Original Investigation

Monochromatic Spectral Computed Tomography with Low Iodine Concentration Contrast Medium in a Rabbit VX2 Liver Model: Investigation of Image Quality and Detection Rate

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Abbreviations and Acronyms

ASiR adaptive statistical iterative reconstruction

FBP filtered back projection

SNR signal-to-noise ratio

CNR contrast-to-noise ratio

CTDIvol CT dose index volume

DLP dose length product

ED effective dose

Rationale and Objectives: This study aimed to validate the feasibility of using virtual monochromatic spectral computed tomography (CT) with isotonic low iodine concentration contrast medium for VX2 hepatic tumors.

Materials and Methods: Sixty New Zealand white rabbits with implanted VX2 hepatic tumors underwent two-phase contrast-enhanced spectral CT imaging on the 14th day after tumor implantation. They were randomly divided into groups A, B, and C, with 20 rabbits each (group A: 270 mg I/mL, monochromatic spectral images; group B: 370 mg I/mL, conventional 120 kVp images, 100% filtered back projection [FBP]; group C: 270 mg I/mL, conventional 120 kVp images, 100% FBP). Group A was further divided into two subgroups (subgroup A1: 100% FBP; subgroup A2: 50% FBP + 50% adaptive statistical iterative reconstruction). Objective evaluation (signal-to-noise ratio [SNR], contrast-to-noise ratio [CNR], and image noise), subjective rating score (image noise score, anatomical details score, overall image quality score, and lesion conspicuity score), CT dose index volume, and dose length product were compared between groups during two-phase contrast enhancement. The detection rates of the four groups were calculated as percentages.

Results: Image noise (SNR and CNR) among the four groups was statistically significant ($P < 0.05$). The image noise in group A2 was lower than in group A1, but higher than that in groups B and C ($P < 0.05$). SNR and CNR in group A2 were the highest, followed by group A1, and group C was the lowest ($P < 0.05$ for all). The image noise score of group A2 was higher than that of the other three groups. In terms of the anatomic details score, the overall image quality score, and the lesion conspicuity score, the images of group A2 were superior to that of groups A1 and C. For hepatic tumor diameters more than or equal to 1.0 cm and less than 3.0 cm, group A achieved a higher detection rate than groups B and C. The CT dose index volume, dose length product, and effective dose in group A were significantly lower than that in groups B and C ($P < 0.05$). On average, group A reduced the effective radiation dose by 27.2% compared to group B, whereas group B reduced the effective radiation dose by 28% compared to group C. Group A reduced the iodine load by 22.86% compared to group B.

Conclusions: The use of monochromatic images combined with 50% adaptive statistical iterative reconstruction with an isotonic low concentration contrast medium of 270 mg I/mL can optimize image quality, reduce image noise, increase detection rate for small tumors, and decrease radiation dose and iodine load in hepatic tumor CT examinations.

Key Words: Spectral computed tomography; rabbit VX2 liver model; image quality.

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INTRODUCTION

The high iodine concentration in contrast agents or fast injection rates in computed tomography (CT) contrast-enhanced scanning can produce high-quality images; however, it can expose the patient to an increased radiation dose and place a high burden on the kidneys (1,2). McDonald et al. (3) and Silver et al. (4) found a close relationship between the dose of contrast agents and the occurrence of contrast-induced nephropathy. Moreover, reducing the injection dose of a contrast agent could further reduce the risk of intravenous access failure, which could especially benefit patients with poor venous access (5).

Currently, scholars are concerned about low-dose scanning for patients, that is, reducing the radiation dose as much as possible and still ensuring good CT image quality (6,7). Dual-energy spectral CT capable of rapidly alternating between two peak voltage settings (140 kVp and 80 kVp) allows the reconstruction of conventional polychromatic images corresponding to 140 kVp and monochromatic images with energies ranging from 40 to 140 keV, which provides the ability to reduce beam-hardening artifacts and optimize contrast with monochromatic energy (8,9). Compared to traditional filtered back projection (FBP), a new low-dose spectral scanning technique called adaptive statistical iterative reconstruction (ASiR) for spectral CT was reported to reduce image noise, improve image quality, and reduce the radiation dose during contrast-enhanced CT (10). Because of the upgrade of CT postprocessing software, it was feasible to reconstruct monochromatic spectral CT images using the ASiR technique.

A rabbit model bearing VX2 hepatic tumors has been widely used in evaluating functional imaging and interventional effects (11). In this study, monochromatic spectral CT with a low iodine concentration contrast medium was used to evaluate the image quality and detection rate of hepatic tumors compared to conventional 120 kVp CT images and images with a high iodine concentration contrast medium.

MATERIALS AND METHODS

Animals

This study was conducted in accordance with the guidelines of the National Institutes of Health for the care and use of laboratory animals and was approved by the local animal ethics committee. A flowchart for the experiment is described in Figure 1. Sixty healthy New Zealand white rabbits (male or female, 2.0–3.0 kg) were supplied by the Henan Medical Animal Research Center (Zhengzhou, China). The rabbits were randomly divided into groups A, B, and C, and each group contained 20 rabbits.

Preparation of the VX2 Tumor Cells

Rabbits bearing VX2 tumors were provided by the Medical Animal Research Center of Zhongshan University (Guangzhou, China). A solid palpable mass had developed in the inguinal region by about 23 days after implantation. The rabbits were anesthetized with an injection of 10% chloral hydrate (7–8 mL/kg); subsequently, the gray tumors were carefully dissected and cut into small pieces under aseptic conditions.

A Rabbit VX2 Hepatic Tumor Model

The healthy rabbits were anesthetized, and the left lobe of the liver was exposed through a midline abdominal incision. The liver parenchyma was punctured using smooth forceps to create a small nick. Fresh VX2 tumor masses (~2 mm^3) were implanted into the nick, and then the wound was closed. The rabbits were treated with gentamicin at a dose of 80,000 units by intraperitoneal injection on the day of the operation and intramuscularly for 3 days afterwards.

Spectral CT Examination

After 14 days of tumor inoculation, spiral CT was performed with a spectral CT scanner (Discovery CT750 HD,

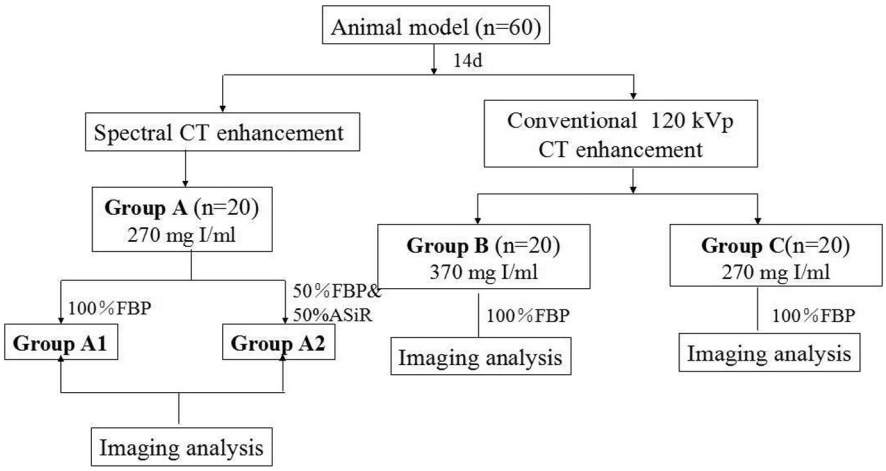

Figure 1. Flowchart of the experimental study.

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