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Diagnostic value of CT scan compared with ultrasound-guided needle biopsy in the diagnosis of liver masses; a retrospective diagnostic study

Hamid Mahboobi[1], Gholam Reza Hemmasi[2], Alireza Aghajani[3], Eshagh Sedighi[4], Mohammad Reza Babaei[5*]

[1]Department of Radiology, School of Medicine, Firoozgar Hospital, Iran University of Medical Sciences, Tehran, Iran
[2]Gastrointestinal and Liver Diseases Research Center, Iran University of Medical Sciences, Tehran, Iran
[3]Student Research Committee, School of Medicine, Anzali International Campus, Guilan University of Medical Sciences, Rasht, Iran
[4]Department of Veterinary Medicine, Islamic Azad University Branch of Urmia, Urmia, Iran
[5]Department of Interventional Radiology, School of Medicine, Firoozgar Hospital, Iran University of Medical Sciences, Tehran, Iran

***Correspondence to**
Mohammad Reza Babaei,
Email: Doctorreza2012@yahoo.com,
Babaei.mr@iums.ac.ir

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Abstract

Introduction: Liver masses present a significant clinical challenge due to their diverse etiologies, ranging from benign lesions to malignant tumors. Accurate diagnosis is crucial for determining appropriate management strategies and improving patient outcomes.

Objectives: This study aims to evaluate the diagnostic value of computed tomography (CT) scans compared with ultrasound-guided needle biopsy in assessing liver masses.

Patients and Methods: This retrospective diagnostic study, conducted at Firoozgar hospital in Tehran, Iran, aimed to compare the diagnostic value of CT scans and ultrasound-guided needle biopsies in identifying liver masses among 99 adult patients who underwent both procedures between 2015 and 2020. Data collected included patient demographics, clinical characteristics, imaging findings from intravenous contrast-enhanced CT scans, and pathology results from biopsies. Using biopsy pathology as the reference standard, the study calculated the diagnostic accuracy, sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of CT scans to evaluate their reliability in diagnosing liver masses and determining tumor nature and metastatic potential.

Results: The diagnostic value of CT scans compared to ultrasound-guided needle biopsy pathology as the gold standard in diagnosing liver tumor characteristics is summarized as follows; for malignant tumors, the accuracy is 73.6%, with a sensitivity of 97.2%, specificity of 50%, PPV of 66.03%, NPV of 94.7%, and a Kappa value of 0.542. In contrast, for metastatic tumors, the accuracy is higher at 81.2%, with a sensitivity of 94.9%, specificity of 67.5%, PPV of 74.4%, NPV of 93%, and a Kappa value of 0.650.

Conclusion: In conclusion, these findings indicate that while CT scan is a valuable non-invasive tool for diagnosing liver masses, its observer-based nature necessitates the use of ultrasound-guided needle biopsy to improve diagnostic accuracy. Combining these methods will enhance clinical decision-making and ensure more reliable assessments of liver tumors.

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Introduction

Liver lesions, which are abnormal growths or masses in the liver, have become a frequent clinical concern due to the widespread use of advanced imaging techniques like ultrasound, computed tomography (CT), and magnetic resonance imaging (MRI). While most liver lesions are benign and can be diagnosed non-invasively using imaging and blood tests, a biopsy may be required in cases where imaging results are inconclusive. MRI, particularly with specialized contrast agents, is often the preferred method for its detailed visualization of soft tissues and ability to differentiate between benign and malignant lesions. However, noninvasive methods generally suffice for characterizing liver lesions in the majority of cases, reducing the need for invasive procedures (1). The widespread use of advanced radiologic imaging has significantly increased the detection of incidental liver masses, ranging from benign asymptomatic lesions to potentially malignant tumors. Improved imaging techniques now identify smaller lesions, which may present with or without symptoms. The management of these findings depends on clinical and radiologic features, guiding decisions toward further imaging studies, biopsy, laparoscopy, observation, or intervention. Proper characterization of these masses is essential for differential diagnosis, as factors such as

