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Balancing Image Quality and Iodine Intake: Insights from CT Spectral Imaging of the Portal Vein

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Statistical Analysis C
Data Interpretation D
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Background: Portal vein tumor thrombus (PVTT) is a critical complication in hepatocellular carcinoma (HCC). Spectral computed tomography (CT) is increasingly used to enhance the diagnosis of such conditions. This study examines the effect of different iodine concentrations in contrast media on portal vein image quality and iodine intake using spectral CT to improve imaging techniques.

Material/Methods: A total of 88 patients were divided into 3 groups based on iodine concentration in contrast media: Group A (300 mgI/mL, n=30), Group B (320 mgI/mL, n=28), and Group C (350 mgI/mL, n=30). Each underwent a GSI scan with an injection rate of 4.5 mL/s and a dose of 1.5 mL/kg. Eleven sets of 40-140 keV images were reconstructed for each group. CT value, image noise, contrast noise ratio (CNR), signal-to-noise ratio (SNR), and subjective image scores of intra-hepatic and extra-hepatic portal veins were analyzed. Optimal monochromatic levels and iodine intake were assessed for each group.

Results: The optimal monochromatic level for portal veins was between 80 keV-110 keV across groups. Significant differences were noted in CT values and image noise among groups ($P<0.05$), but not in CNR, SNR, or subjective scores ($P>0.05$). Iodine intake was reduced by 21.29% in Group A and 14.60% in Group B compared to Group C.

Conclusions: GSI scans with low-concentration contrast media effectively reduce iodine intake while maintaining image quality during liver CT-enhanced scans.

Keywords: **Portal Vein • Radiographic Image Enhancement • Contrast Media • Iodine**

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Introduction

Based on global cancer statistics from 2022 [1], approximately 865 300 new cases of primary liver cancer (PLC, hereafter referred to as liver cancer) were reported, making it the sixth most common cancer worldwide. Additionally, about 757 900 deaths were attributed to liver cancer, ranking it as the third leading cause of cancer-related deaths globally. In China alone, there were 367 700 liver cancer cases, placing it fifth in cancer incidence, with 316 500 deaths, making it the second leading cause of cancer-related mortality [2]. Hepatocellular carcinoma (HCC) is the predominant pathological type of PLC, accounting for 75-85% of cases [2]. This type of cancer easily invades nearby hepatic blood vessels, including main portal veins and their branches, hepatic veins, and inferior vena cava. Among these, portal vein tumor thrombus (PVTT) is the most prevalent form of vascular invasion and is associated with a particularly poor prognosis. The incidence of PVTT ranges from 44% to 62.2% [3,4], with untreated patients having a median survival time of just 2.7 months. Unfortunately, most cases are diagnosed at advanced stages. Early detection of liver conditions involving vascular complications is thus critical for developing effective treatment plans, improving prognosis, and enhancing quality of life.

At present, CT examination technology is more and more widely used in clinical application. Enhanced CT scan has important clinical value in diagnosing trauma, inflammation, tumors, and vascular diseases. For tumors, multiple phases of enhanced CT scans are often necessary during detection, treatment, and follow-up [5]. However, the risks associated with CT, including ionizing radiation and iodine contrast-induced nephropathy, cannot be overlooked, especially for overweight patients. To address these concerns, optimizing CT protocols is vital. It includes choosing optimal contrast media and iodine concentrations, and minimizing contrast medium dose to ensure patient safety [6,7].

In recent years, spectral CT imaging (GSI) is being widely used. This technology produces 101 sets of virtual monochromatic images within an energy range of 40-140 keV. By refining the contrast-to-noise ratio (CNR) curve, it allows for optimal visualization of blood vessels against surrounding tissues. Studies have shown that spectral CT can substantially reduce the amount of iodinated contrast medium required, highlighting its clinical relevance [8-10]. This study seeks to evaluate how different iodine concentrations in contrast media influence portal vein image quality and iodine intake when using spectral CT.

Material and Methods

Research Methods

This study was approved by the First Affiliated Hospital of Guangxi Medical University Ethical Review Committee (Approval Number: 2024-E787-01, Date of Approval: November 02, 2024) and conducted under its supervision. All patients or their immediate family members were informed and signed written informed consent prior to the examination. We prospectively enrolled 88 patients who underwent upper abdominal spectral CT scans for focal liver lesions from February to December 2023 at the Department of Radiology, the First Affiliated Hospital of Guangxi Medical University. The patient's age, sex, height, weight, tumor location, maximum tumor diameter, cirrhosis and hepatitis infections, AFP, among others were collected as baseline characteristics. Based on the iodine concentration of administered contrast medium, 88 patients were divided into 3 groups: Group A (n=30, iodine concentration: 300 mgI/mL; mean age: 53.00±10.29 years old, age range: 32-68 years old; 4 females, 26 males), Group B (n=28, iodine concentration: 320 mgI/mL; mean age: 56.82±10.34 years old, age range: 41-79 years old; 6 females, 22 males), and Group C (n=30, iodine concentration: 350 mgI/mL; mean age: 54.53±11.74 years old, age range: 31-76 years old; 3 females, 27 males).

