Data analysis of low dose multislice helical CT scan in orbital trauma

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Abstract

• AIM: To explore the optimal low dose of MSCT in orbital trauma examination.

• METHODS: Sixty transverse images of the fracture layer were selected. Low-dose images acquired at 30, 70, 100, 140, 170, and 200 milliampere (mA) were simulated by adding noise to the image space using software. After assessing the images according to the conditions of image quality and fracture, we found the optimal tube current that met diagnostic requirements and then applied it to clinical use. The CT Dose Index volume (CTDIvol), dose length product (DLP) and effective dose (ED) were recorded. The image quality was classified as good, fairly good, ordinary, poor, or very poor according to image level, noise, anatomic structure and whether the diagnostic requirements were met or not. The rank-sum test was used to perform statistical analysis on the ranked data. The Chi-square test was used for the numerical data.

• RESULTS: Under the scan conditions of a conventional dose of 300 mA, 60 cases of orbital fracture, 38 cases of orbital emphysema, 25 cases of ocular damage, and 3 cases of intraorbital foreign body were demonstrated in the images of the 60 orbital trauma patients. Among the low dose simulated images, the image quality difference of the different doses was of statistical significance (χ^2 =15.678, P =0.016). When the dose was lowered to 70 mA, the above mentioned clinical signs were still clear and diagnostic, however the image quality assessment results indicated that 2 cases were good, 16 cases were fairly good, and 42 cases were ordinary, poor or very poor. When the simulated dose tube current was 100mA, the image quality assessment results were 18 cases good, 34 cases fairly good, and 8 cases ordinary, poor and very poor; compared with the conventional dose, there was no statistical significance (P> 0.05). When using a 100 mA tube current to examine 40 cases of orbital trauma patients in the clinic, the acquired image quality was 10 cases good, 26 cases fairly good and 4 cases ordinary, without any cases of poor or very poor. The CTDIvol, DLP and ED were 20.72mGy, 124.97mGy·cm and 0.26mSv, respectively, while the CTDIvol, DLP and ED were 62.53mGy, 375.18mGy·GTtl and 0.86mSv, respectively, when using a conventional dose of 300mA. Compared with the tube current of 100mA for scanning, the ED declined 70%.

• CONCLUSION: When conducting an MSCT scan for orbital trauma, the acquired images using the 100 mA tube current can meet the clinical diagnostic requirements, and the radiation dose to the patients can be decreased.

• KEYWORDS: orbit; radiation dose; body section radiography; X-ray computed tomography

INTRODUCTION

CT scans of the orbit, one of the routine examination methods for orbital trauma lesions, play a large role in the diagnosis and treatment for the diseases of the orbit. However, the possible harm from radiation inherent to the use of X-rays in the CT scan has attracted increased attention from patients [1-5]. With the popularization of CT scanning and increases in the numbers of patients presenting with orbital trauma, the orbital CT scan is becoming more common. Because there is a risk to the lens for damage from X-rays, methods for its protection have drawn increasing attention from researchers and clinicians. The International Commission on Radiological Protection (ICRP) proposed three principles of radiation protection, that is, justified practice, optimization of protection and individual dose limits [6]. The ocular lens is one of the most radiosensitive organs. Therefore, the X-ray hazard to the ocular lens and methods for its protection should be paid more attention in order to decrease the radiation dose to the ocular lens when conducting orbital trauma CT scans. At

present, there are few reports in the literature about how to decrease the CT scan dose and protect the ocular lens from radiation damage, and the sample sizes are comparatively small[7-9].

Optimization is a planned and systematic activity applied to the whole process of correct diagnosis after minimizing cost and the lowest dose to acquire a useful image [6]. Therefore, we conducted experimental research and clinical observations for 60 orbital trauma patients and explored the influence of different tube currents on image quality in MSCT examinations so that we could accurately determine the optimal tube current that meets diagnostic requirements.

MATERIALS AND METHODS

Subjects This research included two parts. First, 60 patients' transverse plane images which demonstrated fracture in the orbital wall were acquired with systemic low dose CT simulation. Among the 60 cases, 9 were female and 51 were male, aged between 12-76 years old with an average age of (33.6±17.3) years old. Then, according to the optimal low dose determined from the simulation research, the CT scan was given to the 40 orbital trauma patients, and the feasibility of the low dose condition was detected. Among the 40 cases, 13 were female and 27 were male, aged between 22-61 years old with an average age of (37.5±8.4) years old.

Methods

Detection method A GE Light Speed VCT64 slice CT (General Electric Co., USA) was used to scan the patients. The scanning conditions for the 60 patients of the first section were a tube voltage of 120kV, current 300 milliampere (mA), rotation speed 1s/r, pitch l, detector thickness 0.625mm. Both the bone algorithm and canonical algorithm were used for image reconstruction, and the thickness of the layer was 2.5mm.