Key point

In this retrospective diagnostic study, the findings highlight the importance of using CT imaging as a reliable non-invasive diagnostic tool for liver masses, particularly for ruling out malignancy and metastasis due to its high sensitivity and negative predictive value. However, the moderate specificity and positive predictive value of CT scans suggest challenges in confirming benign or non-metastatic lesions, underscoring the risk of occasional false-positive results.

lesion size, enhancement patterns, margins, and growth behavior can help distinguish benign conditions like cysts or hemangiomas from malignancies such as hepatocellular carcinoma or metastases (2,3). Accurate characterization of liver lesions is crucial for differentiating benign masses from malignant ones, enabling early diagnosis and preventing potentially fatal metastases (4). Distinguishing benign from malignant masses is critical for determining appropriate treatment. Diagnosing liver lesions involves evaluating clinical history, physical examination findings, and sensitive laboratory markers. Imaging and, ultimately, histopathology confirm the diagnosis (5-7).

Since non-invasive imaging is inconclusive, a liver biopsy is required for definitive diagnosis (8). This procedure, common in hepatology, can be performed percutaneous or in a laparoscopic procedure (9). Percutaneous liver biopsy is essential for diagnosing hepatic lesions in oncologic and hematologic patients by enabling histopathological evaluation of tumors, metastasis identification, and tumor characterization (10). While improved imaging lacks specificity for accurate diagnosis of focal hepatic lesions, needle biopsy provides necessary tissue sampling (11). Percutaneous image-guided biopsy, commonly performed by diagnostic and interventional radiologists, has largely replaced open surgical biopsy when feasible (12). Ultrasound guidance is often preferred due to its availability, ease, cost-effectiveness, and lack of radiation; however, CT guidance may be required for accessing specific regions like the sub-phrenic segments (11).

CT scan plays a crucial role in the identification and characterization of hepatic lesions, with multiple protocols available for optimized imaging. Triphasic CT scan, which includes unenhanced, arterial, portal venous, and delayed phases, has demonstrated impressive diagnostic accuracy with a sensitivity of 100%, specificity of 80%, and overall diagnostic accuracy of 95.5% in differentiating benign from malignant focal tumoral liver lesions (13). This non-invasive imaging modality takes advantage of the distinct enhancement patterns exhibited by different types of lesions, as liver parenchyma predominantly enhances during the portal venous phase while liver lesions are supplied by the hepatic artery (14). Despite these advantages, CT scanning has limitations, particularly in the context of indeterminate liver lesions, which are frequently encountered during staging CT in patients with early-stage rectal cancer, where small hypoattenuating lesions often have no clinical significance (15). For hepatocellular carcinoma detection specifically, CT demonstrates limitations with studies showing that approximately 22.5% of patients with hepatocellular carcinoma may be missed using CT alone, while 8.7% of people without hepatocellular carcinoma could be unnecessarily treated (16). In this study, we conducted a diagnostic study to evaluate the diagnostic value of intravenous contrast CT scans compared to biopsy pathology results from percutaneous ultrasound-guided needle biopsy in patients suspected of having a liver mass.

Objectives

The objective of this study is to assess and compare the diagnostic value of CT scans versus ultrasound-guided needle biopsies in identifying and characterizing liver masses, including tumor nature (benign or malignant) and metastatic potential, using pathology results from biopsies as the reference standard. This research aims to evaluate the sensitivity, specificity, and overall diagnostic accuracy of both modalities to determine their agreement and clinical utility in diagnosing liver lesions.

Patients and Methods

Study design and participants

This retrospective diagnostic study aimed to compare the diagnostic value of CT scans and ultrasound-guided needle biopsies in identifying liver masses among 99 adult patients who underwent both procedures between 2015 and 2020 in Firoozgar hospital, Tehran, Iran.

Inclusion and exclusion criteria

The inclusion criteria for this study are adult patients with suspected liver masses referred to Firoozgar hospital, Tehran, Iran, who underwent both CT scans and ultrasound-guided needle biopsies between 2015 and 2020, with complete medical records available, including demographic data, imaging results, and biopsy pathology outcomes. Exclusion criteria include patients with incomplete records and those who had prior treatments for liver masses (e.g., surgery or chemotherapy).

