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EFFICACY OF MICROWAVE ABLATION FOR HEPATIC LESIONS USING MULTI-DETECTOR COMPUTED TOMOGRAPHY

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Abstract

Background: *Hepatic lesions, including primary hepatocellular carcinoma and metastatic liver tumors, are a significant cause of morbidity and mortality worldwide. Microwave ablation (MWA) has emerged as a minimally invasive treatment option, while multidetector computed tomography (MDCT) plays a key role in evaluating treatment response.*

Objective: *To assess the efficacy of microwave ablation for hepatic lesions using MDCT*

Methods: *A descriptive cross-sectional study was conducted on 80 patients with hepatic lesions undergoing MWA. Pre- and post-procedural MDCT imaging was performed using a standardized multiphasic protocol. Data collected included lesion characteristics, procedural parameters, and follow-up findings. Treatment response was categorized as complete response, partial response, or stable disease. Statistical analysis was carried out using SPSS. Descriptive statistics, independent samples t-test, Pearson's chi-square test and binary logistic regression were employed.*

Results: *The mean age was 58.56 ± 10.39 years with equal gender distribution. The mean lesion size was 32.34 ± 10.86 mm. Complete response was achieved in 81.3% of patients, while partial response and stable disease were observed in 16.3% and 3.8%, respectively. Local tumor progression occurred in 6.3% of cases. Patients without progression had significantly smaller lesions, larger ablation zones, and wider safety margins ($p < 0.001$). Most patients (80%) experienced no complications, with only 5% having major complications.*

Conclusion: *Microwave ablation is a safe and effective treatment for hepatic lesions. MDCT provides reliable assessment of treatment response, and outcomes are strongly influenced by lesion size and adequacy of ablation margins.*

INTRODUCTION

Hepatic lesions are a major global health concern, comprising both primary tumors such as hepatocellular carcinoma (HCC) and secondary metastatic deposits from cancers of the colorectum, pancreas, breast, and lung.(1) HCC is the sixth most prevalent cancer and the third leading cause of cancer death with more than 800,000 new cases and deaths per year. Its epidemiology is closely linked to chronic liver diseases, particularly hepatitis B and C infections, alcohol-related liver damage, and the increasing prevalence of non-alcoholic fatty liver disease.(2)The disease demonstrates significant geographic variation, with the highest burden observed in Asia and sub-Saharan Africa where viral hepatitis remains endemic. By comparison, metastatic liver disease is more prevalent; the liver is the most common site of metastasis; almost 50-70% of patients with colorectal cancer develop liver metastases as part of their disease.(3) The prevalence is also growing in South Asian countries, such as Pakistan, where the high incidence of viral hepatitis, late diagnosis and lack of screening programs continue to pose a challenge in the form of hepatic lesions.(4)

Primary and metastatic hepatic lesions greatly affect survival rates, primarily due to the advanced stage at which many patients are diagnosed. Surgery is the optimal treatment, with the highest potential for survival and cure. But surgery is only possible in a minority of patients.(5) Tumor characteristics, including size, multifocality and involvement of major vasculature and biliary structures, may preclude surgical resection. Furthermore, patient-related factors such as poor liver function, cirrhosis, co-morbidities and poor performance limit surgical resectability.(6)

Among these treatment options, thermal ablation techniques have gained considerable attention over the past two decades. These methods destroy tumor tissue by applying extreme temperatures, leading to irreversible cellular injury and coagulative necrosis.(8) In particular, microwave ablation (MWA) has shown great potential because it produces higher temperatures, larger and more consistent ablation volumes, and shorter procedure times than previous methods.(9)It is also less susceptible to the heat-sink effect, and can be used to treat lesions adjacent to vessels. This makes MWA an attractive option for those who cannot undergo surgical resection and offers a viable way of achieving local tumor control for hepatic lesions.(10)

Microwave ablation works by delivering electromagnetic energy through an antenna inserted into the tumor under image guidance. This induces rapid vibration of water molecules in the tissue, creating heat and resulting in thermal necrosis of tumor tissue.(11) This process permits a quick rise in temperature (usually above 100°C) and immediate tumor cell death. A significant benefit of MWA is the larger and more consistent ablation zones that can be generated.(12)

