ISSN 1949-8470 (online)

World Journal of *Radiology*

World J Radiol 2024 June 28; 16(6): 139-240

Published by Baishideng Publishing Group Inc

World Journal of Radiology

Contents

Monthly Volume 16 Number 6 June 28, 2024

REVIEW

MINIREVIEWS

ORIGINAL ARTICLE

Retrospective Study

Observational Study

CASE REPORT

World Journal of Radiology

Monthly Volume 16 Number 6 June 28, 2024

Contents

ABOUT COVER

Editorial Board Member of *World Journal of Radiology*, Xian-Li Lv, MD, Associate Professor, Department of Neurosurgery, Beijing Tsinghua Changgung Hospital, School of Clinical Medicine, Tsinghua University, Beijing, China. lvxianli000@163.com

AIMS AND SCOPE

The primary aim of *World Journal of Radiology* (*WJR*, *World J Radiol*) is to provide scholars and readers from various fields of radiology with a platform to publish high-quality basic and clinical research articles and communicate their research findings online.

WJR mainly publishes articles reporting research results and findings obtained in the field of radiology and covering a wide range of topics including state of the art information on cardiopulmonary imaging, gastrointestinal imaging, genitourinary imaging, musculoskeletal imaging, neuroradiology/head and neck imaging, nuclear medicine and molecular imaging, pediatric imaging, vascular and interventional radiology, and women's imaging.

INDEXING/ABSTRACTING

The *WJR* is now abstracted and indexed in PubMed, PubMed Central, Emerging Sources Citation Index (Web of Science), Reference Citation Analysis, China Science and Technology Journal Database, and Superstar Journals Database. The 2024 Edition of Journal Citation Reports® cites the 2023 journal impact factor (JIF) for *WJR* as 1.4; JIF without journal self cites: 1.4; 5-year JIF: 1.8; JIF Rank: 132/204 in radiology, nuclear medicine and medical imaging; JIF Quartile: Q3; and 5-year JIF Quartile: Q3.

RESPONSIBLE EDITORS FOR THIS ISSUE

NAME OF JOURNAL
World Journal of Radiology

ISSN
ISSN 1949-8470 (online)

LAUNCH DATE
January 31, 2009

FREQUENCY
Monthly

EDITORS-IN-CHIEF
Thomas J Vogl

EDITORIAL BOARD MEMBERS
https://www.wjgnet.com/1949-8470/editorialboard.htm

PUBLICATION DATE
June 28, 2024

INSTRUCTIONS TO AUTHORS
https://www.wjgnet.com/bpg/gerinfo/204

GUIDELINES FOR ETHICS DOCUMENTS
https://www.wjgnet.com/bpg/GerInfo/287

GUIDELINES FOR NON-NATIVE SPEAKERS OF ENGLISH
https://www.wjgnet.com/bpg/gerinfo/240

PUBLICATION ETHICS
https://www.wjgnet.com/bpg/GerInfo/288

PUBLICATION MISCONDUCT
https://www.wjgnet.com/bpg/gerinfo/208

ARTICLE PROCESSING CHARGE
https://www.wjgnet.com/bpg/gerinfo/242

STEPS FOR SUBMITTING MANUSCRIPTS
https://www.wjgnet.com/bpg/GerInfo/239

ONLINE SUBMISSION
https://www.f6publishing.com

World Journal of Radiology

Submit a Manuscript: https://www.f6publishing.com

World J Radiol 2024 June 28; 16(6): 139-167

DOI: 10.4329/wjr.v16.i6.139

ISSN 1949-8470 (online)

REVIEW

Imaging features and management of focal liver lesions

Gökhan Kahraman, Kemal Murat Haberal, Osman Nuri Dilek

Specialty type: Radiology, nuclear medicine and medical imaging

Provenance and peer review: Invited article; Externally peer reviewed.

Peer-review model: Single blind

Peer-review report's classification

Scientific Quality: Grade B
Novelty: Grade B
Creativity or Innovation: Grade B
Scientific Significance: Grade B

P-Reviewer: El-Shabrawi MHF, Egypt

Received: March 11, 2024
Revised: April 28, 2024
Accepted: May 22, 2024
Published online: June 28, 2024
Processing time: 107 Days and 4.1 Hours

Gökhan Kahraman, Department of Radiology, Suluova State Hospital, Amasya 05500, Türkiye

Kemal Murat Haberal, Department of Radiology, Başkent University Faculty of Medicine, Ankara 06490, Türkiye

Osman Nuri Dilek, Department of Surgery, İzmir Katip Celebi University, School of Medicine, İzmir 35150, Türkiye

Corresponding author: Gökhan Kahraman, MD, Chief, Department of Radiology, Suluova State Hospital, Maarif, Yunus Emre St No. 1, Amasya 05500, Türkiye.
gokhankahraman1@outlook.com

Abstract

Notably, the number of incidentally detected focal liver lesions (FLLs) has increased dramatically in recent years due to the increased use of radiological imaging. The diagnosis of FLLs can be made through a well-documented medical history, physical examination, laboratory tests, and appropriate imaging methods. Although benign FLLs are more common than malignant ones in adults, even in patients with primary malignancy, accurate diagnosis of incidental FLLs is of utmost clinical significance. In clinical practice, FLLs are frequently evaluated non-invasively using ultrasound (US), computed tomography (CT), and magnetic resonance imaging (MRI). Although US is a cost-effective and widely used imaging method, its diagnostic specificity and sensitivity for FLL characterization are limited. FLLs are primarily characterized by obtaining enhancement patterns through dynamic contrast-enhanced CT and MRI. MRI is a problem-solving method with high specificity and sensitivity, commonly used for the evaluation of FLLs that cannot be characterized by US or CT. Recent technical advancements in MRI, along with the use of hepatobiliary-specific MRI contrast agents, have significantly improved the success of FLL characterization and reduced unnecessary biopsies. The American College of Radiology (ACR) appropriateness criteria are evidence-based recommendations intended to assist clinicians in selecting the optimal imaging or treatment option for their patients. ACR Appropriateness Criteria Liver Lesion-Initial Characterization guideline provides recommendations for the imaging methods that should be used for the characterization of incidentally detected FLLs in various clinical scenarios. The American College of Gastroenterology (ACG) Clinical Guideline offers evidence-based recommendations for both the diagnosis and management of FLL. American Association for the Study of Liver Diseases (AASLD) Practice Guidance provides an approach to the diagnosis and management of patients with hepatocellular carcinoma. In this article, FLLs are reviewed with a comprehensive analysis of ACR Appropri-

ateness Criteria, ACG Clinical Guideline, AASLD Practice Guidance, and current medical literature from peer-reviewed journals. The article includes a discussion of imaging methods used for the assessment of FLL, current recommended imaging techniques, innovations in liver imaging, contrast agents, imaging features of common nonmetastatic benign and malignant FLL, as well as current management recommendations.

Key Words: Focal liver lesions; Imaging; Ultrasonography; Computed tomography; Magnetic resonance imaging; Management

Core Tip: The incidence of incidentally detected focal liver lesions (FLL) has risen significantly due to increased radiological imaging use. While benign FLLs are more common, even in patients with primary malignancy, accurate diagnosis is clinically significant. Non-invasive evaluation, such as ultrasound, computed tomography, and magnetic resonance imaging (MRI), is common in clinical practice. MRI, particularly with hepatobiliary-specific contrast agents, has enhanced FLL characterization, reducing unnecessary biopsies. Guidelines from the American College of Radiology, American College of Gastroenterology, and American Association for the Study of Liver Diseases offer evidence-based recommendations for optimal imaging and management. This article provides a comprehensive review of FLL, covering imaging methods, current techniques and modalities, innovations in imaging, contrast agents, features of nonmetastatic benign and malignant FLLs, and current management recommendations.

Citation: Kahraman G, Haberal KM, Dilek ON. Imaging features and management of focal liver lesions. *World J Radiol* 2024; 16(6): 139-167
URL: https://www.wjgnet.com/1949-8470/full/v16/i6/139.htm
DOI: https://dx.doi.org/10.4329/wjr.v16.i6.139

INTRODUCTION

The number of incidental liver lesions detected in asymptomatic patients has significantly increased as a result of the increased use of imaging modalities[1]. Focal liver lesions (FLLs) are solid or cystic masses found in the liver, as well as abnormal findings that can be distinguished from normal liver tissue. Therefore, the term "lesion" is preferred over "mass" as it describes a broader range of abnormalities.

Most of the FLLs detected in non-cirrhotic livers are benign, even in patients with primary malignancies[2]. Managing incidental FLLs, a common encounter for clinicians can be challenging. Even though the likelihood of them being benign is higher, the accurate diagnosis and management of incidental FLLs hold significant clinical importance.

The accurate diagnosis of FLL is established through a well-documented, detailed medical history, physical examination, and radiological imaging. The evaluation of a FLL should begin with obtaining a detailed medical history. Factors such as history of malignancy and renal function status that may affect the choice of imaging should be questioned, as well as conditions that may help in the characterization of FLL. For instance, in patients with chronic liver disease, consideration should be given to excluding hepatocellular carcinoma (HCC), while in patients using oral contraceptive pills (OCP), hepatocellular adenoma (HCA) should be considered. Physical examination and appropriate blood tests such as alpha-fetoprotein (AFP), cancer antigen 19-9, and complete blood count are important components that complement the diagnosis.

In recent years, advances in imaging modalities have made radiological imaging sufficient for the characterization of most FLLs, eliminating the need for biopsy in many cases. The liver is primarily evaluated noninvasively using ultrasound (US), computed tomography (CT), and magnetic resonance imaging (MRI). Although US is often used as the initial imaging method in many patients due to its non-ionizing nature, easy accessibility, and cost-effectiveness, its sensitivity and specificity for FLL characterization are limited compared to CT and MRI[3].

Standardization of liver imaging is essential for diagnosis. Imaging performed with the appropriate technique helps not only to provide lesion characterization but also to accurately evaluate the size, localization, and relationship of the lesion with surrounding anatomical structures. Contrast enhancement patterns of the lesions are highly important in the diagnosis of FLL. Therefore, CT and MRI studies of patients with both normal liver and chronic liver disease require at least two dynamic imaging phases, including the arterial and portal venous phases[4,5].

In FLL characterization, alongside technological advancements in imaging modalities, the contribution of new contrast agents is significant. Extracellular gadolinium MRI contrast agents are frequently used and aid in lesion characterization with dynamic postcontrast imaging. Hepatobiliary-specific contrast agents (HSCA) are absorbed by hepatocytes, aiding in the differentiation of hepatocellular lesions from non-hepatocellular ones. Gadoxetate disodium and gadobenate dimeglumine are among the available hepatobiliary contrast agents[6]. One of the emerging imaging modalities is contrast-enhanced US (CEUS). It has the potential to be useful in FLL characterization[7].

Despite the significant improvement in diagnostic accuracy due to technological advancements in imaging methods, biopsy should be performed for FLLs that cannot be characterized radiologically. Core biopsy is preferred over fine-needle aspiration in FLL biopsy because it allows both architectural and cytological evaluation[8].

For the approach, characterization, and management of FLLs, many studies and guidelines are available. American College of Radiology (ACR) appropriateness criteria are evidence-based recommendations intended to assist clinicians in selecting the optimal imaging or treatment option for their patients. ACR Appropriateness Criteria Liver Lesion-Initial Characterization guideline provides recommen-dations for the imaging methods that should be used for the characterization of incidentally detected FLLs in various clinical scenarios[9]. American College of Gastroenterology (ACG) Clinical Guideline offers evidence-based recommendations for both the diagnosis and management of FLL[10]. American Association for the Study of Liver Diseases (AASLD) Practice Guidance provides recommendations on the prevention, diagnosis, and treatment of HCC[11].

In this article, FLLs are reviewed with a comprehensive analysis of ACR Appropriateness Criteria, ACG Clinical Guideline, AASLD Practice Guidance; and current medical literature from peer-reviewed journals. The article includes a discussion of the approach to FLL imaging methods used for the assessment of FLL, current imaging techniques, and protocols, innovations in liver imaging, contrast agents, and imaging features of common nonmetastatic benign and malignant FLL, as well as current management recommendations.

LITERATURE SEARCH

A comprehensive literature search was conducted using the following search terms in the MEDLINE/PubMed and Web of Science databases: "Hepatic/liver lesion," "hepatic/liver mass," "hepatic/liver tumor," "hepatic/liver cancer," "hepatic hemangioma," "focal nodular hyperplasia," "hepatocellular adenoma," "hepatic cyst," "polycystic liver disease," "hepatic hydatid cyst," "mucinous cystic neoplasm of the liver," "hepatic cystadenoma," "hepatic cystadenocarcinoma," "cholangiocarcinoma," and "hepatocellular carcinoma." The research was limited to articles written in English. The literature from peer-reviewed journals was examined in accordance with the purpose of this review, and the most relevant and informative articles focusing on the diagnosis and management of FLLs were included.

IMAGING MODALITIES AND PROTOCOLS

US, CT, and MRI are the primary imaging modalities for FLL evaluation. US is a non-ionizing, easily accessible, and cost-effective imaging modality used as a surveillance method in patients with chronic liver disease. The disadvantages of the US include its operator-dependency, the presence of conditions that may limit imaging quality, such as obesity, and its limited sensitivity and specificity compared to other modalities.

Multiphase CT and MRI play a crucial role in FLL characterization. In multiphase imaging, liver images are obtained in a series at specific time intervals following the administration of intravenous (IV) contrast. As a result, it is possible to obtain the FLL contrast enhancement pattern, which enables lesion characterization. Both patients with normal liver and those with chronic liver disease should have at least two dynamic imaging phases, including the arterial and the portal venous phases, in their CT and MRI studies[4,5].

Non-contrast (pre-contrast) images obtained before IV contrast administration are used to compare with contrast-enhanced images to evaluate whether the FLL is enhanced or not. Moreover, the diagnosis of features like calcification and macroscopic fat content can be easily established with non-contrast CT imaging. Without non-contrast MRI images, T1 hyperintense lesions, such as those containing blood elements or proteinaceous fluids, may mistakenly give the impression that FLL is enhanced. Late arterial phase images are obtained 35-45 seconds after IV contrast injection[6]. In this phase, the hepatic artery is significantly enhanced, while the portal vein is in the early enhancement stage. There should be little to no contrast enhancement in the liver parenchyma. The importance of this phase is to detect hypervascular tumors such as HCC, and neuroendocrine tumor metastases[12]. Portal venous phase images are obtained 60-75 seconds after IV contrast injection[6]. All hepatic vascular structures and the parenchyma should be enhanced in this phase[13]. This phase aids in detecting hypovascular lesions, such as many metastases, and in evaluating characteristics like washout, which is a feature of tumors like HCC[6,12]. Delayed phase images, when extracellular contrast agents are used (for both CT and MRI), are obtained approximately 2-5 minutes after IV contrast injection[6]. This phase is used for detecting slowly enhancing and fibrous lesions like cholangiocarcinoma (CCA) and confluent fibrosis, as well as for evaluating washout[6,14]. The hepatobiliary phase is of great diagnostic value, which is discussed in more detail in the contrast agents section.

Liver Imaging Reporting and Data System (LI-RADS) is a system that guides the management of liver lesions detected in high-risk patients by stratifying HCC risks using a uniform lexicon[4]. LI-RADS technical recommendations for CT and MRI are summarized in Table 1[4,6].

INNOVATIONS IN LIVER IMAGING

Accurate diagnosis of FLLs is crucial to improve patient outcomes, and imaging plays a significant role in this process. Over the past few years, notable progress has been made in the field of liver imaging, marked by the emergence of novel technologies and methods that enhance sensitivity and specificity. While these advancements are not yet widely applicable in routine clinical practice, they hold promise for liver imaging.

Table 1 Technical considerations for computed tomography and magnetic resonance imaging

	CT	MRI
Recommended equipment	Multidetector CT with minimum of 8 detector rows	1.5 Tesla or 3 Tesla
	≤ 5 mm axial reconstructed slice thickness	Phased array multichannel torso coil
	Dual-chamber injector with a saline flush	Current-generation high-speed gradients
		Dual-chamber power injector
Contrast injection rate	≥ 3 mL/s of contrast, ≥ 300 mg iodine/mL	2-3 mL/s of gadolinium chelate
	1.5 mL/kg of body weight	
Required images	Arterial phase (late arterial phase strongly preferred over early arterial phase)	Unenhanced T1-weighted in phase and opposed phase imaging
	Portal venous phase	T2-weighted imaging (fat suppression optional)
	Delayed phase	All contrast agents: Multiphase T1-weighted imaging, preferably using a three dimensional sequence with ≤ 5 mm slice thickness
		Pre-contrast imaging
		Arterial phase (late arterial phase strongly preferred over early arterial phase)
		Portal venous phase
		MRI with extracellular contrast agents or gadobenate dimeglumine
		Delayed phase (2 to 5 minutes after injection)
		MRI with gadoxetate disodium
		Transitional phase (2 to 5 minutes after injection)
		Hepatobiliary phase (about 20 minutes after injection)
Suggested images	Pre-contrast, for initial diagnosis and patients treated with local-regional therapy	Multi-planar acquisition
	Multi-planar reformations	Subtraction imaging
	Thinner slices with section thickness ≤ 3 mm	Diffusion-weighted imaging
		1-3 hours hepatobiliary phase with gadobenate dimeglumine
Dynamic phases	Bolus tracking or fixed timed delay is suggested	Bolus tracking or fixed timed delay is suggested

Technical considerations for computed tomography and magnetic resonance imaging[4,6,10]. CT: Computed tomography; LI-RADS: Liver imaging reporting and data system; MRI: Magnetic resonance imaging.

CEUS is a diagnostic technique that offers higher sensitivity and specificity in the detection and characterization of liver lesions compared to conventional grayscale US. Contrast enhancement patterns of liver lesions are evaluated using microbubble contrast agents. CEUS can be safely used in patients with renal disease for whom the use of contrast agents in CT and/or MRI is contraindicated. There is no need for pre-evaluation of renal function with blood tests before CEUS [15].

In recent years, advancements in CT technology have led to improved image quality, enabling the acquisition of multiplanar images with lower radiation doses and contrast agents[16]. Dual-energy CT (DECT) is a novel CT technique that utilizes two separate X-ray energy spectra, a high-energy spectrum at around 140 kV and a lower-energy spectrum at 80 or 100 kV. DECT can detect substances based on their different attenuation at various X-ray energy spectra. DECT has been demonstrated as a technique that reduces artifacts, enhances lesion detection, and improves the characterization of lesions in liver imaging[17]. Photon counting detector CT (PCD-CT) is one of the new CT techniques with detectors that sort photons based on their energies. Its small detectors enable the production of images with minimal artifacts, high spatial resolution, and lower radiation dose. PCD-CT has the potential to detect and accurately diagnose FLLs at low radiation doses[18].

Magnetic resonance elastography (MRE) is a technique that quantifies the stiffness of tissues. It has a wide range of applications for various types of tumors.

MRE, being highly effective in distinguishing normal liver parenchyma from liver fibrosis, contributes to the assessment of cirrhosis, the most significant risk factor for the development of HCC. At the same time, it can provide an accurate diagnosis of focal nodular hyperplasia (FNH) and liver malignancies[19]. Magnetic resonance spectroscopy (MRS) is a technique with many clinical applications that assesses the concentrations of various metabolites based on the chemical shift phenomenon. MRS can be used in conjunction with other sequences for the detection and characterization

of liver tumors[20]. Diffusion-weighted imaging (DWI) is a method that measures the diffusion (Brownian motion) of water molecules within a tissue voxel. DWI can be used to distinguish benign from malignant liver tumors and evaluate treatment response. The combination of DWI and contrast-enhanced T1-weighted imaging enables the high-sensitivity diagnosis of malignant liver lesions[21].

In the primary diagnosis of liver tumors, especially in well-differentiated HCC patients, fluorodeoxyglucose positron emission tomography (FDG PET)/CT has low sensitivity. To overcome this issue, several radiolabeled fibroblast activation protein inhibitor (FAPI) tracers are being tested in the diagnosis of HCC. Ga-FAPI PET/CT, with a sensitivity similar to contrast-enhanced CT and MRI in detecting primary hepatic tumors, exhibits significantly higher sensitivity than FDG PET/CT[22].

Optical imaging is an imaging technique that uses light to create detailed images of various materials. In the medical field, images are created through the interaction of light with materials such as cells and tissues[23]. It has been demonstrated that optical imaging can aid in achieving maximal tumor resection in liver tumor surgery by distinguishing normal liver tissue from the tumor at the microscopic level[24,25]. Although it is not widely used due to its limited tissue penetration, it has the potential to improve the diagnosis of FLL.

Early and accurate detection of cancer significantly improves the likelihood of successful treatment across various types of tumors. This involves screening individuals at risk without symptoms and promptly investigating those with symptoms. Artificial intelligence (AI) has the potential to enhance early cancer diagnosis. The medical use of AI has become increasingly popular in recent years. AI can recognize specific lesion patterns by analyzing medical images, thereby improving diagnostic accuracy, and reducing workload. In CT imaging, one of the primary methods for detecting pancreatic cancer, about 40% of tumors smaller than 2 cm may be missed. AI has enabled the accurate differentiation of pancreatic cancers smaller than 2 cm from normal pancreatic tissue in CT scans with acceptable sensitivity[26]. A randomized trial comparing AI-assisted mammography screening to standard double reading demonstrated similar cancer detection rates and significantly reduced workload[27]. The study by Zhou *et al*[28] has shown that AI can accurately detect and classify FLLs. In this study, an AI algorithm used for the diagnosis of FLLs in CT images evaluated a total of 616 FLLs. The algorithm successfully distinguished FLLs as benign or malignant and additionally provided diagnoses such as HCC, hepatic cyst, and others. The algorithm achieved an overall accuracy of 82.8%, with an 82.5% accuracy in distinguishing between benign and malignant tumors and a 73.4% accuracy in identifying the specific type of tumor. The authors have stated that AI has the potential to assist physicians in diagnosing FLLs in their daily clinical practice[28]. Although there is a need for more extensive clinical studies in this field, AI could be applied as a decision-support tool in routine clinical practice in the future[29].