Data collection

Data from 99 patients were collected, including information on demographics, clinical characteristics, imaging results (such as findings from intravenous contrast CT scans), and pathology outcomes from ultrasound-guided needle biopsies. This data was used to calculate the diagnostic accuracy, sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of CT scans in comparison to the pathology results obtained from ultrasound-guided needle biopsies, which will serve as the reference standard.

Outcomes

The outcome of this study is to evaluate the inter-modality agreement between CT scans and ultrasound-

guided needle biopsies in diagnosing the tumor nature (benign or malignant) and metastatic characteristics of liver masses. By comparing the diagnostic accuracy, sensitivity, and specificity of these two methods, the study aims to determine how well they align in identifying and characterizing liver lesions, ultimately providing valuable insights to guide clinical decision-making and improve diagnostic strategies for patients with suspected liver masses.

Statistical analysis

The statistical analysis was conducted using IBM SPSS Statistics version 27.0 (IBM Corp., Armonk, NY, USA). Categorical data were presented as frequencies and percentages. To determine the statistical analysis methods for evaluating the diagnostic value of CT scans compared to ultrasound-guided needle biopsy (gold standard) in liver mass diagnosis, the following approach was applied based on standard diagnostic accuracy frameworks. Diagnostic performance of CT scans versus ultrasound-guided needle biopsy (the standard reference) was assessed through sensitivity, specificity, accuracy, PPV, NPV, false-positive, and false-negative rates. Inter-rater agreement between imaging (CT-scan) and histopathological findings (needle biopsy pathology) was evaluated using Cohen's kappa coefficient, with values >0.6 indicating substantial concordance. Positive and negative likelihood ratios (LR+ >10 and LR- <0.01 denoting strong diagnostic significance) were computed to quantify clinical utility.

Results

In this study, the liver masses of 99 patients, comprising 50 females and 49 males with a mean age of 56.62 ± 13.42 years, were evaluated using intravenous contrast-enhanced CT scans and ultrasound-guided needle biopsy pathology. This dual-modality approach aimed to assess the diagnostic performance of CT imaging in comparison to biopsy, which served as the gold standard for characterizing liver tumors. Table 1 reported the diagnostic distribution of liver masses by ultrasound-guided needle biopsy pathology and CT scan. The results showed that both methods identified hepatocellular carcinoma and hemangioma as relatively common diagnoses, with metastasis from other organs being the most frequently observed condition across both tools. Needle biopsy pathology also detected cases of abscess, biliary adenocarcinoma, fibrosis, foreign body presence, granulation tissue, and hematoma, which CT did not identify. Conversely, CT detected adenomas and a slightly higher cyst prevalence than needle biopsy. Cholangiocarcinoma, fibrolamellar carcinoma, focal nodular hyperplasia, gastrointestinal stromal tumors, fatty liver, and hematoma were diagnosed with varying frequencies by both methods (Table 1).

The results indicated that the histopathological analysis via biopsy identified a substantial proportion of benign lesions alongside a predominant diagnosis of malignant masses, while CT imaging revealed a higher detection rate of malignant tumors. Both modalities detected metastatic potential in a majority of cases, with biopsy results showing a notable frequency of non-metastatic lesions compared to imaging findings (Table 2).

The evaluation of inter-modality agreement between CT scans and ultrasound-guided needle biopsies in diagnosing the tumor nature and metastatic characteristics of liver masses revealed moderate to substantial agreement based on Kappa values. The agreement was moderate for determining the tumor nature of liver masses as malignant or non-malignant, indicating a fair level of consistency between the two modalities. In contrast, for identifying metastatic characteristics, the agreement was higher,

Table 1. Diagnostic distribution of liver mass by CT scan and ultrasound-guided needle biopsy

