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Diagnostic Performance of Multimodality Imaging for Detecting Recurrent Hepatocellular Carcinoma Following Transarterial Chemoembolization in Geriatric Patients: A Retrospective Cohort Study.

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Abstract

Background:
Recurrence after transarterial chemoembolization (TACE) remains a major challenge in hepatocellular carcinoma (HCC), especially in older adults, where comorbidities and post-treatment imaging changes complicate surveillance. This study evaluated multimodality imaging for detecting recurrent HCC after TACE in geriatric patients and identified predictors of recurrence.

Methodology:
This retrospective cohort study included patients aged ≥65 years with HCC who underwent TACE between January 2018 and December 2025 at a tertiary care center. Follow-up imaging included multiphasic contrast-enhanced CT, MRI with diffusion-weighted imaging (DWI), and PET/CT when clinically indicated. Recurrence was confirmed using serial imaging, multidisciplinary tumor board consensus, clinical assessment, retreatment decisions, and histopathology when available. Diagnostic accuracy was assessed using sensitivity, specificity, and AUC. Multivariable Cox regression identified predictors of recurrence.

Results:
A total of 180 patients were included, with a mean age of 72.4 ± 5.6 years; 68.3% were male. During a median follow-up of 24 months, recurrence occurred in 78 patients (43.3%). MRI with DWI showed the best diagnostic performance, with sensitivity of 91.0%, specificity of 88.2%, and AUC of 0.92, outperforming CT, which showed sensitivity of 76.9% and AUC of 0.78. Multimodality imaging improved diagnostic confidence by reducing false positives caused by lipiodol deposition and inflammatory post-treatment changes. Tumor size >5 cm and multifocal disease were independent predictors of recurrence.

Conclusion:
MRI with DWI demonstrated superior accuracy to conventional CT for detecting recurrent HCC after TACE in geriatric patients. Multimodality imaging may enhance surveillance and reduce diagnostic uncertainty. Prospective multicenter studies are needed to validate standardized imaging strategies for elderly patients with HCC.

Keywords:
Hepatocellular Carcinoma, Transarterial Chemoembolization, Recurrence, Geriatric Oncology, Magnetic Resonance Imaging, Diffusion-Weighted Imaging.

Introduction

Hepatocellular carcinoma (HCC) is the most common primary malignancy of the liver and remains one of the leading causes of cancer-related mortality worldwide. According to recent global cancer statistics, HCC ranks among the most frequently diagnosed malignancies and contributes substantially to the global burden of cancer-related deaths. Improvements in life expectancy, enhanced surveillance of chronic liver disease, and advances in cancer management have resulted in an increasing proportion of elderly patients being diagnosed with HCC. Consequently, optimizing management strategies for geriatric patients has become an increasingly important priority in contemporary hepatobiliary oncology. Older adults frequently present with multiple comorbidities, impaired physiological reserve, frailty, and age-related alterations in hepatic and renal function, all of which influence treatment selection, surveillance strategies, and overall clinical outcomes [1-3].

HCC most commonly develops in individuals with chronic liver disease, particularly cirrhosis secondary to chronic hepatitis B or C infection, alcohol-associated liver disease, and metabolic dysfunction-associated steatotic liver disease. Although surgical resection and liver transplantation remain the preferred curative treatment options, a substantial proportion of patients are ineligible because of advanced tumor stage, impaired liver function, limited hepatic reserve, or significant medical comorbidities. Consequently, locoregional therapies have become fundamental components of HCC management. Among these, transarterial chemoembolization (TACE) is the recommended treatment for patients with intermediate-stage disease and for those who are unsuitable candidates for curative surgical intervention. By selectively delivering chemotherapeutic agents combined with embolic materials into tumor-feeding arteries, TACE induces ischemic necrosis while minimizing damage to surrounding liver parenchyma [4,5]. Despite its widespread clinical application and proven therapeutic benefit, recurrence following TACE remains a major challenge in the long-term management of HCC. Residual viable tumor cells, incomplete tumor necrosis, and the development of new intrahepatic lesions contribute to high recurrence rates following treatment, adversely affecting prognosis and overall survival. Early identification of recurrent disease is therefore essential because timely retreatment may improve local disease control and prolong survival. However, accurate post-treatment imaging assessment remains difficult. Lipiodol retention, reactive hyperemia, inflammatory changes, fibrosis, coagulative necrosis, and granulation tissue frequently produce imaging appearances that mimic residual or recurrent tumor, thereby reducing the diagnostic accuracy of conventional imaging modalities [6,7].