CONTRAST AGENTS

MRI contrast agents contain gadolinium chelates, whereas CT contrast agents contain iodine. Conventional extracellular MRI contrast agents and CT contrast agents are distributed into the extracellular space and provide similar information about the contrast enhancement of lesions. In contrast to extracellular MRI contrast agents, HSCAs not only show extracellular distribution but are also taken up by hepatocytes *via* hepatocyte-specific molecular transporters, providing valuable information in lesion characterization. There are currently two HSCAs in use: Gadoxetic acid and gadobenate dimeglumine[6].

CT contrast agents, conventional MRI contrast agents, and HSCAs all exhibit extracellular distribution, allowing for the acquisition of arterial (35-45 seconds), portal venous (60-75 seconds), and delayed phase (2-5 minutes) images. An additional image is obtained in the hepatobiliary phase when HSCA is used. Gadoxetic acid has approximately 50% hepatobiliary uptake, while gadobenate dimeglumine has around 3%-5% hepatobiliary uptake. Therefore, hepatobiliary phase images are obtained approximately 20 minutes after IV contrast administration for gadoxetic acid and 1-2 hours after IV contrast administration for gadobenate dimeglumine. In the hepatobiliary phase, the contrast uptake in a lesion indicates the presence of functional hepatocytes connected to functional bile ducts. Liver parenchyma and hepatocellular lesions are enhanced in the hepatobiliary phase, whereas nonhepatocellular lesions do not show contrast enhancement. For example, FNHs show enhancement in the hepatobiliary phase because they contain both functional hepatocytes and bile ducts. In contrast, lesions such as hemangioma, HCA, metastases, CCA, and dedifferentiated HCC, which do not contain functional hepatocytes, do not show contrast enhancement. HSCA can also be used to diagnose pseudo-lesions such as focal fatty infiltration[30].

APPROACH TO FLLS

The management of liver lesions that are detected in imaging studies conducted for other purposes can be challenging. First, it is necessary to decide which imaging will be used for further evaluation of FLL, which cannot be characterized by the initial imaging (Figure 1). ACR Appropriateness Criteria Liver Lesion-Initial Characterization guideline provides recommendations for the imaging methods that should be used for the characterization of incidentally detected FLLs in various clinical scenarios[9]. Among the initial procedures performed for the first time, US, non-contrast or contrast-enhanced CT, or non- contrast or contrast- enhanced MRI are included. In most cases, contrast-enhanced MRI is recommended for FLL characterization. In cases where MRI cannot be performed, multiphase contrast-enhanced CT is recommended[9]. Variants and appropriate procedures are summarized in Table 2. The approach to surveillance in patients with chronic HBV and cirrhosis, as well as the management of liver lesions detected in these patients are

Table 2 Variants of incidental liver lesions and recommended appropriate imaging recommended by American College of Radiology

Variants	Initial imaging	Size	Extrahepatic malignancy	Underlying chronic liver disease	Appropriate imaging
Variant 1	US	> 1 cm	No	No	US abdomen with IV contrast
					MRI abdomen without and with IV contrast
					CT abdomen with IV contrast multiphase
Variant 2	CT (non-contrast or single-phase)	> 1 cm	No	No	MRI abdomen without and with IV contrast
	MRI (non-contrast)				CT abdomen with IV contrast multiphase
Variant 3	US	> 1 cm	Yes	No	MRI abdomen without and with IV contrast
					CT abdomen with IV contrast multiphase
Variant 4	CT (non-contrast or single-phase)	> 1 cm	Yes	No	MRI abdomen without and with IV contrast
	MRI (non-contrast)				CT abdomen with IV contrast multiphase
					FDG-PET/CT skull base to mid-thigh
Variant 5	US	> 1 cm	No	Yes	US abdomen with IV contrast
	CT (non-contrast or single-phase)				MRI abdomen without and with IV contrast
	MRI (non-contrast)				CT abdomen with IV contrast multiphase
Variant 6	US	< 1 cm	Yes	No	MRI abdomen without and with IV contrast
Variant 7	CT (non-contrast or single-phase)	< 1 cm	Yes	No	MRI abdomen without and with IV contrast
	MRI (non-contrast)				CT abdomen with IV contrast multiphase
Variant 8	US	< 1 cm	No	Yes	MRI abdomen without and with IV contrast
	CT (non-contrast or single-phase)				CT abdomen with IV contrast multiphase
	MRI (non-contrast)				

Variants of incidental liver lesions and recommended appropriate imaging recommended by American College of Radiology[9]. ACR: The American College of Radiology; CT: Computed tomography; IV: Intravenous; MRI: Magnetic resonance imaging; US: Ultrasound; FDG-PET: Fluorodeoxyglucose positron emission tomography.

discussed in the HCC section of the article.

A biopsy can be used to establish the definitive diagnosis of FLLs that cannot be characterized with imaging. FLLs identified through imaging or biopsy may require follow-up (*e.g.*, HCA) or treatment (*e.g.*, CCA). Some FLLs, such as simple cysts, may not need follow-up or treatment. The last step is to choose the treatment methods for FLLs that are required to be treated (Figure 1).

Imaging features of common benign and malignant FLLs are presented in Table 3.

Hepatic hemangioma

Hepatic hemangiomas are the most common benign tumors of the liver. Hemangiomas are tumors characterized by blood-filled spaces lined with endothelial cells, supplied by the hepatic arterial circulation. The etiology is not fully understood but it is believed to result from the dilatation of normally developed blood vessels. The increase in hemangioma size is thought to be due to progressive dilatation[31]. Although it is more common in women, a clear relationship with pregnancy or the use of OCP has not been established[32]. Hemangiomas are often asymptomatic and detected incidentally. Hemangiomas can be seen in all age groups, but they are often detected in individuals aged 30-50

Table 3 Imaging features of common liver lesions

	US	CT (non-contrast)	MRI	Enhancement pattern (CT and MRI)
Hepatic hemangioma	Hyperechoic	Hypodense well-defined homogeneous lesion	T1: Hypointense	Arterial phase: Discontinuous, peripheral, nodular
	Well-defined homogeneous		T2: Markedly hyperintense	Enhancement
	lesions with acoustic enhancement			Portal venous and delayed phases: Progressive
	Rarely hypoechoic due to hepatic steatosis			Centripetal filling
				Hepatobiliary phase: Pseudo washout
Focal nodular hyperplasia	Difficult to detect (stealth lesion)	Difficult to detect (stealth lesion)	T1: Homogeneous isointense to slightly hypointense with hypointense stellate central scar	Arterial phase: Intense, homogenous enhancement
				Portal venous and delayed phases: Isointense or slightly hyperintense to the liver parenchyma
	Variable echogenicity	Hypodense or isodense well-defined lesions		
			T2: Isointense to slightly hyperintense	
			± Hyperintense central scar	
				Hepatobiliary phase: Isointense or slightly hyperintense to the liver parenchyma
				± Central scar: Enhanced with extracellular gadolinium contrast agents, but not enhanced with HSCA
Hepatocellular adenoma	Heterogenous, well-defined lesions	Well-defined heterogenous lesion	T1: Variable signal intensity loss of signal	Arterial phase: Intense enhancement
	Highly variable echogenicity	± Hyperdense if hemorrhagic		
		± Hypodense if fatty	On opposed-phase if fatty	
		± Calcification in areas of old hemorrhage	T2: Hyperintense	
Hepatic cyst	Anechoic, well-defined, homogenous lesion	Well-defined homogenous, hypodense lesion	T1: Hypointense	No enhancement with contrast agents
			T2: Hyperintense	
			Well-defined, homogenous lesion	
Polycystic liver disease	Multiple cysts with features, resembling hepatic cysts US findings	Multiple cysts with features, resembling hepatic cysts CT findings	Multiple cysts with features, resembling hepatic cysts MRI findings	No enhancement with contrast agents
Mucinous cystic neoplasm of liver	Solitary, well-defined, multiloculated anechoic lesion with septations	Well defined heterogenous lesion	T1: Variable signal intensity	± Enhancement of wall/septations
		± Calcification	T2: Hyperintense	
	± Septal/mural nodules			
	± Calcification			
Cholangiocarcinoma	Heterogenous	Heterogenous hypodense lesion with capsular retraction and parenchymal atrophy	T1: Heterogeneous hypointense	Arterial phase: Peripheral, enhancement (targetoid appearance)

	Variable echogenicity			
	± Hypoechoic rim		T2: Peripherally hyperintense and centrally hypointensite	Portal venous and delayed phases: Progressive, persistent heterogeneous enhancement
	± Dilated intrahepatic bile ducts	± Dilated intrahepatic bile ducts		
	± Satellite lesions	± Satellite lesions		
		± Vascular encasement		
Hepatocellular carcinoma	Variable echogenicity	Early HCC, isodense, ± hypodense if fatty	T1: Variable signal intensity, ± loss of signal	Arterial enhancement
				Portal venous, delayed and hepatobiliary phases: Washout
		Progressed HCC, isodense or hypodense, occasionally hyperdense	On opposed-phase if fatty	
			T2: Variable signal intensity, typically moderately hyperintense	

CT: Computed tomography; MRI: Magnetic resonance imaging; US: Ultrasound; HSCA: Hepatobiliary-specific contrast agents.

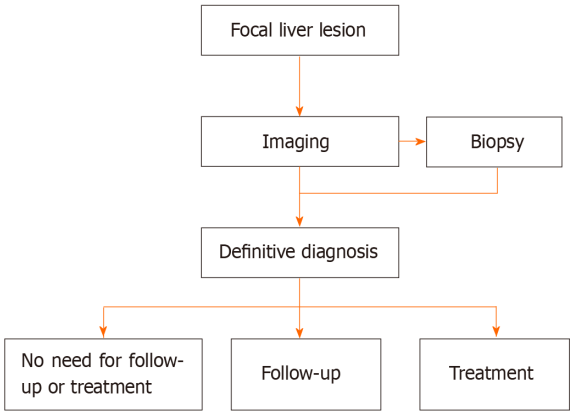

Figure 1 Approach to focal liver lesions which cannot be characterized by the initial imaging.

years[31]. Right upper quadrant pain and fullness are common in patients presenting with symptoms. Less commonly, patients may complain of nausea, early satiety, and dyspepsia. These symptoms may arise due to the mass effect of large hemangiomas[31,33]. Rarely, patients may present with acute pain as a result of thrombosis or hemorrhage, or with hemobilia due to a rupture into the biliary tract[34,35]. Giant hemangiomas can lead to Kasabach-Merritt syndrome (thrombocytopenia, disseminated intravascular coagulation, systemic bleeding)[36].

Hemangiomas appear on US as hyperechoic, well-defined, homogeneous lesions (Figure 2). Hemangiomas can appear hypoechoic in fatty liver due to a hyperechoic background[37]. Most hemangiomas have no blood flow on color Doppler US[38]. CEUS increases the sensitivity and specificity of US in the diagnosis of hemangiomas. In the arterial phase, it demonstrates peripheral nodular enhancement, following partial or complete centripetal filling[7]. Hemangiomas are well-circumscribed lesions that are hypodense on non-contrast CT and T1 hypointense and T2 markedly hyperintense on MRI. On contrast-enhanced CT and MRI, the presence of discontinuous peripheral nodular enhancement in the arterial phase and progressive centripetal filling in the portal venous and delayed phases is typical for hemangiomas (Figures 2 and 3)[31]. Hemangiomas may not show enhancement in cystic, fibrotic, and thrombosed areas, and atypical imaging findings may be seen. Fibrosis appears as hypointense on T2-weighted images[39]. Hemangiomas that appear as hypointense in the hepatobiliary phase should not be confused with other lesions showing true washout[40].

There is no need for further evaluation of hepatic hemangiomas smaller than 3 cm that exhibit typical characteristics such as a well-defined, hyperechoic appearance on US in patients without cirrhosis or extrahepatic malignancy. If these criteria are not met, the lesions should be evaluated with cross-sectional imaging (contrast-enhanced MRI or CT)[33]. Due to its higher sensitivity and specificity, MRI should be the first choice in diagnosing hemangiomas[41]. Because of their vascular nature and the risk of bleeding, it is recommended to avoid biopsy[10]. Follow-up should be preferred over biopsy in the management of small lesions with uncertain diagnosis[31].

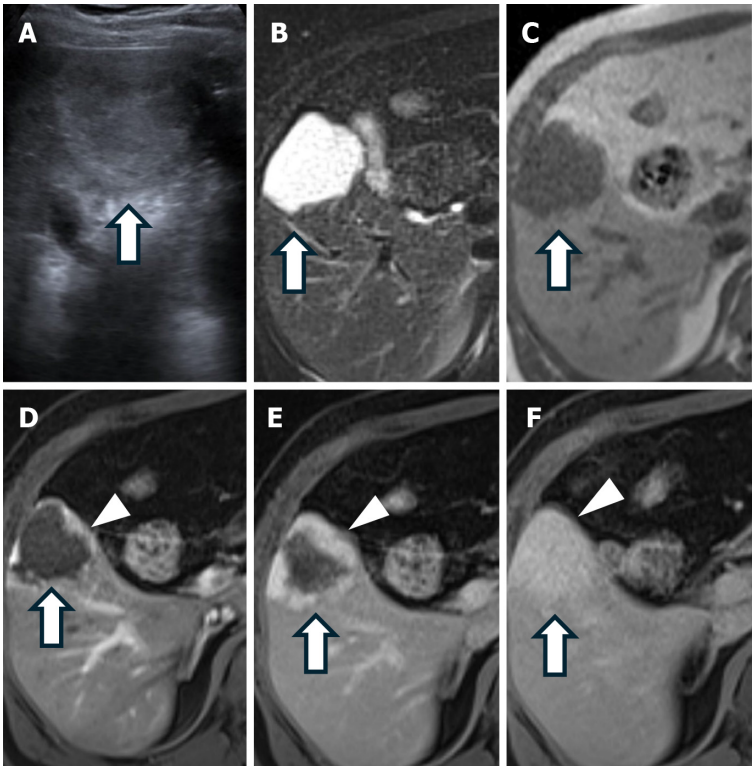

Figure 2 Hemangioma. A: Ultrasound shows a well-defined hyperechoic lesion (arrow); B: Axial T2-weighted magnetic resonance imaging (MRI) shows a markedly hyperintense lesion (arrow); C: Axial T1-weighted MRI shows a hypointense lesion (arrow); D: Arterial phase T1-weighted MRI with an extracellular gadolinium-based contrast agent demonstrates peripheral, nodular, and discontinuous enhancement (arrowhead); E: Portal venous phase T1-weighted MRI shows continued progressive enhancement (arrowhead); F: Delayed phase T1-weighted MRI emphasizes these enhancement characteristics even further (arrowhead).

Treatment and follow-up of asymptomatic, small-sized hemangiomas are not recommended[10]. Some authors recommend follow-up of hemangiomas larger than 5 cm at 6-12 months[42]. Surgery is not recommended for most hemangiomas because they are usually asymptomatic and stable in their course. Surgical intervention may be considered in cases of lesions larger than 10 cm, progressive increase in lesion size, symptomatic compression, life-threatening complications such as intraperitoneal bleeding or Kasabach-Merritt syndrome, and patients with recurrent pain complaints[10,43]. Surgical treatment of hemangioma includes hepatic resection, enucleation, hepatic artery ligation, and liver transplantation[43]. Hemangiomas can also be treated non-surgically with procedures such as transarterial embolization (TAE) and radiofrequency ablation (RFA)[44,45].

During the first six months of life, infantile hepatic hemangiomas usually show rapid growth, which is followed by regression. While asymptomatic cases might not need any treatment at all, propranolol is frequently used as the first line of treatment for symptomatic cases, particularly those that result in high-output cardiac failure. Embolization or surgery may be considered if medical management proves to be ineffective[46].

Focal nodular hyperplasia

FNH is the second most common benign tumor of the liver[31]. Arteriovenous shunts, which are caused by damage to the portal tract, lead to the development of FNH. Hyperperfusion resulting from arteriovenous shunts leads to oxidative stress which stimulates hepatic stellate cells to produce the central scar[47]. FNH is more prevalent among women aged 30 to 40. Most FNH cases are incidentally detected, and they may present with symptoms in 20%-40% of cases[31]. The most common symptom is abdominal pain[48].

FNH is referred to as a "stealth lesion" because it is difficult to detect on US, non-contrast CT, and MRI. A "spoke-wheel pattern" of vascularity can be revealed by color Doppler ultrasonography[49]. Due to the strong and homogeneous enhancement of FNH in the arterial phase, contrast-enhanced CT and MRI play a significant role in the diagnosis of FNH. It becomes difficult to distinguish it from the liver parenchyma in the portal venous phase and delayed phase (Figure 4). These imaging features are typical for FNH, and the diagnosis can be made with confidence[50,51]. The central scar with a "spoke-wheel" appearance, seen in 50%-70% of FNHs, shows contrast enhancement in the delayed phase, unlike fibrolamellar HCC[52]. Because of their different managements, HCA and FNH should be distinguished. HSCA can be used as problem solvers in cases where a definitive diagnosis cannot be established. In the hepatobiliary phase, FNH shows contrast enhancement, whereas HCA appears hypointense compared to the liver parenchyma, as HCA lacks functional hepatocytes[53,54]. CEUS has a high sensitivity and specificity for the diagnosis of FNH[55]. On CEUS, contrast enhancement is observed in the arterial and early portal venous phases, and the central artery can also be seen in a "spoke-wheel pattern" in the arterial phase[56]. In ambiguous cases where a definitive radiological diagnosis cannot be made, a biopsy should be performed. FNH and HCA can be differentiated from each other through immunohistochemical analyses[57].

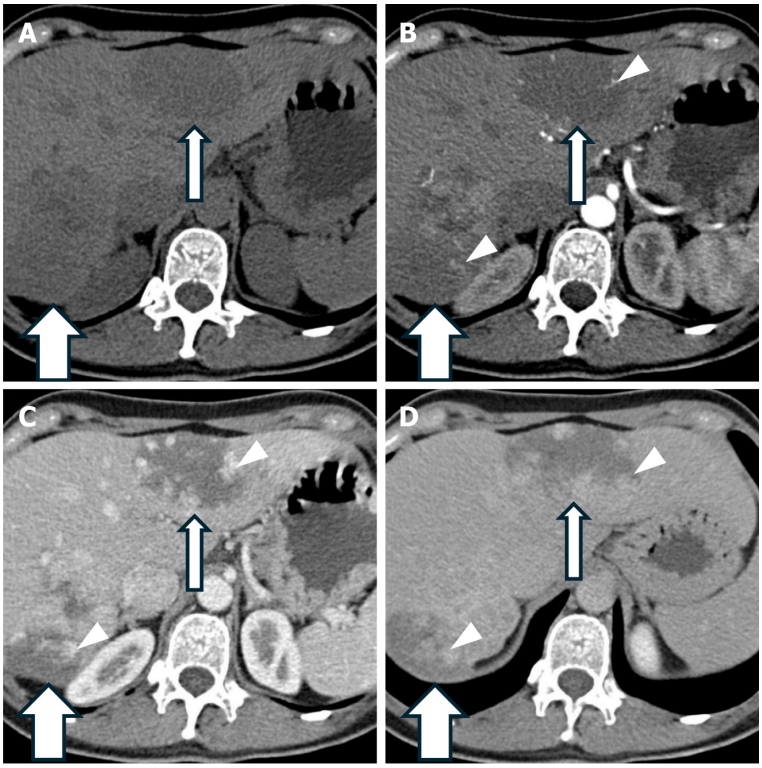

Figure 3 Hemangioma. A: Axial non-contrast computed tomography (CT) image shows lesions in the right lobe (thick arrow) and left lobe (thin arrow) of the liver; B: Arterial phase contrast-enhanced CT image demonstrates peripheral, nodular, and discontinuous enhancement of the lesions (arrowhead); C: Portal venous phase contrast-enhanced CT image shows progressive enhancement patterns (arrowhead); D: Delayed phase contrast-enhanced CT image further highlights the enhancement characteristics (arrowhead).

FNH cases are usually asymptomatic. Spontaneous rupture and malignant transformation are rare[58]. Therefore, they do not require surgical treatment or follow-up. In patients diagnosed with FNH who wish to continue using OCP, annual US follow-up for 2-3 years can be conducted. Surgery may be required only in symptomatic cases where the definitive diagnosis of FNH is not established[10]. Due to the presence of large vascular structures around the lesion, enucleation is preferred over hepatectomy[59]. TAE and RFA may be preferred over hepatic resection due to lower complications and morbidity[60,61].