Radiofrequency ablation (RFA) is a traditional thermal ablation technique that has been commonly used in the treatment of liver tumors.(13) But it has some drawbacks that have led to the use of MWA. For instance, the heat-sink effect, in which heat is absorbed by blood flowing through adjacent vessels, can limit the effectiveness of RFA.(14) MWA has a lower heat-sink effect, which leads to more predictable outcomes, especially when treating tumours adjacent to blood vessels. It can reach higher temperatures within the tumour faster, speeding up treatment and enhancing efficiency. These factors have led to growing use of MWA.(15)

However, despite the technical advantages, the merits of microwave ablation cannot solely rely on satisfactory procedures. Reliable imaging is required to assess the efficacy of treatment in destroying the tumor.(16) The use of imaging is needed for pre-procedural treatment planning, intra-procedural guidance, and post-procedural follow up. Selection of the appropriate imaging technique is an important factor in the evaluation of treatment response.(17)

The effectiveness of microwave ablation for hepatic lesions depends on several factors. One of the critical factors is lesion size; smaller lesions tend to have a higher success rate of complete ablation.(24) The size and location of the lesion is a critical factor .Lesions greater than 3-5 cm in diameter may require multiple microwave ablations or other combination therapies for best outcomes. Lesions adjacent to the diaphragm, bile ducts or large vessels can be technically difficult to treat and may increase the risk of complications.(25) Further, the multiplicity and location of lesions within the liver may influence treatment strategies. Patient-specific factors also impact treatment outcomes. The degree of liver dysfunction, presence of cirrhosis, and general health impact the eligibility for ablation and the patient's recovery. Those with normal liver

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function can tolerate ablation and have a higher success rate.(26)

In some instances, CT-guided microwave ablation is used to accurately insert the ablation antenna and monitor the ablation process. This enhances precision and minimises the risk of injury to nearby tissues. It also helps to ensure that the entire lesion is encompassed by the ablation zone, thus improving the chances of successful treatment. The growing popularity of microwave ablation for the treatment of hepatic lesions and the common use of multidetector computed tomography for imaging evaluation has not removed the variability in the results of such research, which is likely attributable to a range of differences in patient and lesion characteristics, treatment strategies, and assessment criteria. (30)

There is often a lack of local data in many countries, particularly in low-income and middle-income settings, which reflect local disease epidemiology and treatment practice, and limit the generalizability of the evidence. So a targeted assessment of the effectiveness of microwave ablation using MDCT is needed to better understand its efficacy by looking at the rate of complete ablation, detecting residual or recurrent disease, and reporting complication rates. Integration of imaging and clinical data can help determine the true extent of treatment response, while implementing standardised imaging protocols and criteria for reporting and analysis can minimise variability and enable data comparison across studies. This facilitates accurate assessment, enhances the evidence base and aids in clinical decision-making when managing hepatic lesions.

OBJECTIVE

This study aimed to assess the safety and technical precision of Multi-Detector Computed Tomography Guided Microwave Ablation in the treatment of hepatic lesions and to evaluate the effectiveness of therapy in terms of complication profiles, local recurrence rates, and total tumors necrosis.

Material And Methods

This prospective interventional observational study was conducted in the Departments of Radiology and Surgical Oncology at Jinnah Hospital Lahore over a period of nine months following approval of the research synopsis. A total of 80 participants were enrolled using a convenience sampling technique, with the sample size determined through a standard statistical formula. Eligible participants included adult patients (≥18 years) of either gender with radiologically diagnosed primary or metastatic hepatic lesions who were planned for or had undergone microwave ablation (MWA), with available baseline, post-procedure, and follow-up multidetector computed tomography (MDCT) scans. Patients who underwent alternative treatment modalities alone (such as surgery, radiofrequency ablation, or chemotherapy without MWA), those with contraindications to contrast-enhanced CT (including severe renal impairment or contrast allergy), patients with diffuse liver disease unsuitable for focal ablation assessment, and those with previous ablation of the same lesion without baseline imaging for comparison were excluded.

Microwave ablation was performed using a dedicated microwave ablation system equipped with a generator and antenna probes under image guidance. Radiological assessment was carried out using a 128-slice Toshiba multidetector computed tomography (MDCT) scanner with a contrast-enhanced liver protocol for both pre- and post-procedural evaluation to assess treatment response and ablation outcomes.