Current post-treatment surveillance primarily relies on multiphasic contrast-enhanced computed tomography (CT) and magnetic resonance imaging (MRI). Although these anatomical imaging techniques provide valuable structural information, they may not reliably distinguish viable tumor tissue from treatment-related changes in all patients. Functional imaging techniques including diffusion-weighted MRI (DWI), contrast-enhanced ultrasound (CEUS), perfusion imaging, and positron emission tomography-computed tomography (PET/CT) have emerged as complementary modalities capable of improving diagnostic confidence through the assessment of tissue cellularity, vascularity, and metabolic activity. Integration of multiple imaging techniques has therefore gained increasing attention as a strategy for improving detection of recurrent HCC following locoregional therapies [8].

The challenges associated with post-treatment imaging are particularly relevant in elderly patients. Age-related renal dysfunction may limit administration of iodinated contrast agents or gadolinium-based contrast media, while reduced mobility, frailty, cognitive impairment, and respiratory motion frequently compromise image quality. Furthermore, older adults commonly present with multiple coexisting illnesses that may influence treatment response and complicate interpretation of surveillance imaging. These considerations suggest that surveillance strategies developed for younger populations may not always be directly applicable to geriatric patients, highlighting the need for individualized imaging approaches tailored to this growing patient population [9,10]. Recent international clinical practice guidelines have increasingly emphasized individualized management of HCC based on tumor burden, liver function, patient performance status, and treatment response. The introduction of standardized imaging frameworks, particularly the Liver Imaging Reporting and Data System (LI-RADS) Treatment Response Algorithm, has improved consistency in post-treatment assessment following locoregional therapies and enhanced communication among multidisciplinary teams [11,12]. Nevertheless, evidence specifically addressing the comparative performance of multimodality imaging in elderly patients following TACE remains limited.

Therefore, the present retrospective cohort study aimed to evaluate the diagnostic performance of multimodality imaging for detecting recurrent hepatocellular carcinoma after TACE in geriatric patients. In addition, the study investigated imaging-related diagnostic challenges and identified clinicoradiological predictors associated with recurrence in order to support more individualized surveillance strategies for this increasingly important patient population.

Methodology

Study Design

This retrospective cohort study was conducted to evaluate the diagnostic performance of multimodality imaging for detecting recurrent hepatocellular carcinoma (HCC) following transarterial chemoembolization (TACE) in geriatric patients. The study reviewed routinely collected clinical and radiological data from consecutive eligible patients treated at a tertiary care referral center between January 2018 and December 2025. The study adhered to the principles of the Declaration of Helsinki and followed institutional recommendations for retrospective observational research. Because of the retrospective design, no intervention or modification of patient management occurred during the study period. The study was designed and reported according to recommendations for observational cohort studies.

Ethics

The study was conducted in accordance with institutional ethical standards governing retrospective analyses of anonymized clinical records. As only existing medical records and imaging studies were reviewed and no direct patient contact or intervention was involved, formal ethics committee approval and individual informed consent were waived in accordance with institutional policy. All patient information was de-identified before data extraction and analysis to ensure confidentiality. Data were securely stored and accessed only by study investigators. The conduct of the study complied with the ethical principles outlined in the Declaration of Helsinki.

Setting

The study was performed at the Department of Radiology, Sindh Institute of Urology and Transplantation (SIUT), Karachi, Pakistan, a high-volume tertiary referral center providing multidisciplinary management of hepatobiliary malignancies. Patients were managed through a multidisciplinary tumor board comprising hepatologists, interventional radiologists, diagnostic radiologists, hepatobiliary surgeons, oncologists, and pathologists. TACE was performed according to institutional protocols, and patients underwent standardized post-treatment surveillance using cross-sectional imaging. The institutional imaging archive and electronic medical record system served as the primary sources for patient identification and data retrieval.

Participants

Consecutive patients aged 65 years or older with imaging-confirmed or histopathologically confirmed hepatocellular carcinoma who underwent TACE as their primary locoregional treatment between January 2018 and December 2025 were screened for eligibility. Patients were required to have baseline pre-treatment imaging and a minimum imaging follow-up period of six months after TACE. Initially, 237 consecutive patients were identified. Fifty-seven patients were excluded because of incomplete imaging records (n=21), loss to follow-up (n=18), previous liver transplantation (n=8), concurrent systemic anti-cancer therapy at baseline (n=6), or poor image quality preventing reliable interpretation (n=4). After applying the eligibility criteria, 180 patients constituted the final study cohort. Recurrence status was determined using a composite reference standard consisting of serial imaging progression during follow-up, multidisciplinary tumor board consensus, clinical evaluation, subsequent treatment decisions, and histopathological confirmation whenever tissue diagnosis was available. In patients without pathological confirmation, recurrence was established on the basis of interval radiological progression or sustained stability demonstrated during longitudinal follow-up.