HCA

HCAs are the third most common benign tumor of the liver. They are generally solitary and are liver lesions with a risk of bleeding. Differentiating them from other benign liver lesions is necessary due to the distinct approach to their management. They are common in women in their 30 and 40 seconds[31]. Most of them are symptomatic. Approximately 35% of HCAs are incidentally detected[62]. They are more common in women using OCPs and especially in young men using anabolic androgen steroids[63-65]. In addition, the risk of developing HCA increases in situations where endogenous androgens and estrogens are elevated. These findings support a causal relationship between HCA and hormonal abnormalities[66]. Other risk factors for HCA include metabolic syndrome, obesity, glycogen storage diseases (Types 1 and 3), maturity-onset diabetes of the young type 3, and McCune-Albright syndrome[67-69]. They are typically seen as well-defined masses in the right lobe of the liver. When they are multiple (> 10), the term “hepatic adenomatosis” is used[70]. These lesions share similar characteristics with HCA and are managed similarly[31]. HCA has many subtypes with distinct clinical and histopathological characteristics. These subtypes have different complications and risks of malignant transformation. The most common molecular subtypes of HCA include HNF1α inactivated HCA, β-catenin exon 3-mutated HCA, β-catenin exon 7 or 8-mutated HCA, sonic hedgehog HCA, and unclassified HCA[62,71].

It can be difficult to distinguish HCA from other hypervascular liver tumors, and the imaging characteristics of its subtypes can vary significantly. HCAs appear as heterogeneous lesions on US, with no specific echo pattern[31]. CEUS is not as sensitive and specific as MRI in the diagnosis of HCAs and their subtypes[72]. HCAs are observed as well-defined masses with strong peripheral enhancement in the arterial phase on contrast-enhanced CT. Hemorrhagic areas appear hyperdense on non-contrast CT[73]. Non-contrast CT can demonstrate calcifications associated with prior bleeding in 5%-10% of cases[74].

MRI is the best imaging modality for the diagnosis and subtype classification of HCA. In the HNF1α inactivated HCA subtype, diffuse and homogeneous signal dropout on opposed-phase T1 is observed due to intracellular fat. It shows contrast enhancement in the arterial phase while demonstrating washout in the portal venous and delayed phases. Inflammatory HCA appears hyperintense on T2, with peripheral contrast uptake continuing in the delayed phase with extracellular contrast agents (Figure 5). A peripheral hyperintense rim (atoll sign) may be seen. Intracellular fat is rare[75,76]. Intralesional bleeding is seen in up to 30% of cases[77]. β-catenin mutated HCA and unclassified HCA do not have

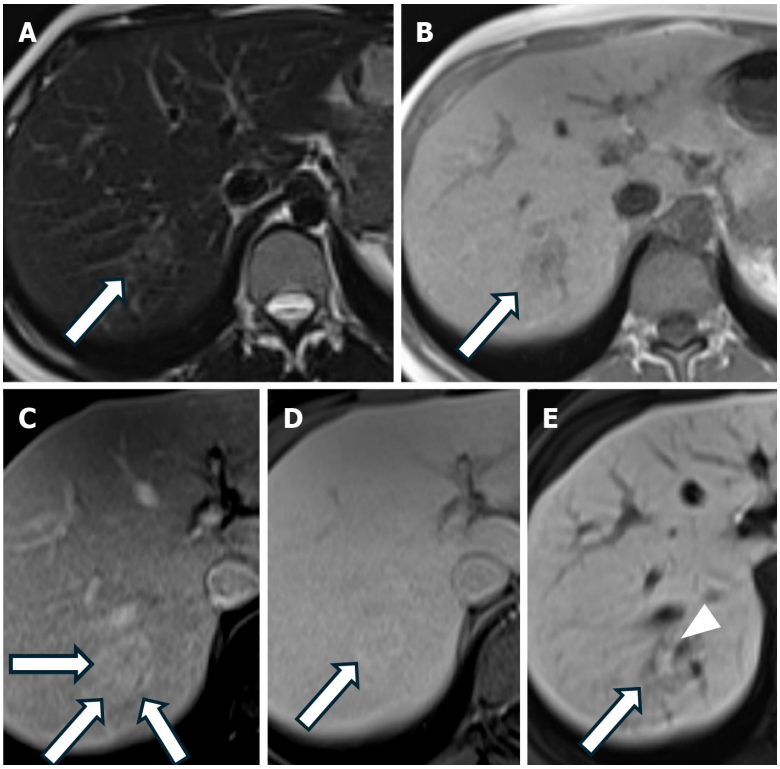

Figure 4 Focal nodular hyperplasia. A: Axial T2-weighted magnetic resonance imaging (MRI)shows a slightly hyperintense lesion (arrow); B: Axial T1-weighted MRI reveals a slightly hypointense lesion (arrow); C: Arterial phase T1-weighted MRI with a hepatobiliary-specific contrast agent shows homogenous enhancement of the lesion (arrows); D: Portal venous phase T1-weighted MRI indicates the lesion is isointense (arrow); E: Hepatobiliary phase T1-weighted MRI shows persistent peripheral enhancement of the lesion (arrow) with a hypointense central scar (arrowhead).

characteristic MRI features. β-catenin mutated HCAs typically do not contain microscopic fat. Since β-catenin mutated HCA has a high risk of malignant transformation, attention should be paid to indicative findings for malignant transformation, such as an increase in lesion size, local invasion, and washout[78]. HSCA-enhanced MRI is particularly useful in distinguishing HCA from FNH. While FNHs show contrast enhancement in the hepatobiliary phase, most HCAs do not show contrast enhancement[53,54]. However, it should be kept in mind that some inflammatory and β-catenin mutated HCAs may show contrast enhancement in the hepatobiliary phase on MRI with HSCA[79]. Although biopsy is the gold standard method for diagnosis and subclassification of HCA, biopsy should be considered for cases where a definitive diagnosis cannot be made by imaging due to the bleeding risk[31].

In the article published by Vernuccio *et al*[80], it is mentioned that most HCAs (78%) remained stable or resolved[80]. Nonetheless, HCAs are managed differently from other benign liver lesions due to the risk of bleeding and progression to HCC[10,31]. Patients with HCA should avoid using OCP, hormone-containing intrauterine devices, and anabolic steroids. Pregnancy is not contraindicated in cases of HCA smaller than 5 cm, and it is recommended to manage them with an individualized approach[10]. The conservative approach can be considered in the management of HCA smaller than 5 cm due to the low risk of bleeding and progression to HCC[10,81]. Even after discontinuing OCPs and anabolic steroids, some HCAs can progress to HCC[82]. Therefore, it is recommended to have follow-up imaging every six months for at least two years and then annually to assess lesion stability[10]. Patients with suspected HCC should be screened more frequently with MRI, and the option of biopsy or surgical resection may be considered[82,83].

In the past, surgical intervention and lifelong follow-up were recommended for the management of HCA[84]. However, only about 15%-20% of HCAs require surgery, and different subtypes of HCA have distinct clinical characteristics[85]. HCAs are vascularized tumors, and bleeding is a common complication. In a systematic review involving 1176 patients with HCAs, the overall frequency of bleeding was reported as 27.2%[86]. Since the vast majority of reported cases of HCAs bleeding spontaneously are greater than 5 cm in diameter, resection or embolization is advised for HCAs exceeding this size[10]. Due to the higher risk of malignant transformation in male patients and the β-catenin mutated HCA subtype, resection should be considered[10,31,71]. Because inflammatory and sonic hedgehog HCA subtypes are associated with obesity, overweight patients with these subtypes are advised to lose weight. In such cases, bariatric surgery may be considered[87].

Due to the risk of malignant transformation, hepatectomy or segmental resection is preferred in the surgical management of HCAs. TAE may be an alternative treatment method to surgery in selected patients. TAE can be used as a preoperative intervention to reduce blood loss during surgery. However, the risk of malignant transformation after TAE is not well understood[88]. RFA can be used as a treatment for residual or progressive tumors after surgery or as an initial treatment[89]. Conservative treatment to maintain hemodynamic stability can help avoid the need for emergency liver resection in cases of bleeding. In cases where bleeding cannot be controlled, options such as hepatic packing, hepatectomy, embolization, and even liver transplantation can be considered[90,91].

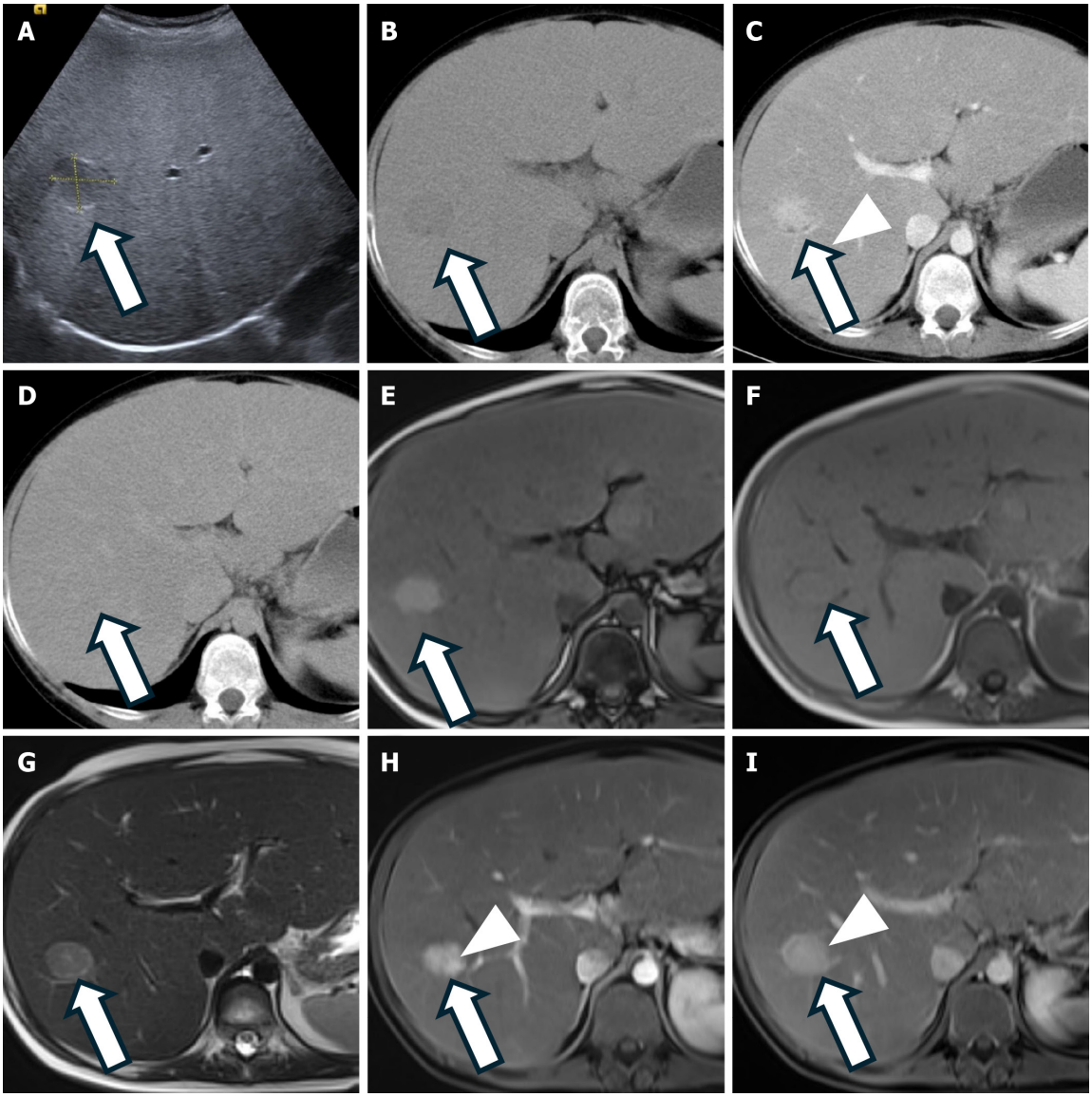

Figure 5 Hepatocellular adenoma, inflammatory subtype. A: Ultrasound shows a hypoechoic well-defined lesion (arrow) in the right lobe of the liver; B: Axial non-contrast computed tomography (CT) image demonstrates a hypodense lesion (arrow); C: Arterial phase CT shows the lesion with homogenous enhancement (arrowhead); D: In the portal venous phase, the lesion appears isodense to the surrounding liver parenchyma (arrow); E and F: Axial T1-weighted images in opposed phase (E) and in-phase (F) show the lesion (arrow) with no signal drop on the opposed-phase image; G: Axial T2-weighted magnetic resonance imaging (MRI) shows a hyperintense lesion (arrow). H: Arterial phase T1-weighted MRI with an extracellular gadolinium-based contrast agent demonstrates heterogeneous enhancement (arrowhead); I: Portal venous phase T1-weighted MRI continues to show heterogeneous enhancement of the lesion (arrowhead) with no washout.

Hepatic cyst

Hepatic cysts are benign liver lesions often found incidentally in imaging studies conducted for other indications. The etiology of hepatic cysts is unknown. They are not considered as premalignant precursors. Hepatic cysts are more common in individuals over the age of 40, with a higher prevalence in women[92]. They are not associated with OCP or pregnancy. Patients with large-sized cysts may present with symptoms such as abdominal pain, epigastric fullness, and early satiety. Bleeding, infection, rupture, biliary obstruction, or rapid growth in lesion size may cause symptoms[93,94].

Simple hepatic cysts appear as homogeneous anechoic lesions with well-defined borders and posterior acoustic enhancement on US[95]. They are non-enhancing hypodense lesions on contrast-enhanced CT. On MR, they appear hypointense on T1-weighted sequences and hyperintense on T2-weighted sequences (Figure 6)[96,97]. Symptomatic cases, a high number of cysts (> 20), large size (> 4-5 cm), rapid increase in lesion size, irregular wall, septations, calcifications, fenestrations, loculations, heterogeneity, solid components, or daughter cysts are not among the typical features of hepatic cysts. In such cases, further investigation with CT or MRI is required[98].

Due to the lack of sufficient clinical studies on the management of incidentally detected asymptomatic hepatic cysts, there are no evidence-based recommendations available. However, follow-up and treatment of hepatic cysts is not recommended[10]. Intervention may be necessary in the case of bleeding, infection, rupture, or significant growth of hepatic cysts. Simple aspiration is not recommended due to the risk of recurrence[99]. Surgical intervention may be considered in symptomatic patients and in those with lesions where the need for histological diagnosis is necessary,

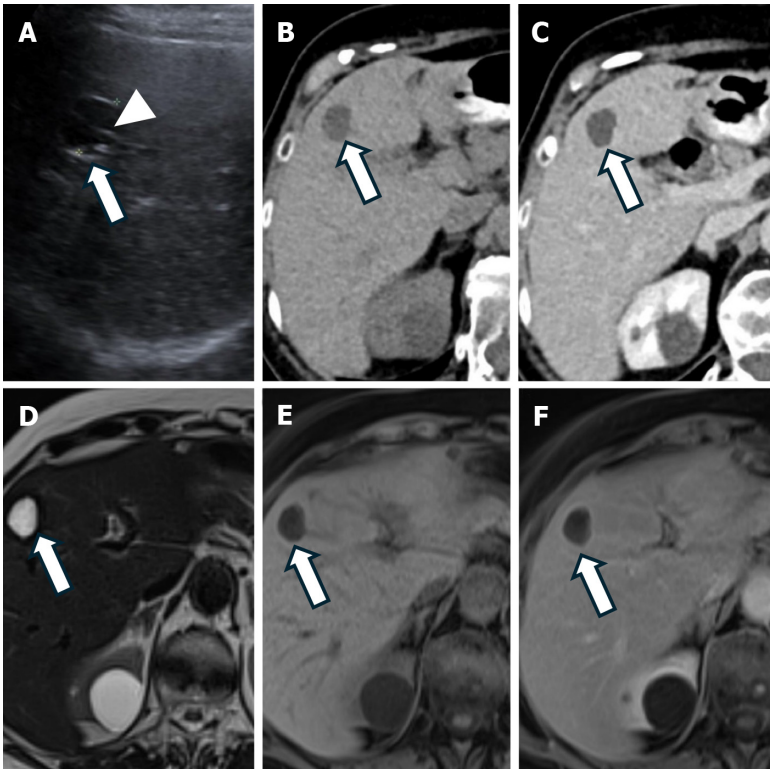

Figure 6 Hepatic cyst. A: Ultrasound shows an anechoic well-defined lesion (arrow) with a single thin septation (arrowhead); B: Axial non-contrast computed tomography (CT) image demonstrates a hypodense lesion (arrow); C: Axial contrast-enhanced CT image in the portal venous phase shows a hypodense lesion (arrow) with no enhancement; D: Axial T2-weighted magnetic resonance imaging (MRI) shows a markedly hyperintense lesion (arrow); E: Axial T1-weighted MRI shows a hypointense lesion (arrow); F: Axial T1-weighted MRI with an extracellular gadolinium-based contrast agent in the portal venous phase shows the lesion (arrow) with no enhancement.

especially when malignancy cannot be ruled out[100]. Surgical treatments include open or laparoscopic cyst fenestration (deroofing, unroofing, or marsupialization) and hepatic resection[101]. The laparoscopic approach has been reported to have lower morbidity and reduced length of hospital stay compared to open surgery. Therefore, when available, a laparoscopic approach may be preferred[102]. Patients who are not candidates for surgery can be treated with cyst aspiration followed by sclerotherapy using sclerosing agents such as alcohol[103]. The studies comparing aspiration and surgery in hepatic cyst management are limited. ACG recommends laparoscopic fenestration for the treatment of symptomatic simple cysts. ACG Clinical Guideline also states that the choice of treatment should be determined based on the available resources, and the patient's preference[10].

Polycystic liver disease

Polycystic Liver Disease (PCLD), which has similar histopathological features to simple liver cysts, is characterized by cysts that are typically numerous (usually > 20) and large[104]. PCLD is considered part of the clinical spectrum of ciliopathies associated with mutations causing cholangiocyte ciliary dysfunction. Congenital hepatic fibrosis, choledochal cysts, hamartomas, and Caroli disease are among the ciliopathies. The most commonly associated disease with PCLD is autosomal dominant polycystic kidney disease (ADPKD)[105]. The most common extrarenal manifestation of ADPKD is PCLD[106]. Although patients are generally asymptomatic, they may present with many complications such as infection, hemorrhage, rupture, biliary, or gastrointestinal compression, extrinsic compression of the inferior vena cava, and even portal hypertension[107-109].

The diagnosis of PCLD can be easily made through imaging, revealing multiple hepatic cysts (Figure 7). Although there is no universally accepted criterion for the diagnosis of PCLD using imaging, a study has suggested that a diagnosis can be considered for individuals with a positive family history and more than four hepatic cysts[110]. The differential diagnosis of PCLD includes biliary hamartomas (von Meyenburg complexes) and Caroli disease. Compared to PCLD, the cyst sizes in biliary hamartomas are smaller. The central dot sign, which indicates intrahepatic portal vein branches surrounded by dilated bile ducts, is a significant finding in Caroli disease[111].

The treatment of PCLD is generally dependent on the presence of symptoms. Although there are a few reports on medical treatment, its routine use is not recommended[10,112,113]. Typically, the determining factor in treatment is the liver volume rather than the volume of the cysts. Treatment aims to reduce cyst volume, alleviate symptoms related to mass effect, and decompress the liver[104]. Laparoscopic surgery is recommended as the treatment of choice[102]. Liver transplantation may be considered for patients with refractory symptoms[114].

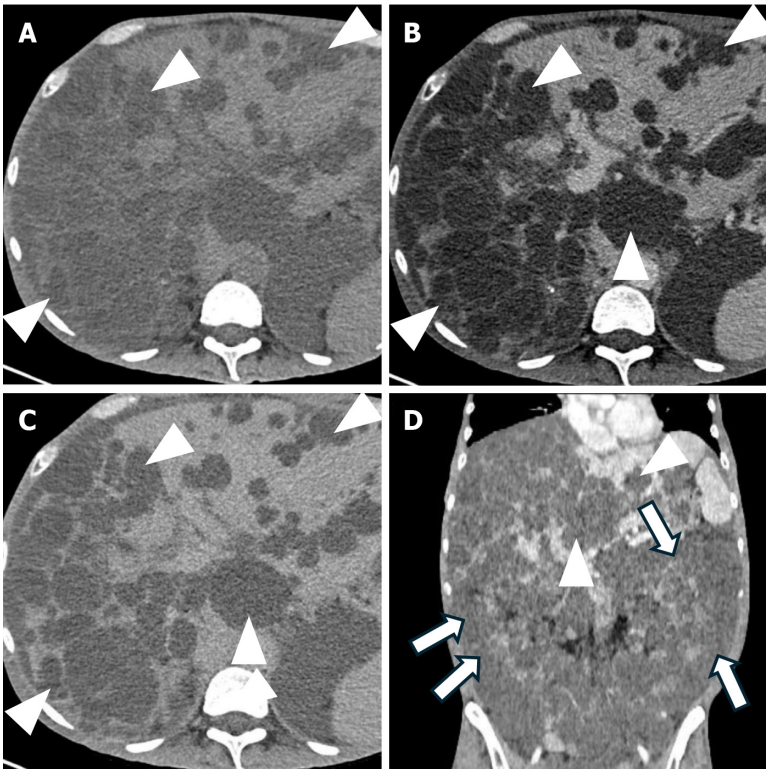

Figure 7 Polycystic liver disease. A: Axial non-contrast computed tomography (CT) image demonstrates multiple hypodense lesions (arrowheads); B: Axial contrast-enhanced CT image in the portal venous phase shows multiple hypodense lesions with no enhancement (arrowheads); C: Axial contrast-enhanced CT image in the delayed phase demonstrates multiple hypodense lesions with no enhancement (arrowheads); D: Coronal contrast-enhanced CT image in the portal venous phase shows multiple hepatic (arrowheads) and renal (arrows) cysts.