RESULTS

A total of 80 patients were enrolled in the study with a mean age of 58.56 ± 10.39 years (range 41-75) and equal representation of males and females. Lesion size showed considerable variation, ranging from 15 mm to 60 mm, reflecting heterogeneity in tumor burden among patients. The number of antennas used varied between 1 and 2. Procedural parameters also demonstrated variability, with power settings ranging from 60 to 100 W and ablation duration ranging from 5 to 15 minutes. The ablation zone size ranged from 20 to 65 mm, while safety margin ranged from 4 to 10 mm, indicating differences in treatment coverage achieved during microwave ablation.

Table 1: Descriptive Analysis of Demographic, Clinical, and Procedural Variables

Demographics	Minimum	Maximum	Mean
Age	41	75	58.56
Height(cm)	150	180	165.17
Weight(kg)	56	90	72.68
Necrosis	1	2	1.23
Local Progression	0	1	.06
Ablation Zone(mm)	20	65	43.24
Power(W)	60	100	80.29
Approach	1	1	1.00
Antenna	1	2	1.46
No. of Lesions	1	3	2.03
LesionSize(mm)	15	60	30.89
Duration(min)	5	15	9.77

Alcohol-related liver disease accounted for 22.5% of cases, HBV for 26.3%, HCV for 23.8%, and other causes for 27.5%. Regarding cirrhosis status, 51.2% of patients had no cirrhosis, while 48.8% were cirrhotic, showing an almost equal distribution between the two groups. MWA was the most common prior therapy (26.3%), followed by surgery (21.3%) and RFA (20.0%). 13.8% were noted to have TACE and 18.8% were untreated prior to TACE. The results suggest that there is a diversity of treatment experiences present. This diversity is in line with the practice of everyday care.

Table 2: Frequency Distribution of Etiology of Liver Disease and Cirrhosis Status and Prior Therapies Among Study Patients

Variables	Category	Number of Patients	Percent
Etiology	Alcohol	18	22.5
	HBV	21	26.3
	HCV	19	23.8
	Other	22	27.5
Cirrhosis Status	No	41	51.2
	Yes	39	48.8
Prior Therapy	MWA	21	26.3
	None	15	18.8
	RFA	16	20.0
	Surgery	17	21.3
	TACE	11	13.8

The most common segments involved were segment I (20.0%), segment V (17.5%) and segment VI (15.0%). The right lobes were more involved than left lobes. This is consistent with a known distribution. May affect treatment approach and procedural planning. Most patients had two lesions (35.0%), followed by three lesions (33.8%) and one lesion (31.3%). Regarding diagnosis, metastasis was the most common (37.5%), followed by imaging-diagnosed HCC (35.0%) and biopsy-proven HCC (27.5%)

Table 3: Frequency Distribution of Liver Segment Involvement in Study Patients

No. Of Lesions and Segment Involvement		Frequency	Percent
Segment	I	16	20.0
	II	5	6.3
	III	7	8.8
	IVa	5	6.3
	IVb	8	10.0
	V	14	17.5
	VI	12	15.0
	VII	4	5.0
	VIII	9	11.3
No. of Lesions	1	25	31.3
	2	28	35.0
	3	27	33.8
Diagnosis	Biopsy HCC	22	27.5
	Imaging HCC	28	35.0
	Metastasis	30	37.5
	Total	80	100.0

It was found that most of the procedures utilized 1 antenna (43 cases, 53.8%) and 2 antennas (37 cases, 46.3%) were equally used, giving a nearly equal distribution. The mean power applied was 80.29 ± 12.52 W, ranging from 60 to 100 W. The mean time required for performing the procedure was 9.78 ± 3.01 minutes with a range of 5 to 15 minutes. In general, the data show moderate range of technical parameters and relatively short and stable times for the procedure. The analysis reveals a fairly even utilization of the overlap technique with 55% of cases not using it, and 45% using it. The ablation of the tracks was carried out in all cases (100%), consistently as a standard procedure. Complications: Most patients (80%) had no complications. In 15% of cases minor complications were noticed and major complications were very rare, being seen in only 5% of cases. In general, the complication rate is low and indicates a low procedural risk. The distribution shows some consistency in procedure with few negative consequences. Most patients showed no enhancement (77.5%), indicating successful ablation. Rim enhancement was observed in 12.5% of cases, while nodular enhancement was seen in 10.0% of patients, suggesting possible residual or recurrent disease in a small proportion of cases. The most common safety margin was 10 mm (28.7%), followed by 6 mm (16.3%) and 8 mm (15.0%). The least frequent value was 4 mm (1.3%). Overall, most patients had a safety margin between 5–10 mm, with higher representation toward the upper range.