Inclusion criteria were as follows: (1) Liver disease had no significant impact on vascular observation; (2) Clinical data were complete, with good mental status and no contraindications to examination.

Exclusion criteria were as follows: (1) People with severe hepatic or renal insufficiency; (2) People allergic to iodinated contrast media; (3) People with coagulation disorders or autoimmune diseases; (4) People with psychiatric disorders or cognitive impairment. The inclusion and exclusion process is shown in **Figure 1**.

Technical Parameters

Enhanced upper abdominal scans were performed using a GE Revolution 256 Slice CT Scanner (GE Healthcare, USA), with patients placed supine, head first. A routine plain scan of the upper abdomen was first performed with a tube voltage of 120 kV and automatic tube current modulation. The scan range extended from the diaphragm dome to the lower poles of both kidneys. After the lesion was located, a one-stop spectral CT scan centered on the lesion was performed. A DUAL SHOT alpha contrast injector (Nemoto Kyorindo, Japan) was used to administer the contrast medium through the antecubital vein. The contrast medium dose and flow rate were set at 1.5 mL/kg (body weight) and 4.5 mL/s, respectively. Then 30 mL of normal saline was injected at the same flow rate. Spectral enhanced scans were performed approximately 33 seconds, 65

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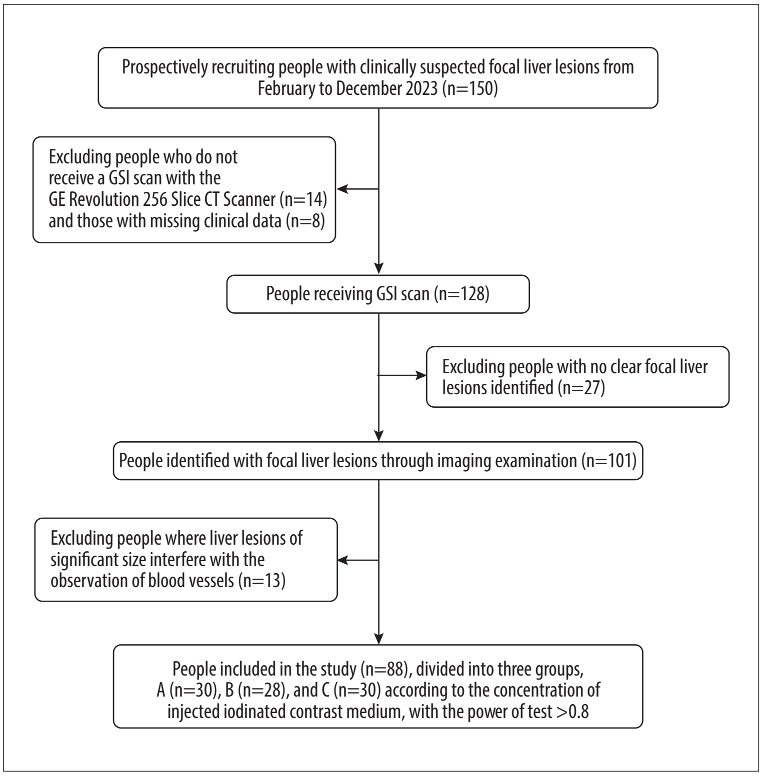

Figure 1. Flow chart of patient screening. *Figure was created using Microsoft Word (version 2021, Microsoft Corporation).*

seconds, and 127 seconds after contrast medium injection to obtain spectral enhancement images of the arterial phase, the portal venous phase, and the delayed phase, respectively. The scan range was the same as that of a plain scan, with both slice thickness and inter-slice spacing of 5 mm. GSI was performed using helical scanning with instantaneous tube voltage switching between 80 and 140 kVp. The tube current was automatically adjusted based on the GSI Assist function. The reconstruction algorithm utilized 60% ASIR, with both slice thickness and inter-slice spacing set at 5 mm. The pitch was 0.992: 1, and the rotation time was 0.5 seconds per revolution.

Image Reconstruction

For all groups, monochromatic images with energy levels ranging from 40 to 140 keV in 10 keV increments were reconstructed at a 50% post-ASiR level. The reconstructed slice thickness and inter-slice spacing were both set at 1.25 mm. These images were then transferred to GE AW8.0 workstation for measurement and analysis, multiplanar reformation (MPR) and maximum intensity projection (MIP) images of the portal vein were reconstructed.