Hepatic hydatid cyst

Hydatid disease is caused by the larval stages of cestodes belonging to the genus Echinococcus. *Echinococcus granulosus* and *Echinococcus multilocularis*, respectively, lead to cystic echinococcosis (hydatid cyst) and alveolar echinococcosis. The diagnosis and treatment of cystic and alveolar echinococcosis are distinct[115]. In this article, cystic echinococcosis, which is more common than alveolar echinococcosis, is discussed.

Hepatic hydatid cyst is an endemic disease caused by *Echinococcus granulosus*, leading to significant public health problems in many countries[116]. The ingestion of eggs of *Echinococcus granulosus* leads to the development of oncospheres, which primarily settle in the liver and lungs through the vascular and lymphatic systems[117].

Hepatic hydatid cysts are generally asymptomatic. As the size of the cysts increases, they can lead to symptoms. Cyst rupture or secondary infection may lead to acute pain. Cyst rupture can also lead to peritonitis and even shock by inducing an allergic reaction. Rarely, cysts may open into the bile ducts, presenting with jaundice and cholangitis[117-119].

US is the primary modality used for the diagnosis of hydatid cyst. On US, hydatid cysts initially appear similar to simple hepatic cysts. In the later stages, the cyst wall begins to thicken and calcify, and daughter cysts develop around the periphery of the main cyst (Figures 8 and 9). The water lily sign, which refers to floating membranes following the complete detachment of membranes within the cyst, is a specific sign of a hydatid cyst (Figure 8). Several classifications have been developed to determine the treatment strategy for hydatid cysts. The classifications are based on features such as calcifications, daughter cysts, detachment of the membrane, and heterogeneous components. The World Health Organization (WHO) classification based on US findings has replaced the older Gharbi classification for hydatid cysts (Table 4)[120-122].

In the case of a suspected hydatid cyst on US, it is necessary to evaluate it further with CT or MRI[123]. CT and MRI are more sensitive modalities than the US for the diagnosis of hydatid cyst. CT and MRI better demonstrate the presence of daughter cysts, extrahepatic involvement, recurrence, and complications such as peritonitis, and rupture[124]. CT can demonstrate better calcifications, while MRI is the preferred modality for evaluating the relationship of lesions with the bile duct[125]. Hydatid cyst lesions do not show contrast enhancement. Particularly in lesions with a heterogeneous pattern (Type IV/CE4), the presence of internal contrast-enhancing components should rule out a diagnosis of hydatid cyst[117].

There is no best option for the treatment of hydatid cysts due to the lack of sufficient studies comparing treatment efficacy. The treatment of hydatid cysts depends on various factors, including the type, location, and size of the cyst, accompanying complications, symptoms, available medical resources, and patient preferences. Treatment recommendations of the WHO-Informal Working Group on Echinococcosis (WHO-IWGE) according to cyst types are stated in Table 5[115].

Table 4 Classification of hydatid cyst and imaging features

Gharbi	WHO-IWGE	US findings	CT findings	MRI findings
Type 1	CE1	Unilocular cyst with wall	Well-defined hypoattenuating cyst	T1 hypointense
		Hydatid sand	Perceptible wall with mild delayed enhancement	Very T2 hyperintense
		Snowstorm sign	No internal enhancement	Perceptible wall with mild delayed enhancement
		No internal vascularity		No internal enhancement
Type 3	CE2	Multilocular, multiseptated cyst	Multivesicular multiseptated cyst	Multivesicular multiseptated
		Honeycomb sign	Hypoattenuating daughter cysts	T2 hyperintense daughter cysts
		Daughter cysts	No septal enhancement	No septal enhancement
Type 2	CE3	Cyst with detached membrane, water-lily sign (CE3a)	Heterogeneous	Heterogeneous
		Cyst with daughter vesicles in a solid matrix (CE3b)	High-attenuating internal content	T2 hypointense detached membranes
			Detached membranes	No internal enhancement
			No internal enhancement	
Type 4	CE4	Cyst with heterogenous content	Solid appearance	T2 iso- to hypointense
		No daughter cysts	No daughter cysts	No daughter cysts
		Ball of wool sign	Avascular	Avascular
Type 5	CE5	Thick calcified wall	Capsular and/or central calcifications	Very hypointense wall and intermediate to low internal signal intensity on T2-weighted images
			Complete calcification	No internal enhancement
			No internal enhancement	

Classification of hydatid cyst and imaging features[119,121]. CT: Computed tomography; MRI: Magnetic resonance imaging; US: Ultrasound; WHO-IWGE: World Health Organization Informal Working Group on Echinococcosis.

Among the treatment options for hydatid cysts are antihelminthic drugs, percutaneous treatment, and surgery. The drug of choice for the treatment of hydatid cysts, either alone or in conjunction with percutaneous treatment, is albendazole[126]. Puncture, aspiration, injection, and re-aspiration (PAIR) is an effective percutaneous treatment method with lower complication rates and lower costs compared to surgery[127,128]. PAIR is the recommended treatment method for patients who have CE1 and CE3a (Gharbi type 1 and 2) hydatid cysts larger than 5 cm, and are not suitable for or refuse surgical intervention, have postoperative relapse, or fail to respond to albendazole alone. PAIR is not recommended for treatment of CE2 and CE3b, CE4, and CE5 cysts, or cysts communicating with the biliary tract. Cysts that are difficult to drain or tend to relapse after PAIR (CE2 and CE3b) are candidates for other percutaneous treatments, such as large-bore catheters[129].

Surgery should be the primary treatment option for hydatid cysts that are difficult to reach, complicated, multivesicular, or associated with the biliary system[130]. Especially in cases where percutaneous treatment is not available, surgical intervention should also be preferred. The surgical treatment strategy for hydatid cysts has also progressed over the years in response to advances in surgical techniques. Partial liver resection, pericystectomy, and cystectomy are preferred surgical options in the treatment of hydatid cysts. Laparoscopic surgery may be preferred over open surgery in selected cases, but the risk of complications has not been definitively assessed[131-133]. Another method used in the management of hydatid cysts is the "watch-and-wait" approach, where the patient is closely monitored without treatment. This method should be preferred in cases where the cysts are largely calcified and inactive (CE4 and CE5)[134].

Mucinous cystic neoplasm of the liver

In 2010, the WHO divided mucin-producing liver bile duct tumors into two separate categories: "Mucinous cystic neoplasm of the liver (MCNL)" and "intraductal papillary mucinous neoplasm of the bile duct"[135]. MCNL was formerly known as biliary cystadenoma or biliary cystadenocarcinoma. While MCNLs are generally asymptomatic, the mass effect of larger MCNLs can cause the manifestation of symptoms such as abdominal pain, nausea, and early satiety[136].

The differential diagnosis of MCNL includes a wide range of lesions such as cystic HCC, choledochal cysts, hydatid cysts, liver abscesses, hemorrhagic cysts, PCLD, and cystic hemangioma[137-139]. Although imaging plays a crucial role in the diagnosis of MCNL, it may not always clearly distinguish these lesions from others due to variations in imaging findings.

Table 5 Stage-specific treatments of hepatic hydatid cysts recommended by World Health Organization Informal Working Group on Echinococcosis

WHO-IWGE classification	Surgery	Percutaneous treatment	Drug therapy	Suggested optimal treatment
CE1		Yes	Yes	< 5 cm
				Albendazole
				> 5 cm
				PAIR + Albendazole
CE2	Yes	Yes	Yes	Non-PAIR percutaneous treatment + Albendazole
CE3a		Yes	Yes	< 5 cm
				Albendazole
				> 5 cm
				PAIR + Albendazole
CE3b	Yes	Yes	Yes	Non-PAIR percutaneous treatment + Albendazole
CE4				Watch and wait
CE5				Watch and wait

Stage-specific treatments of hepatic hydatid cysts recommended by World Health Organization Informal Working Group on Echinococcosis[114]. PAIR: Puncture, aspiration, injection, and re-aspiration; WHO-IWGE: World Health Organization Informal Working Group on Echinococcosis.

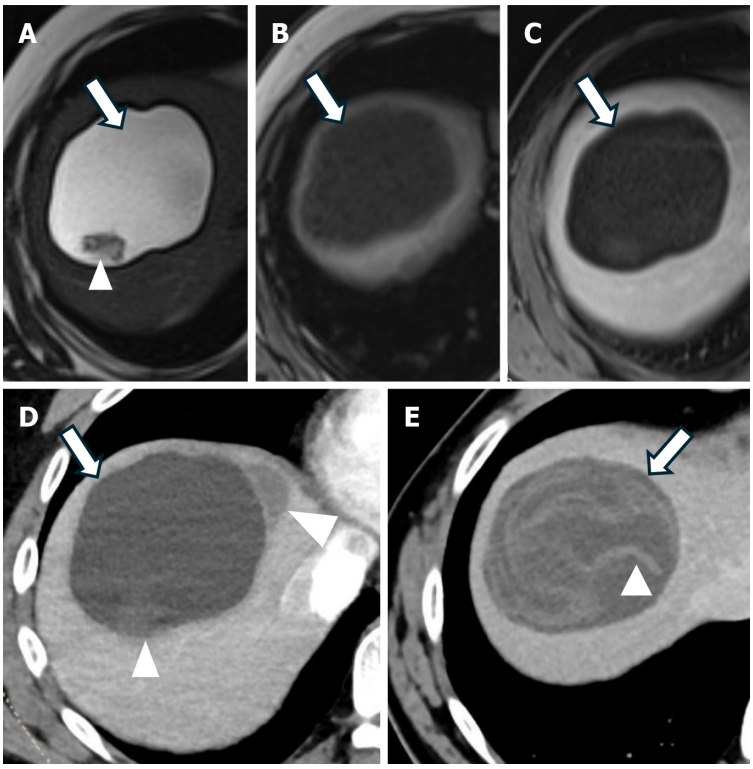

Figure 8 World Health Organization CE2 and CE3a type hydatid cysts. A 35-year-old man with nonspecific right upper quadrant pain. A: Axial T2 weighted magnetic resonance imaging (MRI) shows a T2 hyperintense hydatid cyst [World Health Organization (WHO) type CE2] with a solitary main cyst (arrow) and small daughter cysts (arrowhead) posteriorly; B: Axial T1 weighted MRI shows a T1 hypointense hydatid cyst with a solitary main cyst (arrow); C: Axial T1 weighted MRI with an extracellular gadolinium-based contrast agent in the portal venous phase shows a hydatid cyst that demonstrates no enhancement; D: Axial contrast-enhanced computed tomography (CT) image shows a hydatid cyst with the main cyst (arrow) and daughter cysts (arrowheads); E: Axial contrast-enhanced CT image of the same patient after one year shows a hydatid cyst (arrow) (WHO type CE3a) with detached membranes (arrowhead) floating within the main cyst.

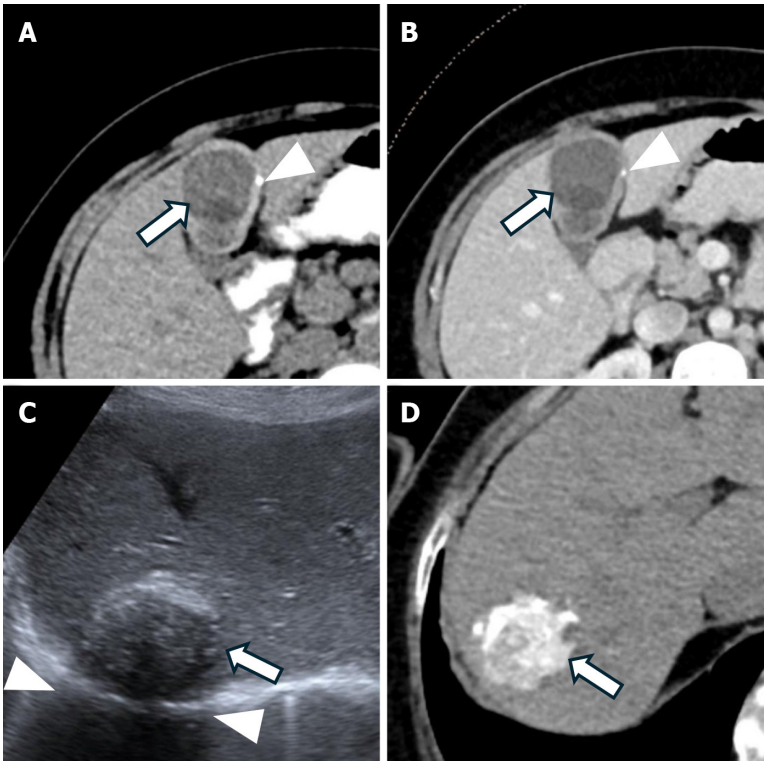

Figure 9 Inactive hydatid cysts. A: Axial non-contrast computed tomography (CT) image shows a heterogeneous hypodense hydatid cyst (arrow) with a partially calcified wall (arrowhead); B: Axial contrast-enhanced CT image shows a heterogeneous hypodense hydatid cyst (arrow) with a partially calcified wall (arrowhead); C: Ultrasound image of another patient demonstrates a heterogeneous calcified hydatid cyst (World Health Organization type CE5, arrow) with acoustic shadowing (arrowheads); D: Axial non-contrast CT image shows a calcified hydatid cyst (arrow).

On US, they are generally seen as single, giant, multilocular lesions with septate and mural calcification. Mural nodules can be seen in some MCNLs. They are rarely unilocular[140]. There is no typical contrast enhancement pattern on CEUS that can reliably differentiate between benign and malignant lesions[141]. Cystic lesions suspected to be MCNL on US should be further evaluated with CT or MRI for a more comprehensive assessment. On CT, MCNLs typically appear as large, well-defined, multilocular cystic lesions with septations (Figure 10). Other imaging features of MCNL on CT include wall irregularities, mural nodules, and mural calcifications. Contrast enhancement can be observed in the wall, septations, or mural nodules of cysts[2,142]. MRI is more effective at demonstrating the contrast enhancement of these components compared to CT. MCNLs appear hyperintense on T2-weighted sequences, while on T1-weighted sequences, they can exhibit different signals depending on their content such as proteinaceous material or blood products (Figure 10). Calcifications are hypointense on all MRI sequences[142]. Magnetic resonance cholangiopancreatography is quite helpful in assessing the relationship between MCNL and the biliary system[143].

While some studies have demonstrated the association of calcifications, mural nodules, and wall enhancement with malignancy, the reliable differentiation between benign and malignant lesions is generally not achievable through imaging alone. Due to limited sensitivity and the possibility of causing dissemination in the presence of malignancy, aspiration or biopsy of cystic masses suspected to be MCNL is not recommended. Instead, complete surgical excision should be performed for diagnosis and treatment[140,144]. Enucleation can be considered due to the presence of a pseudo capsule[145]. Laparoscopic surgery can be preferred because of its lower morbidity and fewer complications[102]. In cases that are not candidates for surgery, cystic lesions with suspected MCNL should be followed with imaging[10].

Cholangiocarcinoma

CCAs are rare tumors that originate from the epithelium of the bile ducts and can be found in any part of the biliary system. CCAs are classified into two groups: Intrahepatic CCA (ICCA) and extrahepatic CCA[146]. In this section, ICCAs, which can manifest as FLL, are addressed. Since ICCAs are often detected in advanced stages and are unresectable, their survival rates are low, and their treatment can be challenging[147]. ICCAs are the second most common primary liver malignancy[146]. Risk factors for CCA include primary sclerosing cholangitis, inflammatory bowel disease, smoking, alcohol consumption, age (> 65 years), liver fluke infestation, Caroli's disease, choledochal cyst, intrahepatic bile duct stones, cirrhosis, and viral hepatitis[148,149]. ICCAs are often detected incidentally. They can present with symptoms such as pain, loss of appetite, and weight loss[150].

In cases of suspected ICCA, FLL should be evaluated with CT or MRI. On contrast-enhanced CT, ICCAs appear hypodense in the non-contrast phase and show peripheral enhancement in the arterial phase (targetoid appearance). Due to intense desmoplastic reaction and fibrous stroma, it exhibits progressive heterogeneous enhancement in the portal venous and delayed phases[151]. On MRI, they can appear as masses that are peripherally hyperintense due to cellularity and centrally hypointense due to fibrosis (Figure 11)[152]. Other imaging features include hepatic capsular retraction,

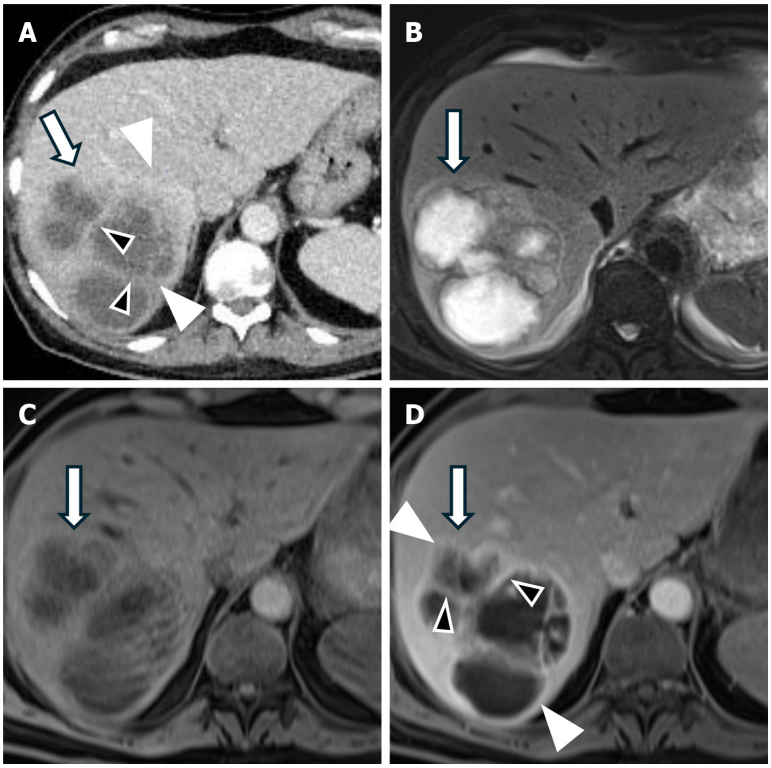

Figure 10 Mucinous cystic neoplasm of the liver. A: Axial contrast-enhanced computed tomography image shows a lobulated lesion (arrow) with an enhancing wall (white arrowheads) and septations (black arrowheads) in the right lobe of the liver; B: Axial T2 weighted MR image shows a T2 hyperintense lobulated lesion (arrow) with an thick wall and septations; C: Axial T1 weighted MR image shows a T1 hypointense lobulated lesion; D: Axial T1 weighted MR image with an extracellular gadolinium-based contrast agent in the portal venous phase shows a T1 hypointense lobulated lesion (arrow) with an enhancing thick wall (white arrowheads) and septations (black arrowheads).

parenchymal atrophy, dilated peripheral intrahepatic bile ducts, vascular encasement, and satellite lesions[149,153]. MRI should be preferred over CT for staging of ICCAs[154]. In patients with ICCA who are considered resectable, PET scanning should be performed to evaluate lymph node metastases that cannot be detected on CT or MRI[155,156].

Because a reliable diagnosis of ICCA cannot often be made with imaging, histopathological diagnosis is often required. If there is no surgical indication, a biopsy should be performed for a definitive diagnosis[151,157]. If there is an indication for surgery in the case of FLL with suspected primary hepatic malignancy, surgery should be performed without biopsy, as a biopsy may not change the treatment strategy and can potentially lead to dissemination[158,159]. Surgery followed by adjuvant chemotherapy is recommended in resectable patients. Surgical options for ICCA include hepatic resection and liver transplantation. For unresectable patients, treatment options include chemotherapy and liver-directed therapies such as RFA, transarterial chemoembolization, and radioembolization. Radiation therapy is not recommended for unresectable liver-limited ICCA cases due to insufficient evidence[159]. Unfortunately, even in experienced centers, ICCAs have low rates of curative resection (10%-49%), resulting in high rates of postoperative recurrence[160,161].

HCC

Primary liver tumors are the sixth most common worldwide and the third leading cause of cancer-related deaths[162]. HCC is the most common primary liver tumor, constituting 75%-86% of cases[163]. HCC has a higher incidence and mortality rate in males[164]. The most important risk factor for HCC is cirrhosis. More than 80% of HCC patients have cirrhosis[165]. Although the rates of HCC due to chronic HBV or HCV infections have decreased, they continue to be the predominant factors for HCC in many countries[166]. However, the incidence of HCC associated with alcohol and NAFLD is increasing[167].