Type of mass	Diagnostic tool			
	Needle biopsy pathology (n = 99)		CT scan (n = 99)	
	No.	%	No.	%
Abscess	1	1	-	-
Biliary adenocarcinoma	1	1	-	-
Cholangiocarcinoma	1	1	2	2
Adenoma	-	-	1	1
Cyst	3	3	4	4
Fatty liver	2	2	1	1
Fibrosis	1	1	-	-
FLC	1	1	2	2
FNH	4	4	2	2
Foreign body	1	1	-	-
GIST	1	1	1	1
Granulation tissue	1	1	-	-
HCC	10	10.1	10	10.1
Hemangioma	14	14.1	9	9.1
Hematoma	1	1	-	-
Metastasis from other organs	57	57.8	67	67.8

CT: Computed tomography, HCC: Hepatocellular carcinoma, FNH: Focal nodular hyperplasia, GIST; Gastrointestinal stromal tumor, FLC; Fibrolamellar carcinoma.

reflecting a stronger correlation between CT scan findings and the gold standard of needle biopsy pathology (Table 3).

The diagnostic evaluation of CT scans compared to ultrasound-guided needle biopsy pathology as the gold standard in assessing liver tumor characteristics demonstrates varied levels of diagnostic value across malignant and metastatic tumor types. For malignant tumors, CT scans exhibited high sensitivity and NPV, indicating their strength in correctly identifying true positive cases and ruling out malignancy when negative. However, specificity and PPV are moderate, reflecting limitations in distinguishing non-malignant cases accurately. CT imaging exhibits high sensitivity in detecting metastatic lesions, effectively identifying true positive cases, though with moderate specificity that reflects occasional false-positive interpretations. The moderate PPV indicated reliable confirmation of metastatic presence when CT results are positive, while the notably high NPV underscores CT's utility in ruling out metastasis. The Kappa values suggest moderate agreement for malignant tumors and substantial agreement for metastatic tumors, emphasizing the reliability of CT scans in detecting metastatic characteristics relative to needle biopsy pathology (Table 4).

Discussion

The results demonstrated that CT scans, when compared to ultrasound-guided needle biopsy pathology as the gold standard, exhibit high sensitivity and NPV for detecting malignant liver tumors, making them highly effective for ruling out malignancy. However, the moderate specificity and PPV highlight challenges in accurately confirming benign cases. Similarly, for metastatic liver lesions, CT scans maintain high sensitivity and NPV, but their moderate specificity and PPV suggest occasional false-positive findings, indicating some limitations in distinguishing metastatic from non-metastatic lesions.

The results describing CT scans as having high sensitivity and NPV for malignant liver tumors, yet moderate specificity and PPV, align closely with findings from multiple studies in the literature. In a study by Hafeez et al, the triphasic CT scanning demonstrated impressive diagnostic performance with reported sensitivity of 100%, specificity of 80%, PPV of 94.5%, NPV of 100%, and overall diagnostic accuracy of 95.5% in differentiating benign from malignant focal tumoral liver lesions (13). Similarly, dynamic contrast CT evaluation in a study by Ominde et al showed comparable sensitivity (93%) but lower specificity (50%) with a PPV of 91% and diagnostic accuracy of 95.5% (17). These findings support the conclusion that CT scanning excels at ruling out malignancy but may have limitations in definitively confirming benign lesions. The diagnostic performance of CT varies by lesion type and size, with studies demonstrating that arterial phase

Table 2. The frequency distribution of tumor nature and metastasis characteristics of the liver masses diagnosed by CT scan and ultrasound-guided needle biopsy

Type of mass		Diagnostic tool			
		Needle biopsy pathology (n = 99)		CT scan (n = 99)	
		No.	%	No.	%
Nature of tumor	Benign	28	28.3	16	16.2
	Malignant	71	71.7	83	83.8
Metastasis	Non-metastatic	40	40.4	30	30.3
	Metastatic	59	59.6	69	69.7

Table 3. The inter-modality agreement between CT scan and ultrasound-guided needle biopsy in the diagnosis of the tumor nature and metastatic characteristic of the liver masses

