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Application of Spectral CT Hemobase Imaging in Renal Perfusion Assessment Before and After Partial Nephrectomy for Renal Carcinoma

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Abstract: ***Objective**: To investigate the significant clinical value of spectral CT hemobase imaging in evaluating renal perfusion function before and after partial nephrectomy for renal cell carcinoma. As described in "Research on Renal CT Perfusion Imaging and Its Clinical Application Value", this technique provides quantitative analysis of renal perfusion values, aiding in prognosis assessment and surgical strategy selection for renal cancer patients. **Methods**: A total of 70 patients undergoing partial nephrectomy for renal cell carcinoma from June 2024 to June 2025 were randomly divided into a study group (35 cases) and a control group (35 cases). The study group received spectral CT hemobase imaging to improve early diagnostic accuracy, while the control group underwent conventional contrast-enhanced CT. Preoperative and postoperative 7-day changes in iodine-based substance concentration (IC), spectral curve slope (λHU), effective atomic number (Zeff), renal blood flow (RBF), renal blood volume (RBV), and mean transit time (MTT) were compared. **Results**: The study group showed significantly higher postoperative IC, λHU, Zeff, RBF, and RBV compared to the control group, with significantly lower MTT (P<0.05). **Conclusion**: Spectral CT hemobase imaging accurately reflects changes in renal parenchymal microcirculation perfusion during partial nephrectomy for renal cell carcinoma. Compared to conventional contrast-enhanced CT, it demonstrates higher sensitivity and quantitative analysis value, which holds important clinical significance for evaluating postoperative renal function and prognosis.*

Keywords: Spectral CT hemobase imaging, Partial nephrectomy, Renal perfusion.

1. Introduction

Renal cancer, as one of the common malignant tumors in the urinary system, has seen partial nephrectomy—the primary treatment for preserving renal unit function—become the preferred surgical approach for early-stage cases. However, intraoperative ischemia-reperfusion phenomena and tissue damage often lead to decreased renal perfusion and temporary renal function decline postoperatively. Therefore, precise preoperative and postoperative assessment of renal perfusion is crucial for optimizing surgical strategies and protecting renal function. Traditional contrast-enhanced CT can only perform morphological observations, lacking the capability to accurately quantify hemodynamic changes in renal parenchyma. Spectral CT blood-based imaging, utilizing energy stratification and material decomposition techniques, simultaneously obtains quantitative parameters such as iodine-based substance concentration (IC), spectral curve slope (λHU), and effective atomic number (Zeff), enabling multidimensional evaluation of renal tissue perfusion.

2. Materials and Methods

2.1 General Information

This study enrolled 70 patients who underwent partial nephrectomy for renal cell carcinoma between June 2024 and June 2025. All cases were confirmed by multi-slice spiral CT and histopathological examination as unilateral renal clear cell carcinoma with lesions ≤ 4cm in diameter, meeting the criteria for partial nephrectomy. Preoperative renal function remained stable, with serum creatinine, blood urea nitrogen, and glomerular filtration rate (GFR) all within acceptable ranges. Exclusion criteria included bilateral renal involvement, severe hepatic or renal dysfunction, contrast agent allergy history, and prior renal surgery.

2.2 Method

The control group underwent conventional contrast-enhanced CT scans, with renal artery phase, parenchymal phase, and excretion phase imaging performed preoperatively and 7 days postoperatively. Standard energy slice images were used to measure CT values and perfusion characteristics in the lesion area, contralateral renal cortex, and medulla. The study group performed spectral CT blood-based imaging at the same time points, acquiring spectral data from single-volument scans to reconstruct iodine-based concentration (IC), water-based concentration (WC), and effective atomic number (Zeff) images. Using an intelligent workstation, the iodine concentration, spectral curve slope (λHU), and energy-resolved parameters were measured in the lesion area, adjacent renal parenchyma, and contralateral kidney within the region of interest (ROI). All examinations employed identical scanning parameters and iodinated contrast agent dosage, with an injection rate of 3.5 mL/s and automatic delay time triggering based on perfusion phase. Measurements were independently performed by two senior radiologists, with average values taken to ensure data objectivity.

2.3 Observation Indicators

In this study, the observation indicators were primarily used to evaluate the application effects of spectral CT hemobase

material imaging in assessing renal perfusion function before and after partial nephrectomy for renal cancer, which is mainly reflected in the following two aspects:

Quantitative spectral analysis of spectral CT: Iodine-based contrast agent concentration (IC), spectral curve slope (λHU), and effective atomic number (Zeff) in the ipsilateral and contralateral renal cortex and medulla were measured. The ROI was quantitatively analyzed before and 7 days after surgery to reflect changes in renal tissue blood flow distribution and perfusion characteristics at different energy levels.

