Study on the Effect of Individual Factors on the Radiation Dose in Chest CT

Dechuan Zhang
Department of Radiology, Traditional Chinese Medicine Hospital

Longling Fan
Key Laboraroty of Biorheological Science and Technology, Ministry of Education, Bioengineering College of Chongqing University

Xuqian Liang
Department of Radiology, Traditional Chinese Medicine Hospital

Teiying Yin
Key Laboratory of Biorheological Science and Technology, Ministry of Education, Bioengineering College of Chongqing University

Qigen Li
Department of Radiology, Traditional Chinese Medicine Hospital

Renrong Liang
Department of Radiology, Traditional Chinese Medicine Hospital

Yuhong Chen
Department of Radiology, Traditional Chinese Medicine Hospital

LV Lei
Department of Radiology, Chongqing Emergency Medical Center, Affiliated Center Hospital of Chongqing University

Xi Liu
Department of Radiology, Traditional Chinese Medicine Hospital

Hua Yang
Department of Radiology, Traditional Chinese Medicine Hospital

GuiXue Wang ( wanggx@cqu.edu.cn )
Key Laboratory of Biorheological Science and Technology, Ministry of Education; Bioengineering College of Chongqing University
https://orcid.org/0000-0003-1883-8023

Research

Keywords: individual factors, chest CT scan, radiation dose, Multivariate regression analysis

DOI: https://doi.org/10.21203/rs.3.rs-46918/v1
Abstract

Objective

To explore the influence of patient’s individual factors on the radiation dose in chest computed tomography (CT) scan.

Methods

Based on the clinical chest CT scan scheme and the scanning conditions were unified, Basic data of 103 patients who underwent chest CT scanning, including gender, age, height, weight and underlying diseases, were prospectively collected, and the dose length product (DLP) of each patient was recorded, Multivariate regression analysis was made on the obtained data.

Results

Under the same scanning parameters, image quality had no significant effect on chest CT radiation dose (P = 0.404 > 0.05); among the 103 cases, there were 20 kinds of basic diseases, only calcified lesion has a significant effect on chest CT radiation dose (P = 0.009 < 0.05), the other had no significant effects (P > 0.05); the major effect individual factors of radiation dose in CT scan were: gender (P = 0.000003 < 0.05), age (P = 0.016 < 0.05), height (P = 0.000021 < 0.05), weight (P = 4.30E-16 < 0.05). Age (P = 8.08E-8 < 0.05) and weight (P = 5.52E-21 < 0.05) were the only decisive factors in multiple regression analysis, while other influencing factors were not decisive (P > 0.05). The regression model was as follows: DLP = -39.45 + 2.19*age + 5.54*weight, the coefficient of multiple correlation R being 0.786, F(2,100) = 77.128, P < 0.01. Mean that gradually increase in age was related with 2.19 mGy•cm increase in the DLP value, 1 kg increase in weight was associated with 5.54 mGy•cm increase in the DLP value.

Conclusion

For chest CT, age and weight are the major impact individual factors of radiation dose. This model has shown obvious clinical significance and can provide solid theoretical basis for clinical application in reducing the radiation dose in chest CT.

Background

With the rapid development of medical science and technology, X-ray computed tomography (CT) has been widely used in clinical practice and the low-dose chest CT has become one of the means of lung cancer screening[1–2], but its accompanying radiation problem was also closely watched[3], so how to practice the as low as reasonably achievable (ALARA) principle and reduce the radiation dose has
become the hot topic in the field[4]. In this study, the influence of individual factors on radiation dose was studied.

Results

Research data

The data of 103 patients were collected, including gender, age, height, weight, dose length product (DLP), and the prevalence of 20 basic diseases such as interstitial changes, infection, inflammation, proliferation, fiber, pneumatocele, lung nodules, pleural effusion, lung cancer, mediastinal lymph nodes, atelectasis, pulmonary bullae, emphysema, breast carcinoma, calcified lesion, pulmonary congestion, pleural thickness, bronchiectasis, mosaic perfusion, lung destroyed and so on. There were 51 males and 52 females, aged 27–88 years, 58 ± 14.2 years on average. The baseline data of all patients are summarized in Table 1. For continuous variables, the description method is determined according to whether the data obeys normal distribution or not, if obeys the normal distribution, use the available mean ± standard deviation (SD); if not obey the normal distribution, use the median (1/4 quartile-3/4 quartile). For the classification variables such as basic diseases, the number of patients and the percentage of the total number of patients are used to describe the data.
Table 1
Baseline data of all patients