Objective Image Evaluation

Regions of interest (ROI) measuring 30-50 mm^2 were placed on the main trunk of the extra-hepatic portal vein, the erector spinae muscle at the same level, the intra-hepatic portal vein branches and the liver parenchyma at the same level. All measurements were conducted with the ROI size, shape, and location consistent across different phases and at different energy levels within the same phase. Each measurement was repeated 3 times, and the average value was taken as the final result. The CT values and standard deviations (SD) of each ROI were measured. The contrast-to-noise ratio (CNR) and signal-to-noise ratio (SNR) of the images were then calculated. The formulas for calculating CNR and SNR are as follows [8,11]:

$$CNR_{\text{extra-hepatic}} = (CT_{\text{extra-hepatic portal vein trunk}} - CT_{\text{erector spinae}})/SD_{\text{erector spinae}}$$
$$CNR_{\text{intra-hepatic}} = (CT_{\text{intra-hepatic portal vein branch}} - CT_{\text{liver parenchyma}})/SD_{\text{liver parenchyma}}$$
$$SNR_{\text{extra-hepatic}} = CT_{\text{extra-hepatic portal vein trunk}}/SD_{\text{extra-hepatic portal vein trunk}}$$
$$SNR_{\text{intra-hepatic}} = CT_{\text{intra-hepatic portal vein branch}}/SD_{\text{intra-hepatic portal vein branch}}$$

Subjective Image Evaluation

All images were independently evaluated by 2 radiologists with 5 and 7 years of experience in abdominal diagnosis, respectively, using a 5-point Likert scale. They did not know the CT scan parameters. Discrepancies were resolved through discussion after re-reading the images. The scoring criteria are detailed in **Table 1**. An image with a score of ≥3 was considered diagnostically acceptable [9,11].

Iodine Intake

The body weight of each patient was recorded, and iodine intake was calculated based on the contrast medium injection protocol for each group. The calculation formula is as follows [9]:

Table 1. Five-point scale for subjective evaluation of portal vein CT.

Score	Sharpness of portal vein margins	Vessel contrast	Visibility
5	Very sharp	Excellent	4th-order branches and higher
4	Sharp	Very good	3rd-order branches
3	Fairly sharp	Good	2nd-order branches
2	Less sharp	Poor	1st-order branches
1	Blurry	Very poor	Only the stem visible

Table 2. Baseline patient characteristics.

	Group A (n=30)	Group B (n=28)	Group C (n=30)	P
Age (year)	53.00±10.29	56.82±10.34	54.53±11.74	0.406
Height (m)	1.64±0.06	1.65±0.08	1.65±0.09	0.727
Weight (kg)	62.43±9.89	61.95±11.03	61.25±17.50*	0.556
BMI (kg/m^2)	23.24±3.01	22.66±3.43	23.80±3.82	0.450
Maximum diameter (cm)	5.78±3.14	4.65±5.40*	5.26±2.73	0.789
AFP*	78.38±1075.06	105.40±1863.98	37.21±1816.05	0.790
Sex, n(%)				0.464
Male	26 (86.67)	22 (78.57)	27 (90.00)	
Female	4 (13.33)	6 (21.43)	3 (10.00)	
Tumor location, n (%)				0.563
Right	26 (86.67)	19 (67.86)	23 (76.67)	
Left	3 (10.00)	6 (21.43)	5 (16.67)	
Right+left	1 (3.33)	3 (10.71)	2 (6.67)	
Cirrhosis, n (%)				0.755
Yes	22 (73.33)	21 (75.00)	20 (66.67)	
No	8 (26.67)	7 (25.00)	10 (33.33)	
Hepatitis virus infection, n (%)				0.972
Yes	24 (80.00)	23 (82.14)	24 (80.00)	
No	6 (20.00)	5 (17.86)	6 (20.00)	

Except where indicated, data are presented as means±standard deviations (SD). * Data are expressed as median±interquartile range. p<0.05 is considered statistically significant. AFP – alpha-fetoprotein.

Iodine intake (g) = [Patient's weight (kg)×1.2 mL/kg×contrast medium concentration (mgI/mL)]/1000.

Statistical Methods

SPSS (RRID: SCR_002865, version 26.0) was used for analysis. Quantitative statistics were expressed as mean±standard deviation (SD) or median±interquartile range. One-way analysis of variance (ANOVA) was conducted to compare the CT values, image noise values, CNR, and SNR of the portal vein across different monochromatic images and the optimal monochromatic images among the groups. Multiple comparisons were performed using the Bonferroni method. The Kruskal-Wallis test was carried out to compare subjective scores of the optimal monochromatic images. Analysis of variance (ANOVA) was conducted to evaluate differences in age, weight, height, BMI, maximum tumor diameter and iodine intake among the 3 groups. The chi-square test was performed to assess differences in sex, tumor location, cirrhosis, and hepatitis infection. P<0.05 was considered statistically significant [9].

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Table 3. Comparison of objective scores of 40-140 keV image quality in Group A.