Variables

The primary outcome variable was the diagnostic performance of multimodality imaging for identifying recurrent HCC following TACE. Diagnostic accuracy measures included sensitivity, specificity, and area under the receiver operating characteristic (ROC) curve (AUC). Secondary outcome variables included time to recurrence and clinicoradiological predictors associated with recurrent disease. Predictor variables included patient age, sex, presence of cirrhosis, diabetes mellitus, tumor size, multifocal disease, and imaging characteristics suggestive of viable tumor, including arterial phase hyperenhancement, washout appearance, interval lesion enlargement, restricted diffusion on diffusion-weighted imaging (DWI), and increased metabolic activity on PET/CT when available. Treatment response was primarily evaluated using the Liver Imaging Reporting and Data System (LI-RADS) Treatment Response Algorithm. Modified Response Evaluation Criteria in Solid Tumors (mRECIST) were used as a complementary enhancement-based assessment method, whereas RECIST version 1.1 findings were recorded descriptively. In cases of disagreement between assessment methods, final classification was established through consensus using LI-RADS treatment response criteria [3,12].

Data Sources / Measurement

Clinical and demographic information was extracted from institutional electronic medical records, while radiological findings were obtained from the institutional Picture Archiving and Communication System (PACS). Baseline imaging was performed before TACE, followed by surveillance examinations at approximately one month, three months, six months, and every six months thereafter according to institutional practice. All patients underwent multiphasic contrast-enhanced computed tomography (CT) as part of routine surveillance. Magnetic resonance imaging (MRI), including diffusion-weighted imaging and apparent diffusion coefficient (ADC) mapping, was performed when clinically indicated and available. MRI protocols included T1-weighted, T2-weighted, diffusion-weighted, ADC mapping, and dynamic contrast-enhanced sequences. CT examinations included arterial, portal venous, and delayed phases. Positron emission tomography-computed tomography (PET/CT) was selectively performed in patients with equivocal imaging findings or when recurrent disease was clinically suspected; therefore, PET/CT was not uniformly performed across the entire cohort. All imaging examinations were independently reviewed by two fellowship-trained radiologists with more than ten years of experience in hepatobiliary oncologic imaging. Both readers were blinded to patient clinical outcomes and independently assessed imaging findings. Discrepancies were resolved through consensus review to establish the final imaging interpretation.

Bias

Several measures were implemented to minimize potential sources of bias. Consecutive patient inclusion reduced selection bias, while predefined inclusion and exclusion criteria ensured uniform participant selection. Independent blinded review by two experienced radiologists minimized observer bias during image interpretation. Consensus adjudication was used to resolve disagreements between readers. Because pathological confirmation was not available for all patients, a composite reference standard incorporating serial imaging, multidisciplinary consensus, clinical follow-up, and histopathological confirmation when available was adopted to reduce verification bias. Nevertheless, the retrospective design and selective use of MRI and PET/CT according to clinical indication may have introduced residual selection bias and confounding that could not be entirely eliminated.

Study Size

The study sample represented all eligible consecutive patients meeting the predefined inclusion criteria during the study period. No formal prospective sample size calculation was performed because of the retrospective nature of the study. The final cohort consisted of 180 patients, including 78 recurrence events, providing an adequate number of outcome events to support multivariable regression analyses while maintaining an appropriate events-per-variable ratio for stable model estimation.

Quantitative Variables

Continuous variables, including age, tumor size, and duration of follow-up, were analyzed as continuous measurements and summarized using mean ± standard deviation or median with interquartile range depending on data distribution. Tumor size was additionally categorized (>5 cm versus ≤5 cm) for regression analyses. Categorical variables, including sex, cirrhosis, diabetes mellitus, multifocal disease, recurrence status, and imaging findings, were summarized as frequencies and percentages. Diagnostic accuracy measures were calculated with corresponding 95% confidence intervals.

Statistical Methods

Statistical analyses were performed using IBM SPSS Statistics version 29.0 (IBM Corp., Armonk, NY, USA) and R software version 4.3. Continuous variables were assessed for normality before analysis. Normally distributed variables were summarized as mean ± standard deviation and compared using the independent Student's t-test, whereas non-normally distributed variables were expressed as

median (interquartile range) and compared using the Mann–Whitney U test. Categorical variables were summarized as frequencies and percentages and compared using the Chi-square test or Fisher's exact test where appropriate. Variables demonstrating a univariable association with recurrence at $p<0.10$ were entered into multivariable Cox proportional hazards regression models to identify independent predictors of recurrence. Hazard ratios (HRs) with 95% confidence intervals (CIs) were reported. Diagnostic performance of CT, MRI with diffusion-weighted imaging, and PET/CT was evaluated by calculating sensitivity, specificity, and receiver operating characteristic (ROC) curves with corresponding AUC values and 95% confidence intervals. All statistical tests were two-tailed, and a p-value <0.05 was considered statistically significant.

