Clinical significance of prospective ECG-gated dual-source CT in centralvenous angiography

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ABSTRACT

Background: The study aimed to elucidate the clinical application significance of prospective ECG-gated dual-source CT in central venous (CV) imaging. ***Materials and Methods***: Eighty patients who took CT imaging of CV (CTV) check using dual-source Force CT were enrolled. The control group (helical pitch, 0.8; rotation speed, 0.5 s) and the experimental group (rotation speed, 0.25 s). For both groups, image quality and radiation dose were computed. ***Results***: Cases in the experimental group required longer scanning durations than those in the contro lgroup. In respect to the experimental group, the image quality scores of the superior vena cava and left and right brachiocephalic veins of the patients sharply increased relative to those in the control group. Individuals in the experimental group also presented better image quality scores in left and right subclavian veins, left and right jugular veins, however, this difference was not statistically significant. Lastly, no increase in the radiation dose was bited with the application of prospective ECG gating. ***Conclusion***: The clinical use of prospective ECG-gated technology significantly reduced cardiovascular pulsing artifact interference on the central vein, especially the superior vena cava segment, and remarkably improved the image quality without increasing the radiation dose to patients.

INTRODUCTION

The central vein comprises the superior vena cava and its main branches, including the bilateral brachiocephalic vein, subclavian vein, and internal jugular vein [1, 2]. It's the main route of blood following back to the heart [3, 4]. Central venous (CV) access is an essential for maintaining hemodialysis patients to establish cardiopulmonary bypass [5]. Long-term indwelling central venous catheters contribute to the occurrence of central venous stenosis (CVS), which is a prominent reason for lossing of dialysis vascular access [6, 7]. Clinically, >20% of all dialysis patients require central venous catheters for dialysis vascular access [8]. Therefore, the early diagnosis of central venous stenosis and interventions for avoiding it are crucial for prolonging the life of the vascular access.

Doppler ultrasound and angiography are essential imaging techniques for diagnosing CV vascular dysfunctions [8]. However, due to gas interference, ultrasound can not accurately detect the central vein [8]. Angiographyis the gold criteria for diagnosing vascular diseases [9], however, digital subtraction angiography (DSA) is an invasive test and can just demonstrate the vessel lumen with bloodflow and cannot show the spatial relationship between adjacent tissue structures [10]. Presently, CTV of the central vein is mainly performed using conventional spiral CT scans [11]. However, the beating of the heart and aorta generates artifacts during the imaging of the central vein [12]. Prospective ECG-gated technology is being widely used in coronary CTA imaging [13, 14], nevertheless, its application in central vein CTA is yet to be reported.

The study first investigated the application significance of the prospective ECG-gated method in CT imaging of CV (CTV), in order to provide some theoretical basis for its clinical application.

MATERIALS AND METHODS

Study population

Eighty patients who took CTV examination by Siemens third-generation dual-source ForceCT in Beijing Shijitan Hospital from June 2019 to March 2022 were recruited. Two groups of control group and experimental group were constructed. Cases in the control group were scanned at the conventional helical scanning mode, while cases in the experimental group were scanned at the prospective ECG-gated scanning mode. Patients had the below conditions were excluded: (1) allergy to an iodinated contrast agent; (2) can not cooperate with breath-holding; (3) heart, liver, or renal dysfunction; (4) severe arrhythmia. The study was performed under the license of the Ethics committee of Beijing Shijitan Hospital (approval number: sjtkyll-lx-2019-7) on 9th April 2019, and all patients endorsed

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informed consent.

Examination method

A Siemens third-generation dual-source CTscanner (SomatomForce, Siemens Healthineers, Forchheim, Germany) was applied for scanning the patients from the mandibular angle to the diaphragmatic plane. All patients underwent breath hold training prior to the scans. Apart from these, all other scanning parameters were different between the two groups. The control group patients were scanned at a helical pitch of 0.8 and a rotation speed of 0.5 s; whereas, the experimental group patients were scanned at a rotation speed of 0.25, and the system automatically reconstructed the optimal phase image. Iodoproamine (370 mgI/mL), a non-ionic contrast agent, was given via the median cubital vein with a dose of 1.5 mL/kg and an injection rate of 4.0 mL/s. The intravenous scanning was performed at 40-50 s after giving contrast agent.

