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Dual energy computed tomography of focal lesions of the liver with iodine mapping

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Abstract
Introduction: Liver is an important constituent of the digestive tract and is involved in maintenance of the body's metabolic homeostasis. Liver cancer is a major cancer in less developed countries where 83% of worldwide incidence of new cases has been reported with China alone accounting for nearly 50% of new incident cases of liver cancer. As per an estimate about 7 Lakhs death due to hepatocellular carcinoma occur annually.
Aim: To compare the imaging findings of focal hepatic lesions by dual-energy computed tomography, multi-detector computed tomography, and ultrasonography and its follow up by medical treatment/aspiration/biopsy.
Methods: All individuals with suggested liver illness and undergoing liver imaging were included and all of them underwent Ultrasound, MDCT and DECT protocol. Analysis of radiological images and/or verification of the lesion type by biopsy/ aspiration, surgery, or follow-up was done.
Results: Though majority of the malignancies were detected by the USG (75.0%), USG underdiagnosed malignancies in 3 of the cases. Diagnostic accuracy of USG was found to be 93.8%. Though majority of the malignancies were detected by MDCT (91.7%), MDCT undiagnosed malignancies in 1 of the cases. Diagnostic accuracy of MDCT was found to be 98.5%. All the cases with malignancies were accurately detected by the DECT (100.0%), all Benign cases were also accurately detected by DECT (100.0%). Thus, Diagnostic accuracy of DECT was found to be 100.0% with the help of iodine concentration mapping.
Conclusion: In this study, we have concluded that iodine quantification using dual energy computed tomography is helpful in characterisation and follow-up after treatment of liver lesions. Thus DECT with the help of iodine quantification can be used as a highly specific and sensitive imaging modality for malignant and benign liver lesions as compared to MDCT and USG.

Keywords: Assess refers to process of the critical analysis and valuation and judgement of the status or

Introduction

"The liver is a crucial component of the digestive tract and plays a significant role in maintaining metabolic homeostasis. Owing to its primary function of detoxification and the rich blood supply through the hepatic artery and portal vein, it is susceptible to various diseases, including liver cancer, which is among the most common types of cancer. Liver cancer is the sixth most prevalent and third most fatal cancer worldwide. Less developed countries account for 83% of the global incidence of new liver cancer cases, with China alone contributing to nearly 50% of new incident cases, [1, 2]. Estimates indicate that approximately 700,000 deaths annually are attributable to hepatocellular carcinoma (HCC) [3]. In India, the incidence rate of Hepatocellular carcinoma ranges from 0.7 to 7.5 and 0.2 to 2.2 per 100,000 population per year for men and women, respectively [4].

Advancements in technology have made it easy to identify liver masses using imaging modalities such as ultrasonography (USG), computed tomography (CT), and magnetic resonance imaging (MRI). However, most of these lesions are detected incidentally in asymptomatic patients, leading to inaccuracies in diagnosis [5]. While accurate history and physical examination are essential to diagnosing and treating solid liver masses, it can be challenging to differentiate benign hepatic lesions from malignant ones, and some benign lesions have malignant potential. Although some non-invasive imaging methods can be useful in detecting and characterizing these lesions, each imaging modality has its limitations [6].

On ultrasound examination, HCC is usually detected as having different echogenicity from the surrounding liver. HCC derives its blood supply predominantly from the hepatic artery whereas the remainder of the liver receives both arterial and portal blood [7]. Ronzoni *et al*. in their study showed that MDCT correctly depicted 89 of 139 hepatocellular carcinomas sensitivity, 64% at the original examination and 102 at re-evaluation sensitivity, 73.3%. Patient-by-patient analysis showed a specificity of 75% in the original reports and of 77.5% at re-evaluation. However, in nodules smaller than 1 cm, the false positivity rate was quite high [8]. Computed tomography has become one of the most popular advanced imaging tools due to its relatively lower cost to the patient and increased availability [9-10]. It has evolved from a cross-sectional technique to spiral (helical) CT and then to true volumetric imaging modality with multi-slice (multidetector-row) CT (MDCT). MDCT has overcome the limitations of single-slice CT scanners and offered benefits in scanning time and limited z-axis resolution [11]. It allows imaging of the liver in arterial, portal, and equilibrium phases and thus better characterization of lesions. Multiphasic CT examination of the liver plays an important role in the differentiation of hemangioma from primary or secondary malignant hepatic tumors [12]. Recently, Dual-energy CT (DECT) has gained popularity for clinical practice, which can improve material differentiation by using 2 different x-ray effective energies. Current DECT acquisition methods consist of dual tubes either with or without beam filtration, rapid voltage switching with a 6 Introduction single tube, a dual-layer detector with a single tube, a single tube with a split filter, or a single tube with sequential dual scans. Dual-source DECT features a three-substance (fat, soft tissue, and iodine) separation algorithm, which can eliminate the influences of calcification and necrosis on the assessment of nodules. Moreover, DECT can truly separate and quantify iodine in each pixel of the enhanced image [13].