| Factor                          | Indicators |
|--------------------------------|------------|
| Patient (n)                     | 103        |
| Age (years)                     | 58.21 ± 1.40 |
| Height (cm)                     | 162.5 ± 0.78 |
| Weight (Kg)                     | 65 (60-77.2) |
| DLP (mGy•cm)                    | 404.3 (359.5-488.5) |
| Interstitial changes (n [%])    | 6 [5.8]    |
| Infection (n [%])               | 5 [4.9]    |
| Inflammation (n [%])            | 39 [37.9]  |
| Proliferation (n [%])           | 9 [8.7]    |
| Fiber (n [%])                   | 25 [24.3]  |
| Pneumatocele (n [%])            | 2 [1.9]    |
| Lung Nodules (n [%])            | 32 [31.1]  |
| Pleural Effusion (n [%])        | 4 [3.9]    |
| Lung Cancer (n [%])             | 5 [4.9]    |
| Mediastinal Lymph Node (n [%])  | 6 [5.8]    |
| Atelectasis (n [%])             | 2 [1.9]    |
| Pulmonary Bullae (n [%])        | 10 [9.7]   |
| Emphysema (n [%])               | 9 [8.7]    |
| Breast Carcinoma (n [%])        | 1 [1.0]    |
| Calcified Lesion (n [%])        | 8 [7.8]    |
| Pulmonary Congestion (n [%])    | 1 [1.0]    |
| Pleural Thickness (n [%])       | 6 [5.8]    |
| Bronchiectasis (n [%])          | 5 [4.9]    |
| Mosaic Perfusion (n [%])        | 1 [1.0]    |
| Lung Destroyed (n [%])          | 1 [1.0]    |
Image quality assessment $\geq 4$ is classified as high-quality image, $\leq 3$ is classified as inferior image (Fig. 1). There was no correlation between image quality and chest CT radiation dose ($r=-0.083$, $P = 0.407 > 0.05$). Furthermore, image quality had no effect on chest CT radiation dose (Table 2).

**Table 2 Image evaluation statistics**

| Classification                      | 5 | 4 | 3 | 2 | 1 | DLP  |
|-------------------------------------|---|---|---|---|---|------|
| Case                                | 52| 38| 13| 0 | 0 | 0    |
| Case of high-quality image $\geq 4$ | 90|    |    |   |   | 417.1±77.95 |
| Case of poor-quality image $\leq 3$ |   |    |    | 13|   | 444.0±119.1 |
| The $P$ value of all images          |   |    |    |   |   | $0.404 > P=0.05$ |

**Correlation Index Of Dlp**

The correlation analysis of DLP with individual factors and underlying diseases are shown in Table 3. The DLP was significantly correlated with gender, height, weight, age and calcified lesion and there was no correlation with interstitial changes, infection, inflammation, proliferation, fiber, pneumatocele, lung nodules, pleural effusion, lung cancer, mediastinal lymph nodes, atelectasis, pulmonary bullae, emphysema, breast carcinoma, pulmonary congestion, pleural thickness, bronchiectasis, mosaic perfusion and lung destroyed (Table 3).
Table 3  
Correlation between DLP and respective variables

| DLP        | Gender | Height | Weight | Age | Interstitial changes | Infection |
|------------|--------|--------|--------|-----|----------------------|-----------|
|            | r      |        |        |     |                      |           |
| DLP        |        |        |        |     |                      |           |
| Gender     | 0.431**| 0.419**| 0.723**| 0.238*| -0.137               | -0.047    |
| Height     | 0.0000003 | 0.00002 | 4.3E-16 | 0.016 | 0.169               | 0.637     |
| Weight     |        |        |        |     |                      |           |
| Age        |        |        | 0.234  | 0.379 | 0.476               |           |
| Interstitial changes |        |        |        |     |                      |           |
| Infection  |        |        |        |     |                      |           |
| DLP        | Inflammation | Proliferation | Fiber | Pneumatocele | Lung Nodules | Pleural Effusion |
|            | -0.042 | 0.126  | 0.142  | 0.118 | -0.087               | -0.071    |
|            | 0.671  | 0.205  | 0.153  | 0.234 | 0.379               | 0.476     |
|            |        |        |        |     |                      |           |
| DLP        | Lung Cancer | Mediastinal Lymph Node | Atelectasis | Pulmonary Bullae | Emphysema | Breast Carcinoma |
|            | -0.076 | -0.116 | -0.088 | 0.170 | 0.102               | -0.093    |
|            | 0.446  | 0.244  | 0.379  | 0.086 | 0.306               | 0.349     |
|            |        |        |        |     |                      |           |
| DLP        | Calcified Lesion | Pulmonary Congestion | Pleural Thickness | Bronchiectasis | Mosaic Perfusion | Lung Destroyed |
|            | -0.26** | -0.103 | -0.093 | -0.084 | -0.153               | -0.143    |
|            | 0.009  | 0.299  | 0.348  | 0.401 | 0.122               | 0.149     |

