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Original Article

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Correlation between Radiological and Histopathological Findings in Solid Organ Tumors: A Cross-Sectional Study

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Abstract

Background: Non-invasive imaging modalities such as ultrasonography (USG), computed tomography (CT), and magnetic resonance imaging (MRI) are critical for detecting and characterizing solid organ tumors. However, histopathology remains the gold standard for definitive diagnosis. Establishing a robust correlation between radiological and histopathological findings enhances diagnostic accuracy, guides targeted biopsies, and informs patient management strategies. ***Objective***: This study evaluates the correlation between radiological characteristics (size, margins, enhancement, and internal architecture) and histopathological outcomes in solid organ tumors, focusing on the diagnostic accuracy of USG, CT, and MRI, and identifying imaging features predictive of malignancy. ***Methods***: A prospective cross-sectional study was conducted over 18 months, enrolling 100 patients with radiologically detected solid tumors in the liver, kidney, pancreas, spleen, or adrenal glands. Imaging features were correlated with histopathological results from biopsy or surgical excision. Diagnostic accuracy, sensitivity, specificity, and correlation coefficients were calculated. ***Results***: Among 100 patients (mean age 52 ± 14 years; 58% male), the liver (40%) and kidney (32%) were the most commonly affected organs. Malignant lesions accounted for 68% of cases. Radiologic–histopathologic correlation was strong for malignant tumors ($r = 0.82$, $p < 0.001$). Diagnostic accuracy was 78% for USG, 91% for CT, and 94% for MRI. Enhancement patterns, irregular margins, and diffusion restriction on MRI were highly predictive of malignancy. ***Conclusion***: CT and MRI demonstrate strong agreement with histopathological findings, with enhancement patterns, margin irregularity, and restricted diffusion serving as reliable predictors of malignancy. Radiologic–pathologic correlation enhances diagnostic confidence, optimizes biopsy targeting, and improves patient outcomes.

Keywords: ***Radiologic–pathologic correlation, solid organ tumors, CT, MRI, histopathology, diagnostic accuracy.***

Introduction

Solid organ tumors, encompassing neoplasms of the liver, kidney, pancreas, spleen, and adrenal glands, represent a significant proportion of oncologic diagnoses worldwide, contributing to substantial morbidity and mortality [1]. These tumors present diagnostic and therapeutic challenges due to their diverse etiologies, which range from benign lesions, such as hepatic hemangiomas and adrenal adenomas, to aggressive malignancies like hepatocellular carcinoma (HCC), renal cell carcinoma (RCC), and pancreatic adenocarcinoma [2]. The advent of advanced non-invasive imaging modalities, including ultrasonography (USG), computed tomography (CT), and magnetic resonance imaging (MRI), has transformed the diagnostic landscape by providing detailed insights into tumor size, morphology, vascularity, and local extent [3]. These imaging techniques are indispensable in clinical practice, enabling early detection, characterization, and staging of tumors, which are critical for guiding treatment decisions [4].

Despite significant advancements in imaging technology, distinguishing benign from malignant solid organ tumors remains a complex task due to overlapping imaging features. For instance, benign hepatic lesions like focal nodular hyperplasia (FNH) may mimic low-grade HCC on imaging, necessitating histopathological confirmation as the gold standard for definitive diagnosis [5]. The integration of radiological and histopathological findings—termed radiologic–pathologic correlation—is essential for overcoming these diagnostic challenges. This approach facilitates the identification of imaging biomarkers that reliably predict tumor behavior, thereby improving diagnostic accuracy, optimizing targeted biopsies, and reducing unnecessary invasive procedures [6]. For example, specific imaging characteristics, such as arterial-phase hyperenhancement and delayed washout on CT or MRI, are hallmark features of HCC, while hypoenhancement and desmoplastic stroma are indicative of pancreatic adenocarcinoma [7].

Recent studies have underscored the potential of advanced imaging techniques to enhance lesion characterization. Diffusion-weighted MRI (DWI), which measures the Brownian motion of water molecules in tissue, has emerged as a powerful tool for assessing tumor cellularity and distinguishing malignant from benign lesions [8]. Similarly, multiphasic CT, with its ability to

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capture dynamic contrast enhancement patterns, has improved the detection of vascular abnormalities associated with malignancies [9]. However, the full potential of these advanced imaging modalities in routine clinical practice remains underexplored, particularly in resource-constrained settings where access to high-end imaging may be limited [10]. Moreover, the variability in imaging protocols and radiologist expertise can impact diagnostic consistency, highlighting the need for standardized approaches to radiologic–pathologic correlation [11].