Surveillance for primary HCC has been proven to improve the early detection of HCC. Patients at high risk should be included in surveillance, provided they are candidates for HCC treatment[168]. AASLD recommends HCC surveillance in patients with chronic HBV infection and in those with cirrhosis of any etiology. While surveillance is recommended to increase survival in patients with Child-Turcotte-Pugh A or B cirrhosis, it is not recommended in patients with Child-Turcotte-Pugh C cirrhosis (except for liver transplantation). All patients on the liver transplant waiting list should have HCC surveillance every six months because detecting early-stage HCC can alter their transplantation priority. HCC surveillance should be performed semiannually using both US and AFP. The use of CT and MRI, as well as tumor markers other than AFP, is not recommended. Lesions smaller than 1 cm detected during surveillance should be closely monitored with US every 3-6 months. If the lesion is stable on two or more follow-up US examinations, surveillance is returned to semiannual surveillance. In cases where US is suboptimal, contrast-enhanced CT or MRI may be preferred for HCC surveillance. The presence of a lesion larger than 1 cm on US and rising (doubling on two consecutive tests) or high AFP levels (> 20 ng/mL), even in the absence of a visible lesion, are indications for imaging with contrast-enhanced CT or

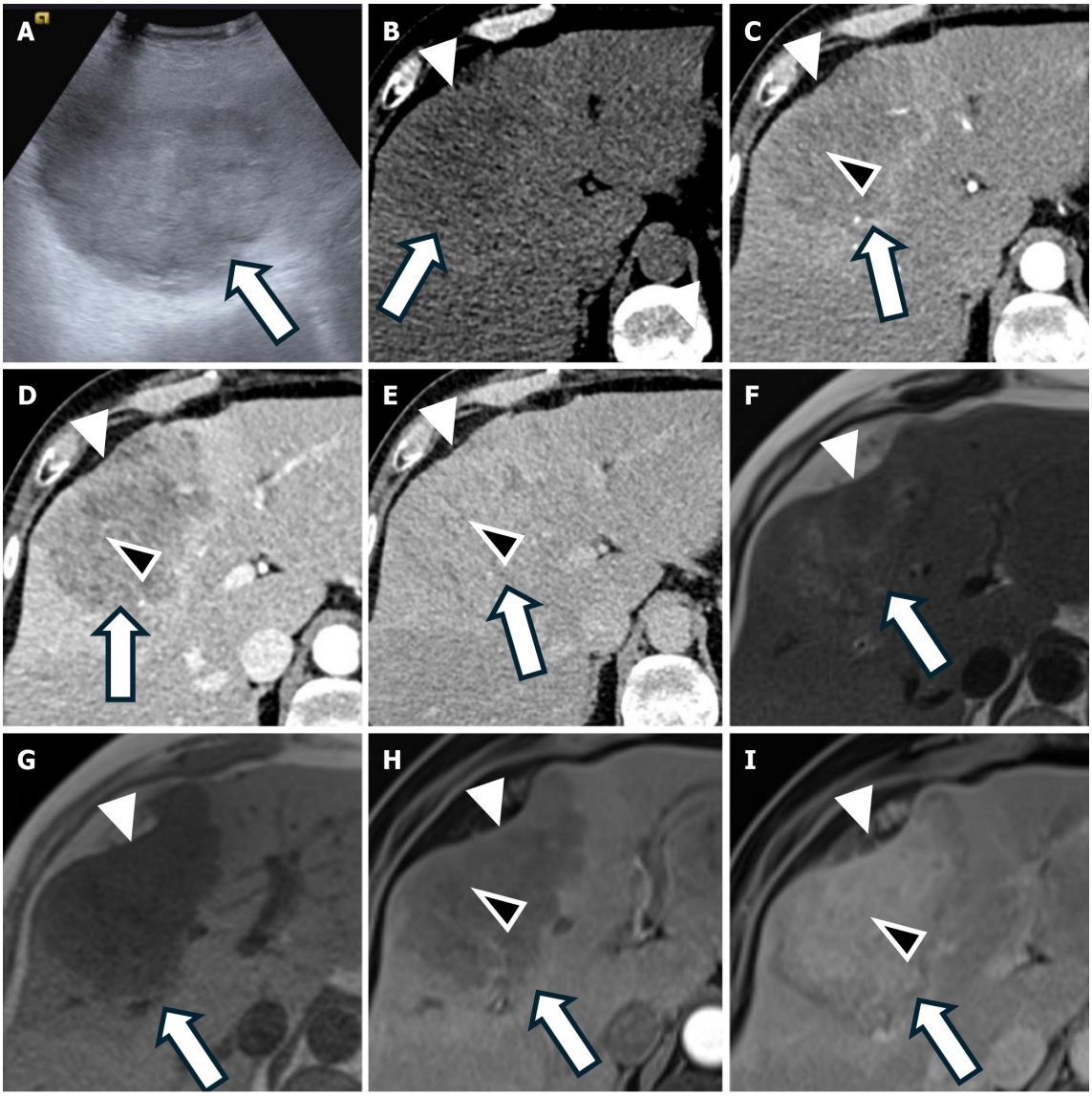

Figure 11 Intrahepatic cholangiocarcinoma. A: Ultrasound shows a heterogeneous slightly hyperechoic lesion (arrow); B: Axial non-contrast computed tomography (CT) image demonstrates an ill-defined hypodense lesion (arrow) that causes capsular retraction (white arrowheads); C: Axial contrast-enhanced CT image in the arterial phase shows peripheral enhancement (targetoid appearance) of the lesion (arrow); D: Axial contrast-enhanced CT image in the portal venous phase shows progressive enhancement (black arrowheads) of the lesion (arrow); E: Axial contrast-enhanced CT image in the delayed phase shows further progressive enhancement (black arrowheads) of the lesion (arrow); F: Axial T2 weighted magnetic resonance imaging (MRI) shows a T2 peripherally hyperintense, centrally hypointense ill-defined, heterogeneous lesion (arrow) with capsular retraction (white arrowheads); G: Axial T1 weighted MRI shows a T1 hypointense ill-defined, heterogeneous lesion (arrow) with capsular retraction (white arrowheads); H: Axial T1 weighted MRI with an extracellular gadolinium-based contrast agent in the portal venous phase shows a T1 hypointense lesion (arrow) with progressive enhancement (black arrowheads); I: Axial T1 weighted MR image in the delayed phase shows a hypointense lesion (arrow) with further progressive enhancement (black arrowheads).

MRI. The recall algorithm for HCC surveillance recommended by AASLD is presented in Figure 12[11].

Although some studies suggest that MRI may be slightly more effective than CT in diagnosing HCC, the available data is limited. Therefore, both modalities can be safely used for the diagnosis of HCC[169-171]. HSCA and extracellular contrast agents are both useful in MRI[11]. HCC is a hypervascular tumor. In lesions larger than 1 cm in size, HCC diagnosis can be established with high sensitivity and specificity using contrast-enhanced CT or MRI when they demonstrate contrast enhancement in the arterial phase and washout in the portal venous or delayed phases (Figures 13 and 14)[172,173].

LI-RADS is a system that guides the management of liver lesions observed in high-risk patients by stratifying the risk of HCC using a uniform lexicon[174]. LI-RADS should only be used in the management of patients with cirrhosis or chronic HBV infection. Lesions are categorized from LR-1 to LR-5 using major and ancillary features. LR-1 represents definitely benign lesions, while LR-5 indicates definite HCC. Nonrim arterial phase hyperenhancement (APHE), size, enhancing capsule, nonperipheral washout, and threshold growth are among the major features of the LI-RADS diagnostic criteria. Threshold growth indicates an increase in size equal to or greater than 5 mm within 6 months or less. In lesions ≥ 2 cm in size, the presence of APHE and one other major feature is sufficient for the diagnosis of HCC. For lesions sized 10-19 mm, the diagnosis of HCC requires APHE and either washout or threshold growth, or APHE and two

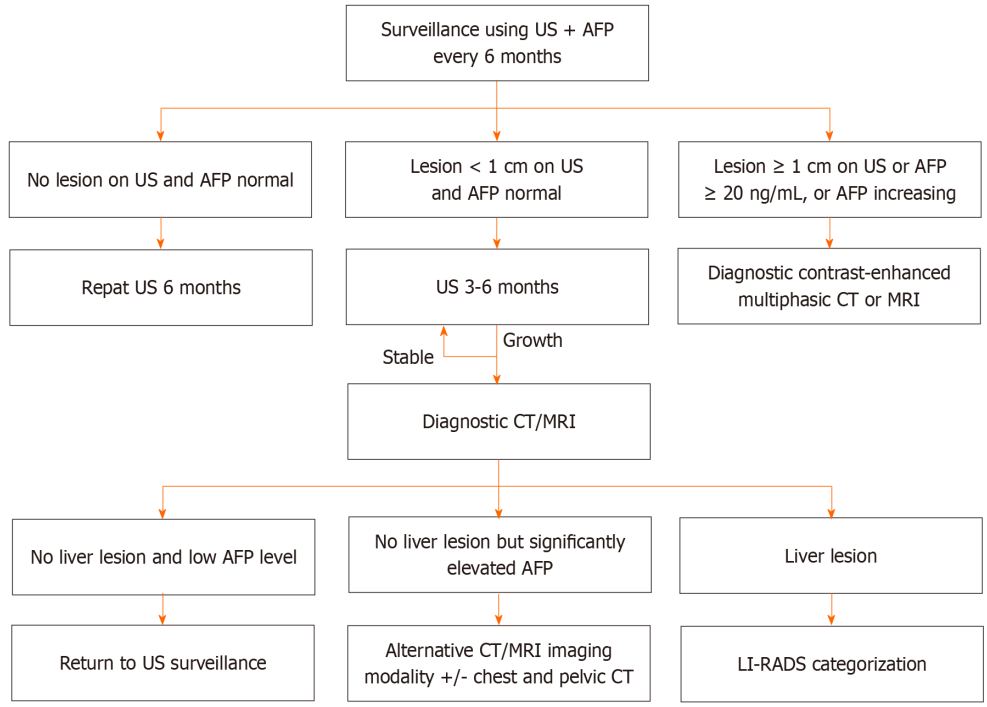

Figure 12 Recall algorithm for hepatocellular carcinoma surveillance recommended by the American Association for the Study of Liver Diseases[12]. AFP: Alpha-fetoprotein; CT: Computed tomography; LI-RADS: Liver Imaging Reporting and Data System; MRI: Magnetic resonance imaging; US: Ultrasound.

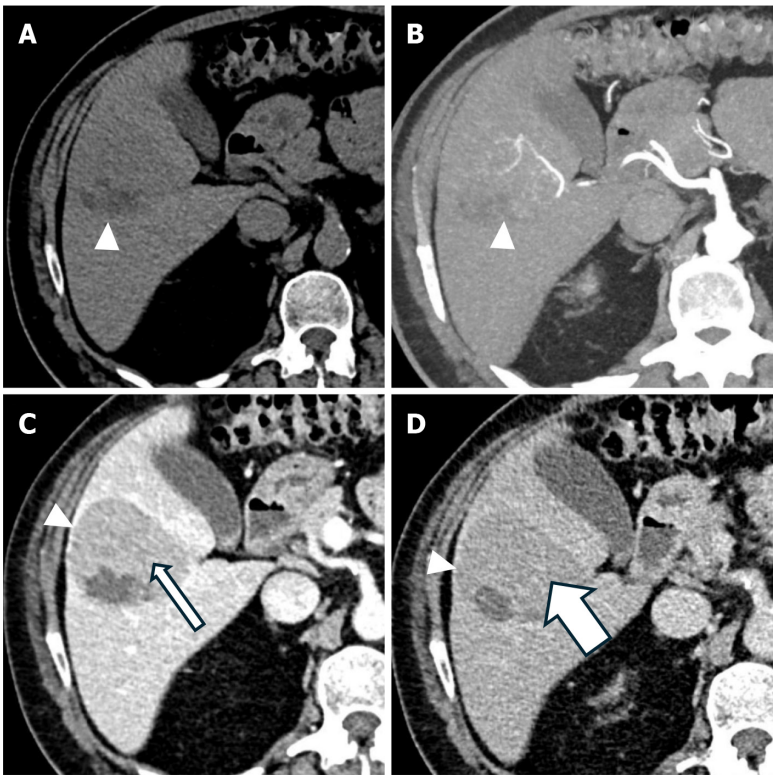

Figure 13 Hepatocellular carcinoma in a 58-year-old man with chronic hepatitis B infection. A: Axial non-contrast computed tomography (CT) image shows the hypodense lesion(arrowhead); B: Axial contrast-enhanced CT image in the arterial phase shows an enhancing lesion (arrowhead); C: Axial contrast-enhanced CT image in the portal venous phase shows the lesion(arrowhead) with a washout (thin arrow); D: Axial contrast-enhanced CT image in the delayed phase shows the lesion(arrowhead) with further washout (thick arrow).

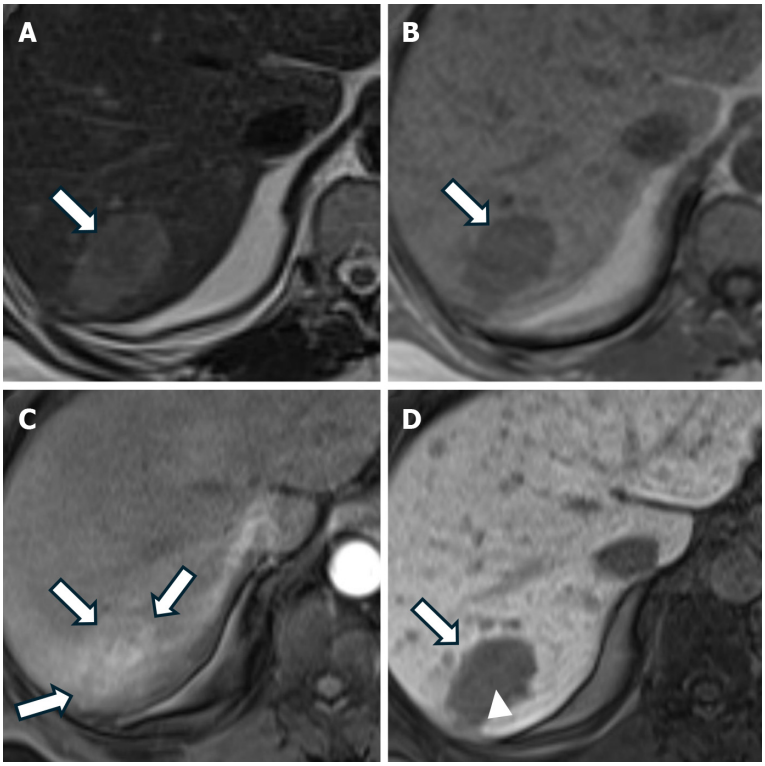

Figure 14 Hepatocellular carcinoma in a 53-year-old man with chronic hepatitis B infection. A: Axial T2 weighted magnetic resonance imaging (MRI) shows a T2 mildly hyperintense lesion (arrow); B: Axial T1 weighted MRI image shows a T1 hypointense lesion (arrow); C: Axial post-contrast T1 weighted MRI with a hepatobiliary-specific contrast agent in the arterial phase shows an enhancing lesion (arrows); D: Axial post-contrast T1 weighted MRI in the hepatobiliary phase shows a lesion(arrow) with a washout (arrowhead).

major features. The categories of lesions can be upgraded or downgraded using ancillary features. It should be noted that a lesion cannot be upgraded to the LR-5 category using ancillary features[4]. CEUS has acceptable specificity for LR-5 lesions, but it is inadequate for treatment planning due to its limitations. When MRI and CT are inconclusive, unavailable, or contraindicated, and tumor biopsy is not feasible, CEUS can be used[11,175].

AASLD advises returning to US-based HCC surveillance every 6 months for patients with LR-1 and LR-2 observations. For patients with an LR-3 observation, AASLD suggests repeat diagnostic imaging in 3 to 6 months. AASLD recommends multidisciplinary counseling for patients with an LR-4 observation to provide tailored optimal management[11]. Even though LI-RADS has largely replaced biopsy in many cases, biopsy may still be required to confirm the diagnosis of suspicious lesions that do not have characteristic features[176]. Atypical HCCs may not be distinguishable from other malignant liver tumors with imaging. Lesions classified as LR-M (definite or probable malignancy, not specific for HCC) should be evaluated with a biopsy when detected during HCC surveillance. The coaxial biopsy technique is recommended as it may reduce the risk of tumor seeding[177].

Patients diagnosed with HCC should be treated by a multidisciplinary team. HCC treatment options include surgery (*e.g.*, hepatic resection, transplantation), locoregional therapies (*e.g.*, RFA, transarterial chemoembolization, radioembolization), and systemic therapies (*e.g.*, chemotherapy). The details of treatment are beyond the scope of this text, and reference can be made to the current AASLD guidelines for further information[11].

Focal hepatic steatosis

Focal hepatic steatosis (FHS), also known as focal hepatosteatosis or focal fatty infiltration, refers to small areas of liver fat accumulation primarily linked to abnormal hepatopetal venous flow, termed the third inflow, including veins of Sappey, pancreaticoduodenal vein, and aberrant right and left gastric veins[178]. This condition shares epidemiological factors with diffuse hepatic steatosis, such as diabetes, obesity, alcohol abuse, and specific medications. Typically found in the medial segment of the left liver lobe near the porta hepatis or falciform ligament, the gallbladder fossa, and the subcapsular region[179].

FHS can be distinguished from other lesions by its characteristic location, lack of mass effect, and the presence of normal vascular structures passing through the lesion. FHS is typically seen as a hyperechoic geographic area on US. Although FHS appears hypodense on CT, MRI can be quite helpful in cases if CT cannot provide a definitive diagnosis. On MRI, it shows signal drop on out-of-phase T1-weighted images (Figure 15)[180].

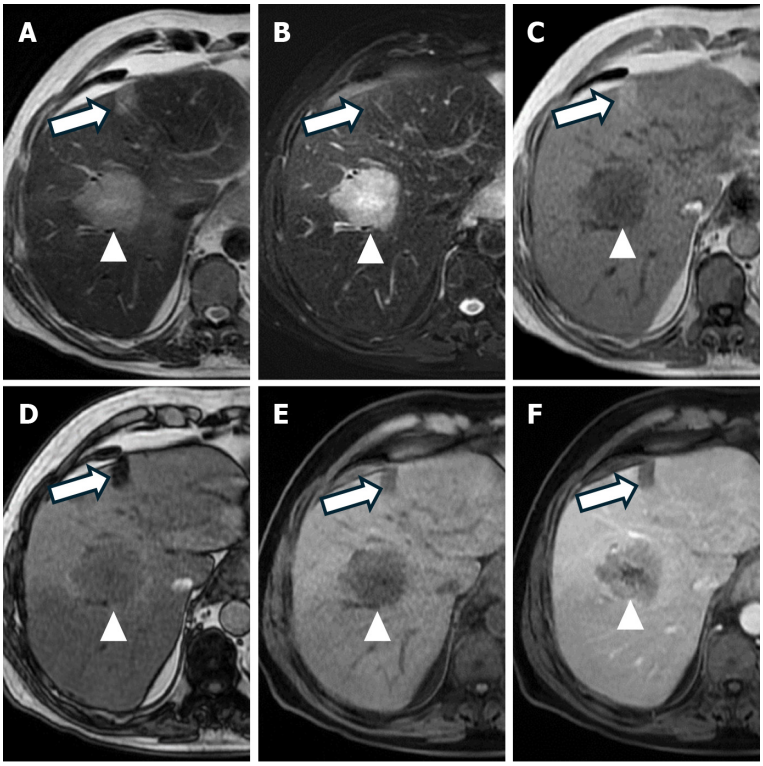

Figure 15 Focal hepatic steatosis. A: Axial T2 weighted magnetic resonance imaging (MRI) shows hyperintensity(arrow) in segment 4A of the liver adjacent to the falciform ligament and a hyperintense mass lesion (arrowhead); B: Axial fat-suppressed T2 weighted MRI shows the same imaging findings (arrow and arrowhead); C: Axial in-phase T1 weighted MRI shows hyperintensity in the same area (arrow) and a hypointense mass lesion(arrowhead); D: Axial out-of-phase T1 weighted image shows signal suppression compared to in-phase (arrow); E: Axial pre-contrast fat-suppressed T1 weighted image shows hypointense lesions (arrow and arrowhead); F: Axial post-contrast fat-suppressed T1 weighted image shows no contrast enhancement in the lesion(arrow) that is consistent with focal hepatic steatosis. The mass lesion in segment 8 (arrowhead) is consistent with metastasis.

CONCLUSION

The increased utilization of imaging modalities has resulted in a notable rise in the detection of FLLs among asymptomatic patients. The characterization and management of FLLs can be challenging. Although most FLLs are benign, the characterization of FLLs is of clinical importance. For instance, HCAs require different management than other benign liver lesions due to the risk of bleeding and malignant transformation. The evaluation of FLLs should always begin with obtaining a comprehensive medical history. Physical examination and blood tests are other crucial components that assist in the diagnosis. ACR Appropriateness Criteria Liver Lesion-Initial Characterization is a guideline, that provides recommendations based on variants involving different scenarios related to what the next imaging study should be when a FLL is detected. US is often the first imaging method for FLL characterization, but its sensitivity and specificity are lower than CT and MRI. Most FLLs can be characterized using contrast-enhanced CT and MRI. Due to recent advancements in imaging technologies, radiological imaging is sufficient for the proper characterization of FLL in many cases. AI has the potential to improve early detection of many types of cancer, increase the accuracy of diagnosis, and reduce the workload. While there is a need for more comprehensive studies on the use of AI in the diagnosis of FLLs, existing researches indicate that AI has the potential to assist physicians in diagnosing FLLs in their daily clinical practice in the future. Common benign FLLs include hepatic cysts, PCLD, hydatid cysts, hemangioma, FNH, and HCA, while malignant FLLs include tumors such as HCC, and ICCA. Management of FLLs is as important as their diagnosis because of their diverse clinical characteristics. For instance, HCAs, due to the risk of malignant transformation in some subtypes, and MCNL, where the benign-malignant differentiation cannot be reliably made through imaging methods, are managed differently from liver lesions such as hemangiomas and FNH that do not require treatment. It has been demonstrated that HCC surveillance increases the survival of patients by enabling the early detection of HCC in individuals with cirrhosis, as well as those with chronic hepatitis B infection. After the lesions detected during surveillance are categorized with LI-RADS, they can be managed according to the recommendations of AASLD. Once a treatment decision is made, FLLs can be treated with treatment methods such as surgery, percutaneous treatment, and drug therapy.