Note: ** means $P<0.01$ (double tail), and the correlation is significant. * means $P<0.05$ (double tail), and the correlation is significant.

Further analysis shows that, correlations between the respective variables. there was a correlation between gender and height ($r = 0.628$, $P = 2.22E-10 < 0.01$), weight ($r = 0.416$, $P = 0.00003 < 0.01$), pulmonary bullae ($r = 0.266$, $P = 0.007 < 0.01$). there was a correlation between height and weight ($r = 0.569$, $P = 3.48E-10 < 0.01$), age ($r = 0.203$, $P = 0.039 < 0.05$), pulmonary bullae ($r = 0.276$, $P = 0.005 < 0.01$). there was a correlation between weight and calcified lesion ($r=-0.240$, $P = 0.015 < 0.05$), pleural effusion ($r =-0.234$, $P = 0.018 < 0.05$), proliferation ($r =0.229$, $P = 0.02 < 0.05$). there was a significant correlation between age and image quality ($r =-0.369$, $P = 0.00013 < 0.01$), emphysema ($r =0.321$, $P = 0.001 < 0.01$). there was a correlation between inflammation and fiber ($r =0.255$, $P = 0.009 < 0.01$), bronchiectasis ($r =0.196$, $P = 0.047 < 0.05$). there was a correlation between lung cancer and mediastinal lymph node ($r =0.522$, $P = 1.51E-08 < 0.01$), atelectasis ($r =0.296$, $P = 0.002 < 0.01$), there was a correlation between mediastinal lymph node and bronchiectasis ($r =0.330$, $P = 0.002 < 0.01$). there was a correlation between atelectasis and emphysema ($r =0.206$, $P = 0.037 < 0.05$). there was a correlation between calcified lesion and emphysema ($r =0.206$, $P = 0.037 < 0.05$). there was a correlation between pleural thickness and lung destroyed ($r =0.341$, $P = 0.0004 < 0.01$). there was a correlation between bronchiectasis and lung destroyed ($r =0.398$, $P = 0.00003 < 0.01$). there was a correlation between mosaic perfusion and image quality ($r =0.438$, $P = 0.000004 < 0.01$). there was a correlation between mosaic perfusion and image quality ($r =-0.261$, $P = 0.008 < 0.01$).
Because DLP does not obey normal distribution, Mann-Whitney U test was used to analyze the differences and effects of basic diseases such as gender and interstitial changes on DLP. There was a significant difference between DLP and gender ($P = 0.000013 < 0.01$), and calcified lesion had effect on DLP ($P = 0.01 < 0.05$).

**Multiple Regression Analysis**

By observing the scatter plots of individual factors (age, height, weight) and DLP of patients, it can be seen that the radiation dose has a good linear relationship with height and weight, and an approximate linear relationship with age (Fig. 2).

According to the previous correlation analysis, there was a significant correlation between DLP and sex, height, weight, age and calcification. Furthermore, multivariate stepwise regression analysis was used to investigate the influence of five significantly correlated indexes on DLP. According to the significant results in Table 4, Only weight and age had significant effects on DLP, while other variables had effects on DLP but had no statistical significance.

| Variable   | Regression Coefficient | Standard Error | t      | P        | Confidence Interval of Regression Coefficient |
|------------|------------------------|----------------|--------|----------|---------------------------------------------|
| Constant term                     | -39.449                | 39.259         | -1.005 | 0.317    | [-117.3, 38.44]                             |
| Weight      | 5.543                  | 0.464          | 11.954 | 5.52E-21 | [4.623, 6.463]                              |
| Age         | 2.191                  | 0.378          | 5.792  | 8.08E-8  | [1.440, 2.941]                              |