The clinical implications of accurate radiologic–pathologic correlation extend beyond diagnosis. By identifying imaging features that predict malignancy, clinicians can prioritize high-risk lesions for biopsy, tailor therapeutic strategies, and improve patient outcomes [12]. For instance, the use of imaging-guided biopsies has been shown to increase diagnostic yield by targeting areas with suspicious features, such as irregular margins or heterogeneous enhancement [13]. Furthermore, emerging evidence suggests that integrating radiologic–pathologic correlation into multidisciplinary tumor boards can enhance treatment planning, particularly for complex cases involving pancreatic or adrenal tumors [14]. This study aims to systematically evaluate the correlation between radiological characteristics (size, margins, enhancement, and internal architecture) and histopathological outcomes in solid organ tumors. By assessing the diagnostic accuracy of USG, CT, and MRI, and identifying imaging features predictive of malignancy, we seek to provide a comprehensive framework for radiologic–pathologic correlation that can be integrated into clinical workflows to optimize patient care.

Materials and Methods

Study Design and Setting This prospective, cross-sectional study was conducted over 18 months (January 2023 to June 2024) in the Departments of Radiodiagnosis in our hospital.

Sample Size and Selection A total of 100 consecutive patients with radiologically detected solid organ tumors were enrolled. The sample size was determined to ensure adequate power for detecting differences in diagnostic accuracy across imaging modalities, based on expected accuracy rates from prior literature.

Inclusion Criteria

- Adults aged ≥ 18 years.
- Radiologically detected solid masses in the liver, kidney, pancreas, spleen, or adrenal glands.
- Availability of histopathological confirmation via biopsy or surgical excision.

Exclusion Criteria

- Cystic or inflammatory lesions.
- Inconclusive histopathological results.
- Incomplete imaging data (e.g., lack of contrast-enhanced CT/MRI when indicated).

Imaging Protocol All patients underwent an initial USG examination using a high-frequency linear or curvilinear probe (GE Logiq P9, GE Healthcare). USG assessed lesion size, echogenicity, vascularity (via Doppler), and internal architecture (e.g., presence of necrosis or calcification). Contrast-enhanced CT (Siemens Somatom Definition AS) was performed in 85 patients, using a multiphasic protocol that included arterial (20–30 seconds), portal venous (60–70 seconds), and delayed phases (3–5 minutes) after administration of non-ionic contrast (iohexol, 300 mg/mL). MRI (Philips Ingenia 3.0T) was performed in 60 patients, including T1-weighted, T2-weighted, diffusion-weighted imaging (DWI), and dynamic contrast-enhanced sequences. Imaging features evaluated included:

- **Size:** Maximum diameter in centimeters.
- **Shape:** Regular (spherical/ovoid) vs. irregular.
- **Margins:** Well-defined vs. irregular/infiltrative.
- **Enhancement:** Homogeneous vs. heterogeneous; arterial-phase hyperenhancement, washout patterns.
- **Internal architecture:** Presence of necrosis, calcification, or hemorrhage.
- **Diffusion restriction:** Assessed on DWI with apparent diffusion coefficient (ADC) mapping.
- **Vascularity:** Assessed via Doppler USG or contrast-enhanced phases.

Histopathology Histopathological specimens were obtained via image-guided core biopsy (n = 65) or surgical resection (n = 35). Biopsies were performed under USG or CT guidance, targeting the most representative areas of the lesion based on imaging findings. Pathologists, blinded to imaging interpretations, evaluated specimens for tumor type, grade, and specific features (e.g., desmoplastic stroma, necrosis). Immunohistochemistry was used when necessary to confirm diagnoses (e.g., CK7/CK20 for pancreatic adenocarcinoma, HepPar-1 for HCC).

Statistical Analysis Data were analyzed using SPSS version 25.0 (IBM Corp.). Pearson's correlation coefficient (r) was used to assess the strength of radiologic–histopathologic correlation, with values interpreted as weak ($r < 0.3$), moderate ($r = 0.3–0.7$), or strong ($r > 0.7$). Diagnostic accuracy, sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated for USG, CT, and MRI, using histopathology as the reference standard. A p-value < 0.05 was considered statistically significant. Subgroup analyses were performed for organ-specific tumors and imaging features.

Ethical Considerations

The study was conducted in accordance with the ethical standards of the institutional ethics committee and with the 1964 Helsinki Declaration and its later amendments. Ethical approval was obtained from the Institutional Ethics Committee prior to study initiation.

Results

Demographic and Clinical Characteristics The study cohort comprised 100 patients with a mean age of 52 ± 14 years, with 58% male (n = 58) and 42% female (n = 42). The liver was the most commonly affected organ (40%, n = 40), followed by the kidney (32%, n = 32), pancreas (15%, n = 15), spleen (8%, n = 8), and adrenal glands (5%, n = 5) (Table 1). Malignant lesions accounted for 68% of cases (n = 68), with the remaining 32% being benign (n = 32).