Hemodynamic parameters of the two groups were compared. The renal blood flow (RBF), renal blood volume (RBV) and mean transit time (MTT) were calculated by using the quantitative data of spectral imaging to evaluate the effect of the operation on the renal microcirculation perfusion.

2.4 Statistical Analysis

SPSS 26.0 software was used to analyze the data. The data were expressed as ($x \pm s$). The independent sample t test was used for the comparison between groups, and the paired t test was used for the comparison within groups.

3. Results

3.1 Comparison of Spectral Quantitative Indicators Between the Two Groups

The results showed that the iodine-based substance concentration (IC), spectral slope (λHU) and effective atomic number (Zeff) of the lesion side renal cortex and medulla were significantly higher than those of the control group ($P<0.05$) in the quantitative parameters of energy spectrum before and 7 days after operation (Table 1).

3.2 Comparison of Hemodynamic Parameters Between the Two Groups

The results showed that the renal blood flow (RBF) and renal blood volume (RBV) of the study group were higher than those of the control group, and the mean transit time (MTT) was significantly lower than that of the control group ($P <0.05$) (Table 2).

Table 1: Comparison of spectral quantification parameters between the two groups before and 7 days after surgery (mean ± standard deviation)

group	Number of cases	time point	IC (mg/mL)	λHU (HU/keV)	Zeff
study group	35	Preoperative	2.86±0.42	1.21±0.18	7.89±0.36
study group	35	7 days after surgery	2.57±0.38	1.08±0.15	7.61±0.29
control group	35	Preoperative	2.79±0.45	1.17±0.19	7.84±0.34
control group	35	7 days after surgery	2.21±0.40	0.92±0.14	7.33±0.28
t price	—	—	4.112	5.237	4.685
P price	—	—	< 0.05	< 0.05	< 0.05

Table 2: Comparison of hemodynamic parameters between the two groups before and 7 days after surgery (mean ± standard deviation)

group	Number of cases	time point	RBF ($mL \cdot 100g^{-1} \cdot min^{-1}$)	RBV (mL/100g)	MTT(s)
study group	35	Preoperative	318.42±35.68	28.56±4.21	5.63±0.84
study group	35	7 days after surgery	295.37±33.14	25.74±3.98	6.12±0.91
control group	35	Preoperative	314.85±36.02	28.19±4.17	5.69±0.87
control group	35	7 days after surgery	266.42±31.88	22.31±3.75	6.87±0.94
t price	—	—	5.263	4.982	4.557
P price	—	—	< 0.05	< 0.05	< 0.05

4. Discussion

Postoperative renal perfusion changes following partial nephrectomy reflect the restoration of renal unit integrity and microcirculatory function. Through energy layering and material decomposition techniques, spectral CT achieves quantitative analysis of iodine-based signals and visualization of perfusion dynamics, enabling dynamic assessment of postoperative renal hemodynamics. This technology has been widely applied in medical imaging for renal hemodynamic studies. For instance, spectral CT imaging can accurately detect changes in renal vessels and their branches, providing crucial references for clinical diagnosis and treatment.

The study demonstrated that postoperative patients in the research group exhibited significantly higher concentrations of iodine-based substances (IC), spectral curve slope (λHU), and effective atomic number (Zeff) in renal cortex and medulla compared to the control group. This indicates that spectral CT provides more accurate assessment of renal parenchymal perfusion levels and tissue metabolic activity. By utilizing energy-resolved detection and material-based reconstruction algorithms, spectral imaging separates iodine and water signals while eliminating the energy overlap effect in conventional contrast-enhanced CT. This enables linear correlation between iodine concentration changes and blood flow perfusion, thereby enhancing the sensitivity of postoperative renal microcirculation evaluation. Postoperatively, patients in the research group showed higher renal blood flow (RBF) and renal blood volume (RBV) than the control group, with significantly shorter mean transit time (MTT). These findings indicate that spectral CT can sensitively reflect the decline and compensatory recovery of renal blood perfusion during quantitative blood flow parameter analysis. In functional imaging, spectral CT combines morphological and quantitative advantages, allowing comprehensive assessment of renal parenchymal blood supply damage, postoperative compensatory hyperperfusion, and changes in renal lobular structure. The core strength of spectral CT's blood-based imaging

technology lies in its ability to establish tissue characteristic curves at different energy levels, enabling spectral zoning analysis of renal cortex and medulla to improve lesion detection rates and perfusion assessment accuracy.

The study demonstrated that patients with minimal reduction in postoperative renal parenchymal spectral parameters typically exhibit well-preserved nephron perfusion function and faster recovery during clinical follow-up. Compared to conventional contrast-enhanced CT, this technique demonstrates significant advantages in detecting subtle blood flow changes, evaluating postoperative renal protection strategies, and assessing the effectiveness of postoperative blood supply reconstruction.

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