Image quality evaluation

Thin-layer images (0.75 mm layer thickness and 0.5 mm layer spacing) were reconstructed for all the patients, then Syngo VIA post-processing workstation (Siemens Healthineers, Forchheim, Germany) was applied for the image analysis. The image quality was analyzed by maximum intensity projection (MIP), multi-planner reconstruction (MPR) and volume reproduction. Two experienced radiologists used a double-blind method to evaluate the image sharpness of seven segments of the central veins in both groups, including the superior vena cava, the left and right brachiocephalic veins, the left and right subclavian veins, and the left and right jugular veins. In case of differences of opinion, the radiologists concluded via a discussion.

Each image was scored from 0 - 5 (15). The scoring was as follows: 1, the lumen could not be identified and could not be used for diagnosis; 2, blurred vascular margins and obvious motion artifacts; 3, moderately blurred vascular margins with moderate motion artifacts, but it does not affect the diagnosis; 4, slightly blurred vascular edge with mild motion artifacts; and 5, clear blood vessel edges without motion artifacts.

Calculation of radiation dose

The computed tomographic dose index (CTDIvol) and dose length product (DLP) were obtained voluntarily from CT. According to the formula ED (mSv) = DLP × k, the effective dose (ED) was calculated, and the conversion factor k was 0.017 mSv/(mGy cm).

Data analysis

Data analysis was performed by SPSS 24.0 software. The χ2 test or an independent sample *t-test* was employed to compare the variable differences. *P*<0.05 was set as the significant standard.

RESULTS

Basic clinical data of the study population

Each group comprised 40 patients (table 1). 28 males and 12 females made up the control group, while the experimental group had 25 males and 15 females. Data on the age, BMI, heart rate and scan length were also compared between the two groups, and no significant difference was tested between the two group (*P*>0.05). However, relative to control group, cases in the experimental group required a longer scanning duration (*P*<0.05).

Table 1. Basic clinical data of the patients.

Items	Control group	Experimental group	P value
Sex, male/female	28/12	25/15	0.478
Age, years	57.69 ± 9.93	61.61 ± 11.21	0.102
BMI, kg/m^2	24.56 ± 2.45	23.68 ± 1.79	0.072
Heart rate, beats/min	75.56 ± 15.47	75.88 ± 11.00	0.915
Scan length, mm	241.99 ± 22.01	240.37 ± 19.99	0.732
scanning time, s	3.34 ± 0.33	10.22 ± 0.88	< 0.001

Note: BMI, body mass index.

Comparison of the image resolution of the two study groups

The image resolution of the two groups was compared (table 2). The non-parametric test results indicated that the image quality score of the superior vena cava, left and right brachiocephalic veins of the patients in the experimental group sharply increased relative to those in control group (*P*<0.05). Additionally, between the two groups, the experimental group showed better image quality scores of left and right subclavian veins, left and right jugular veins with no remarkable difference (*P*<0.05).

Table 2. comparison of the image quality scores of the two study groups.

Items	Control group	Experimental group	*P* value
Superior vena cava	3 (3, 4)	4 (4, 4)	0.002
Left brachiocephalic vein	4 (3, 4)	4 (4, 5)	0.005
Right brachiocephalic vein	3 (2, 4)	4 (4, 5)	< 0.001
Left subclavian vein	4 (4, 5)	4 (4, 5)	0.785
Right subclavian vein	4 (4, 5)	4 (4, 5)	0.090
Left jugular vein	4 (4, 5)	4 (4, 5)	0.335
Right jugular vein	4 (4, 5)	4 (4, 5)	0.829

Comparison of radiation dose of various study groups

DLP, CTDIvol and ED values were calculated for evaluating the radiation dose. Notably, no remarkable difference was seen in the results of DLP, CTDIvol, and ED values between the control group and the experimental group (*P*>0.05) (table 3). This discovery suggested that the application of prospective ECG gating did not increase the radiation dose.

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Table 3. comparison of the radiation dose of the two study groups.