Nature of tumor	Tools		Needle biopsy pathology (Gold standard)		Kappa	*P* value
			Positive (n = 71)	Negative (n = 28)		
Malignant	CT-scan	Positive	69 (97.2%)	14 (50%)	0.542	<0.001
		Negative	2 (2.8%)	14 (50%)		
			Needle biopsy pathology (Gold standard)			
			Positive (n = 59)	Negative (n = 40)		
Metastatic	CT-scan	Positive	56 (94.9%)	13 (32.5%)	0.650	<0.001
		Negative	3 (5.1%)	27 (67.5%)		

Table 4. Diagnostic value of CT scan compared to ultrasound-guided needle biopsy pathology as a diagnostic gold standard in the diagnosis of liver tumors characteristics

Tumor characteristics	Diagnostic value parameters (%)									
	ACC	SEN	FN	SPE	FP	PPV	NPV	Kappa	LR+	LR-
Malignant	73.6	97.2	2.8	50	50	66.03	94.7	0.542	1.95	0.05
Metastatic	81.2	94.9	5.1	67.5	32.5	74.4	93	0.650	2.92	0.07

ACC: Accuracy, SEN: Sensitivity, FN: False negative, SPE: Specificity, FP: False positive, PPV: Positive predictive value, NPV: Negative predictive value, LR+: Positive likelihood ratio, LR-: Negative likelihood ratio.

scanning significantly improves detection of small malignant hepatic neoplasms (≤1.5 cm), particularly in hypervascular tumors where lesion conspicuity improved in 39% of cases compared to only 20% for hypovascular lesions (18). Recent advancements in CT technology show further improvements, with photon-counting CT demonstrating superior sensitivity compared to conventional energy-integrating detector CT (82.1% versus 77.6%) for liver lesion detection, with even greater advantages for subcentimeter lesions (74.0% versus 67.2%) (19). These findings collectively confirm that while CT scanning offers excellent sensitivity and NPV for excluding malignancy, its moderate specificity underscores the continued need for histopathological confirmation in equivocal cases, with contrast enhancement protocols and newer CT technologies helping to address some of these diagnostic limitations.

The finding that CT scans demonstrate high sensitivity and NPV but moderate specificity and PPV for metastatic liver lesions aligns partially with previous research, though with some notable variations across studies. This diagnostic profile suggests CT effectively rules out metastatic disease while occasionally generating false positives, a pattern that broadly correlates with existing literature but warrants nuanced interpretation. In a multicenter study on dynamic contrast CT findings, researchers reported high sensitivity but limited specificity for distinguishing benign from malignant liver lesions (17). This contrasts somewhat with a triphasic CT study that demonstrated more balanced performance with high sensitivity and moderate specificity (13). The variable performance metrics reflect CT's known limitations, particularly for smaller lesions, as detection rates significantly decline from 72% for lesions measuring 10-20 mm to just 16% for those smaller than 10 mm (20). Literature reviews further illustrate this variability, with sensitivity estimates ranging from 64.7% for colorectal liver metastases to 74.8% for general hepatic metastases, while specificity tends to be higher at 95.6% (17). These findings collectively suggest that while CT remains a mainstay for initial lesion detection and treatment response assessment, its performance limitations, especially for smaller or certain types of metastases, must be recognized when interpreting results, with MRI potentially offering superior sensitivity particularly for hypervascular metastases (98.2% versus 37.1% for CT) and lesions in the context of hepatic steatosis (20).

Overall, our findings highlight the strengths and limitations of CT scans in the evaluation of liver tumors and metastatic lesions. CT scans demonstrate high sensitivity and NPV, making them reliable tools for ruling out malignancy and metastatic disease when results are negative. However, their moderate specificity and PPV indicate challenges in accurately confirming benign conditions or distinguishing metastatic from non-metastatic lesions, leading to occasional false-positive results. While CT scans are effective for initial screening and exclusion of malignancy, their limitations suggest the need for complementary diagnostic methods, such as ultrasound-guided needle biopsy, to improve diagnostic accuracy, particularly in confirming benign or non-metastatic cases.