Based on Table 4, the regression equation of the influence of individual factors on chest CT radiation dose was established as:

$$DLP = -39.45 + 5.54*Weight + 2.19*Age$$

Formula (7), the regression equation of DLP depend on individual factors, the radiation dose can be calculated by knowing the body weight and age of the person being examined. The constant of the regression equation is -39.45, the slope of weight is 5.54, that is, the DLP increases by 5.543 for every 1 kg of weight; the slope of age is 2.19, that is, the DLP increases by 5.543 for every 1 year increase (In this equation, the unit of weight is: kg; the unit of age is: year).
Next, the fitting degree of the regression model will be illustrated by the multiple correlation coefficient $R$ value, variation degree variable $R^2$ and analysis of variance table. Regression model statistics show that the value of index $R$ is 0.779 indicates the regression model has medium-high correlation, the value of adjusted $R^2$ is 0.599 indicates the regression model has high influence intensity, and the Durbin-Watson test value is 2.058, which further indicates that the observed indicators are related and independent (Table 5). Variance analysis of regression model shows that the regression model has statistical significance, $F(2,100) = 77.128, P = 5.45E-21 < 0.01$, suggesting that there is a linear correlation between dependent variables and independent variables. It also further shows that the effects of the two indicators included in the model on DLP are statistically significant (Table 6).

| Table 5  | Regression model statistics |
|---------|-----------------------------|
| $R$     | 0.779                       |
| $R^2$   | 0.607                       |
| Adjusted $R^2$ | 0.599               |
| Error of standard estimation | 53.18535               |
| Durbin-Watson | 2.058               |

| Table 6  | Variance analysis of regression model |
|---------|--------------------------------------|
| Model   | Quadratic sum | DOF | Mean square    | $F$     | $P$     |
| Regression | 436341.453 | 2   | 218170.726    | 77.128  | 5.45E-21 |
| Residual   | 282868.184 | 100 | 2828.682     |
| Sum total  | 719209.637 | 102 |                  |

**Discussion**

Since the clinical application of spiral CT, the radiation dose of CT is high, accounting for about 1/2 of the total medical radiation exposure [5]. Therefore, low-dose CT scanning has been the focus of clinical and scientific research [6]. Previous studies have explored the factors affecting the radiation dose of patients from the aspects of scanning methods and reconstruction methods, but have not discussed the factors affecting the radiation dose from the factors of the patients themselves.

In the early stage, the scanning radiation dose was reduced mainly by reducing the tube current, tube voltage, reducing the scanning time and applying automatic tube current modulation technology (auto mA) [7]. Some researchers [8–12] believe that the image quality can meet the diagnostic requirements when the dose is 40mAs. Zhang [8–9] reduces radiation dose through tube voltage, detector width and pitch combined with organ dose modulation technology. Song [10] found that the dose of some models of spiral CT is inversely proportional to the pitch when the tube current is constant, while some models adopt the technology of automatically adjusting tube current, and the radiation dose remains unchanged when the pitch changes. Of course, the matching of detector and pitch not only affects the volume coverage and image quality, but also affects the radiation dose to a certain extent [11–12].
In terms of reconstruction method, excessive reduction of radiation dose will lead to insufficient data acquisition and increased noise in filtered back projection (FBP) reconstruction, which will result in image quality not meeting the needs of diagnosis [13]. Model-based iterative reconstruction (MBIR) is an iterative algorithm based on original data, and a new generation of model-based iterative reconstruction (the new version of MBIR, MBIRn), which has unique advantages in reducing X-ray radiation dose and improving image quality [14]. Iterative reconstruction (IR) is to improve image quality and reduce image noise and artifacts through many iterations at lower radiation dose [15]. Adaptive statistical iterative reconstruction (ASIR) is based on the system statistical model, and its clinical application value has been confirmed [16–17]. When the iterative intensity of conventional chest CT plain scan ASIR is set at 40%-60%, the image quality, noise, and contrast noise are higher, the lung window and mediastinal window score is the highest [18], while the image quality is guaranteed, the radiation dose is significantly reduced [19].