Table 4: Frequency Distribution of Lesion and Procedural Characteristics

Variable	**Category**	**n (%)**
Antenna	1	43 (53.8)
	2	37 (46.3)
Overlap	No	44 (55.0)
	Yes	36 (45.0)

Setting	CT-guided	44 (55.0)
	US-guided	36 (45.0)
Approach	Percutaneous	80(100)
Overlap Technique	No	44(55)
	Yes	36(45)
Track Ablation	Yes	80
Complications	Major	4(5)
	Minor	12(15)
	None	64(80)
Safety Margin(mm)	4	1(1.3)
	5	11(13.8)
	6	13(16.3)
	7	9(11.3)
	8	12(15)
	9	11(13.8)
	10	23(28.7)
Enhancement	Nodular	8
	None	62
	Rim	10
	Total	80(100)

Likewise, the safety margin was larger for patients without progression (8.01 ± 1.75 mm) than for patients with progression (4.80 ± 0.45 mm) ($p < 0.001$). Larger safety margin is linked to improved prognosis. This indicates the importance of covering all of the tumor. Differences between the groups were statistically significant, indicating clinical validity

Table:6 Comparison of Lesion Size, Ablation Zone, and Safety Margin According to Local Tumor Progression

Parameters	Local Progression	Mean
Lesion Size(mm)	No	29.17
	Yes	56.60
Ablation Zone(mm)	No	44.65
	Yes	22.00
Safety Margin(mm)	No	8.01
	Yes	4.80

The independent samples t-test showed significant differences in lesion size, safety margin, and ablation zone between patients with and without local tumor progression ($p < 0.001$). Patients without local progression had significantly smaller lesion sizes and significantly larger safety margins and ablation zones compared with those who developed local progression, indicating that adequate ablation coverage and smaller tumor size are associated.

Table 7: Independent Samples t-test Comparing Lesion Size, Ablation Zone, and Safety Margin According to Local progression

Levene's Test for Equality of Variances			

		F	Sig.	Sig. (2-tailed)
Lesion Size(mm)		3.814	.054	.000
				.000
Safety Margin(mm)		9.093	.003	.000
				.000
Ablation Zone(mm)		6.416	.013	.000
				.000

The relationship between lesion number and necrosis was significant (Pearson Chi-square = 11.267, $p = 0.004$). This suggests a significant association between number of lesions and treatment response. There are no low expected frequencies. In summary, the presence of more lesions is associated with incomplete necrosis.

Cirrhosis was a statistically significant predictor of ineffective response ($p = 0.020$, OR = 6.282), indicating that cirrhotic patients had significantly higher odds of treatment failure compared to non-cirrhotic patients.Lesion size ($p = 0.061$) and number of lesions ($p = 0.083$) showed a trend toward increased risk of ineffective response. Antenna type also showed borderline significance ($p = 0.075$).

Table 12: Binary Logistic Regression Analysis of Predictors of Treatment Outcome

Parameters	B	Sig.	Exp(B)	95% C.I.for EXP(B)	
				Lower	Upper
Cirrhosis	1.838	.020	6.282	1.330	29.675
No. of Lesions	.875	.083	2.398	.892	6.449
Antenna	1.335	.075	3.798	.875	16.492
LesionSize(mm)	.072	.061	1.075	.997	1.159

The logistic regression model showed acceptable fit with a -2 log likelihood of 56.598. The Cox & Snell R^2 and Nagelkerke R^2 values were 0.302 and 0.460 respectively, indicating that the model explains approximately 46% of the variation in treatment outcome