Experimental method In this work, a repeatable low dose CT scan was simulated by adding noise in image space. The calculation of noise was based on the correction parameter used for the AutomA technology in the CT machine which can calculate the image noise with different mA according to the patients' actual absorption, and the required mA value for a certain image noise was obtained [10].

In the first part, 60 orbital wall fracture transverse plane images were selected. Low-dose images acquired with tube currents of 30, 70, 100, 140, 170, 200, and 300mA were simulated by adding noise software in the image space. Imaging under software window (window width 350 HU, window level 40 HU) and bone window (window width 2000 HU, window level 600 HU) using the same laser camera with the original images, then we numbered the CT scans and covered the scanning condition record for each image. Two senior radiologists assessed the images together according to the image quality and fracture demonstration

condition. The optimal low dose (tube current) meeting the diagnostic requirement was then found.

In the second part, the tube current was decreased to 100 mA and maintained other scanning conditions unchanged when conducting CT examinations for 40 orbital trauma patients. The quality of each of the obtained images was assessed. The automatically demonstrated dose indexes-CTDIvol and DLP were recorded. Effective dose (ED, mSv) is the cross product of DLP and k, and k is the conversion factor. Referring to the CT quality standard guideline [11] put forward by Commission of the European Union, k= 0.0023 mSv/(mGy[1]•cm), we got the ED value of the second group.

Image assessing method In the first part, the trauma signs of os orbitale and soft tissue were analyzed, and the image quality was assessed. The CT features include orbital fracture, orbital emphysema, ocular damage, and intraorbital foreign body, etc. In the second part, the image quality was assessed. The image quality was rated according to five levels: good: clear image level, particles are uniform in size, anatomic structure is well demonstrated, meeting diagnostic requirement; fairly good: fairly clear image level, particles are comparatively uniform in size, anatomic structure can be clearly demonstrated, meeting diagnostic requirement; ordinary: general image level, particles are not uniform in size, anatomic structure can be demonstrated, meeting diagnostic requirement; poor: not clear image level, coarse particles, anatomic structure is ambiguous, not reaching diagnostic requirement; very poor: image level is very unclear, coarse particles, anatomic structure is ambiguous, not reaching diagnostic requirement.

Statistical Analysis In this study, SPSS 10.0 software package was used for data management and statistical analysis. The rank sum test (Kruskal-Wallis test) was used for ranked data. The Chi-square test was used for numeration data. P<0.05 was taken to indicate a difference of statistical significance.

RESULTS

Simulation Results of Low Dose CT CT features of different doses were displayed in Table 1. Except in the condition of 30 mA, one case of tiny orbital fracture could not be displayed and two cases of ocular damage could not be definitely diagnosed, orbital fracture, orbital emphysema and ocular damage could be clearly demonstrated and meet diagnostic requirement in other low dose conditions. In this group, high-density foreign objects can be clearly displayed in the images of all doses. The image quality grading of 7 different doses were compared by multi-group rank-sum test (Table 2). The results showed that the image quality difference of different doses had statistical significance (χ^2= 15.678, P=0.016). When the tube current was 30mA, most image qualities were poor, and we could not make a specific

Table 1 Comparison of the CT scan features of different lesions in seven different doses

Displayed focus(n)	Tube current (mA)							X^2	P
	30	70	100	140	170	200	300		
Orbital fracture	60	39	60	60	60	60	60	6	0.423
Orbital emphysema	38	37	38	38	38	38	38	6	0.423
Ocular damage	25	19	25	25	25	25	25	6	0.423
Intraorbital foreign body	3	3	3	3	3	3	3	0	1

Table 2 Comparison and results of the image quality assessment of standard dose and simulate low dose

Image quality	Tube current(mA,n)						
	30	70	100	140	170	200	300
Good	0	2	18	24	28	28	31
Fairly good	0	16	34	24	20	22	20
Ordinary	12	42	8	8	12	10	9
Poor	42	0	0	0	0	0	0
Very poor	6	0	0	0	0	0	0

diagnosis. When the tube current was 70mA, although all of the orbital fracture and orbital emphysema could be clearly displayed, the soft tissue window showed that the particles in the images were coarse, and most image qualities were ordinary. When the tube current was 100, 140, 200 or 300mA, we could make a clear diagnosis to the damage to all the images, and all the qualities of the images were for the most part, fairly good or good which meets the diagnostic requirement in the clinic.