In 2015, the World Health Organization determined that the body mass index (BMI) of normal adults was 18.5–24.9 kg/m2. BMI ≥ 25.0 kg/m2 was obese, and BMI < 18.5 kg/m2 was emaciated. Qin [20] conducted a low-dose chest scan study using 256 iCT according to this grouping standard, which only revealed that this grouping was beneficial to reducing radiation dose. Other domestic researchers [21–23] also studied the reduction of radiation dose based on body mass, but did not explain the relationship between body mass and radiation dose. Saade et al. [24] divides people according to their different body weight into four grades, ≤ 60, 60–80, 81–100 and ≥ 101 kg, to study the effect of body weight and radiation dose. It was found that there was a certain relationship between body weight and radiation dose. As the body weight of Chinese population is generally lower than that of European and American people [25], Chen et al. [26] divides people with a body weight of 60 kg into two groups: ≤60 kg and > 60 kg. Different scanning parameters are selected respectively, and it is also found that body weight can affect the dose of CT radiation. This study shows that body weight not only affects the radiation dose, but also reveals that there is a positive correlation between individual radiation dose and body weight, the slope is 5.54, that is, each increase in body weight of 1 kg, DLP will increase 5.54 mGy•cm (regression equation 0). Although there was a significant correlation between height and DLP (P = 0.00002 < 0.01, see Table 3), the multiple regression analysis showed that it had no significant effect on DLP (P = 0.917 > 0.05).

In radiological dosimetry, the difference of individual response to ionizing radiation is the key factor affecting the accurate estimation of biological dose. Studies have shown that individual differences in gene expression are mainly related to gender, age, smoking, lifestyle and inflammatory response [27–29]. The results of Li [30] showed that the relative expression level of mRNA of most genes in peripheral blood of female irradiated in vitro was higher than that of male, indicating that the radio sensitivity of women was higher than that of men. This study also showed that there was a very significant correlation between gender and DLP (P = 0.000003 < 0.01 (Table 3)), and there was a very significant difference between gender and DLP (P = 0.000013 < 0.01). However, in the regression analysis, the effect of gender on DLP was not statistically significant (P = 0.177 > 0.05). The main reason may be that there was a strong correlation between sex and height (r = 0.416, P = 0.00003 < 0.01). The expression of FDXR gene is
most affected by age. When Kajimura et al. [31] conducted cluster analysis on the number of dicentric cells and the expression level of related genes mRNA in 229 Japanese primary explosive population, it was found that both of them decreased with age, suggesting that the age of the recipients may affect the changes of radiation-induced gene expression, but its molecular mechanism remains to be further studied. The results show that the number of bicentric cells and the mRNA expression level of related genes decrease with the increase of age, suggesting that the age of the recipients may affect the changes of gene expression induced by radiation, but its molecular mechanism remains to be further studied. This study shows that there is not only a significant correlation between age and DLP (P = 0.016 < 0.05 (Table 3)), but also a main influencing factor in the establishment of regression equation (P = 8.08E < 0.01 (Table 4)). It also reveals that there is a positive correlation between individual radiation dose and age, the slope is 2.19, that is, gradually increase in age was related with 2.19mGy•cm increase in the DLP value (regression equation).

In general, the radiation dose assessment parameters of CT scanning are volume CT dose index (CTD_{Ivol}) and DLP [32–34]. The effective radiation dose (ED) of the patient can be calculated by the formula: ED = DLP × k (chest conversion coefficient, k = 0.014 mSv•mGy^{-1}•cm^{-1}) [35]. Their consistency is good [36]. CTD_{Ivol} will underestimate the radiation dose received by the patient, and the smaller the BMI, the greater the underestimated dose value [37]. In 2014, the American Society of Medical physicists proposed the method of body type-specific dose estimation (size specific dose estimation, SSDE) [38], which uses the water equivalent diameter (Dw) to estimate SSDE. SSDE refers to the estimated CT dose accepted by the patient after body size correction, which is based on the volume CT dose index CTD_{Ivol} displayed on the CT interface. Compared with CTD_{Ivol} and DLP assessment methods, SSDE is relatively accurate, but there is still a certain gap between the estimated value of SSDE and the true value of radiation exposure of patients. Based on this, this paper chooses the DLP value which is easy to obtain directly instead of SSDE value as the index of radiation dose, which may be the deficiency of this study.

**Conclusions**

Through the analysis of the influence of individual factors on chest CT radiation dose, the regression equation of individual factors affecting chest radiation dose is established: DLP=-39.45 + 5.54*Wight + 2.19*Age. The regression equation establishes a theoretical model for reducing the radiation dose of chest CT. According to the model, the radiation dose is reduced based on the individual factors and combined with a variety of scanning parameters, which will be the focus of the next research. It will also bring important guiding significance to clinical work.