Results

Participants

A total of 237 consecutive geriatric patients with hepatocellular carcinoma (HCC) who underwent transarterial chemoembolization (TACE) during the study period were initially screened for eligibility. Following application of the predefined inclusion and exclusion criteria, 57 patients were excluded because of incomplete imaging records (n=21), loss to follow-up (n=18), previous liver transplantation (n=8), concurrent systemic anti-cancer therapy (n=6), or inadequate image quality (n=4). Consequently, 180 patients were included in the final analysis. All patients underwent contrast-enhanced computed tomography (CT) during follow-up, while magnetic resonance imaging (MRI) with diffusion-weighted imaging (DWI) was available in 146 patients, and positron emission tomography-computed tomography (PET/CT) was performed in 47 patients when clinically indicated for equivocal imaging findings or suspected recurrence. The median duration of imaging follow-up was 24 months (interquartile range [IQR]: 14–38 months).

Descriptive data

The baseline demographic and clinical characteristics of the study population are summarized in Table 1. The mean age of the participants was 72.4 ± 5.6 years, and the majority were male (68.3%, n=123). Tumor recurrence developed in 78 patients (43.3%), whereas 102 patients (56.7%) demonstrated sustained treatment response throughout the follow-up period. Patients who experienced recurrence tended to have larger tumors than those without recurrence (4.8 ± 1.7 cm versus 3.9 ± 1.3 cm, p=0.003). Multifocal disease was also significantly more frequent among patients with recurrent HCC (56.4% versus 38.2%, p=0.02). In contrast, no statistically significant differences were observed between the recurrence and non-recurrence groups regarding age, sex distribution, presence of cirrhosis, or diabetes mellitus (Table 1). Table 1 therefore demonstrates that tumor burden, particularly larger tumor size and multifocal disease, differed significantly between patients with and without recurrence, whereas baseline demographic characteristics were generally comparable.

Outcome data

During the follow-up period, recurrent hepatocellular carcinoma was identified in 78 patients (43.3%) according to the predefined composite reference standard incorporating serial imaging findings, multidisciplinary consensus, clinical assessment, repeat treatment decisions, and histopathological confirmation when available. The diagnostic performance of the evaluated imaging modalities is presented in Table 2. MRI incorporating diffusion-weighted imaging demonstrated the highest diagnostic accuracy for detecting recurrent disease, achieving a sensitivity of 91.0% (95% CI: 82.4–96.3%), specificity of 88.2% (95% CI: 80.4–93.8%), and an area under the receiver operating characteristic curve (AUC) of 0.92 (95% CI: 0.88–0.97). Conventional multiphasic CT demonstrated lower diagnostic performance, with sensitivity of 76.9% (95% CI: 66.2–85.5%), specificity of 78.4% (95% CI: 69.1–86.0%), and an AUC of 0.78 (95% CI: 0.71–0.85). PET/CT, performed selectively in patients with clinically indicated equivocal findings, also demonstrated favorable diagnostic accuracy, with sensitivity of 87.2%, specificity of 84.9%, and an AUC of 0.86.

Main results

Multivariable Cox proportional hazards regression identified two independent predictors of recurrent hepatocellular carcinoma following TACE (Table 3). Patients with tumors measuring greater than 5 cm had more than twice the risk of recurrence compared with those having smaller tumors (hazard ratio [HR] 2.11, 95% CI: 1.35–3.92, p=0.002).

Similarly, multifocal disease independently increased the likelihood of recurrence (HR 1.84, 95% CI: 1.12–2.90, p=0.01). Comparison of imaging modalities demonstrated that MRI with diffusion-weighted imaging consistently outperformed conventional CT for identifying recurrent HCC after TACE, showing higher sensitivity, specificity, and overall diagnostic accuracy (Table 2). Functional imaging characteristics obtained through DWI provided additional information beyond conventional morphologic assessment and improved differentiation between viable tumor tissue and post-treatment changes. The principal imaging pitfalls encountered following TACE and their distinguishing radiological features are summarized in Table 4. Common post-treatment findings such as reactive hyperemia, lipiodol deposition, granulation tissue, peritumoral edema, and treatment-related necrosis occasionally mimicked recurrent disease on conventional imaging.