ACKNOWLEDGEMENTS

We would like to express our appreciation to Associate Professor Şebnem Karasu for her valuable support in providing radiological image assistance for this article.

FOOTNOTES

Author contributions: Kahraman G wrote the paper; Haberal KM collected and reported the patients' data and images; Dilek ON revised the article critically for scientific content.

Conflict-of-interest statement: All the authors report no relevant conflicts of interest for this article.

Country/Territory of origin: Türkiye

ORCID number: Gökhan Kahraman 0000-0001-9902-8844; Kemal Murat Haberal 0000-0002-8211-4065; Osman Nuri Dilek 0000-0002-6313-3818.

S-Editor: Li L
L-Editor: A
P-Editor: Che XX

REFERENCES

1 **Völk M**, Strotzer M, Lenhart M, Techert J, Seitz J, Feuerbach S. Frequency of benign hepatic lesions incidentally detected with contrast-enhanced thin-section portal venous phase spiral CT. *Acta Radiol* 2001; **42**: 172-175 [PMID: 11259945 DOI: 10.1080/028418501127346468]
2 **Cogley JR**, Miller FH. MR imaging of benign focal liver lesions. *Radiol Clin North Am* 2014; **52**: 657-682 [PMID: 24889166 DOI: 10.1016/j.rcl.2014.02.005]
3 **Ros PR**, Mortele KJ. Hepatic imaging. An overview. *Clin Liver Dis* 2002; **6**: 1-16 [PMID: 11933584 DOI: 10.1016/S1089-3261(03)00063-1]
4 **Chernyak V**, Fowler KJ, Kamaya A, Kielar AZ, Elsayes KM, Bashir MR, Kono Y, Do RK, Mitchell DG, Singal AG, Tang A, Sirlin CB. Liver Imaging Reporting and Data System (LI-RADS) Version 2018: Imaging of Hepatocellular Carcinoma in At-Risk Patients. *Radiology* 2018; **289**: 816-830 [PMID: 30251931 DOI: 10.1148/radiol.2018181494]
5 **Hope TA**, Petkovska I, Saranathan M, Hargreaves BA, Vasanawala SS. Combined parenchymal and vascular imaging: High spatiotemporal resolution arterial evaluation of hepatocellular carcinoma. *J Magn Reson Imaging* 2016; **43**: 859-865 [PMID: 26340309 DOI: 10.1002/jmri.25042]
6 **Kambadakone AR**, Fung A, Gupta RT, Hope TA, Fowler KJ, Lyshchik A, Ganesan K, Yaghmai V, Guimaraes AR, Sahani DV, Miller FH. LI-RADS technical requirements for CT, MRI, and contrast-enhanced ultrasound. *Abdom Radiol (NY)* 2018; **43**: 56-74 [PMID: 28940042 DOI: 10.1007/s00261-017-1325-y]
7 **Burrowes DP**, Medellin A, Harris AC, Milot L, Lethebe BC, Wilson SR. Characterization of Focal Liver Masses: A Multicenter Comparison of Contrast-Enhanced Ultrasound, Computed Tomography, and Magnetic Resonance Imaging. *J Ultrasound Med* 2021; **40**: 2581-2593 [PMID: 33576003 DOI: 10.1002/jum.15644]
8 **International Consensus Group for Hepatocellular NeoplasiaThe International Consensus Group for Hepatocellular Neoplasia**. Pathologic diagnosis of early hepatocellular carcinoma: a report of the international consensus group for hepatocellular neoplasia. *Hepatology* 2009; **49**: 658-664 [PMID: 19177576 DOI: 10.1002/hep.22709]
9 **Expert Panel on Gastrointestinal Imaging**, Chernyak V, Horowitz JM, Kamel IR, Arif-Tiwari H, Bashir MR, Cash BD, Farrell J, Goldstein A, Grajo JR, Gupta S, Hindman NM, Kamaya A, McNamara MM, Porter KK, Solnes LB, Srivastava PK, Zaheer A, Carucci LR. ACR Appropriateness Criteria® Liver Lesion-Initial Characterization. *J Am Coll Radiol* 2020; **17**: S429-S446 [PMID: 33153555 DOI: 10.1016/j.jacr.2020.09.005]
10 **Marrero JA**, Ahn J, Rajender Reddy K; Americal College of Gastroenterology. ACG clinical guideline: the diagnosis and management of focal liver lesions. *Am J Gastroenterol* 2014; **109**: 1328-47; quiz 1348 [PMID: 25135008 DOI: 10.1038/ajg.2014.213]
11 **Singal AG**, Llovet JM, Yarchoan M, Mehta N, Heimbach JK, Dawson LA, Jou JH, Kulik LM, Agopian VG, Marrero JA, Mendiratta-Lala M, Brown DB, Rilling WS, Goyal L, Wei AC, Taddei TH. AASLD Practice Guidance on prevention, diagnosis, and treatment of hepatocellular carcinoma. *Hepatology* 2023; **78**: 1922-1965 [PMID: 37199193 DOI: 10.1097/HEP.0000000000000466]
12 **Fleischmann D**, Kamaya A. Optimal vascular and parenchymal contrast enhancement: the current state of the art. *Radiol Clin North Am* 2009; **47**: 13-26 [PMID: 19195531 DOI: 10.1016/j.rcl.2008.10.009]
13 **Donato H**, França M, Candelária I, Caseiro-Alves F. Liver MRI: From basic protocol to advanced techniques. *Eur J Radiol* 2017; **93**: 30-39 [PMID: 28668428 DOI: 10.1016/j.ejrad.2017.05.028]
14 **Brancatelli G**, Baron RL, Federle MP, Sparacia G, Pealer K. Focal confluent fibrosis in cirrhotic liver: natural history studied with serial CT. *AJR Am J Roentgenol* 2009; **192**: 1341-1347 [PMID: 19380559 DOI: 10.2214/AJR.07.2782]
15 **Piscaglia F**, Bolondi L; Italian Society for Ultrasound in Medicine and Biology (SIUMB) Study Group on Ultrasound Contrast Agents. The safety of Sonovue in abdominal applications: retrospective analysis of 23188 investigations. *Ultrasound Med Biol* 2006; **32**: 1369-1375 [PMID: 16965977 DOI: 10.1016/j.ultrasmedbio.2006.05.031]
16 **McCollough CH**, Leng S, Yu L, Fletcher JG. Dual- and Multi-Energy CT: Principles, Technical Approaches, and Clinical Applications. *Radiology* 2015; **276**: 637-653 [PMID: 26302388 DOI: 10.1148/radiol.2015142631]
17 **Patel BN**, Rosenberg M, Vernuccio F, Ramirez-Giraldo JC, Nelson R, Farjat A, Marin D. Characterization of Small Incidental Indeterminate Hypoattenuating Hepatic Lesions: Added Value of Single-Phase Contrast-Enhanced Dual-Energy CT Material Attenuation Analysis. *AJR Am J Roentgenol* 2018; **211**: 571-579 [PMID: 30040464 DOI: 10.2214/AJR.17.19170]
18 **Racine D**, Mergen V, Viry A, Eberhard M, Becce F, Rotzinger DC, Alkadhi H, Euler A. Photon-Counting Detector CT With Quantum

Iterative Reconstruction: Impact on Liver Lesion Detection and Radiation Dose Reduction. *Invest Radiol* 2023; **58**: 245-252 [PMID: 36094810 DOI: 10.1097/RLI.0000000000000925]

19 **Calle-Toro JS**, Serai SD, Hartung EA, Goldberg DJ, Bolster BD Jr, Darge K, Anupindi SA. Magnetic resonance elastography SE-EPI vs GRE sequences at 3T in a pediatric population with liver disease. *Abdom Radiol (NY)* 2019; **44**: 894-902 [PMID: 30600386 DOI: 10.1007/s00261-018-1884-6]

20 **Qayyum A**. MR spectroscopy of the liver: principles and clinical applications. *Radiographics* 2009; **29**: 1653-1664 [PMID: 19959513 DOI: 10.1148/rg.296095520]

21 **Lewis S**, Dyvorne H, Cui Y, Taouli B. Diffusion-weighted imaging of the liver: techniques and applications. *Magn Reson Imaging Clin N Am* 2014; **22**: 373-395 [PMID: 25086935 DOI: 10.1016/j.mric.2014.04.009]

22 **Guo W**, Pang Y, Yao L, Zhao L, Fan C, Ke J, Guo P, Hao B, Fu H, Xie C, Lin Q, Wu H, Sun L, Chen H. Imaging fibroblast activation protein in liver cancer: a single-center post hoc retrospective analysis to compare [(68)Ga]Ga-FAPI-04 PET/CT versus MRI and [(18)F]-FDG PET/CT. *Eur J Nucl Med Mol Imaging* 2021; **48**: 1604-1617 [PMID: 33179149 DOI: 10.1007/s00259-020-05095-0]

23 **Durduran T**, Choe R, Baker WB, Yodh AG. Diffuse Optics for Tissue Monitoring and Tomography. *Rep Prog Phys* 2010; **73** [PMID: 26120204 DOI: 10.1088/0034-4885/73/7/076701]

24 **Kobayashi K**, Kawaguchi Y, Kobayashi Y, Matsumura M, Ishizawa T, Akamatsu N, Kaneko J, Arita J, Sakamoto Y, Kokudo N, Hasegawa K. Identification of liver lesions using fluorescence imaging: comparison of methods for administering indocyanine green. *HPB (Oxford)* 2021; **23**: 262-269 [PMID: 32675045 DOI: 10.1016/j.hpb.2020.06.006]

25 **Andreou C**, Neuschmelting V, Tschaharganeh DF, Huang CH, Oseledchyk A, Iacono P, Karabeber H, Colen RR, Mannelli L, Lowe SW, Kircher MF. Imaging of Liver Tumors Using Surface-Enhanced Raman Scattering Nanoparticles. *ACS Nano* 2016; **10**: 5015-5026 [PMID: 27078225 DOI: 10.1021/acsnano.5b07200]

26 **Chen PT**, Wu T, Wang P, Chang D, Liu KL, Wu MS, Roth HR, Lee PC, Liao WC, Wang W. Pancreatic Cancer Detection on CT Scans with Deep Learning: A Nationwide Population-based Study. *Radiology* 2023; **306**: 172-182 [PMID: 36098642 DOI: 10.1148/radiol.220152]

27 **Lång K**, Josefsson V, Larsson AM, Larsson S, Högberg C, Sartor H, Hofvind S, Andersson I, Rosso A. Artificial intelligence-supported screen reading versus standard double reading in the Mammography Screening with Artificial Intelligence trial (MASAI): a clinical safety analysis of a randomised, controlled, non-inferiority, single-blinded, screening accuracy study. *Lancet Oncol* 2023; **24**: 936-944 [PMID: 37541274 DOI: 10.1016/S1470-2045(23)00298-X]

28 **Zhou J**, Wang W, Lei B, Ge W, Huang Y, Zhang L, Yan Y, Zhou D, Ding Y, Wu J. Automatic Detection and Classification of Focal Liver Lesions Based on Deep Convolutional Neural Networks: A Preliminary Study. *Front Oncol* 2020; **10**: 581210 [PMID: 33585197 DOI: 10.3389/fonc.2020.581210]

29 **Zhou LQ**, Wang JY, Yu SY, Wu GG, Wei Q, Deng YB, Wu XL, Cui XW, Dietrich CF. Artificial intelligence in medical imaging of the liver. *World J Gastroenterol* 2019; **25**: 672-682 [PMID: 30783371 DOI: 10.3748/wjg.v25.i6.672]

30 **Jhaveri K**, Cleary S, Audet P, Balaa F, Bhayana D, Burak K, Chang S, Dixon E, Haider M, Molinari M, Reinhold C, Sherman M. Consensus statements from a multidisciplinary expert panel on the utilization and application of a liver-specific MRI contrast agent (gadoxetic acid). *AJR Am J Roentgenol* 2015; **204**: 498-509 [PMID: 25714278 DOI: 10.2214/AJR.13.12399]

31 **Shaked O**, Siegelman ES, Olthoff K, Reddy KR. Biologic and clinical features of benign solid and cystic lesions of the liver. *Clin Gastroenterol Hepatol* 2011; **9**: 547-62.e1 [PMID: 21397723 DOI: 10.1016/j.cgh.2011.03.007]

32 **Gemer O**, Moscovici O, Ben-Horin CL, Linov L, Peled R, Segal S. Oral contraceptives and liver hemangioma: a case-control study. *Acta Obstet Gynecol Scand* 2004; **83**: 1199-1201 [PMID: 15548156 DOI: 10.1111/j.0001-6349.2004.00551.x]

33 **European Association for the Study of the Liver (EASL)**. EASL Clinical Practice Guidelines on the management of benign liver tumours. *J Hepatol* 2016; **65**: 386-398 [PMID: 27085809 DOI: 10.1016/j.jhep.2016.04.001]

34 **Tait N**, Richardson AJ, Muguti G, Little JM. Hepatic cavernous haemangioma: a 10 year review. *Aust N Z J Surg* 1992; **62**: 521-524 [PMID: 1610320 DOI: 10.1111/j.1445-2197.1992.tb07043.x]

35 **Mikami T**, Hirata K, Oikawa I, Kimura M, Kimura H. Hemobilia caused by a giant benign hemangioma of the liver: report of a case. *Surg Today* 1998; **28**: 948-952 [PMID: 9744407 DOI: 10.1007/s005950050259]

36 **Amico A**, Mammino L, Palmucci S, Latino R, Milone P, Li Destri G, Antonio B, Di Cataldo A. Giant hepatic hemangioma case report: When is it time for surgery? *Ann Med Surg (Lond)* 2020; **58**: 4-7 [PMID: 32874569 DOI: 10.1016/j.amsu.2020.08.003]

37 **Kim KW**, Kim TK, Han JK, Kim AY, Lee HJ, Park SH, Kim YH, Choi BI. Hepatic hemangiomas: spectrum of US appearances on gray-scale, power Doppler, and contrast-enhanced US. *Korean J Radiol* 2000; **1**: 191-197 [PMID: 11752954 DOI: 10.3348/kjr.2000.1.4.191]

38 **Perkins AB**, Imam K, Smith WJ, Cronan JJ. Color and power Doppler sonography of liver hemangiomas: a dream unfulfilled? *J Clin Ultrasound* 2000; **28**: 159-165 [PMID: 10751735 DOI: 10.1002/(sici)1097-0096(200005)28:4<159::aid-jcu1>3.0.co;2-b]

39 **Yamashita Y**, Ogata I, Urata J, Takahashi M. Cavernous hemangioma of the liver: pathologic correlation with dynamic CT findings. *Radiology* 1997; **203**: 121-125 [PMID: 9122378 DOI: 10.1148/radiology.203.1.9122378]

40 **Tamada T**, Ito K, Yamamoto A, Sone T, Kanki A, Tanaka F, Higashi H. Hepatic hemangiomas: evaluation of enhancement patterns at dynamic MRI with gadoxetate disodium. *AJR Am J Roentgenol* 2011; **196**: 824-830 [PMID: 21427331 DOI: 10.2214/AJR.10.5113]

41 **Vilgrain V**, Boulos L, Vullierme MP, Denys A, Terris B, Menu Y. Imaging of atypical hemangiomas of the liver with pathologic correlation. *Radiographics* 2000; **20**: 379-397 [PMID: 10715338 DOI: 10.1148/radiographics.20.2.g00mc01379]

42 **Bajenaru N**, Balaban V, Săvulescu F, Campeanu I, Patrascu T. Hepatic hemangioma -review-. *J Med Life* 2015; **8** Spec Issue: 4-11 [PMID: 26361504]

43 **Leon M**, Chavez L, Surani S. Hepatic hemangioma: What internists need to know. *World J Gastroenterol* 2020; **26**: 11-20 [PMID: 31933511 DOI: 10.3748/wjg.v26.i1.11]

44 **Gao J**, Fan RF, Yang JY, Cui Y, Ji JS, Ma KS, Li XL, Zhang L, Xu CL, Kong XL, Ke S, Ding XM, Wang SH, Yang MM, Song JJ, Zhai B, Nin CM, Guo SG, Xin ZH, Lu J, Dong YH, Zhu HQ, Sun WB. Radiofrequency ablation for hepatic hemangiomas: A consensus from a Chinese panel of experts. *World J Gastroenterol* 2017; **23**: 7077-7086 [PMID: 29093616 DOI: 10.3748/wjg.v23.i39.7077]

45 **Furumaya A**, van Rosmalen BV, Takkenberg RB, van Delden OM, Dejong CHC, Verheij J, van Gulik TM. Transarterial (Chemo-)Embolization and Lipiodolization for Hepatic Haemangioma. *Cardiovasc Intervent Radiol* 2019; **42**: 800-811 [PMID: 30783780 DOI: 10.1007/s00270-019-02169-x]

46 **Macdonald A**, Durkin N, Deganello A, Sellars ME, Makin E, Davenport M. Historical and Contemporary Management of Infantile Hepatic Hemangioma: A 30-year Single-center Experience. *Ann Surg* 2022; **275**: e250-e255 [PMID: 33064395 DOI: 10.1097/SLA.0000000000003881]

47 **Wanless IR**, Mawdsley C, Adams R. On the pathogenesis of focal nodular hyperplasia of the liver. *Hepatology* 1985; **5**: 1194-1200 [PMID: 4065824 DOI: 10.1002/hep.1840050622]

48 **Nguyen BN**, Fléjou JF, Terris B, Belghiti J, Degott C. Focal nodular hyperplasia of the liver: a comprehensive pathologic study of 305 lesions and recognition of new histologic forms. *Am J Surg Pathol* 1999; **23**: 1441-1454 [PMID: 10584697 DOI: 10.1097/00000478-199912000-00001]

49 **Vidili G**, Piscaglia F, Ainora ME, Solinas G, Sagrini E, Gianstefani A, Cintoni M, Gasbarrini A, Zocco MA. Focal nodular hyperplasia: new findings at Doppler ultrasonography. *Eur Rev Med Pharmacol Sci* 2020; **24**: 12288-12295 [PMID: 33336747 DOI: 10.26355/eurrev_202012_24020]

50 **Lin MC**, Tsay PK, Ko SF, Lui KW, Tseng JH, Hung CF, Hsueh C, Wan YL. Triphasic dynamic CT findings of 63 hepatic focal nodular hyperplasia in 46 patients: correlation with size and pathological findings. *Abdom Imaging* 2008; **33**: 301-307 [PMID: 17632749 DOI: 10.1007/s00261-007-9258-5]

51 **Mortelé KJ**, Praet M, Van Vlierberghe H, de Hemptinne B, Zou K, Ros PR. Focal nodular hyperplasia of the liver: detection and characterization with plain and dynamic-enhanced MRI. *Abdom Imaging* 2002; **27**: 700-707 [PMID: 12395259 DOI: 10.1007/s00261-001-0140-6]

52 **Venturi A**, Piscaglia F, Vidili G, Flori S, Righini R, Golfieri R, Bolondi L. Diagnosis and management of hepatic focal nodular hyperplasia. *J Ultrasound* 2007; **10**: 116-127 [PMID: 23396642 DOI: 10.1016/j.jus.2007.06.001]

53 **Grazioli L**, Morana G, Kirchin MA, Schneider G. Accurate differentiation of focal nodular hyperplasia from hepatic adenoma at gadobenate dimeglumine-enhanced MR imaging: prospective study. *Radiology* 2005; **236**: 166-177 [PMID: 15955857 DOI: 10.1148/radiol.2361040338]

54 **Huppertz A**, Haraida S, Kraus A, Zech CJ, Scheidler J, Breuer J, Helmberger TK, Reiser MF. Enhancement of focal liver lesions at gadoxetic acid-enhanced MR imaging: correlation with histopathologic findings and spiral CT--initial observations. *Radiology* 2005; **234**: 468-478 [PMID: 15591431 DOI: 10.1148/radiol.2342040278]

55 **Trillaud H**, Bruel JM, Valette PJ, Vilgrain V, Schmutz G, Oyen R, Jakubowski W, Danes J, Valek V, Greis C. Characterization of focal liver lesions with SonoVue-enhanced sonography: international multicenter-study in comparison to CT and MRI. *World J Gastroenterol* 2009; **15**: 3748-3756 [PMID: 19673015 DOI: 10.3748/wjg.15.3748]

56 **Quaia E**. The real capabilities of contrast-enhanced ultrasound in the characterization of solid focal liver lesions. *Eur Radiol* 2011; **21**: 457-462 [PMID: 21107578 DOI: 10.1007/s00330-010-2007-0]

57 **Bioulac-Sage P**, Cubel G, Taouji S, Scoazec JY, Leteurtre E, Paradis V, Sturm N, Nhieu JT, Wendum D, Bancel B, Ramos J, Paraf F, Saint Paul MC, Michalak S, Fabre M, Guettier C, Le Bail B, Zucman-Rossi J, Balabaud C. Immunohistochemical markers on needle biopsies are helpful for the diagnosis of focal nodular hyperplasia and hepatocellular adenoma subtypes. *Am J Surg Pathol* 2012; **36**: 1691-1699 [PMID: 23060349 DOI: 10.1097/PAS.0b013e3182653ece]