**Materials And Methods**

**General Information**

Basic data of 103 patients, including age, gender, height, weight and radiation dose were prospectively collected. There were 51 males and 52 females, aged 27-88 years, 58±14.2 years on average. Inclusion
criteria: only single-site chest CT scan of adult patients were included. Exclusion criteria: multi-site chest CT scan, emergency and minor (≤18 years old) patients. This study was approved by the hospital ethics committee, and all enrolled patients signed the informed consent.

Scan Methods

GE spiral VCT scanner was used. The patients were required to raise their hands and place them on the top of their head, scan ranged from the thoracic entrance to the lower lung, including the entire lung field. Scan conditions, 120kV tube voltage, auto-milliampere technique, 100-400mA, 0.5s/r rotation speed, 0.984:1 pitch, 5 mm scan slice thickness, 5mm scan slice gap, 1.25 mm reconstruction slice thickness, 1mm reconstruction slice gap, totally 65 slice, data is automatically uploaded to GE AW4.6 workstation and PACS server after scan. DLP was used to evaluate the total radiation dose received by subjects after a CT exposure scan. DLP=CTDIPv×L, CTDIPv is the volume CT dose index of multi-slice spiral CT scanning, and L is the scanning length along the Z axis.

Image Evaluation

Chest CT images which met the inclusion criteria were evaluated for image quality to assess if the image quality would affect the chest radiation dose. Blind evaluation of image quality was conducted by 3 senior attending physicians and above, and the overall image quality was rated by 5 levels: 5 point, anatomical details distinctly displayed and can be easily evaluated; 4 point, anatomical details clearly displayed and able to evaluate; 3 point, most of the anatomical structures can be used for diagnosis, and a few anatomical structures (diaphragm, bronchial fine grading, etc.) cannot be evaluated; 2 point, basic anatomical structure is not clear and details are not enough to be found; 1 point, anatomical structure is fuzzy and cannot be used for diagnosis [39].

Data Processing

IBM SPSS Statistics 23.0 was used for statistical analysis. Pearson correlation analysis was used to analyze the correlation between DLP and height and age, and Spearman rank correlation analysis was used to analyze the correlation with sex, weight, underlying diseases and image quality. Mann-Whitney U test was used to analyze the differences between DLP and gender, image quality and underlying diseases. The effect of radiation dose was analyzed by multivariate stepwise regression analysis. P<0.05 means the difference had statistical significance. (*, P <0.05 was statistically significant, and **, P <0.01 was extremely significant. )

Abbreviations

CT: computed tomography; ALARA:as low as reasonably achievable; DLP:dose length product; SD:standard deviation; FBP:filtered back projection; MBIR:model-based iterative reconstruction; MBIRn:the new version of MBIR; IR:iterative reconstruction; ASIR:adaptive statistical iterative reconstruction;
BMI: body mass index; CTD_{vol}: volume CT dose index; ED: effective radiation dose; SSDE: size specific dose estimation; Dw: water equivalent diameter.

Declarations

Ethics approval and consent to participate

Human subjects Experimental protocols were approval by the local ethics committee of the Traditional Chinese Medicine Hospital. Written informed consent was obtained from the patient before screening.

Consent for publication

Not applicable.

Availability of data and materials

The datasets supporting the conclusions of this article are included within the article.

Competing interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

Funding

This study was supported in part by grants from the Chengdu University of Traditional Chinese Medicine 2019 “Xinglin Scholar” hospital special (YYZX2019082), Chongqing Science and Health United Medical Scientific Research Key Project (2019ZDXM022), and Science and Technology Project of Chongqing Education Commission (KYYJ202001).

Authors’ contributions

DZ conceived and designed the study. XL and QL performed the image scan. RL and YC performed the data collection and collation. TY performed the data processing. LL, XL and HY performed image quality evaluation. LF completed statistical analysis. DZ, LF, HY and GW wrote the paper. All authors read and approved the final manuscript.

Acknowledgments

Not applicable.

References

1. Zhang D. Fan L, Wang Y, et al. Lung cancer screening with low-dose CT: a study on risk factors and establishing the high-risk model for lung cancer. Chinese Journal of Radiology. 2018; 52(5): 369–73.
2. Committee of Cardiothoracic of Chinese Society of Radiology. Expert consensus of low-dose Spiral CT Lung Cancer screening. Chinese Journal of Radiology. 2015;49(5):328–35.