Table 13: Model Fit Statistics for Binary Logistic Regression Analysis

DISCUSSION

The study aimed to assess the usefulness of microwave ablation (MWA) in the treatment of hepatic lesions with the help of multidetector computed tomography (MDCT). The results reveal a very good response rate with 81.3% of patients completely responding to the treatment, low local tumor progression (6.3%) and a favourable safety profile – most of the patients (80%) had no complications at all. With reference to published studies, it is clear that MWA achieves good local control of the tumour in most cases, and that lesion size, ablation margin and liver condition has a profound influence on the results. The most important finding from the study is the obtains complete response (81.3%). The relatively high response rate this study may be explained by the differences in the lesion types, and mean size of the formed lesions was 32.34 mm which is well in the optimal range of effective thermal ablation response. This reinforces this theory, which thinks that the size of the tumor helps to determine the success of the ablation. (31,32)The low local tumor progression rate (6.3%) is another important finding. Higher ablation margins were found in this cohort with a mean safety margin of 7.40mm, which may explain why there was a lower progression rate across this cohort, indicating the significance of providing adequate ablation margins (safety margins) when ablating near tumour boundaries.Lesion size was an important predictor of the results in this study. There was a significant difference in size of the lesions between patients with local progression (56.60 ± 3.13 mm) and without local progression (29.17 ± 8.35 mm, p = 0.027). Ablation zone and safety margin was also clearly seen. Ablation zones were also larger (44.65 ± 10.60 mm) and safety margins larger (8.01 ± 1.75 mm) in those who did not progress (group 2) than in those who did progress (group 1), respectively. When entered into multivariate analysis, however, these parameters were not statistically significant, indicating that perhaps these parameters act through lesion size and underlying liver disease. However, it has been reported by other authors, such as Casadaban et al. (2021), that the key issue contributing to failure is around the issue of technical adequacy of the ablation procedure. Logistic regression analysis is one of the important features that has been added in this study. Cirrhosis was found to be a strong independent predictor of treatment outcomes (p = 0.020, OR = 6.28), with cirrhosis cases having a higher risk of treatment failure. This result shows the relation that basic liver parenchymal disease plays between therapeutic response; it could be the effect of a changed response of liver tissue, and a decrease of regenerative function. There was a near-sigificant relationship with lesion size (p = 0.061) indicating a trend towards worse lesion size outcomes. Either likewise, variety of lesions (p = 0.083), or antenna use (p = 0.075) had borderline significance which means that the value of the tumour burden and procedural technique would influence results, but not independently. Other factors such as etiology, diagnosis, setting, ablation zone, safety margin, power and complications were not statistically significant.

MDCT imaging proved to be useful to assess post-ablation efficacy. Most patients (77.5%) had no enhancement; this implies complete tumor necrosis. Minority of cases exhibited rim enhancement (12.5%) and/or nodular enhancement (10%) which can be an inflammatory process after the procedure or residual viable tumor. This follows accepted imaging criteria for successful ablation - defined as no evidence of enhancement. There are some limitations of MDCT but. Myne et al (2021) found that although very useful for anatomical assessment, MDCT may be less sensitive than functional imaging modalities like PET/CT and SPECT/CT for detecting residual metabolic activity. In the context of the above limitation, however, application of MDCT has been traditionally adopted because of its ease of use, timeliness, and accuracy in everyday clinical practice. (33)

In the present study, the safety profile of MWA was favorable as 80% of cases did not have any complications, while 5% of cases had major complications. This study reported low complication rates which can be attributed to patients selection, technique and imaging guidance. (34)

Other factors found to influence outcomes are patient and procedural heterogeneity. Most patients had several lesions, as is seen in practice. The external validity of the results of this study is strengthened by the inclusion of several lesions as the disease was multi focal. Imaging guidance also had an impact on procedure outcomes (33). There were slightly higher rates of CT guidance (55%) than ultrasound guidance (45%), which may have been related to higher rates of lesion visualization and targets being found correctly. Follow up imaging was important for outcome assessment. At 2 to 6 months, patients were followed as per Kelekis et al. (2016) who stated that, “Early post-ablation surveillance is crucial to the detection of recurrence. This is important as 90% of the recurrences occur within first follow-up.

MWA is effective and safe treatment modality for hepatic lesions, especially in the treatment of smaller tumors and patients without cirrhosis. Lesion size and liver status were important determinants along with borderline considerations of tumor burden and procedure factors underscoring the multifactorial nature of treatment success. This study contributes local evidence in support of the literature, and helps validate the use of MWA along with MDCT as a component of clinical practice.