58 **Fodor M**, Primavesi F, Braunwarth E, Cardini B, Resch T, Bale R, Putzer D, Henninger B, Oberhuber R, Maglione M, Margreiter C, Schneeberger S, Öfner D, Stättner S. Indications for liver surgery in benign tumours. *Eur Surg* 2018; **50**: 125-131 [PMID: 29875801 DOI: 10.1007/s10353-018-0536-y]

59 **Margonis GA**, Ejaz A, Spolverato G, Rastegar N, Anders R, Kamel IR, Pawlik TM. Benign solid tumors of the liver: management in the modern era. *J Gastrointest Surg* 2015; **19**: 1157-1168 [PMID: 25560181 DOI: 10.1007/s11605-014-2723-x]

60 **Yan JY**, Duan F, Fu JX, Wang Y, Zhang JL, Guan Y, Yuan B, Yuan K, Zhang H, Meng LM, Wang MQ. Outcomes of transarterial embolization for large symptomatic focal nodular hyperplasia in 17 pediatric patients. *Dig Liver Dis* 2023; **55**: 899-906 [PMID: 36669995 DOI: 10.1016/j.dld.2022.12.025]

61 **Yu X**, Chang J, Zhang D, Lu Q, Wu S, Li K. Ultrasound-Guided Percutaneous Thermal Ablation of Hepatic Focal Nodular Hyperplasia--A Multicenter Retrospective Study. *Front Bioeng Biotechnol* 2021; **9**: 826926 [PMID: 35071222 DOI: 10.3389/fbioe.2021.826926]

62 **Nault JC**, Couchy G, Balabaud C, Morcrette G, Caruso S, Blanc JF, Bacq Y, Calderaro J, Paradis V, Ramos J, Scoazec JY, Gnemmi V, Sturm N, Guettier C, Fabre M, Savier E, Chiche L, Labrune P, Selves J, Wendum D, Pilati C, Laurent A, De Muret A, Le Bail B, Rebouissou S, Imbeaud S; GENTHEP Investigators, Bioulac-Sage P, Letouzé E, Zucman-Rossi J. Molecular Classification of Hepatocellular Adenoma Associates With Risk Factors, Bleeding, and Malignant Transformation. *Gastroenterology* 2017; **152**: 880-894.e6 [PMID: 27939373 DOI: 10.1053/j.gastro.2016.11.042]

63 **Rooks JB**, Ory HW, Ishak KG, Strauss LT, Greenspan JR, Hill AP, Tyler CW Jr. Epidemiology of hepatocellular adenoma. The role of oral contraceptive use. *JAMA* 1979; **242**: 644-648 [PMID: 221698 DOI: 10.1001/jama.1979.03300070040020]

64 **Hernandez-Nieto L**, Bruguera M, Bombi J, Camacho L, Rozman C. Benign liver-cell adenoma associated with long-term administration of an androgenic-anabolic steroid (methandienone). *Cancer* 1977; **40**: 1761-1764 [PMID: 198105 DOI: 10.1002/1097-0142(197710)40:4<1761::AID-CNCR2820400454>3.0.CO;2-C]

65 **Socas L**, Zumbado M, Pérez-Luzardo O, Ramos A, Pérez C, Hernández JR, Boada LD. Hepatocellular adenomas associated with anabolic androgenic steroid abuse in bodybuilders: a report of two cases and a review of the literature. *Br J Sports Med* 2005; **39**: e27 [PMID: 15849280 DOI: 10.1136/bjsm.2004.013599]

66 **Triantafyllopoulou M**, Whitington PF, Melin-Aldana H, Benya EC, Brickman W. Hepatic adenoma in an adolescent with elevated androgen levels. *J Pediatr Gastroenterol Nutr* 2007; **44**: 640-642 [PMID: 17460501 DOI: 10.1097/MPG.0b013e31802e9a4a]

67 **Labrune P**, Trioche P, Duvaltier I, Chevalier P, Odièvre M. Hepatocellular adenomas in glycogen storage disease type I and III: a series of 43 patients and review of the literature. *J Pediatr Gastroenterol Nutr* 1997; **24**: 276-279 [PMID: 9138172 DOI: 10.1002/j.1536-4801.1997.tb00424.x]

68 **Bioulac-Sage P**, Taouji S, Possenti L, Balabaud C. Hepatocellular adenoma subtypes: the impact of overweight and obesity. *Liver Int* 2012; **32**: 1217-1221 [PMID: 22429502 DOI: 10.1111/j.1478-3231.2012.02786.x]

69 **Haring MPD**, Peeks F, Oosterveer MH, Brouwers MCGJ, Hollak CEM, Janssen MCH, Langendonk JG, Rennings AJM, Wagenmakers MAEM, Verkade HJ, Derks TGJ, de Meijer VE. High childhood serum triglyceride concentrations associate with hepatocellular adenoma development in patients with glycogen storage disease type Ia. *JHEP Rep* 2022; **4**: 100512 [PMID: 35811762 DOI: 10.1016/j.jhepr.2022.100512]

70 **Giovanoli O**, Heim M, Terracciano L, Bongartz G, Ledermann HP. MRI of hepatic adenomatosis: initial observations with gadoxetic acid contrast agent in three patients. *AJR Am J Roentgenol* 2008; **190**: W290-W293 [PMID: 18430814 DOI: 10.2214/AJR.07.3198]

71 **Tse JR**, Felker ER, Naini BV, Shen L, Shen J, Lu DSK, Kamaya A, Raman SS. Hepatocellular Adenomas: Molecular Basis and Multimodality Imaging Update. *Radiographics* 2023; **43**: e220134 [PMID: 36821508 DOI: 10.1148/rg.220134]

72 **Bröker MEE**, Taimr P, de Vries M, Braun LMM, de Man RA, Ijzermans JNM, Dwarkasing RS. Performance of Contrast-Enhanced

Sonography Versus MRI With a Liver-Specific Contrast Agent for Diagnosis of Hepatocellular Adenoma and Focal Nodular Hyperplasia. *AJR Am J Roentgenol* 2020; **214**: 81-89 [PMID: 31573852 DOI: 10.2214/AJR.19.21251]

73 **Grazioli L**, Federle MP, Brancatelli G, Ichikawa T, Olivetti L, Blachar A. Hepatic adenomas: imaging and pathologic findings. *Radiographics* 2001; **21**: 877-92; discussion 892 [PMID: 11452062 DOI: 10.1148/radiographics.21.4.g01jl04877]

74 **Faria SC**, Iyer RB, Rashid A, Whitman GJ. Hepatic adenoma. *AJR Am J Roentgenol* 2004; **182**: 1520 [PMID: 15149999 DOI: 10.2214/ajr.182.6.1821520]

75 **Laumonier H**, Bioulac-Sage P, Laurent C, Zucman-Rossi J, Balabaud C, Trillaud H. Hepatocellular adenomas: magnetic resonance imaging features as a function of molecular pathological classification. *Hepatology* 2008; **48**: 808-818 [PMID: 18688875 DOI: 10.1002/hep.22417]

76 **van Aalten SM**, Thomeer MG, Terkivatan T, Dwarkasing RS, Verheij J, de Man RA, Ijzermans JN. Hepatocellular adenomas: correlation of MR imaging findings with pathologic subtype classification. *Radiology* 2011; **261**: 172-181 [PMID: 21875850 DOI: 10.1148/radiol.11110023]

77 **Dokmak S**, Paradis V, Vilgrain V, Sauvanet A, Farges O, Valla D, Bedossa P, Belghiti J. A single-center surgical experience of 122 patients with single and multiple hepatocellular adenomas. *Gastroenterology* 2009; **137**: 1698-1705 [PMID: 19664629 DOI: 10.1053/j.gastro.2009.07.061]

78 **Dharmana H**, Saravana-Bawan S, Girgis S, Low G. Hepatocellular adenoma: imaging review of the various molecular subtypes. *Clin Radiol* 2017; **72**: 276-285 [PMID: 28126185 DOI: 10.1016/j.crad.2016.12.020]

79 **Reizine E**, Ronot M, Ghosn M, Calderaro J, Frulio N, Bioulac-Sage P, Trillaud H, Vilgrain V, Paradis V, Luciani A. Hepatospecific MR contrast agent uptake on hepatobiliary phase can be used as a biomarker of marked β-catenin activation in hepatocellular adenoma. *Eur Radiol* 2021; **31**: 3417-3426 [PMID: 33146794 DOI: 10.1007/s00330-020-07434-z]

80 **Vernuccio F**, Ronot M, Dioguardi Burgio M, Cauchy F, Choudhury KR, Dokmak S, Soubrane O, Valla D, Zucman-Rossi J, Paradis V, Vilgrain V. Long-term Evolution of Hepatocellular Adenomas at MRI Follow-up. *Radiology* 2020; **295**: 361-372 [PMID: 32181728 DOI: 10.1148/radiol.2020191790]

81 **van der Windt DJ**, Kok NF, Hussain SM, Zondervan PE, Alwayn IP, de Man RA, IJzermans JN. Case-orientated approach to the management of hepatocellular adenoma. *Br J Surg* 2006; **93**: 1495-1502 [PMID: 17051603 DOI: 10.1002/bjs.5511]

82 **Gordon SC**, Reddy KR, Livingstone AS, Jeffers LJ, Schiff ER. Resolution of a contraceptive-steroid-induced hepatic adenoma with subsequent evolution into hepatocellular carcinoma. *Ann Intern Med* 1986; **105**: 547-549 [PMID: 3019201 DOI: 10.7326/0003-4819-105-4-547]

83 **Leese T**, Farges O, Bismuth H. Liver cell adenomas. A 12-year surgical experience from a specialist hepato-biliary unit. *Ann Surg* 1988; **208**: 558-564 [PMID: 3190282 DOI: 10.1097/00000658-198811000-00003]

84 **Cho SW**, Marsh JW, Steel J, Holloway SE, Heckman JT, Ochoa ER, Geller DA, Gamblin TC. Surgical management of hepatocellular adenoma: take it or leave it? *Ann Surg Oncol* 2008; **15**: 2795-2803 [PMID: 18696154 DOI: 10.1245/s10434-008-0090-0]

85 **Nault JC**, Paradis V, Ronot M, Zucman-Rossi J. Benign liver tumours: understanding molecular physiology to adapt clinical management. *Nat Rev Gastroenterol Hepatol* 2022; **19**: 703-716 [PMID: 35835851 DOI: 10.1038/s41575-022-00643-5]

86 **van Aalten SM**, de Man RA, IJzermans JN, Terkivatan T. Systematic review of haemorrhage and rupture of hepatocellular adenomas. *Br J Surg* 2012; **99**: 911-916 [PMID: 22619025 DOI: 10.1002/bjs.8762]

87 **Goonawardena J**, Ratnayake C, Cheung KT, Fox A. Should bariatric surgery be offered for hepatocellular adenomas in obese patients? *Surg Obes Relat Dis* 2020; **16**: 2117-2124 [PMID: 32771427 DOI: 10.1016/j.soard.2020.06.043]

88 **van Rosmalen BV**, Coelen RJS, Bieze M, van Delden OM, Verheij J, Dejong CHC, van Gulik TM. Systematic review of transarterial embolization for hepatocellular adenomas. *Br J Surg* 2017; **104**: 823-835 [PMID: 28518415 DOI: 10.1002/bjs.10547]

89 **van Vledder MG**, van Aalten SM, Terkivatan T, de Man RA, Leertouwer T, Ijzermans JN. Safety and efficacy of radiofrequency ablation for hepatocellular adenoma. *J Vasc Interv Radiol* 2011; **22**: 787-793 [PMID: 21616431 DOI: 10.1016/j.jvir.2011.02.024]

90 **Maoz D**, Sharon E, Chen Y, Grief F. Spontaneous hepatic rupture: 13-year experience of a single center. *Eur J Gastroenterol Hepatol* 2010; **22**: 997-1000 [PMID: 20555270 DOI: 10.1097/MEG.0b013e3283293d27]

91 **Mueller J**, Keeffe EB, Esquivel CO. Liver transplantation for treatment of giant hepatocellular adenomas. *Liver Transpl Surg* 1995; **1**: 99-102 [PMID: 9346548 DOI: 10.1002/lt.500010205]

92 **Charlesworth P**, Ade-Ajayi N, Davenport M. Natural history and long-term follow-up of antenatally detected liver cysts. *J Pediatr Surg* 2007; **42**: 494-499 [PMID: 17336186 DOI: 10.1016/j.jpedsurg.2006.10.041]

93 **Salemis NS**, Georgoulis E, Gourgiotis S, Tsohataridis E. Spontaneous rupture of a giant non parasitic hepatic cyst presenting as an acute surgical abdomen. *Ann Hepatol* 2007; **6**: 190-193 [PMID: 17786149 DOI: 10.1016/S1665-2681(19)31929-5]

94 **Hanazaki K**, Wakabayashi M, Mori H, Sodeyama H, Yoshizawa K, Yokoyama S, Sode Y, Kawamura N, Miyazaki T. Hemorrhage into a simple liver cyst: diagnostic implications of a recent case. *J Gastroenterol* 1997; **32**: 848-851 [PMID: 9430029 DOI: 10.1007/BF02936967]

95 **Spiegel RM**, King DL, Green WM. Ultrasonography of primary cysts of the liver. *AJR Am J Roentgenol* 1978; **131**: 235-238 [PMID: 98001 DOI: 10.2214/ajr.131.2.235]

96 **Vachha B**, Sun MR, Siewert B, Eisenberg RL. Cystic lesions of the liver. *AJR Am J Roentgenol* 2011; **196**: W355-W366 [PMID: 21427297 DOI: 10.2214/AJR.10.5292]

97 **Albiin N**. MRI of Focal Liver Lesions. *Curr Med Imaging Rev* 2012; **8**: 107-116 [PMID: 23049491 DOI: 10.2174/157340512800672216]

98 **Taylor BR**, Langer B. Current surgical management of hepatic cyst disease. *Adv Surg* 1997; **31**: 127-148 [PMID: 9408491]

99 **Saini S**, Mueller PR, Ferrucci JT Jr, Simeone JF, Wittenberg J, Butch RJ. Percutaneous aspiration of hepatic cysts does not provide definitive therapy. *AJR Am J Roentgenol* 1983; **141**: 559-560 [PMID: 6603770 DOI: 10.2214/ajr.141.3.559]

100 **Fong ZV**, Wolf AM, Doria C, Berger AC, Rosato EL, Palazzo F. Hemorrhagic hepatic cyst: report of a case and review of the literature with emphasis on clinical approach and management. *J Gastrointest Surg* 2012; **16**: 1782-1789 [PMID: 22688416 DOI: 10.1007/s11605-012-1922-6]

101 **Gall TM**, Oniscu GC, Madhavan K, Parks RW, Garden OJ. Surgical management and longterm follow-up of non-parasitic hepatic cysts. *HPB (Oxford)* 2009; **11**: 235-241 [PMID: 19590653 DOI: 10.1111/j.1477-2574.2009.00042.x]

102 **Gamblin TC**, Holloway SE, Heckman JT, Geller DA. Laparoscopic resection of benign hepatic cysts: a new standard. *J Am Coll Surg* 2008; **207**: 731-736 [PMID: 18954786 DOI: 10.1016/j.jamcollsurg.2008.07.009]

103 **Furumaya A**, van Rosmalen BV, de Graeff JJ, Haring MPD, de Meijer VE, van Gulik TM, Verheij J, Besselink MG, van Delden OM, Erdmann JI; Dutch Benign Liver Tumor Group. Systematic review on percutaneous aspiration and sclerotherapy versus surgery in symptomatic simple hepatic cysts. *HPB (Oxford)* 2021; **23**: 11-24 [PMID: 32830070 DOI: 10.1016/j.hpb.2020.07.005]

104 **Drenth JP**, Chrispijn M, Nagorney DM, Kamath PS, Torres VE. Medical and surgical treatment options for polycystic liver disease. *Hepatology* 2010; **52**: 2223-2230 [PMID: 21105111 DOI: 10.1002/hep.24036]

105 **Chandok N**. Polycystic liver disease: a clinical review. *Ann Hepatol* 2012; **11**: 819-826 [PMID: 23109444 DOI: 10.1016/S1665-2681(19)31406-1]

106 **Pirson Y**. Extrarenal manifestations of autosomal dominant polycystic kidney disease. *Adv Chronic Kidney Dis* 2010; **17**: 173-180 [PMID: 20219620 DOI: 10.1053/j.ackd.2010.01.003]

107 **Qian Q**. Isolated polycystic liver disease. *Adv Chronic Kidney Dis* 2010; **17**: 181-189 [PMID: 20219621 DOI: 10.1053/j.ackd.2009.12.005]

108 **Sallée M**, Rafat C, Zahar JR, Paulmier B, Grünfeld JP, Knebelmann B, Fakhouri F. Cyst infections in patients with autosomal dominant polycystic kidney disease. *Clin J Am Soc Nephrol* 2009; **4**: 1183-1189 [PMID: 19470662 DOI: 10.2215/CJN.01870309]

109 **Hoevenaren IA**, Wester R, Schrier RW, McFann K, Doctor RB, Drenth JP, Everson GT. Polycystic liver: clinical characteristics of patients with isolated polycystic liver disease compared with patients with polycystic liver and autosomal dominant polycystic kidney disease. *Liver Int* 2008; **28**: 264-270 [PMID: 17927714 DOI: 10.1111/j.1478-3231.2007.01595.x]

110 **Drenth JP**, Chrispijn M, Bergmann C. Congenital fibrocystic liver diseases. *Best Pract Res Clin Gastroenterol* 2010; **24**: 573-584 [PMID: 20955960 DOI: 10.1016/j.bpg.2010.08.007]

111 **Borhani AA**, Wiant A, Heller MT. Cystic hepatic lesions: a review and an algorithmic approach. *AJR Am J Roentgenol* 2014; **203**: 1192-1204 [PMID: 25415696 DOI: 10.2214/AJR.13.12386]

112 **Chrispijn M**, Nevens F, Gevers TJ, Vanslembrouck R, van Oijen MG, Coudyzer W, Hoffmann AL, Dekker HM, de Man RA, van Keimpema L, Drenth JP. The long-term outcome of patients with polycystic liver disease treated with lanreotide. *Aliment Pharmacol Ther* 2012; **35**: 266-274 [PMID: 22111942 DOI: 10.1111/j.1365-2036.2011.04923.x]

113 **Serra AL**, Poster D, Kistler AD, Krauer F, Raina S, Young J, Rentsch KM, Spanaus KS, Senn O, Kristanto P, Scheffel H, Weishaupt D, Wüthrich RP. Sirolimus and kidney growth in autosomal dominant polycystic kidney disease. *N Engl J Med* 2010; **363**: 820-829 [PMID: 20581391 DOI: 10.1056/NEJMoa0907419]

114 **Schnelldorfer T**, Torres VE, Zakaria S, Rosen CB, Nagorney DM. Polycystic liver disease: a critical appraisal of hepatic resection, cyst fenestration, and liver transplantation. *Ann Surg* 2009; **250**: 112-118 [PMID: 19561475 DOI: 10.1097/SLA.0b013e3181ad83dc]

115 **Brunetti E**, Kern P, Vuitton DA; Writing Panel for the WHO-IWGE. Expert consensus for the diagnosis and treatment of cystic and alveolar echinococcosis in humans. *Acta Trop* 2010; **114**: 1-16 [PMID: 19931502 DOI: 10.1016/j.actatropica.2009.11.001]

116 **Akhan O**, Ozmen MN. Percutaneous treatment of liver hydatid cysts. *Eur J Radiol* 1999; **32**: 76-85 [PMID: 10580324 DOI: 10.1016/S0720-048X(99)00116-3]

117 **Touma D**, Sersté T, Ntounda R, Mulkay JP, Buset M, Van Laethem Y. The liver involvement of the hydatid disease: a systematic review designed for the hepato-gastroenterologist. *Acta Gastroenterol Belg* 2013; **76**: 210-218 [PMID: 23898558]

118 **Ergüney S**, Tortum O, Taspinar AH, Ertem M, Gazioğlu E. [Complicated hydatid cysts of the liver]. *Ann Chir* 1991; **45**: 584-589 [PMID: 1755624]

119 **Majbar MA**, Souadka A, Sabbah F, Raiss M, Hrora A, Ahallat M. Peritoneal echinococcosis: anatomoclinical features and surgical treatment. *World J Surg* 2012; **36**: 1030-1035 [PMID: 22350483 DOI: 10.1007/s00268-012-1475-6]

120 **WHO Informal Working Group**. International classification of ultrasound images in cystic echinococcosis for application in clinical and field epidemiological settings. *Acta Trop* 2003; **85**: 253-261 [PMID: 12606104 DOI: 10.1016/S0001-706X(02)00223-1]

121 **Gharbi HA**, Hassine W, Brauner MW, Dupuch K. Ultrasound examination of the hydatic liver. *Radiology* 1981; **139**: 459-463 [PMID: 7220891 DOI: 10.1148/radiology.139.2.7220891]

122 **Zalaquett E**, Menias C, Garrido F, Vargas M, Olivares JF, Campos D, Pinochet N, Luna A, Dahiya N, Huete Á. Imaging of Hydatid Disease with a Focus on Extrahepatic Involvement. *Radiographics* 2017; **37**: 901-923 [PMID: 28493801 DOI: 10.1148/rg.2017160172]