However, persistent nodular arterial enhancement, restricted diffusion on MRI, progressive interval lesion growth, washout characteristics, and enhancing viable tissue margins improved recognition of true recurrence and reduced diagnostic uncertainty. Representative imaging findings illustrating recurrent disease after TACE are shown in Figure 1, which demonstrates progressive metabolic activity on serial PET/CT examinations, and Figure 2, which highlights the superior ability of multiparametric MRI with diffusion-weighted imaging to identify recurrent hepatocellular carcinoma compared with conventional CT in a representative patient.

These findings indicate that MRI with diffusion-weighted imaging provides the highest diagnostic performance for post-TACE surveillance in geriatric patients, while multimodality imaging offers complementary value in challenging or equivocal cases by improving diagnostic confidence and facilitating earlier recognition of recurrent disease.

Table 1: Baseline Characteristics of Patients According to Recurrence Status.

Characteristic	Recurrence (n = 78)	No Recurrence (n = 102)
Age (years), mean ± SD	73.1 ± 5.9	71.9 ± 5.3
Male sex, n (%)	54 (69.2)	69 (67.6)
Cirrhosis, n (%)	58 (74.4)	69 (67.6)
Diabetes mellitus, n (%)	34 (43.6)	38 (37.3)
Tumor size (cm), mean ± SD	4.8 ± 1.7	3.9 ± 1.3
Multifocal lesions, n (%)	44 (56.4)	39 (38.2)

SD = standard deviation; SMD = standardized mean difference.

Table 2: Diagnostic Performance of Imaging Modalities for Detection of Recurrent Hepatocellular Carcinoma Following TACE.

Imaging Modality	Sensitivity (95% CI)	Specificity (95% CI)	AUC (95% CI)
Contrast-enhanced CT	76.9% (66.2–85.5)	78.4% (69.1–86.0)	0.78 (0.71–0.85)
MRI with DWI	91.0% (82.4–96.3)	88.2% (80.4–93.8)	0.92 (0.88–0.97)
PET/CT*	87.2% (75.3–94.4)	84.9% (74.8–91.9)	0.86 (0.79–0.93)

CT = computed tomography; MRI = magnetic resonance imaging; DWI = diffusion-weighted imaging; PET/CT = positron emission tomography/computed tomography; AUC = area under the receiver operating characteristic curve; CI = confidence interval.
*PET/CT was performed only in selected patients with clinically indicated equivocal findings or suspected recurrence.