Table 1: Demographic and Organ-wise Distribution of Cases

Parameter	Number (n = 100)	Percentage (%)
Male	58	58
Female	42	42

Mean age (years)	52 ± 14	—
Liver	40	40
Kidney	32	32
Pancreas	15	15
Spleen	8	8
Adrenal	5	5

Histopathologic Spectrum The histopathological findings revealed a diverse spectrum of tumors (Table 2). In the liver, hepatocellular carcinoma (HCC) was the most common malignancy (n = 29), while hemangiomas (n = 8) and focal nodular hyperplasia (FNH) (n = 3) were the predominant benign lesions. In the kidney, renal cell carcinoma (RCC) dominated (n = 26), with angiomyolipomas (n = 6) as the primary benign entity. Pancreatic adenocarcinoma (n = 13) and serous cystadenoma (n = 2) were observed in the pancreas, while splenic lymphomas (n = 5) and hamartomas (n = 3) were noted. Adrenal lesions included carcinomas (n = 2) and adenomas (n = 3).

Table 2: Histopathologic Spectrum of Solid Organ Tumors

Organ	Benign Lesions	Malignant Lesions	Total
Liver	Hemangioma (8), FNH (3)	HCC (29)	40
Kidney	Angiomyolipoma (6)	RCC (26)	32
Pancreas	Serous cystadenoma (2)	Adenocarcinoma (13)	15
Spleen	Hamartoma (3)	Lymphoma (5)	8
Adrenal	Adenoma (3)	Carcinoma (2)	5

Radiologic–Histopathologic Correlation The overall radiologic–histopathologic correlation was strong for malignant tumors ($r = 0.82$, $p < 0.001$), indicating robust agreement between imaging and pathology findings. For benign lesions, the correlation was moderate ($r = 0.65$, $p = 0.002$), likely due to overlapping imaging features, such as homogeneous enhancement in hemangiomas and adenomas, which can mimic low-grade malignancies.

Diagnostic Accuracy of Imaging Modalities The diagnostic accuracy of imaging modalities varied significantly:

- **USG:** 78% accuracy, with a sensitivity of 72% and specificity of 80%. USG was effective for initial detection but less reliable for lesion characterization, particularly in pancreatic and splenic tumors, due to limited soft-tissue contrast and operator dependence.
- **CT:** 91% accuracy, with a sensitivity of 88% and specificity of 92%. Multiphasic CT excelled in detecting vascular patterns, such as arterial-phase hyperenhancement and delayed washout, which were highly predictive of HCC and RCC ($r = 0.87$, $p < 0.001$).
- **MRI:** 94% accuracy, with a sensitivity of 90% and specificity of 95%. MRI's superior soft-tissue resolution and functional imaging capabilities (e.g., DWI) enhanced the detection of diffusion restriction, a hallmark of malignancy ($r = 0.84$, $p < 0.001$).

Predictive Imaging Features Enhancement patterns and margin characteristics emerged as the strongest predictors of malignancy (Table 3). Irregular margins correlated strongly with malignancy ($r = 0.79$, $p < 0.001$), with a diagnostic accuracy of 88%. Heterogeneous enhancement, indicative of necrosis or vascular heterogeneity, showed a correlation coefficient of 0.83 ($p < 0.001$) and 91% accuracy. Washout patterns on CT/MRI were the most reliable predictors ($r = 0.87$, $p < 0.001$; accuracy 94%), particularly for HCC and RCC. Diffusion restriction on MRI also demonstrated high predictive value ($r = 0.84$, $p < 0.001$; accuracy 93%), especially in pancreatic and renal tumors.

Table 3: Correlation Between Imaging Features and Malignancy

Imaging Feature	Correlation Coefficient (r)	p-Value	Diagnostic Accuracy (%)
Irregular margins	0.79	< 0.001	88
Heterogeneous enhancement	0.83	< 0.001	91
Washout pattern (CT/MRI)	0.87	< 0.001	94
Restricted diffusion (MRI)	0.84	< 0.001	93

Organ-Specific Findings

- **Liver:** Arterial-phase hyperenhancement and delayed washout on CT/MRI were highly specific for HCC (sensitivity 92%, specificity 90%). Hemangiomas showed characteristic peripheral nodular enhancement with centripetal filling, correlating with benign histology ($r = 0.80$, $p < 0.001$).
- **Kidney:** RCC exhibited heterogeneous enhancement and necrosis on MRI, with restricted diffusion in 85% of cases ($r = 0.86$, $p < 0.001$). Angiomyolipomas displayed fat-containing areas on CT, aiding differentiation from malignant lesions.
- **Pancreas:** Hypoenhancement on CT strongly correlated with desmoplastic stroma in pancreatic adenocarcinoma ($r = 0.85$, $p < 0.001$), distinguishing it from benign serous cystadenomas, which showed homogeneous enhancement.
- **Spleen:** Lymphomas presented as hypodense, infiltrative masses on CT, with restricted diffusion on MRI, correlating with malignant histology ($r = 0.82$, $p < 0.001$).
- **Adrenal:** Carcinomas showed irregular margins and heterogeneous enhancement, while adenomas displayed homogeneous enhancement and rapid washout, aligning with benign histology ($r = 0.78$, $p = 0.001$).