3. McCollough CH, Bruesewitz MR, Kofler JM. CT dose reduction and dose management tools: overview of available options. Radiographic. 2006; 26(2): 503–12.

4. Hall EJ, Brenner DJ. Cancer risks from diagnostic radiology. Br J Radio. 2008; 81: 362–78.

5. Li W, Liu JX, Wang XY, et al CT angiography of the carotid arteries with low kVp and low dose contrast media. Radiologic Practice. 2013; 28(5):482–5.

6. Naidich DP, Marshall CH, Gribbin C, et al Low dose CT of the lungs: preliminary observations. Radiology. 1990; 175:729–31.

7. Wang Q, Zhao XM, Song JF, et al Application of automatic tube current modulation on image quality and radiation dose at abdominal CT. Chinese Journal of Radiology. 2013; 47(7):648–53.

8. Zhang LY, Geng JH, Wang YB, et al Study on Relationships Between CT Dose and CT Image Quality in PET/CT. Nuclear Electronics Detection Technology. 2012; 32(3): 365–70.

9. Zhang YX, Niu YT, Zhang LL, et al A phantom study on the effects of detector coverage and pitch combined with organ dose modulation techniques on radiation dose and image quality in chest CT. Chinese Journal of Radiology. 2019; 53(6): 464–9.

10. Song SJ, Wang W, Liu CY. Relationship of radiation dose and spiral pitch for multi-slice CT system. Chinese Journal of Radiological Medicine Protection. 2006; 26(5):526–8.

11. You J, Dai Y, Huang N, et al Low-dose computed tomography with adaptive statistical iterative reconstruction and low tube voltage in craniocervical computed tomographic angiography: impact of body mass index. J Comput Assist Tomogr. 2015; 39(5): 774–80.

12. Chen Y, Xue HD, Zhang DM, et al Image quality of low-tube-voltage and high-pitch dual-energy CT angiography of the head and neck arteries using photon detectors with iterative reconstruction methods: compared with conventional detectors. Chinese Journal of Radiology. 2014; 48(7):544–50.

13. Mettler FA Jr, Bhargavan M, Faulkner K, et al. Radiologic and nuclear medicine studies in the United States and worldwide: frequency, radiation dose, and comparison with other radiation sources–1950–2007. Radiology. 2009; 253:520–31.

14. Ohno Y, Yaguchi A, Okazaki T, et al Comparative evaluation of newly developed model-based and commercially available hybrid type iterative reconstruction methods and filter back projection method in terms of accuracy of computer-aided volumetry (CADV) for low-dose CT protocols in phantom study. Eur J Radiol. 2016; 85:1375–82.

15. Wang W, Zhou CS, Lu GM. Strategies for Reducing Radiation Dose in CT Coronary Angiography. Radiologic Practice. 2014; 29(6): 610–2.

16. Dong J, Gao L, Wang XY, et al Functional parameters of pulmonary tumors in low-dose perfusion CT with different reconstruction techniques: comparison of ASIR and FBP. Radiologic Practice. 2013; 28(3): 280–3.
17. Lv PJ, Cai YR, Yan XM, et al. Effect of automatic spectral imaging mode selection and adaptive statistical iterative reconstruction at abdominal CT with low contrast agent dose. Chinese Journal of Radiology. 2016; 50(2): 122–7.

18. Wu YY, Wang WQ, Liu B, et al. Impact of reconstruction techniques on routine dose chest CT image quality: Comparison of FBP, ASiR and VEO. Chinese Journal of Medical Imaging Technology. 2012; 28(3): 575–8.

19. Yan LH, Chen F, Yao LZ, et al. Impact of pre-setted adaptive statistical iterative reconstruction Veo on radiation dose and image quality of chest CT scanning: Chest model and clinical study. Chinese Journal of Medical Imaging Technology. 2017; 33(3): 468–72.

20. Qin DX, Zhu GM, Hu FH, et al. The Exploration of 256-slice iCT Personalized Chest Low-dose Scanning Scheme. China Digital Medicine. 2018; 13(18): 19–21.

21. Zhao B. Liu YL, Li JJ. The Study of Scanning Scheme in Individuation and Low Dose Chest CT Using 256-slice iCT. Chinese Journal of CT MRI. 2017; 15(3): 62–4.