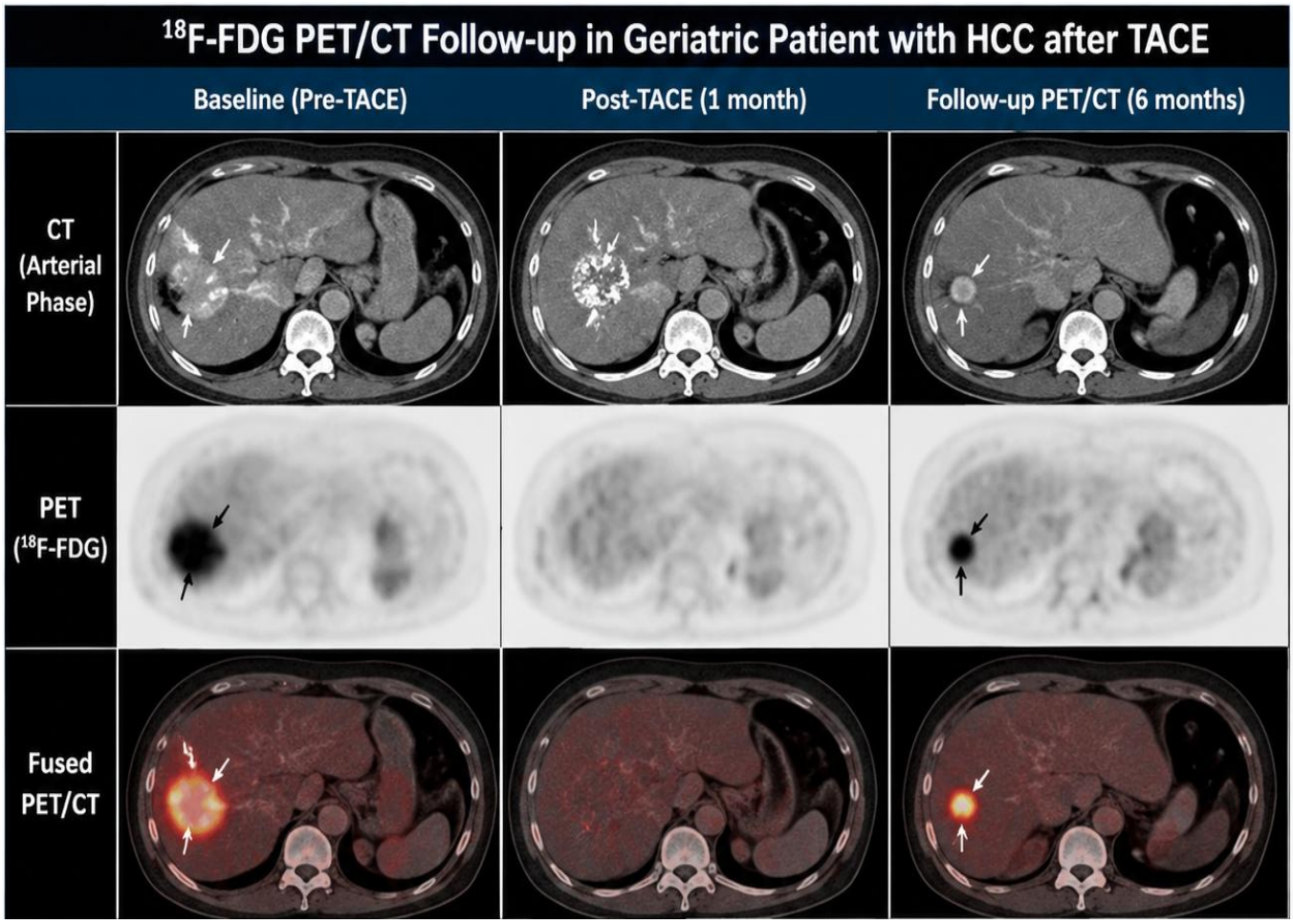

Figure 1: Serial 18F-FDG PET/CT Demonstrating Metabolic Response and Subsequent Recurrence of Hepatocellular Carcinoma Following Transarterial Chemoembolization