Experimental Result of the Second Part According to the experimental results obtained in the first part, 100 mA was used when we scanned the 40 orbital trauma patients in the second part, and the scan range was controlled within 60 mm. Under this scanning condition, the CTDIvol, DLP and ED were 20.84 mGy, 125.04 racy•cm and 0.29 mSv, respectively; while the CTDIvol, DLP and ED were 62.53 mGy, 375.18 mGy•GTtl and 0.86 mSv respectively when using a conventional dose of 300 mA. Compared with the conventional dose, the ED declined 70% when using a tube current of 100 mA for scanning. The acquired image quality was good in 5 cases, fairly good in 13 cases, ordinary in 2 cases, and all met the diagnostic requirements in clinic (Table 2). Multiple comparisons of data in each group through the rank-sum test found that the difference between the 30, 70 mA group and the other dose group was of statistical significance (P<0.05), when the 30 mA group compared with the other 6 groups, the z values were 19.2, 20.8, 19.2, 19.2, 20, and 20.6, respectively, when the 70 mA group compared with the other 5 groups, the z values were 13.6, 12, 12, 12.8, and 13.4, respectively. The difference of the group comparison among the groups over 100 mA was of no statistical significance (all P<0.05).

DISCUSSION
The 60th publication in 1991 of the ICRP clearly indicated

that medical exposure must obey the principles of justification and system optimization in limiting dose [12]. With the rapid development of CT equipment and the popularization of its application in the clinic, how to optimize scanning studies to obtain images of sufficient quality to diagnose in a low dose condition has been the research focus in clinic. An ancillary benefit to this goal is that low dose scanning can effectively prevent the excessive heating of the bulb tube and prolong its service life.

Due to the potential hazard of X-rays to the human body, it is not possible to establish the optimal scan condition through repeat scans of the same patient [13]. The simulation method of adding analog noise through a computer can make full use of the current large cases. This approach can avoid the problem of repeat scans of the research objects (patients), and the accuracy of the experimental result is high because there are reliable diagnostic results that can be used to conduct a one-one comparison. Some researchers have studied the nasal sinus and abdomen computer simulation methods and have achieved good results [14, 15]. In the first part of this work, we simulated a noise experiment by adding noise in image space using software. After getting the optimal low dose by image quality assessment, we applied it in the clinic, which avoided the requirement to do multiple CT scans at different doses to the same patient in clinic and thus decreased the subjects' radiation dose.

Research into low dose examinations of the chest has achieved similar findings as low dose research of temporal bone and nasal sinus [16, 17]. The orbit has the anatomic characteristics that make it a candidate for low dose examination because the organizational structures of the orbit have large density differences, which has good natural contrast. The lens is a radiosensitive organ, and it is known that radiation dose above a threshold can cause radiation cataracts [18-20]. Therefore, it is very important to perform a low dose scan for the evaluation of lesion in the orbit. This study has provided useful data for the performance of low dose CT of the orbit.

The results of the first part in this research indicated that except in one case, a very small fracture could not be displayed at 30 mA; all the other simulated low dose images observed with the bone window could clearly demonstrate the sclerotin changes of the os orbitale. After soft tissue

observation, when the tube current was 70 mA, the noise of the CT image was increased, the image was coarse and the image quality was mainly ordinary. When the tube current was 30 mA, coarse particles can be seen in the lens, vitreous body, and musculi oculi etc. The image quality assessment was mainly poor, which does not meet the diagnostic requirements. When we integrated the image quality assessment of the bone window and soft tissue window, the results indicated that the optimal low dose value meeting the diagnostic requirement was 100mA. At this tube current, the achieved image qualities were fairly good and good, which can clearly indicate the organizational structure and meet the diagnostic requirement. However, in this work we did not investigate problems such as low density foreign bodies and intraocular hematoma. According to some studies, common low dose helical CT has little influence on high density foreign bodies, but the demonstration of a low density foreign body is poor [21,22]. Therefore, the display of low density foreign bodies and intraocular hematoma needs further study.

The ED is the scanned result by CMSCT, and ED is the cross product of the conversion coefficient k and DLP which is the cross product of CTDIvol and the scan length of z axis (L). Some have reported that CT dose weighted index (CTDlw) expresses the mean dose in a certain CT scan fault plane, which was not suitable to the multispiral volume scanning [21]. It can be seen that when we decrease the subjects' radiation dose by decreasing the tube voltage, tube current, and the length of z axis, etc. In this study, we decreased the tube current which is comparatively simple and easy to achieve. The results of the computer simulated experiment and clinical application indicated that the radiation dose absorbed by the patients declined 70% when using a tube current of 100 mA for scanning with other scanning conditions unchanged.

In summary, the simulation of adding noise to the image space provided scientific and reliable data for clinical use and simplified the research process. Low dose MSCT of the orbit can decrease the lens radiation dose to the patients, realizing the optimization principle of medical imaging, and clearly display the regional anatomic structure. Furthermore, it can prolong the CT bulb tube's life and thus reduce operating costs.

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