123 **von Sinner WN**. New diagnostic signs in hydatid disease; radiography, ultrasound, CT and MRI correlated to pathology. *Eur J Radiol* 1991; **12**: 150-159 [PMID: 2037004 DOI: 10.1016/0720-048X(91)90119-G]

124 **Pedrosa I**, Saíz A, Arrazola J, Ferreirós J, Pedrosa CS. Hydatid disease: radiologic and pathologic features and complications. *Radiographics* 2000; **20**: 795-817 [PMID: 10835129 DOI: 10.1148/radiographics.20.3.g00ma06795]

125 **Little AF**, Lee WK, Mathison K. MR cholangiography in the evaluation of suspected intrabiliary rupture of hepatic hydatid cyst. *Abdom Imaging* 2002; **27**: 333-335 [PMID: 12173366 DOI: 10.1007/s00261-001-0073-0]

126 **Franchi C**, Di Vico B, Teggi A. Long-term evaluation of patients with hydatidosis treated with benzimidazole carbamates. *Clin Infect Dis* 1999; **29**: 304-309 [PMID: 10476732 DOI: 10.1086/520205]

127 **Yagci G**, Ustunsoz B, Kaymakcioglu N, Bozlar U, Gorgulu S, Simsek A, Akdeniz A, Cetiner S, Tufan T. Results of surgical, laparoscopic, and percutaneous treatment for hydatid disease of the liver: 10 years experience with 355 patients. *World J Surg* 2005; **29**: 1670-1679 [PMID: 16311852 DOI: 10.1007/s00268-005-0058-1]

128 **Khuroo MS**, Wani NA, Javid G, Khan BA, Yattoo GN, Shah AH, Jeelani SG. Percutaneous drainage compared with surgery for hepatic hydatid cysts. *N Engl J Med* 1997; **337**: 881-887 [PMID: 9302302 DOI: 10.1056/NEJM199709253371303]

129 **Haddad MC**, Sammak BM, Al-Karawi M. Percutaneous treatment of heterogenous predominantly solid echopattern echinococcal cysts of the liver. *Cardiovasc Intervent Radiol* 2000; **23**: 121-125 [PMID: 10795836 DOI: 10.1007/s002709910024]

130 **Kabaalioğlu A**, Ceken K, Alimoglu E, Apaydin A. Percutaneous imaging-guided treatment of hydatid liver cysts: do long-term results make it a first choice? *Eur J Radiol* 2006; **59**: 65-73 [PMID: 16513311 DOI: 10.1016/j.ejrad.2006.01.014]

131 **Daradkeh S**, El-Muhtaseb H, Farah G, Sroujieh AS, Abu-Khalaf M. Predictors of morbidity and mortality in the surgical management of hydatid cyst of the liver. *Langenbecks Arch Surg* 2007; **392**: 35-39 [PMID: 17021792 DOI: 10.1007/s00423-006-0064-2]

132 **Dziri C**, Haouet K, Fingerhut A, Zaouche A. Management of cystic echinococcosis complications and dissemination: where is the evidence? *World J Surg* 2009; **33**: 1266-1273 [PMID: 19350321 DOI: 10.1007/s00268-009-9982-9]

133 **Koea JB**. Laparoscopic treatment of hepatic hydatid disease. *ANZ J Surg* 2012; **82**: 499-504 [PMID: 22715944 DOI: 10.1111/j.1445-2197.2012.06126.x]

134 **Piccoli L**, Tamarozzi F, Cattaneo F, Mariconti M, Filice C, Bruno A, Brunetti E. Long-term sonographic and serological follow-up of inactive echinococcal cysts of the liver: hints for a "watch-and-wait" approach. *PLoS Negl Trop Dis* 2014; **8**: e3057 [PMID: 25122222 DOI: 10.1371/journal.pntd.0003057]

135 **Lee MH**, Katabathina VS, Lubner MG, Shah HU, Prasad SR, Matkowskyj KA, Pickhardt PJ. Mucin-producing Cystic Hepatobiliary Neoplasms: Updated Nomenclature and Clinical, Pathologic, and Imaging Features. *Radiographics* 2021; **41**: 1592-1610 [PMID: 34597230

DOI: 10.1148/rg.2021210011]
136 **Ishak KG**, Willis GW, Cummins SD, Bullock AA. Biliary cystadenoma and cystadenocarcinoma: report of 14 cases and review of the literature. *Cancer* 1977; **39**: 322-338 [PMID: 318915 DOI: 10.1002/1097-0142(197701)39:1<322::AID-CNCR2820390149>3.0.CO;2-P]
137 **Thomas KT**, Welch D, Trueblood A, Sulur P, Wise P, Gorden DL, Chari RS, Wright JK Jr, Washington K, Pinson CW. Effective treatment of biliary cystadenoma. *Ann Surg* 2005; **241**: 769-73; discussion 773 [PMID: 15849512 DOI: 10.1097/01.sla.0000161982.57360.1b]
138 **Hansman MF**, Ryan JA Jr, Holmes JH 4th, Hogan S, Lee FT, Kramer D, Biehl T. Management and long-term follow-up of hepatic cysts. *Am J Surg* 2001; **181**: 404-410 [PMID: 11448430 DOI: 10.1016/S0002-9610(01)00611-0]
139 **Park HJ**, Kim SY, Kim HJ, Lee SS, Hong GS, Byun JH, Hong SM, Lee MG. Intraductal Papillary Neoplasm of the Bile Duct: Clinical, Imaging, and Pathologic Features. *AJR Am J Roentgenol* 2018; **211**: 67-75 [PMID: 29629808 DOI: 10.2214/AJR.17.19261]
140 **Klompenhouwer AJ**, Ten Cate DWG, Willemssen FEJA, Bramer WM, Doukas M, de Man RA, Ijzermans JNM. The impact of imaging on the surgical management of biliary cystadenomas and cystadenocarcinomas; a systematic review. *HPB (Oxford)* 2019; **21**: 1257-1267 [PMID: 31085104 DOI: 10.1016/j.hpb.2019.04.004]
141 **Xu HX**, Lu MD, Liu LN, Zhang YF, Guo LH, Liu C, Wang S. Imaging features of intrahepatic biliary cystadenoma and cystadenocarcinoma on B-mode and contrast-enhanced ultrasound. *Ultraschall Med* 2012; **33**: E241-E249 [PMID: 23154870 DOI: 10.1055/s-0031-1299276]
142 **Boyum JH**, Sheedy SP, Graham RP, Olson JT, Babcock AT, Bolan CW, Menias CO, Venkatesh SK. Hepatic Mucinous Cystic Neoplasm Versus Simple Biliary Cyst: Assessment of Distinguishing Imaging Features Using CT and MRI. *AJR Am J Roentgenol* 2021; **216**: 403-411 [PMID: 33356432 DOI: 10.2214/AJR.20.22768]
143 **Lewin M**, Mourra N, Honigman I, Fléjou JF, Parc R, Arrivé L, Tubiana JM. Assessment of MRI and MRCP in diagnosis of biliary cystadenoma and cystadenocarcinoma. *Eur Radiol* 2006; **16**: 407-413 [PMID: 15983777 DOI: 10.1007/s00330-005-2822-x]
144 **Vogt DP**, Henderson JM, Chmielewski E. Cystadenoma and cystadenocarcinoma of the liver: a single center experience. *J Am Coll Surg* 2005; **200**: 727-733 [PMID: 15848365 DOI: 10.1016/j.jamcollsurg.2005.01.005]
145 **Delis SG**, Touloumis Z, Bakoyiannis A, Tassopoulos N, Paraskeva K, Athanassiou K, Safioleas M, Dervenis C. Intrahepatic biliary cystadenoma: a need for radical resection. *Eur J Gastroenterol Hepatol* 2008; **20**: 10-14 [PMID: 18090983 DOI: 10.1097/MEG.0b013e3282f16a76]
146 **Tyson GL**, El-Serag HB. Risk factors for cholangiocarcinoma. *Hepatology* 2011; **54**: 173-184 [PMID: 21488076 DOI: 10.1002/hep.24351]
147 **Khan SA**, Thomas HC, Davidson BR, Taylor-Robinson SD. Cholangiocarcinoma. *Lancet* 2005; **366**: 1303-1314 [PMID: 16214602 DOI: 10.1016/S0140-6736(05)67530-7]
148 **Welzel TM**, Graubard BI, El-Serag HB, Shaib YH, Hsing AW, Davila JA, McGlynn KA. Risk factors for intrahepatic and extrahepatic cholangiocarcinoma in the United States: a population-based case-control study. *Clin Gastroenterol Hepatol* 2007; **5**: 1221-1228 [PMID: 17689296 DOI: 10.1016/j.cgh.2007.05.020]
149 **Rimola J**, Forner A, Reig M, Vilana R, de Lope CR, Ayuso C, Bruix J. Cholangiocarcinoma in cirrhosis: absence of contrast washout in delayed phases by magnetic resonance imaging avoids misdiagnosis of hepatocellular carcinoma. *Hepatology* 2009; **50**: 791-798 [PMID: 19610049 DOI: 10.1002/hep.23071]
150 **Endo I**, Gonen M, Yopp AC, Dalal KM, Zhou Q, Klimstra D, D'Angelica M, DeMatteo RP, Fong Y, Schwartz L, Kemeny N, O'Reilly E, Abou-Alfa GK, Shimada H, Blumgart LH, Jarnagin WR. Intrahepatic cholangiocarcinoma: rising frequency, improved survival, and determinants of outcome after resection. *Ann Surg* 2008; **248**: 84-96 [PMID: 18580211 DOI: 10.1097/SLA.0b013e318176c4d3]
151 **Valls C**, Gumà A, Puig I, Sanchez A, Andía E, Serrano T, Figueras J. Intrahepatic peripheral cholangiocarcinoma: CT evaluation. *Abdom Imaging* 2000; **25**: 490-496 [PMID: 10931983 DOI: 10.1007/s002610000079]
152 **Ni T**, Shang XS, Wang WT, Hu XX, Zeng MS, Rao SX. Different MR features for differentiation of intrahepatic mass-forming cholangiocarcinoma from hepatocellular carcinoma according to tumor size. *Br J Radiol* 2018; **91**: 20180017 [PMID: 29791202 DOI: 10.1259/bjr.20180017]
153 **Apisarnthanarak P**, Pansri C, Maungsomboon K, Thamtorawat S. The CT appearances for differentiating of peripheral, mass-forming cholangiocarcinoma and liver meatastases from colorectal adenocarcinoma. *J Med Assoc Thai* 2014; **97**: 415-422 [PMID: 24964684]
154 **Kim YY**, Yeom SK, Shin H, Choi SH, Rhee H, Park JH, Cho ES, Park S, Lee SS, Park MS. Clinical Staging of Mass-Forming Intrahepatic Cholangiocarcinoma: Computed Tomography Versus Magnetic Resonance Imaging. *Hepatol Commun* 2021; **5**: 2009-2018 [PMID: 34559470 DOI: 10.1002/hep4.1774]
155 **Lamarca A**, Barriuso J, Chander A, McNamara MG, Hubner RA, ÓReilly D, Manoharan P, Valle JW. (18)F-fluorodeoxyglucose positron emission tomography ((18)FDG-PET) for patients with biliary tract cancer: Systematic review and meta-analysis. *J Hepatol* 2019; **71**: 115-129 [PMID: 30797051 DOI: 10.1016/j.jhep.2019.01.038]
156 **Huang X**, Yang J, Li J, Xiong Y. Comparison of magnetic resonance imaging and 18-fludeoxyglucose positron emission tomography/computed tomography in the diagnostic accuracy of staging in patients with cholangiocarcinoma: A meta-analysis. *Medicine (Baltimore)* 2020; **99**: e20932 [PMID: 32871859 DOI: 10.1097/MD.0000000000020932]
157 **Choi BI**, Lee JM, Han JK. Imaging of intrahepatic and hilar cholangiocarcinoma. *Abdom Imaging* 2004; **29**: 548-557 [PMID: 15185025 DOI: 10.1007/s00261-004-0188-1]
158 **Khan SA**, Davidson BR, Goldin RD, Heaton N, Karani J, Pereira SP, Rosenberg WM, Tait P, Taylor-Robinson SD, Thillainayagam AV, Thomas HC, Wasan H; British Society of Gastroenterology. Guidelines for the diagnosis and treatment of cholangiocarcinoma: an update. *Gut* 2012; **61**: 1657-1669 [PMID: 22895392 DOI: 10.1136/gutjnl-2011-301748]
159 **European Association for the Study of the Liver**. EASL-ILCA Clinical Practice Guidelines on the management of intrahepatic cholangiocarcinoma. *J Hepatol* 2023; **79**: 181-208 [PMID: 37084797 DOI: 10.1016/j.jhep.2023.03.010]
160 **de Jong MC**, Nathan H, Sotiropoulos GC, Paul A, Alexandrescu S, Marques H, Pulitano C, Barroso E, Clary BM, Aldrighetti L, Ferrone CR, Zhu AX, Bauer TW, Walters DM, Gamblin TC, Nguyen KT, Turley R, Popescu I, Hubert C, Meyer S, Schulick RD, Choti MA, Gigot JF, Mentha G, Pawlik TM. Intrahepatic cholangiocarcinoma: an international multi-institutional analysis of prognostic factors and lymph node assessment. *J Clin Oncol* 2011; **29**: 3140-3145 [PMID: 21730269 DOI: 10.1200/JCO.2011.35.6519]
161 **Conci S**, Ruzzenente A, Viganò L, Ercolani G, Fontana A, Bagante F, Bertuzzo F, Dore A, Pinna AD, Torzilli G, Iacono C, Guglielmi A. Patterns of Distribution of Hepatic Nodules (Single, Satellites or Multifocal) in Intrahepatic Cholangiocarcinoma: Prognostic Impact After Surgery. *Ann Surg Oncol* 2018; **25**: 3719-3727 [PMID: 30088126 DOI: 10.1245/s10434-018-6669-1]
162 **Ferlay J**, Colombet M, Soerjomataram I, Parkin DM, Piñeros M, Znaor A, Bray F. Cancer statistics for the year 2020: An overview. *Int J Cancer* 2021 [PMID: 33818764 DOI: 10.1002/ijc.33588]

163 **Sung H**, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, Bray F. Global Cancer Statistics 2020: GLOBOCAN Estimates of Incidence and Mortality Worldwide for 36 Cancers in 185 Countries. *CA Cancer J Clin* 2021; **71**: 209-249 [PMID: 33538338 DOI: 10.3322/caac.21660]

164 **Amini M**, Looha MA, Zarean E, Pourhoseingholi MA. Global pattern of trends in incidence, mortality, and mortality-to-incidence ratio rates related to liver cancer, 1990-2019: a longitudinal analysis based on the global burden of disease study. *BMC Public Health* 2022; **22**: 604 [PMID: 35351047 DOI: 10.1186/s12889-022-12867-w]

165 **Valery PC**, Laversanne M, Clark PJ, Petrick JL, McGlynn KA, Bray F. Projections of primary liver cancer to 2030 in 30 countries worldwide. *Hepatology* 2018; **67**: 600-611 [PMID: 28859220 DOI: 10.1002/hep.29498]

166 **Petrick JL**, Florio AA, Znaor A, Ruggieri D, Laversanne M, Alvarez CS, Ferlay J, Valery PC, Bray F, McGlynn KA. International trends in hepatocellular carcinoma incidence, 1978-2012. *Int J Cancer* 2020; **147**: 317-330 [PMID: 31597196 DOI: 10.1002/ijc.32723]

167 **Han J**, Wang B, Liu W, Wang S, Chen R, Chen M, Fu Z. Declining disease burden of HCC in the United States, 1992-2017: A population-based analysis. *Hepatology* 2022; **76**: 576-588 [PMID: 35073427 DOI: 10.1002/hep.32355]

168 **Trevisani F**, Santi V, Gramenzi A, Di Nolfo MA, Del Poggio P, Benvegnù L, Rapaccini G, Farinati F, Zoli M, Borzio F, Giannini EG, Caturelli E, Bernardi M; Italian Liver Cancer Group. Surveillance for early diagnosis of hepatocellular carcinoma: is it effective in intermediate/advanced cirrhosis? *Am J Gastroenterol* 2007; **102**: 2448-57; quiz 2458 [PMID: 17617210 DOI: 10.1111/j.1572-0241.2007.01395.x]

169 **de Lédinghen V**, Laharie D, Lecesne R, Le Bail B, Winnock M, Bernard PH, Saric J, Couzigou P, Balabaud C, Bioulac-Sage P, Drouillard J. Detection of nodules in liver cirrhosis: spiral computed tomography or magnetic resonance imaging? A prospective study of 88 nodules in 34 patients. *Eur J Gastroenterol Hepatol* 2002; **14**: 159-165 [PMID: 11981340 DOI: 10.1097/00042737-200202000-00010]

170 **Rode A**, Bancel B, Douek P, Chevallier M, Vilgrain V, Picaud G, Henry L, Berger F, Bizollon T, Gaudin JL, Ducerf C. Small nodule detection in cirrhotic livers: evaluation with US, spiral CT, and MRI and correlation with pathologic examination of explanted liver. *J Comput Assist Tomogr* 2001; **25**: 327-336 [PMID: 11351179 DOI: 10.1097/00004728-200105000-00001]

171 **Marrero JA**, Welling T. Modern diagnosis and management of hepatocellular carcinoma. *Clin Liver Dis* 2009; **13**: 233-247 [PMID: 19442916 DOI: 10.1016/j.cld.2009.02.007]

172 **Marrero JA**, Hussain HK, Nghiem HV, Umar R, Fontana RJ, Lok AS. Improving the prediction of hepatocellular carcinoma in cirrhotic patients with an arterially-enhancing liver mass. *Liver Transpl* 2005; **11**: 281-289 [PMID: 15719410 DOI: 10.1002/lt.20357]

173 **Matsui O**, Kobayashi S, Sanada J, Kouda W, Ryu Y, Kozaka K, Kitao A, Nakamura K, Gabata T. Hepatocelluar nodules in liver cirrhosis: hemodynamic evaluation (angiography-assisted CT) with special reference to multi-step hepatocarcinogenesis. *Abdom Imaging* 2011; **36**: 264-272 [PMID: 21267562 DOI: 10.1007/s00261-011-9685-1]

174 **Elsayes KM**, Kielar AZ, Elmohr MM, Chernyak V, Masch WR, Furlan A, Marks RM, Cruite I, Fowler KJ, Tang A, Bashir MR, Hecht EM, Kamaya A, Jambhekar K, Kamath A, Arora S, Bijan B, Ash R, Kassam Z, Chaudhry H, McGahan JP, Yacoub JH, McInnes M, Fung AW, Shanbhogue K, Lee J, Deshmukh S, Horvat N, Mitchell DG, Do RKG, Surabhi VR, Szklaruk J, Sirlin CB. White paper of the Society of Abdominal Radiology hepatocellular carcinoma diagnosis disease-focused panel on LI-RADS v2018 for CT and MRI. *Abdom Radiol (NY)* 2018; **43**: 2625-2642 [PMID: 30155697 DOI: 10.1007/s00261-018-1744-4]

175 **Bartolotta TV**, Taibbi A, Midiri M, Lagalla R. Contrast-enhanced ultrasound of hepatocellular carcinoma: where do we stand? *Ultrasonography* 2019; **38**: 200-214 [PMID: 31006227 DOI: 10.14366/usg.18060]

176 **Forner A**, Vilana R, Ayuso C, Bianchi L, Solé M, Ayuso JR, Boix L, Sala M, Varela M, Llovet JM, Brú C, Bruix J. Diagnosis of hepatic nodules 20 mm or smaller in cirrhosis: Prospective validation of the noninvasive diagnostic criteria for hepatocellular carcinoma. *Hepatology* 2008; **47**: 97-104 [PMID: 18069697 DOI: 10.1002/hep.21966]

177 **Maturen KE**, Nghiem HV, Marrero JA, Hussain HK, Higgins EG, Fox GA, Francis IR. Lack of tumor seeding of hepatocellular carcinoma after percutaneous needle biopsy using coaxial cutting needle technique. *AJR Am J Roentgenol* 2006; **187**: 1184-1187 [PMID: 17056903 DOI: 10.2214/AJR.05.1347]

178 **Unal E**, Ozmen MN, Akata D, Karcaaltincaba M. Imaging of aberrant left gastric vein and associated pseudolesions of segments II and III of the liver and mimickers. *Diagn Interv Radiol* 2015; **21**: 105-110 [PMID: 25698094 DOI: 10.5152/dir.2014.14360]

179 **Valls C**, Iannacconne R, Alba E, Murakami T, Hori M, Passariello R, Vilgrain V. Fat in the liver: diagnosis and characterization. *Eur Radiol* 2006; **16**: 2292-2308 [PMID: 16477402 DOI: 10.1007/s00330-006-0146-0]

180 **Idilman IS**, Ozdeniz I, Karcaaltincaba M. Hepatic Steatosis: Etiology, Patterns, and Quantification. *Semin Ultrasound CT MR* 2016; **37**: 501-510 [PMID: 27986169 DOI: 10.1053/j.sult.2016.08.003]

Published by **Baishideng Publishing Group Inc**
7041 Koll Center Parkway, Suite 160, Pleasanton, CA 94566, USA
Telephone: +1-925-3991568
E-mail: office@baishideng.com
Help Desk: https://www.f6publishing.com/helpdesk
https://www.wjgnet.com