	Extra-hepatic portal vein				Intra-hepatic portal vein			
	CT values	Image noise	CNR	SNR	CT values	Image noise	CNR	SNR
40 keV	367.14±53.10	41.07±5.24	8.51±1.60	9.05±1.47	349.24±58.70	41.39±6.73	3.77±1.11	8.52±1.26
50 keV	254.37±35.49	29.59±3.79	7.65±1.42	8.71±1.42	244.38±38.35	29.62±4.59	3.30±0.88	8.33±1.17
60 keV	185.51±25.19	22.59±2.84	6.53±1.29	8.32±1.36	181.07±27.13	22.55±3.33	2.85±0.80	8.11±1.15
70 keV	141.77±20.51	18.29±2.30	5.40±1.25	7.87±1.44	141.16±20.09	18.03±2.58	2.35±0.69	7.91±1.12
80 keV	115.35±14.88	15.61±1.93	4.48±1.05	7.74±1.99*	115.67±15.88	15.20±2.16	1.89±0.65	7.70±1.11
90 keV	97.29±12.53	13.81±1.72	3.61±0.99	7.15±1.22	98.74±12.73	13.38±1.85	1.49±0.58	7.47±1.11
100 keV	84.67±11.02	12.57±1.56	2.84±0.94	6.84±1.19	86.84±10.87	12.11±1.65	1.12±0.58	7.26±1.12
110 keV	75.67±10.08	11.68±1.44	2.26±0.95	6.58±1.17	78.56±9.62	11.20±1.54	0.82±0.59	7.11±1.13
120 keV	69.53±9.44	11.03±1.38	1.70±0.93	6.40±1.16	72.80±8.73	10.60±1.46	0.57±0.61	6.97±1.14
130 keV	64.64±9.02	10.46±1.23	1.27±0.93	6.26±1.11	68.23±8.10	10.13±1.40	0.37±0.64	6.84±1.15
140 keV	60.87±8.72	10.22±1.27	0.91±0.94	6.05±1.15	64.67±7.62	9.76±1.36	0.21±0.67	6.73±1.16
P value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Except where indicated, data are presented as means±standard deviations (SD). * Data are expressed as median±interquartile range. p<0.05 is considered statistically significant.

Table 4. Comparison of objective scores of 40-140 keV image quality in Group B.

	Extra-hepatic portal vein				Intra-hepatic portal vein			
	CT values	Image noise	CNR	SNR	CT values	Image noise	CNR	SNR
40 keV	438.23±105.09	44.18±6.36	9.70±2.38*	9.99±2.42	429.79±100.91	42.31±10.29*	5.89±2.44	9.67±2.09
50 keV	301.57±67.94	31.52±4.34	8.95±2.28*	9.64±2.04	296.91±65.09	30.21±7.48*	4.40±3.51*	9.38±1.91
60 keV	217.41±45.68	23.96±3.15	7.57±2.10*	9.13±1.80	214.99±43.31	22.79±5.28*	3.72±2.82*	9.04±1.71
70 keV	165.32±30.95	19.25±2.42	6.30±1.95*	8.65±1.54	164.09±30.04	19.09±2.62	3.15±2.18*	8.66±1.52
80 keV	132.21±22.46	16.26±2.00	5.24±1.70*	8.19±1.33	131.54±20.97	16.03±1.98	2.55±1.38*	8.27±1.34
90 keV	110.06±16.69	14.28±1.71	4.37±1.47*	7.77±1.17	110.36±16.01	13.99±1.61	2.01±0.95*	7.95±1.25
100 keV	94.72±12.77	12.91±1.52	3.62±1.40	7.40±1.04	95.42±12.39	12.59±1.36	1.53±1.03*	7.64±1.16
110 keV	83.82±10.14	11.95±1.40	2.91±1.24	7.07±0.94	84.81±10.15	11.63±1.21	1.03±1.04*	7.36±1.08
120 keV	76.27±8.37	11.29±1.32	2.32±1.09	6.82±0.88	77.45±8.72	10.95±1.10	0.66±1.18*	6.94±1.46*
130 keV	69.31±8.58*	10.78±1.26	1.85±1.00	6.59±0.84	71.60±7.96	10.44±1.03	0.38±0.95	6.75±1.35*
140 keV	64.94±7.97*	10.37±1.21	1.44±0.93	6.40±0.82	67.18±7.18	10.04±0.98	0.12±0.91	6.62±1.07*
P value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Except where indicated, data are presented as means±standard deviations (SD). * Data are expressed as median±interquartile range. p<0.05 is considered statistically significant.

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Table 5. Comparison of objective scores of 40-140 keV image quality in Group C.

