value was the minimum of four. It is concerned that these results may be related to Chinese adult subjects' weight and waist are lower than western adults, so this actual value standard may be lower than the display. Therefore, to establish scientific and perfect diagnostic radiology medical reference (guidance) level, calculation is the important measure of promoting medical radiation protection optimization. Chinese current national standard GBZ165-2012 gives the CTDIw values in adult patients with CT scan head, chest and abdomen, for other parts such as lumbar is lack of guidance levels, we can be on the basis of the current standard complement dose reference level of different type checking, and reduce the existing can achieve the minimum level of reasonable guidance to further promote protection optimization.

Weighted CT dose index CTDIw, dose of product of the length of the DLP, and the effective dose all can be well on surface characterization of the dose of CT examination in the patients, but effective dose can't be directly measured, instead of calculation from the measured dose conversion factors and the DLP value is multiplied. In this study, our province adult subjects head, chest and abdominal CT scan of the DLP average 493.16, 256.93 and 408.96 mGy·cm in Jiangsu, so the estimation of the head, chest and abdominal CT scan to client effective doses were 1.04, 3.59 and 6.13 mSv, which were far lower than effective dose of CT examination in the UK and the US. By comparing the hint we can find an actual dose conversion factors based on China's population through further experimental study.

This study by adopting CT equipment management system, under the condition of each patient's actual scanning using CT model measurement of CT dose index and then the method to estimate how radiation dose belong to the fixed mold test. The limitation of the method is that cannot accurately reflect the actual situation of the individual client illuminated. When real-time automatic exposure control technology is used, the fixed die bodies of the limitations of the test will be more obvious. Therefore, we will be having a fixed die body test method, on the basis of the search for more convenient and practical method to detect radiation dose of CT client. The next study step we will acquire real patients' scan parameters such as CTDIw, CTDIvol and DLP value directly from CT image equipment management system and patient dose information, then regular summary and analysis of these data, comparing with the DRL, finally find the cause of the wave data and take corrective action. We can imagine that the result of the guarantee of CT examination will be in a state protection optimization in Jiangsu, China.

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## Footnote

*Conflicts of Interest:* All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/jphe.2016.12.10). BZ serves as an Editor-in-Chief of *Journal of Public Health and Emergency* from Jan 2017 to Dec 2022. The other authors have no conflicts of interest to declare.

*Ethical Statement:* The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Institutional ethical approval and individual informed consent were waived.



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