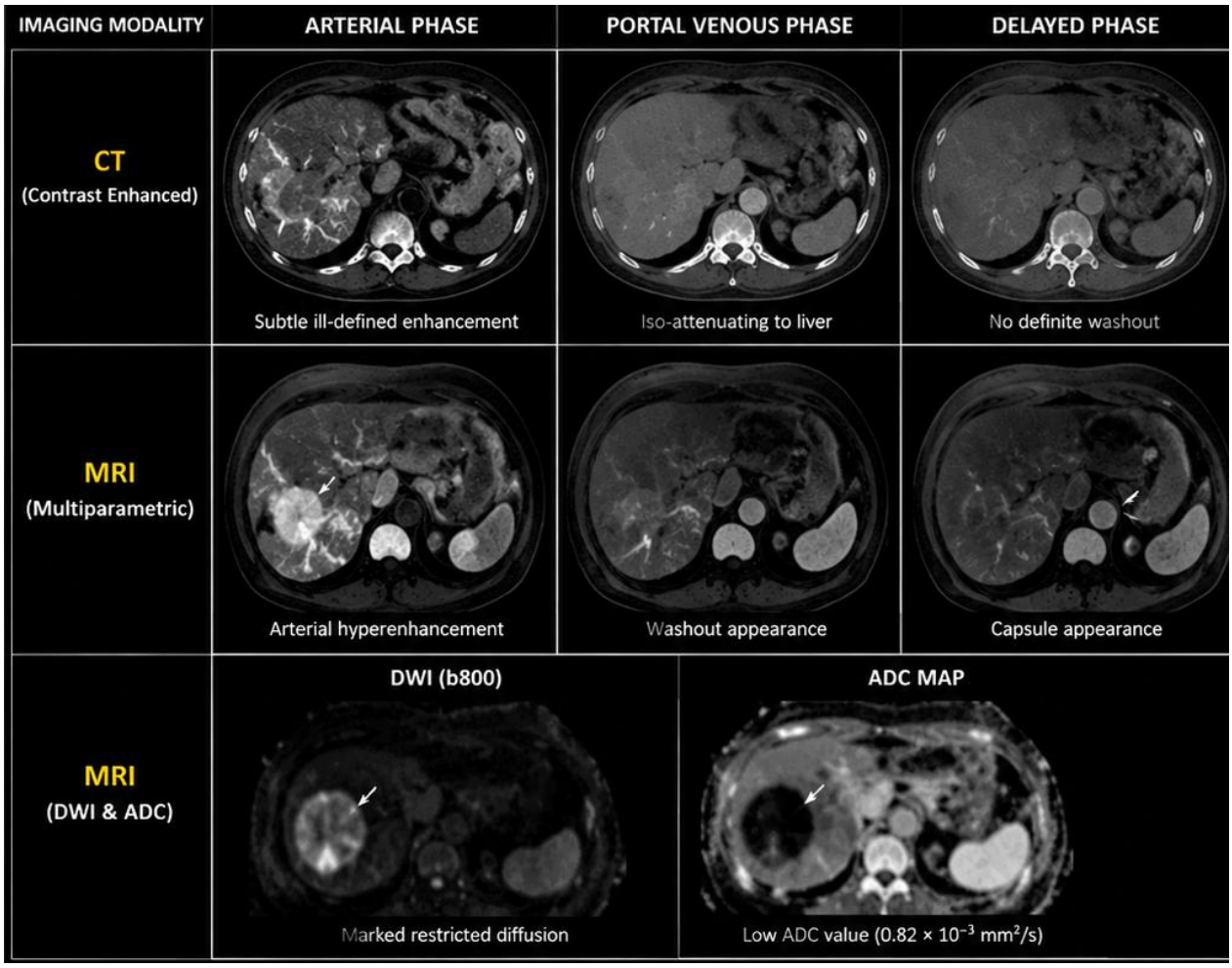

Figure 2: Comparative Contrast-Enhanced CT and Multiparametric MRI for Detection of Recurrent Hepatocellular Carcinoma Following Transarterial Chemoembolization

Table 3: Multivariable Cox Regression Analysis of Independent Predictors of Tumor Recurrence Following TACE.

Variable	Hazard Ratio (HR)	95% Confidence Interval	p-value
Tumor size >5 cm	2.11	1.35–3.92	0.002*
Multifocal disease	1.84	1.12–2.90	0.010*

HR = hazard ratio; CI = confidence interval.
*p<0.05 is considered statistically significant

Table 4: Summary of Principal Imaging Findings.

Finding	Observation
Overall recurrence rate	78/180 patients (43.3%)
Best-performing imaging modality	MRI with DWI
Highest sensitivity	MRI with DWI (91.0%)
Highest specificity	MRI with DWI (88.2%)
Highest diagnostic accuracy	MRI with DWI (AUC 0.92)
Independent predictors of recurrence	Tumor size >5 cm and multifocal disease
Common causes of false-positive CT findings	Lipiodol deposition and post-treatment inflammatory changes
Clinical implication	Multimodality imaging improves diagnostic confidence following TACE

Discussion

The present retrospective cohort study evaluated the diagnostic performance of multimodality imaging for detecting recurrent hepatocellular carcinoma (HCC) following transarterial chemoembolization (TACE) in a geriatric population. The principal findings indicate that magnetic resonance imaging (MRI) incorporating diffusion-weighted imaging (DWI) demonstrated superior diagnostic performance compared with conventional contrast-enhanced computed tomography (CT), while a multimodality imaging approach improved diagnostic confidence in patients with equivocal post-treatment findings. Additionally, larger tumor size and multifocal disease were identified as independent predictors of recurrence. These findings support the growing role of functional imaging techniques in post-TACE surveillance and emphasize the importance of individualized imaging strategies for elderly patients. Tumor recurrence remains one of the major determinants of long-term prognosis after TACE. Although TACE is an established treatment for intermediate-stage HCC, complete pathological necrosis is uncommon, and residual viable tumor tissue frequently persists despite apparent radiological response. Previous studies have reported recurrence rates ranging from approximately 35% to 70%, depending on tumor characteristics, embolization techniques, surveillance duration, and patient selection [1,4,5]. The recurrence rate of 43.3% observed in the present cohort falls within this reported range and likely reflects the heterogeneous disease burden and clinical complexity of elderly patients undergoing locoregional therapy.

Post-treatment imaging assessment remains challenging because treatment-induced changes frequently resemble viable tumor. Lipiodol retention, coagulative necrosis, inflammatory reactions, granulation tissue, fibrosis, and reactive hyperemia may obscure enhancement patterns and complicate differentiation between residual tumor and expected post-treatment appearances. Consequently, reliance on anatomical imaging alone may result in both false-positive and false-negative interpretations. In the present study, multimodality imaging reduced diagnostic uncertainty by integrating structural, functional, and metabolic information, thereby improving confidence in recurrence assessment.

Among the evaluated imaging modalities, MRI incorporating diffusion-weighted imaging demonstrated the highest diagnostic accuracy, with greater sensitivity, specificity, and overall discriminatory performance than conventional CT. These findings are consistent with previous investigations demonstrating the superiority of diffusion-weighted MRI for identifying viable tumor following locoregional therapy [6–8]. Diffusion-weighted imaging provides additional physiological information by detecting alterations in water molecule mobility associated with increased cellularity, allowing recurrent tumor to be identified even before substantial morphologic progression becomes apparent. Combined with dynamic contrast-enhanced sequences, MRI facilitates comprehensive evaluation of both vascularity and tissue viability, making it particularly valuable in post-TACE surveillance.