22. Zhu XL, Fan XL. Application of different body mass index (BMI) and CT model in the low-dose CT scan of lungs. Journal of Clinical Pulmonary Medicine. 2018; 23(3): 497–500.

23. Zeng GF, Yang H, Liang RR. Research progress in individualized double low dose CTA. International Journal of Medical Radiology. 2019; 42(2): 215–8.

24. Saade C, Ammous A, Abi-Ghanem AS, et al. Body weight-based protocols during whole body FDG PET/CT significantly reduces radiation dose without compromising image quality: Findings in a large cohort study. Acad Radiol. 2019; 26(5): 658–63.

25. Fang C, Liang Y. Social disparities in body mass index (BMI) trajectories among Chinese adults in 1991–2011. Int J Equity Health. 2017; 16(1): 146.

26. Chen Z, Chen ZQ, Zhong Q, et al. Study on CT Radiation Dose and Image Quality of PET/CT Based on Optimized CT Scanning Parameters According to the Weight. China Medical Devices. 2019; 34(2): 25–7, 34.

27. Agbenyegah S, Abend M, Atkinson MJ, et al. Impact of inter-individual variance in the expression of a radiation responsive gene panel used for triage. Radiat Res. 2018; 190(3): 225–35.

28. Manning G, Macaeva E, Majewski M, et al. Comparable dose estimates of blinded whole blood samples are obtained independently of culture conditions and analytical approaches. Second RENEB gene expression study. Int J Radiat Biol. 2017; 93(1): 87–98.

29. Kim SJ, Dix DJ, Thompson KE, et al. Effects of storage, RNA extraction, genechip type, and donor sex on gene expression profiling of human whole blood. Clin Chem. 2007; 53(6): 1038–45.

30. Li S, Lu X, Feng JB, et al. Effects of gender and age on expression of radiation-responsive genes in irradiated human peripheral blood samples. Carcinogenesis Teratogenesis Mutagenesis. 2019; 31(6): 421–7.

31. Kajimura J, Lynch HE, Geyer S, et al. Radiation-and age-associated changes in peripheral blood dendritic cell populations among aging atomic bomb survivors in Japan. Radiat Res. 2018; 189(1): 84–94.
32. Brink JA. Morin RL. Size-specific dose estimation for CT: how should it be used and what does it mean? Radiology. 2012; 265(3): 666–8.
33. Huda W. Metter FA. Volume CT dose index and dose-length product displayed during CT: what good are they? Radiology. 2011; 258(1): 236–42.
34. Yan K. Appel E, Thomas C, et al Tailoring CT does to patient size: implementation of the updated 2017 ACR size-specific diagnostic reference levels. Acad Radiol. 2018; 25(12): 1624–31.
35. Dougeni E. Faulkner K, Panayiotakis G. A review of patient dose and optimization methods in adult and pediatric CT scanning. Eur J Radiol. 2012; 81(4): 665–83.
36. Wang B. Wang CY, Shen J. Relationship between dose and effective dose by CT examination and application analysis. Journal of Medical Imaging. 2019; 29(2): 313–6.
37. Wang JN. Wang SW, Xu ZC, et al Application value of the two estimation methods in evaluating the radiation dose of adult chest CT. Chinese Journal of Radiological Medicine Protection. 2019; 39(9): 711–4.
38. McCollough C. Bakalyar DM, Bostani M, et al. Use of water equivalent diameter for calculating patient size and size-specific dose estimates (SSDE) in CT: The Report of AAPM Task Group 220. AAPM Rep. 2014; 2014:6–23.
39. Behrendt FF. Schmidt B, Plumhans C, et al. Image fusion in dual energy computed tomography: effect on contrast enhancement, single-to-radio and image quality in computed tomography angiography. Invest Radiol. 2009; 44(1):1–6.

Figures
Figure 1

Image Evaluation. a 85 years old, disturbance of consciousness, poor breath holding, bronchial tube truncated artifact (red arrow), classified as poor-quality image. b 75 years old, good breath holding, classified as high-quality image. c 78 years old, suffer from inflammation, poor breath holding, bronchial tube truncated artifact (red arrow), classified as poor-quality image. d 50 years old, suffer from inflammation, good breath holding, classified as high-quality image.
Figure 2

Scatter plot of individual factors and radiation dose (DLP). a Scatter plot of the age and the DLP. b Scatter plot of the height and the DLP, which has a good linear relationship. c Scatter plot of the weight and the DLP, which has a good linear relationship.