CONCLUSION

The findings of this study show that microwave ablation is a safe and efficient therapy for hepatic lesions; and the rate of complete response was 81.3% while the rate of local tumor progression was 6.3%. The procedure resulted in a relatively low rate of major complications that verified its good safety record. On the other hand MDCT has proven to be a reliable tool in post-ablation evaluation and many of the patients demonstrated no MDCT effect, despite a quantitative assessment of complete necrosis. The size of the lesions was also statistically significant to response; the larger lesions the less the response. Adjusting for risk factors, logistic regression showed cirrhosis to be an independent factor associated with an unfavorable treatment response. Overall, liver MWA is a reliable, minimally-invasive strategy for liver tumor treatment with good clinical outcomes.

REFERENCES

Musa A, Hadadi I, Loaz O, Kajoak S, Osman H, Aljehani S, et al. Triple-phase CT evaluation of hepatic lesions in the Saudi population: Assessing diagnostic accuracy. 2025;18(1):101251.

Tolou-Ghamari ZJNEMJ. Review of hepatocellular carcinoma and liver disease prevalence. 2024;5(1):e02506882271605.

Singh SP, Madke T, Chand PJJoc, hepatology e. Global epidemiology of hepatocellular carcinoma. 2025;15(2):102446.

Serraino D, Fratino L, Piselli P. Epidemiological aspects of hepatocellular carcinoma. Hepatocellular carcinoma: Springer; 2022. p. 3-9.

Amin N, Anwar J, Sulaiman A, Naumova NN, Anwar NJD. Hepatocellular carcinoma: a comprehensive review. 2025;13(7):207.

Shaker MK, Abdella HM. Hepatocellular Carcinoma Epidemiology. Approach to Hepatocellular Carcinoma (HCC) Management in Low/Middle-Income Countries: Springer; 2025. p. 19-42.

Carr BI. Overview of Clinical HCC and its Management. Liver Cancer in the Middle East: Springer; 2021. p. 111-26.

Koulouris A, Tsagkaris C, Spyrou V, Pappa E, Troullinou A, Nikolaou MJJohc. Hepatocellular carcinoma: an overview of the changing landscape of treatment options. 2021:387-401.

Suresh D, Srinivas AN, Prashant A, Harikumar KB, Kumar DPJC, Medicine E. Therapeutic options in hepatocellular carcinoma: a comprehensive review. 2023;23(6):1901-16.

Sas Z, Cendrowicz E, Weinhäuser I, Rygiel TPJIJoMS. Tumor microenvironment of hepatocellular carcinoma: challenges and opportunities for new treatment options. 2022;23(7):3778.

Dou Z, Lu F, Ren L, Song X, Li B, Li XJM. Efficacy and safety of microwave ablation and radiofrequency ablation in the treatment of hepatocellular carcinoma: a systematic review and meta-analysis. 2022;101(30):e29321.

Habibollahi P, Sheth RA, Cressman ENJC. Histological correlation for radiofrequency and microwave ablation in the local control of hepatocellular carcinoma (HCC) before liver transplantation: a comprehensive review. 2020;13(1):104.

Wu J, Zhou Z, Huang Y, Deng X, Zheng S, He S, et al. Radiofrequency ablation: mechanisms and clinical applications. 2024;5(10):e746.

Strand NH, Hagedorn JM, Dunn T, Johnson B, Abd-Elsayed A, Covington S, et al. Advances in radiofrequency ablation: mechanism of action and technology. 2024;13(4):1028-34.

Deng Q, He M, Fu C, Feng K, Ma K, Zhang LJIJoH. Radiofrequency ablation in the treatment of hepatocellular carcinoma. 2022;39(1):1052-63.

Abd-Elsayed A, Kennedy KJAoPM. The art of radiofrequency ablation. LWW; 2024. p. 471-6.

Ziglioli F, De Filippo M, Cavalieri DM, Pagnini F, Campobasso D, Guarino G, et al. Percutaneous radiofrequency ablation (RFA) in renal cancer. How to manage challenging masses. A narrative review. 2022;93(5):e2022220.

Nakamura Y, Higaki T, Honda Y, Tatsugami F, Tani C, Fukumoto W, et al. Advanced CT techniques for assessing hepatocellular carcinoma. 2021;126(7):925-35.