Materials & Methods

This cross-sectional study was conducted in the Department of Radiodiagnosis in Era's Lucknow Medical college and Hospital for a period of 24 months from February 2021 to February 2023 and a total of 65 patients were included in the study who were referred to the department of Radiodiagnosis from Department of Surgery and Medicine with complaints of mainly abdominal pain or abdominal lump and other associated symptoms like fever, weight loss, nausea, and vomiting, etc. The sampling frame of the study was bound by the following inclusion and exclusion criteria:

Inclusion criteria

1. Subjects of age group 20-60 years.
2. Presence of focal hepatic lesions on Ultrasonography.
3. All subjects presenting with deranged liver function or known cases of liver mass lesions.

Exclusion criteria

1. Traumatic hepatic lesions
2. Diffuse ill-defined hepatic lesions.
3. Patients with deranged renal function.
4. Pregnant females.

Sample size calculations and statistical analysis

Sample size was calculated by taking the sensitivity of MDCT in detection of focal lesions of liver using the formula:

Where S = 83.3%, sensitivity of MDCT in detection of malignancy

A = 0.905 (90.5%), Diagnostic accuracy of MDCT (reference Shrestha Jain et.al.)76 e = 0.1, error factor Type I error (level of significance) α=0.05

Power of study = 90%

Considering data loss = 10%,

The minimum sample size considering data loss = 65.

Ethical approval

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Ethical approval

The study was conducted at the Radiodiagnostic Department in collaboration with the Department of Medicine and Surgery of the Era Medical College and Hospital in Lucknow. Clearance for carrying out the study was obtained from the Institutional Ethical Committee Era's Medical College (Approval number: ELMC & H /RCELL, EC/2021/132), and informed consent was obtained from all the patients.

After obtaining approval from the institutional ethics board and informed consent from all patients, they were submitted to a USG exam followed by a CT exam, DECT. The lesion type was verified by analyzing radiological images and confirming it through biopsy/aspiration, surgery, or follow-up.

DECT protocol

In accordance with our institutional guidance, we have acquired all Computed Tomography (CT) scans of the abdominal region using a dual-energy dual-layer CT scanner. All CT scans were performed on a 384-slice DECT scanner (Somaton Force, Seimens Healthcare) and all the images were post-processed on a workstation using syngo. via software that allows the analysis of images using three material decompositions. To initiate the administration of the contrast agent, we injected it into an ante-cubital vein via a 20 G catheter at a flow rate of 2.5 ml/s using a dual syringe injection system (Stellant, MEDRAD, Indianola, Pennsylvania), succeeded by the infusion of a 50 ml saline chaser. Portal venous phase images were captured 70 seconds after the intravenous injection of the contrast agent (80 ml Ultravist 370 MCT, Bayer Vital GmbH, Leverkusen, Germany). The scan procedure involved craniocaudal imaging with a pitch of 0.6, a tube voltage of 80 kVp, a detector configuration of 128 x 0.625 mm, a rotation time of 0.5 seconds, and an average CTDI vol of 7.8 mGy. The reconstruction of all datasets was performed in the axial view with a slice thickness of 2 mm and a 512-image matrix, utilizing the iDose image reconstruction algorithm at level 2.

Results

The present study was conducted at Department of Radiodiagnosis, ELMC& H to study focal lesions of liver by dual energy computed tomography (DECT), Multi Detector Computed Tomography (MDCT) and Ultrasonography. For this, 65 patients presenting with suspected liver disease/disorder were enrolled in the study. Majority of the cases were males (61.5%), while the remaining were female (38.5%). Gender ratio of the study population was 1.6.

All the patients reported Abdominal Pain and discomfort (100.0%), while other complaints included Fever, Weight Loss. All the patients of age group 20-60 years were included in the study. Two radiologists (more than five years of experience) reviewed the ultrasound images, MDCT and DECT images independently. Both the radiologists who were involved in the study were purposefully blinded to clinical data to avoid any bias.

Most common USG finding was Hypoechoic lesions (38.5%), followed by Cyst (16.9%), Hyperechoic and Heterogenic Hypoechoic Vascularity (15.4%) each type and Cyst with- or without- calcification (7.7%) rest of the 6.2% were normal.