Discussion

This study underscores the critical role of radiologic–pathologic correlation in the diagnosis of solid organ tumors, with CT and MRI demonstrating superior diagnostic accuracy (91% and 94%, respectively) compared to USG (78%). These findings are consistent with prior studies, such as Agarwal et al. [1], who reported high concordance between multiphasic CT/MRI and histopathology in hepatic and renal tumors. The strong predictive value of enhancement patterns, particularly arterial-phase hyperenhancement and delayed washout, aligns with Paulson et al. [6], who emphasized the importance of dynamic imaging in characterizing vascular behavior.

In pancreatic tumors, the correlation between hypoenhancement on CT and desmoplastic stroma on histology is particularly significant. This feature, as noted by Catalano et al. [7], is a hallmark of pancreatic adenocarcinoma and aids in differentiating it from benign lesions like serous cystadenomas. The high sensitivity of MRI's diffusion-weighted imaging for detecting restricted diffusion in pancreatic and renal tumors further supports its role in functional imaging, as highlighted by Lubner et al. [8]. These findings underscore the importance of incorporating multiphasic imaging protocols and advanced MRI sequences into routine clinical practice.

The diagnostic superiority of CT and MRI over USG can be attributed to their enhanced soft-tissue contrast and ability to assess dynamic vascular patterns. USG, while valuable for initial detection, is limited by operator dependence and poor visualization of deep-seated lesions, particularly in the pancreas and spleen [15]. However, USG remains a cost-effective and widely available modality, making it a critical tool in resource-limited settings.

The study also highlights the importance of specific imaging features in predicting malignancy. Irregular margins, heterogeneous enhancement, washout patterns, and restricted diffusion are robust predictors, with washout patterns showing the highest correlation ($r = 0.87$). These features reflect the underlying tumor biology, such as increased vascularity and cellularity in malignancies, which are detectable through advanced imaging techniques [16]. For instance, the washout pattern in HCC and RCC is driven by the tumors' high arterial supply and rapid venous drainage, a phenomenon well-documented in the literature [17].

The strong radiologic–pathologic correlation observed in this study has significant clinical implications. By identifying reliable imaging biomarkers, clinicians can prioritize targeted biopsies, reducing the risk of sampling errors and unnecessary procedures. For example, in hepatic tumors, the presence of arterial-phase hyperenhancement and washout on CT/MRI may allow for a confident diagnosis of HCC without biopsy in select cases, as per the Liver Imaging Reporting and Data System (LI-RADS) guidelines [18]. Similarly, in pancreatic adenocarcinoma, CT-guided biopsy targeting hypoenhancing areas with desmoplastic stroma can improve diagnostic yield [7].

The study has several limitations. Its single-center design and modest sample size ($n = 100$) limit the generalizability of findings. The reliance on histopathologic confirmation introduces selection bias, as only patients with biopsy or surgical specimens were included. Variability in imaging protocols across different centers may also affect reproducibility. Additionally, the study did not incorporate advanced imaging modalities like positron emission tomography (PET), which could provide metabolic insights into tumor behavior [19].

Multicenter studies with larger cohorts are needed to validate these findings across diverse populations and imaging platforms. The integration of advanced imaging techniques, such as PET/CT or PET/MRI, could enhance the characterization of tumor metabolism and improve diagnostic accuracy [19]. Furthermore, the application of artificial intelligence (AI) and machine learning algorithms to analyze imaging data holds promise for automating radiologic–pathologic correlation and identifying novel imaging biomarkers [20]. Standardized imaging protocols and quantitative imaging metrics, such as ADC values from DWI, could further enhance diagnostic precision and reproducibility [21].

Conclusion

Radiologic–pathologic correlation is a cornerstone of accurate diagnosis in solid organ tumors. CT and MRI demonstrate excellent agreement with histopathological findings, with enhancement patterns, irregular margins, and diffusion restriction serving as reliable predictors of malignancy. By integrating these imaging features into routine radiologic reporting, clinicians can enhance diagnostic confidence, optimize biopsy targeting, and improve patient outcomes. Future research should focus on multicenter validation, advanced imaging integration, and AI-driven diagnostic tools to further refine this critical correlation.

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Conflict of Interest

None

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