Conclusion

The diagnostic evaluation of CT scans compared to ultrasound-guided needle biopsy pathology for liver tumor assessment demonstrates distinct strengths and limitations. CT imaging exhibits high sensitivity and NPV for malignant tumors, effectively ruling out malignancy when results are negative, though moderate specificity and PPV indicate challenges in confirming non-malignant cases. For metastatic lesions, CT maintains high sensitivity and NPV, reliably excluding metastasis when negative, while moderate specificity and PPV reflect occasional false-positive interpretations. The Kappa values indicate moderate agreement for malignant tumors and substantial agreement for metastatic tumors, highlighting CT's reliability in detecting metastatic characteristics relative to biopsy. Overall, these findings suggest that while CT scans are a valuable non-invasive diagnostic modality, they should be used in conjunction with ultrasound-guided needle biopsy to enhance diagnostic accuracy and guide clinical decision-making effectively.

Limitations of the study

First, as a retrospective analysis, it is subject to selection bias and relies on the accuracy and completeness of existing medical records, which may have inconsistencies or missing data. Second, CT scans are observer-dependent and may vary in diagnostic accuracy based on the expertise of radiologists and the quality of imaging equipment used. Third, ultrasound-guided needle biopsies can be influenced by sampling errors, particularly for lesions with necrotic areas or those located in challenging anatomical regions.

Authors' contribution

Conceptualization: Hamid Mahboobi and Mohammad Reza Babaei.
Data curation: Hamid Mahboobi and Eshagh Sedighi.
Formal analysis: Gholam Reza Hemmasi.
Investigation: Mohammad Reza Babaei and Eshagh Sedighi.
Methodology: Gholam Reza Hemmasi and Alireza Aghajani.
Project management: Mohammad Reza Babaei.
Resources: All authors.
Supervision: Hamid Mahboobi.
Validation: Alireza Aghajani.
Writing–original draft: All authors.
Writing–review and editing: All authors.

Ethical issues

The research conducted in this study adhered to the principles outlined in the Declaration of Helsinki and was approved by the Ethics Committee of Iran University of Medical Sciences (Ethical code#IR.IUMS.FMD.REC.1400.494; https://ethics.research.ac.ir/EthicsProposalView.php?id=233340. Prior to any intervention,

all participants provided written informed consent. The study was extracted from Hamid Mahboobi thesis in the department of radiology residency at this university (Thesis #21012). The authors have fully complied with ethical issues, such as plagiarism, data fabrication, and double publication.

Conflicts of interest

The authors declare no conflict of interest.