	Extra-hepatic portal vein				Intra-hepatic portal vein			
	CT values	Image noise	CNR	SNR	CT values	Image noise	CNR	SNR
40 keV	407±63.52	41.16±6.10	9.44±2.25	10.04±1.95	394.91±63.94	44.01±7.95	4.68±1.37	8.68±1.86*
50 keV	281.13±41.34	29.63±4.25	8.41±2.01	9.63±1.77	273.97±43.89	31.36±5.30	4.04±1.28	8.84±1.33
60 keV	203.56±28.26	22.49±3.15	7.27±1.77	9.18±1.62	200.18±28.86	23.42±3.67	3.40±1.20	8.64±1.23
70 keV	155.82±19.77	18.13±2.48	6.12±1.53	8.71±1.45	154.92±19.74	18.63±2.70	2.83±0.97	8.42±1.20
80 keV	125.03±14.87	15.32±2.06	5.11±1.34	8.27±1.32	125.38±14.53	15.55±2.13	2.23±0.88	8.16±1.17
90 keV	104.88±11.75	13.54±1.77	4.11±1.15	7.85±1.22	105.99±11.36	13.54±1.78	1.71±0.78	7.93±1.15
100 keV	90.68±10.07	12.24±1.58	3.32±1.05	7.51±1.15	92.44±9.38	12.15±1.56	1.25±0.72	7.71±1.14
110 keV	80.43±8.98	11.35±1.45	2.60±0.97	7.18±1.09	82.82±8.19	11.19±1.43	0.86±0.69	7.51±1.14
120 keV	73.48±8.32	10.72±1.36	2.04±0.92	6.94±1.06	75.95±7.38	10.50±1.35	0.53±0.71	7.34±1.12
130 keV	68.25±8.00	10.27±1.29	1.62±0.91	6.73±1.04	70.95±7.14	9.99±1.29	0.29±0.67	7.22±1.15
140 keV	63.99±7.78	9.87±1.24	1.23±0.91	6.56±1.03	66.87±6.91	9.57±1.26	0.08±0.67	7.10±1.17
P value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Except where indicated, data are presented as means±standard deviations (SD). * Data are expressed as median±interquartile range. p<0.05 is considered statistically significant.

The inter-observer differences were assessed using the kappa coefficient to measure how well 2 radiologists agreed on each parameter. The method for determining consistency is as follows: Poor agreement (k<0); Slight agreement (0<k≤0.2); Fair agreement (0.2<k≤0.4); Moderate agreement (0.4<k≤0.6); Substantial agreement (0.6<k≤0.8); Almost perfect agreement (k>0.8) [12].

Results

General Information on Patients

The study results showed that there were no significant differences in age, height, weight, BMI, sex, maximum tumor diameter, tumor location, cirrhosis, and hepatitis infection among the 3 groups (P>0.05) (**Table 2**).

Optimal Monochromatic Energy Level

The CT values and image noise values of the extra-hepatic and intra-hepatic portal veins in each set of monochromatic images ranging from 40 to 140 keV (in 10 keV intervals) decreased with the increase in keV (P<0.001). The overall differences in CNR and SNR were statistically significant (all P<0.001) (**Tables 3-5, Figure 2**). The results of multiple comparisons are shown in **Figure 3**. The optimal monochromatic level for extra-hepatic and intra-hepatic portal veins for the 3 groups 80-110 keV.

Optimal Monochromatic Image Quality

1) Objective Image Quality Assessment: In Group A, the mean CT values and image noise values of both intra-hepatic and extra-hepatic portal veins were higher than those in Groups B and C, and there were statistically significant differences among the groups (P<0.001). The CNR in Group A was also higher than that in Groups B and C, but there were no statistically significant differences among the groups (P>0.05). The SNR of intra-hepatic and extra-hepatic portal veins in Group C was higher than that in Groups A and B, but there were no statistically significant differences among the groups (P>0.05) (**Table 6**).

2) Subjective Image Quality Assessment: All images were evaluated by 2 radiologists, and the subjective consistency was good (intra-hepatic portal vein kappa=0.758, extra-hepatic portal vein kappa=0.761). There were no statistically significant differences in the subjective scores for the optimal monochromatic images of intra-hepatic and extra-hepatic portal veins among Groups A, B, and C (P=0.756, 0.748). All subjective scores were >3, meeting the diagnostic requirements (**Table 6**).