Conventional multiphasic CT remains the most widely available surveillance modality because of its accessibility, rapid acquisition, and standardized interpretation criteria. However, retained lipiodol frequently generates beam-hardening artifacts and obscures arterial enhancement, thereby reducing diagnostic sensitivity following embolization [3]. The lower diagnostic performance observed for CT in the present study is therefore consistent with previously published evidence and underscores the importance of cautious interpretation of CT findings after TACE.

PET/CT also demonstrated favorable diagnostic performance in selected patients with indeterminate imaging findings. However, PET/CT was performed selectively rather than routinely, reflecting current clinical practice. Consequently, its reported diagnostic performance should not be interpreted as directly comparable to CT or MRI. Nevertheless, metabolic imaging may provide incremental diagnostic value when conventional anatomical imaging remains inconclusive, particularly in complex post-treatment cases. Similarly, previous studies have demonstrated promising diagnostic utility of contrast-enhanced ultrasound (CEUS) for evaluating treatment response following locoregional therapies [9]. Since CEUS was not performed in the present cohort, discussion of its potential benefits is based exclusively on published literature rather than findings from the current study.

An important strength of this study is its exclusive focus on geriatric patients, a population that remains underrepresented in imaging research despite representing an increasing proportion of individuals diagnosed with HCC. Elderly patients present unique diagnostic challenges because age-related physiological alterations, chronic kidney disease, frailty, impaired mobility, respiratory motion, and multiple comorbidities frequently influence both image acquisition and interpretation [10]. These considerations highlight the need for individualized surveillance strategies rather than uniform imaging protocols originally developed for younger patient populations.

The present study also identified larger tumor size and multifocal disease as independent predictors of recurrence after TACE. These findings are biologically plausible and consistent with previous reports demonstrating that greater tumor burden is associated with incomplete treatment response, increased residual microscopic disease, and more aggressive tumor biology [4,5]. Patients with larger or multifocal tumors may therefore benefit from closer imaging surveillance and multidisciplinary follow-up after locoregional treatment.

Treatment response was primarily evaluated using the Liver Imaging Reporting and Data System (LI-RADS) Treatment Response Algorithm, which provides standardized criteria for assessing viable tumor following locoregional therapy [12]. Adoption of standardized reporting systems improves consistency among radiologists, facilitates multidisciplinary communication, and enhances comparability across clinical studies. Continued integration of LI-RADS with advanced functional imaging techniques may further improve post-treatment surveillance strategies.

Limitations

Several limitations should be considered when interpreting the findings of this study. First, the retrospective single-center design is inherently susceptible to selection bias, information bias, and incomplete data capture. Although consecutive patient inclusion and standardized eligibility criteria were used to minimize selection bias, residual confounding cannot be excluded. Second, several clinically important prognostic variables including Child-Pugh classification, Model for End-stage Liver Disease (MELD) score, Barcelona Clinic Liver Cancer (BCLC) stage, serum alpha-fetoprotein (AFP) concentration, viral hepatitis status, and Eastern Cooperative Oncology Group (ECOG) performance status were incompletely available for all patients and therefore could not be comprehensively incorporated into multivariable analyses. Third, pathological confirmation of recurrence was not available in every patient because routine clinical management frequently relied on longitudinal imaging findings, multidisciplinary consensus, and subsequent

treatment decisions. Although a composite reference standard was employed to minimize verification bias, some degree of disease misclassification remains possible. Fourth, imaging protocols evolved over the extended study period, potentially introducing heterogeneity in acquisition parameters and image quality. Furthermore, although all patients underwent routine CT surveillance, MRI with diffusion-weighted imaging was performed according to clinical indication and scanner availability, while PET/CT was reserved for selected patients with indeterminate findings or suspected recurrence. Consequently, comparisons between imaging modalities should be interpreted cautiously because the study was not designed as a head-to-head prospective diagnostic accuracy trial. Finally, the single-center nature of the study and exclusive inclusion of geriatric patients may limit generalizability to younger populations or institutions using different surveillance protocols. Future multicenter prospective studies employing standardized imaging algorithms, uniform reference standards, and comprehensive clinical data are required to validate these findings.

Conclusion

In this retrospective cohort of geriatric patients with hepatocellular carcinoma treated with transarterial chemoembolization, MRI incorporating diffusion-weighted imaging demonstrated higher diagnostic performance than conventional contrast-enhanced CT for detecting suspected tumor recurrence. A multimodality imaging approach provided complementary diagnostic information and improved confidence in distinguishing recurrent tumor from treatment-related imaging changes. Larger tumor size and multifocal disease were independently associated with recurrence and may help identify patients requiring closer surveillance.

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