Items	Control group	Experimental group	*P* value
DLP, mGy/cm	245.49 ± 27.20	243.29 ± 21.84	0.690
CTDIvol, mGy	9.33 ± 0.95	9.07 ± 0.89	0.219
ED, mSv	4.17 ± 0.46	4.14 ± 0.37	0.690

Note: DLP, dose length product; CTDIvol, computed tomographic dose index; ED, effective dose.

DISCUSSION

As an important route of blood returning to the heart, the patency of the central vein is very important [16]. CVS can lead to clinical symptoms, such as lateral limb swelling, venous skin ulceration and so on [17, 18]. CVS occurs due to various reasons, such as long-term catheterization and local tumor invasion [19, 20]. Since most CVS patients have other comorbidities and their clinical symptoms are more critical, it is important to detect CVS early on.

Currently, multi-slice spiral CT angiography (MSCTA) has emerged as an important imaging examination mean for diagnosing central venous vascular diseases [21]. During routine spiral CT scanning, various types of image artifacts are encountered [22]. The most common artifacts are motion artifacts, including respiratory motion and heartbeat artifacts [23]. The appearance of motion artifacts often blurs the image, affects the diagnosis, and ultimately leads to disease progression [24]. Presently, ECG-gated technology, including retrospective ECG-gated technology and prospective ECG-gated technology, the most effective method to VOID cardiac motion artifacts. These have been widely used in examining heart diseases, especially coronary artery diseases [25]. The prospective ECG-gated technique adopts a step scanning mode and synchronizes the scan with the ECG [26]. Retrospective ECG-gated scanning collects scanning data from multiple complete cardiac cycles, and records the patient's ECG signal simultaneously. Next, it reconstructs the original data retrospectively to obtain the best image [27]. Thus, retrospective ECG-gated scanning can substantially increase the radiation dose when the whole process is scanned while recording the ECG, whereas, prospective ECG-gated scanning [28]. In the current study, a Siemensthird-generation dual-source CTscanner was used for scanning. We found no significant difference between the experimental group and the control groups, thus demonstrating that the application of prospective ECG gating did not increase the radiation dose.

In addition to high temporal and spatial resolution, the Siemens third-generation dual-source CT has extremely high temporal resolution and spatial resolution [29]. Due to the inclusion of two X-ray tubes and two corresponding 96-row detector systems, a single scan can cover a width of 1920.6 mm, ensuring a CTV imaging of the central vein can be performed within 5-6 cardiac cycles [30]. The present results illustrated that the average scanning duration of experimental group seemed to be long relative to control group. However, compared with experimental group, the image quality of control group was worse, especially for the superior vena cava segment. The main reason for this was the cardiac and vascular pulsing artifacts, followed by respiratory movement artifacts in the lungs. Thus, prospective ECG-gated technology can effectively reduce cardiac and vascular pulsing artifacts and improve the image quality of brachiocephalic and superior vena cava segments. However, the jugular vein and subclavian vein image qualities in both groups were high, and noremarkable difference was tested between them, indicating that the image quality of prospective ECG-gated group was not affected by the prolonged scanning duration. These findings may be because the subclavian vein and jugular vein are distint from the lungs and heart vessels and are less disturbed by motion artifacts.

This study has some limitations. First. we only evaluated the advantages and disadvantages of the conventional scanning method and gated scanning method from the perspective of inspection technology, and did not involve the accuracy of the diagnosis. Second, the retrospective ECG-gated scanning method was not included in the comparison, and further studies are required to verify the presented results.

In conclusion, the clinical application of prospective ECG-gated technology significantly reduced the interference of cardiovascular pulsing artifacts on the central vein, especially on the superior vena cava segment, and it significantly improved the image quality without increasing the radiation dose.

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Ethical consideration: The study was performed under the license of the Ethics committee of Beijing Shijitan Hospital (approval number: sjtkyll-lx-2019-7) on 9th April 2019, and all patients endorsed informed consent.

Author contribution: XL and RGW conceptualized and designed the study. YLD, WL, ZBH and ZYL collected, organized, and drafted the information. XL, YLD and WL analyzed the data. XL wrote the manuscript. RGW performed manuscript revision. All the authors have read and approved the manuscript.

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