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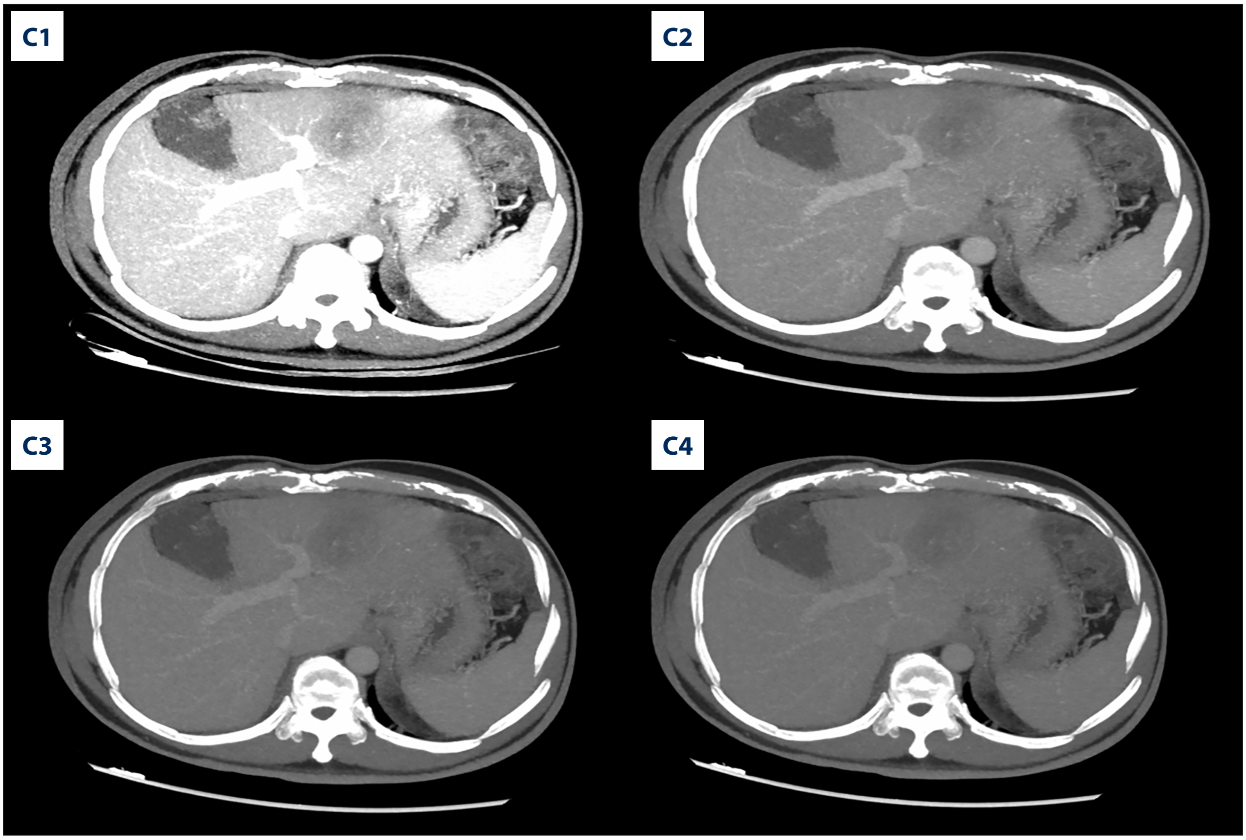

Figure 2. CT images of cases in Group A, B, C. Case A, Male, 67 years old, giant hepatocellular carcinoma, BMI 26.18 kg/m^2. Figures **A1-A4** are 40keV, 70keV, 80keV and 90keV images of cases in Group A at portal venous phase, respectively. Case B, Male, 79 years old, nodular cell hepatocellular carcinoma, BMI 18.90 kg/m^2. Figures **B1-B4** are 40keV, 70keV, 100keV and 110keV images of cases in Group B at portal venous phase, respectively. Case C, Male, 44 years old, nodular hepatocellular carcinoma, BMI 22.84 kg/m^2. Figures **C1-C4** are 40keV, 70keV, 90keV and 100keV images of cases in Group C at portal venous phase, respectively. With the increase of keV, the CT value, image noise, CNR, and SNR gradually decrease. (P<0.001). *All the images in Figure were downloaded from GE AW8.0.*

Iodine Intake

There was a statistically significant difference in iodine intake among Groups A, B, and C (P<0.05). Compared to Group C, iodine intake was reduced by 17.53% in Group A and by 12.73% in Group B (**Table 7**).

Discussion

Dynamic CT-enhanced scan is widely applied in clinical practice for its convenience, speed, and clear display of lesions, and iodinated contrast medium is often used. Traditionally, to improve image quality, higher concentration and dose are usually used. However, excessive iodinated contrast medium can increase the metabolic burden of kidneys and the risk of persistent renal failure, cardiovascular disease and other diseases, especially for the elderly or patients with renal insufficiency [5]. Therefore, how to reasonably reduce iodine intake while ensuring both image quality and patient safety is an important clinical concern.

Some studies indicate that GSI scanning can significantly reduce iodine uptake, help improve image quality and supplement more diagnostic information, so it is increasingly widely used [13-17]. It is capable of generating 101 monochromatic energy images with different CT and noise values in the range of 40-140 keV by instantaneously switching X-rays between 80 kVp and 140 kVp within 0.25 ms. It has been proved by studies [5,13-15,18] that low keV helps improve CNR, making the image details clearer, but the noise is loud, so the image quality is affected, further affecting the accuracy of diagnosis; high keV reduces artifacts but also lowers CNR, resulting in poor image detail and insufficient ability to detect minor lesions. The results of this study further verify the previous findings that the CT value, image noise, CNR and SNR of the intrahepatic and extra-hepatic portal veins of the 3 groups decrease with the increase of keV (P<0.001) and that although there are