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References

1. Venkatesh SK, Chandan V, Roberts LR. Liver masses: a clinical, radiologic, and pathologic perspective. Clin Gastroenterol Hepatol. 2014;12:1414-29. doi: 10.1016/j.cgh.2013.09.017.
2. Boutros C, Katz SC, Espat NJ. Management of an incidental liver mass. Surg Clin North Am. 2010;90:699-718. doi: 10.1016/j.suc.2010.04.005.
3. Shaked O, Reddy KR. Approach to a liver mass. Clin Liver Dis. 2009;13:193-210. doi: 10.1016/j.cld.2009.02.004.
4. Bruix J, Sherman M. Management of hepatocellular carcinoma. Hepatology. 2005;42:1208-36. doi: 10.1002/hep.20933.
5. Venkatesh SK, Yin M, Glockner JF, Takahashi N, Araoz PA, Talwalkar JA, et al. MR elastography of liver tumors: preliminary results. AJR Am J Roentgenol. 2008;190:1534-40. doi: 10.2214/ajr.07.3123.
6. Okada M, Kim T, Murakami T. Hepatocellular nodules in liver cirrhosis: state of the art CT evaluation (perfusion CT/volume helical shuttle scan/dual-energy CT, etc.). Abdom Imaging. 2011;36:273-81. doi: 10.1007/s00261-011-9684-2.
7. Lee E, Edward S, Singal AG, Lavieri MS, Volk M. Improving screening for hepatocellular carcinoma by incorporating data on levels of α-fetoprotein, over time. Clin Gastroenterol Hepatol. 2013;11:437-40. doi: 10.1016/j.cgh.2012.11.029.
8. Kipp BR, Stadheim LM, Halling SA, Pochron NL, Harmsen S, Nagorney DM, et al. A comparison of routine cytology and fluorescence in situ hybridization for the detection of malignant bile duct strictures. Am J Gastroenterol. 2004;99:1675-81. doi: 10.1111/j.1572-0241.2004.30281.x.
9. Sheela H, Seela S, Caldwell C, Boyer JL, Jain D. Liver biopsy: evolving role in the new millennium. J Clin Gastroenterol. 2005;39:603-10. doi: 10.1097/01.mcg.0000170742.59134.60.
10. Steil S, Zerwas S, Moos G, Bittinger F, Hansen T, Mergenthaler U, et al. CT-guided percutaneous core needle biopsy in oncology outpatients: sensitivity, specificity, complications. Onkologie. 2009;32:254-8. doi: 10.1159/000209966.
11. Thanos L, Zormpala A, Papaioannou G, Malagari K, Brountzos E, Kelekis D. Safety and efficacy of percutaneous CT-guided liver biopsy using an 18-gauge automated needle. Eur J Intern Med. 2005;16:571-4. doi: 10.1016/j.ejim.2005.06.010.
12. Kim E, Ward TJ, Patel RS, Fischman AM, Nowakowski S, Lookstein RA. CT-guided liver biopsy with electromagnetic tracking: results from a single-center prospective randomized controlled trial. AJR Am J Roentgenol. 2014;203:W715-23. doi: 10.2214/ajr.13.12061.
13. Hafeez S, Alam MS, Sajjad Z, Khan ZA, Akhter W, Mubarak F. Triphasic computed tomography (CT) scan in focal tumoral liver lesions. J Pak Med Assoc. 2011;61:571-5.
14. Elbanna KY, Kielar AZ. Computed Tomography Versus Magnetic Resonance Imaging for Hepatic Lesion Characterization/Diagnosis. Clin Liver Dis (Hoboken). 2021;17:159-64. doi: 10.1002/cld.1089.
15. van den Broek JJ, Kol SQ, Doodeman J, Schreurs WH, van Geel AM. Indeterminate Liver Lesions in Patients With Early Stage Rectal Cancer: Can They Be Ignored? Pract Radiat Oncol. 2021;11:502-9. doi: 10.1016/j.prro.2021.07.002.
16. Nadarevic T, Giljaca V, Colli A, Fraquelli M, Casazza G, Miletic D, et al. Computed tomography for the diagnosis of hepatocellular carcinoma in adults with chronic liver disease. Cochrane Database Syst Rev. 2021;10:Cd013362. doi: 10.1002/14651858.CD013362.pub2.
17. Ominde ST, Mutala TM. Multicentre study on dynamic contrast computed tomography findings of focal liver lesions with clinical and histological correlation. SA J Radiol. 2019;23:1667. doi: 10.4102/sajr.v23i1.1667.
18. Hollett MD, Jeffrey RB, Jr., Nino-Murcia M, Jorgensen MJ, Harris DP. Dual-phase helical CT of the liver: value of arterial phase scans in the detection of small (< or = 1.5 cm) malignant hepatic neoplasms. AJR Am J Roentgenol. 1995;164:879-84. doi: 10.2214/ajr.164.4.7726040.
19. Wildman-Tobriner B, Felice N, Kalisz KR, Allen BC, Thomas SP, Kruse DE, et al. Photon-Counting CT Effects on Sensitivity for Liver Lesion Detection: A Reader Study Using Virtual Imaging. Radiology. 2025;314:e241568. doi: 10.1148/radiol.241568.
20. Freitas PS, Janicas C, Veiga J, Matos AP, Herédia V, Ramalho M. Imaging evaluation of the liver in oncology patients: A comparison of techniques. World J Hepatol. 2021;13:1936-55. doi: 10.4254/wjh.v13.i12.1936.