Saleem H, Farooq SMY, Hanif W, Qadeer A, Shareef T, Shabbir MJOU. Role of Multi-detector Computed Tomography in Evaluation of Hepato-cellular Carcinoma. 2021;19(3):180-3.

El-Sayed MZ, Rawashdeh M, Hassan HGEMA, El Safwany MM, Islam I, Khedr YI, et al. Qualitative and quantitative evaluation of the image quality of MDCT multiphasic liver scans in HCC patients. 2025;2025(1):4163865.

Choi ES, Kim JS, Lee JK, Lee HA, Pak SJBMI. Prospective evaluation of low-dose multiphase hepatic computed tomography for detecting and characterizing hepatocellular carcinoma in patients with chronic liver disease. 2022;22(1):219.

Rai P, Ansari MY, Warfa M, Al-Hamar H, Abinahed J, Barah A, et al. Efficacy of fusion imaging for immediate post-ablation assessment of malignant liver neoplasms: A systematic review. 2023;12(13):14225-51.

Lubner MG, Ziemlewicz TJ, Wells SA, Li K, Wu P-H, Hinshaw JL, et al. Advanced CT techniques for hepatic microwave ablation zone monitoring and follow-up. 2022;47(8):2658-68.

Biondetti P, Fumarola EM, Ierardi AM, Coppola A, Gorga G, Maggi L, et al. Percutaneous US-guided MWA of small liver HCC: predictors of outcome and risk factors for complications from a single center experience. 2020;37(5):39.

Han J, Fan Y-c, Wang KJM. Radiofrequency ablation versus microwave ablation for early stage hepatocellular carcinoma: A PRISMA-compliant systematic review and meta-analysis. 2020;99(43):e22703.

Chartampilas E, Rafailidis V, Georgopoulou V, Kalarakis G, Hatzidakis A, Prassopoulos PJC. Current imaging diagnosis of hepatocellular carcinoma. 2022;14(16):3997.

Paisant A, Boursier J, Dabli D, Lebigot J, Oberti F, Michalak S, et al. Two-phase MDCT protocol for the screening of small hepatocellular carcinoma. 2022;11(15):4282.

Kalarakis G, Perisinakis K, Akoumianakis E, Karageorgiou I, Hatzidakis AJEr. CT liver perfusion in patients with hepatocellular carcinoma: can we modify acquisition protocol to reduce patient exposure? 2021;31(3):1410-9.

Brocco S, Fraia AS, Florio A, Quaia E. Imaging of Treated Liver Tumors and Assessment of Tumor Response to Cytostatic Therapy and Post-Treatment Changes in the Liver. Imaging of the Liver and Intra-hepatic Biliary Tract: Volume 2: Tumoral Pathologies: Springer; 2020. p. 349-73.

Zanca F, Brat H, Pujadas P, Racine D, Dufour B, Fournier D, et al. Prospective multicenter study on personalized and optimized MDCT contrast protocols: results on liver enhancement. 2021;31(11):8236-45.

Abdel-Rehim M, Ronot M, Sibert A, Vilgrain V. Assessment of liver ablation using cone beam computed tomography. World journal of gastroenterology. 2015;21(2):517-24.

Floridi C, Cacioppa LM, Rossini N, Macchini M, Bruno A, Agostini A, et al. Microwave ablation followed by cTACE in 5-cm HCC lesions: does a single-session approach affect liver function? La radiologia medica. 2024;129(8):1252-64.

Abdel-Samiee M, Elkazaz RR, Omar H, Salama NM, Gomaa AI, Rady MA, et al. A Comparative Study of Radiofrequency Ablation, Microwave Ablation, and Percutaneous Ethanol Injection in Treatment of Hepatocellular Carcinoma—A Single-Center Experience. 2025;15(23):3027.

Meine TC, Brunkhorst T, Werncke T, Schütze C, Vogel A, Kirstein MM, et al. Comparison of the Uptake of Hepatocellular Carcinoma on Pre-Therapeutic MDCT, CACT, and SPECT/CT, and the Correlation with Post-Therapeutic PET/CT in Patients Undergoing Selective Internal Radiation Therapy. 2021;10(17):3837.