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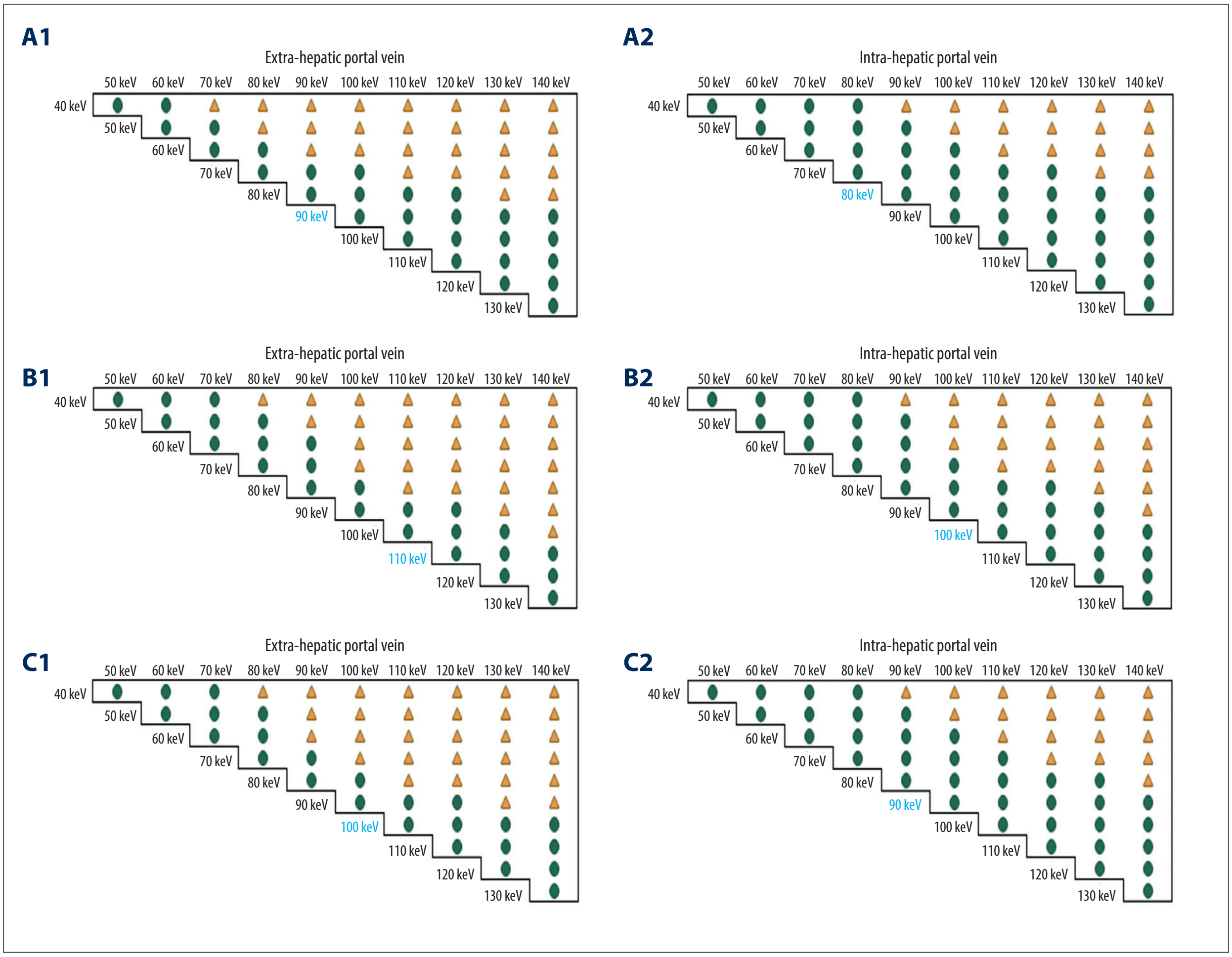

Figure 3. Comparison of SNR for intra-hepatic and extra-hepatic portal veins in monochromatic images (40-140 keV) across Groups A (**A1, A2**), B (**B1, B2**), and C (**C1, C2**). There are significant differences in SNR for intra-hepatic and extra-hepatic portal veins among different monochromatic images in each group (P<0.001) (● P≤0.05, ▲ P<0.05).*Figure was created using Microsoft Excel (version 2021, Microsoft Corporation).*

significant differences in the CT value and image noise of the optimal monochromatic energy images (P<0.001), there is no statistically significant difference in CNR, SNR, and subjective scores (P>0.05). Although the optimal keV value of Group A is relatively low, its image noise is relatively loud. Even if CNR and SNR remain unchanged, its loud image noise might still affect image details and reduce the detection rate of small lesions. Therefore, in clinical applications, CNR should not be blindly increased in pursuit of high image quality while ignoring the effect of image noise. In addition to choosing appropriate monochromatic energy images and reasonably optimizing CNR, noise control and processing should be emphasized to improve the sensitivity and accuracy of diagnosis.

After multiple comparisons, the optimal keV range in this study is 80-110 keV, which is different from the results of other studies. For example, some studies indicate that 70 keV images have the optimal peak iodine contrast-to-noise ratio and that lesion detectability is better between 40 and 70 keV [14-16,18-21]. In our opinion: the examination method used in previous studies was portal vein angiography, whereas in this study, only a GSI-enhanced scan was applied, which did not meet the examination criteria for clinical diagnosis of vascular problems. To obtain higher CNR and SNR to optimize image quality, a higher optimal keV value is required, leading to the inconsistency of the present results with those of previous studies.

Some studies indicate that low-concentration iodinated contrast medium combined with GSI scanning can significantly reduce iodine load and ensure image quality. For example, Sun Kyoung You et al [22] studied the use of a double-low protocol (low-concentration iodinated contrast medium: 270 mgI/mL, low tube voltage) in abdominal CT in children and found that the protocol was effective in reducing the iodine load and maintaining the image quality. Liu Yijun et al [8] used GSI scanning for centrally obese and high BMI patients in combination

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Table 6. Comparison of objective and subjective scores of the optimal monochromatic image quality in Groups A, B, and C.

Groups	CT values	Image noise	CNR	SNR	Subjective scores
Extra-hepatic portal vein					
Group A	97.29±12.53	13.81±1.72	3.61±0.99	7.15±1.22	3.83±0.32*
Group B	83.82±10.14	11.95±1.40	2.91±1.23	7.07±0.94	3.75±0.44*
Group C	90.68±10.07	12.24±1.58	3.32±1.05	7.51±1.15	3.69±0.55
F/H value	10.874	11.846	3.014	1.275	0.580[a]
P value	<0.001	<0.001	0.054	0.285	0.748
Intra-hepatic portal vein					
Group A	115.67±15.88	15.20±2.16	1.89±0.65	7.70±1.11	3.90±0.41
Group B	95.42±12.39	12.59±1.36	1.53±1.03*	7.64±1.16	3.87±0.49*
Group C	105.99±11.36	13.54±1.78	1.71±0.78	7.93±1.15	3.82±0.55
F/H value	16.616	15.611	4.45a	0.536	0.559[a]
P value	<0.001	<0.001	0.132	0.587	0.756

Except where indicated, data are presented as means±standard deviations (SD). * Data are expressed as median±interquartile range. [a] Non-normal distribution, H test is performed. p<0.05 is considered statistically significant.

Table 7. Comparison of iodine intake among Groups A, B, and C, and within each group.

Groups	Iodine intake (g)	Group B vs Group A	Group C vs Group A	Group C vs Group B
Group A	22.48±3.56	–	–	–
Group B	23.79±4.24	–	–	–
Group C	25.26±5.28	–	–	–
P value	<0.001	0.786	<0.001	0.011

All data are expressed as mean±standard deviation (SD). p<0.05 is considered statistically significant.

with low-concentration iodinated contrast medium (270 mgI/mL) and achieved good image quality. Lei Xin et al [14] pointed out that GSI combined with low-concentration iodinated contrast medium (270 mgI/mL) presented better image quality and significantly reduced the use of contrast medium by 28% compared to conventional CTA.

Although lower-concentration iodinated contrast medium is not used in this study, and factors such as tube voltage and injection rate are not considered, and no direct comparisons are made with conventional CT scans, the results are consistent with those of previous studies: The optimal monochromatic energy image in Group A has the highest CNR value and subjective score. Compared to Group C, iodine uptake is reduced by 17.53% in Group A and by 12.73% in Group B. Although there is no significant difference in imaging quality between the 3 groups, the image quality with low-concentration contrast medium still meets the clinical diagnostic requirements. These results further demonstrate that applying GSI scanning and low-concentration iodinated contrast medium can not only significantly reduce iodine load but also ensure good image quality, thereby protecting the patient's kidney. Therefore, we recommend the use of low-concentration iodinated contrast medium with a concentration of 300 mgI/mL in clinical practice, which not only meets the diagnostic requirements but also effectively reduces the iodine load of patients, reduces the side effects associated with the contrast medium, and greatly improves the safety of patients who need to undergo frequent imaging, or suffer renal insufficiency, and obese patients, which has an important clinical application value.

Conclusions

GSI scanning combined with a low-concentration contrast medium (300 mg/mL) can significantly reduce iodine intake during liver CT-enhanced scans while providing image quality that meets diagnostic requirements, helping optimize the use of contrast medium. By reducing the dose of contrast medium,

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this method effectively reduces radiation exposure and side effects for patients and improves safety. This strategy provides feasible progress for the optimization of abdominal CT scanning protocols, which is particularly suitable for patients requiring frequent imaging and has important clinical application value.

Declaration of Figures' Authenticity

All figures submitted have been created by the authors, who confirm that the images are original with no duplication and have not been previously published in whole or in part.

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