Most common MDCT finding was Hypodense structures (53.8%), followed by Heterogeneously Hypodense and Hyperdense (16.9% each), Hypodense with Septation (9.3%) and Calcified Hyperdense (3.1%).

In a majority of the cases, Better Visualization was seen on DECT scan (58.5%), followed by Significant, Moderate and Mild Iodine uptake (18.5%, 15.4% & 7.7%, respectively).

At final diagnosis, most common finding was Liver Abscess (38.5%), followed by Hemangioma (15.4%), Benign Cyst (15.4%), Metastasis (13.8%), Hydatid Cyst (9.2%), HCC (4.6%) and Hepatic Granuloma (3.1%).

On USG findings, all Benign cyst were seen as Cyst (100.0%), all Granulomas were seen as Normal (100.0%), while all others were seen as mixed imaging.

On MDCT findings, among all Benign lesions, Benign Cyst and Liver Abscess were seen as Hypodense lesions (100.0% each), all Hydatid Cyst were seen as Hypodense with Septation (100.0%) and all Granulomas were seen as Calcified Hyperdense (100.0%). On the other hand, all Metastasis cases were seen as Heterogeneously Hypodense (100.0%), while majority of HCC cases were seen as Heterogeneously Hypodense (66.7%) and remaining were seen as Hyperdense (33.3%).

On DECT findings, among all Benign lesions, all the cases with Benign Cyst, Hepatic Granuloma and Liver Abscess were Better Visualised (100.0% each), all Haemangiomas were seen as Moderate iodine Uptake (100.0%), while majority of Hydatid Cyst were seen as Mild Iodine uptake (83.3%). Further, among patients with malignancies, all HCC and Metastasis were seen as Significant Iodine uptake (100.0%) as shown in table 1.

Table 1: Association of Follow-up Findings with MDCT and DECT Findings

SN	MDCT Findings		Benign Cyst		HCC		Haemangioma		Hepatic Granuloma		Hydatid Cyst		Liver Abscess		Metastasis
	DECT	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
1	Mild lodine Uptake Seen	0	0.0	0	0.0	0	0.0	0	0.0	5	83.3	0	0.0	0	0.0
2	Moderate lodine Uptake Seen	0	0.0	0	0.0	10	100.0	0	0.0	0	0.0	0	0.0	0	0.0
3	Significant lodine Uptake Seen	0	0.0	3	100.0	0	0.0	0	0.0	0	0.0	0	0.0	9	100.0
4	Visualization Was Seen Better	10	100.0	0	0.0	0	0.0	2	100.0	1	16.7	25	100.0	0	0.0

Table 2: Association of Cancer status in USG, MDCT and DECT with Follow-up Findings

Cancer Status in		Benign		Malignant	
		No.	**%**	**No.**	**%**
USG (χ 2=40.179; p<0.001)	Benign	52	98.1	3	25.0
	Malignant	1	1.9	9	75.0
MDCT (χ 2=58.480; p<0.001)	Benign	53	100.0	1	8.3
	Malignant	0	0.0	11	91.7
DECT (χ 2=65.00; p<0.001)	Benign	53	100.0	0.0	0.0
	Malignant	0	0.0	12	100.0
	Sensitivity	Specificity	PPV	NPV	Diagnostic accuracy
USG	90.0%	94.5%	75.0%	98.1%	93.8%
MDCT	91.7%	100.0%	100.0%	98.1%	98.5%
DECT	100.0%	100.0%	100.0%	100.0%	100.0%

On follow-up visits and final diagnosis, majority of the cases had benign malignancies 53 (81.5%), while the remaining had Malignant Lesions 12 (18.5%).

Though majority of the malignancies were detected by MDCT (91.7%), MDCT underdiagnosed malignancies in 1 (8.3%) of the cases. The Sensitivity, Specificity, PPV, NPV of MDCT was 91.7%, 100.0%, 100.0%, 98.1%. Diagnostic accuracy of the model was 98.5%.

All the cases with malignancies were accurately detected by the DECT (100.0%), also, all benign cases were also accurately detected by DECT (100.0%). Thus Sensitivity, Specificity, PPV, NPV of DECT was 100.0%, 100.0%, 100.0%, 100.0%. Diagnostic accuracy of the model was 100.0%.

Though majority of the malignancies were detected by the USG (75.0%), USG underdiagnosed malignancies in 3 (25.0%) of the cases. The Sensitivity, Specificity, PPV, NPV of USG was 90.0%, 94.5%, 75.0%, 98.1%. Diagnostic accuracy of the model was 93.8%.

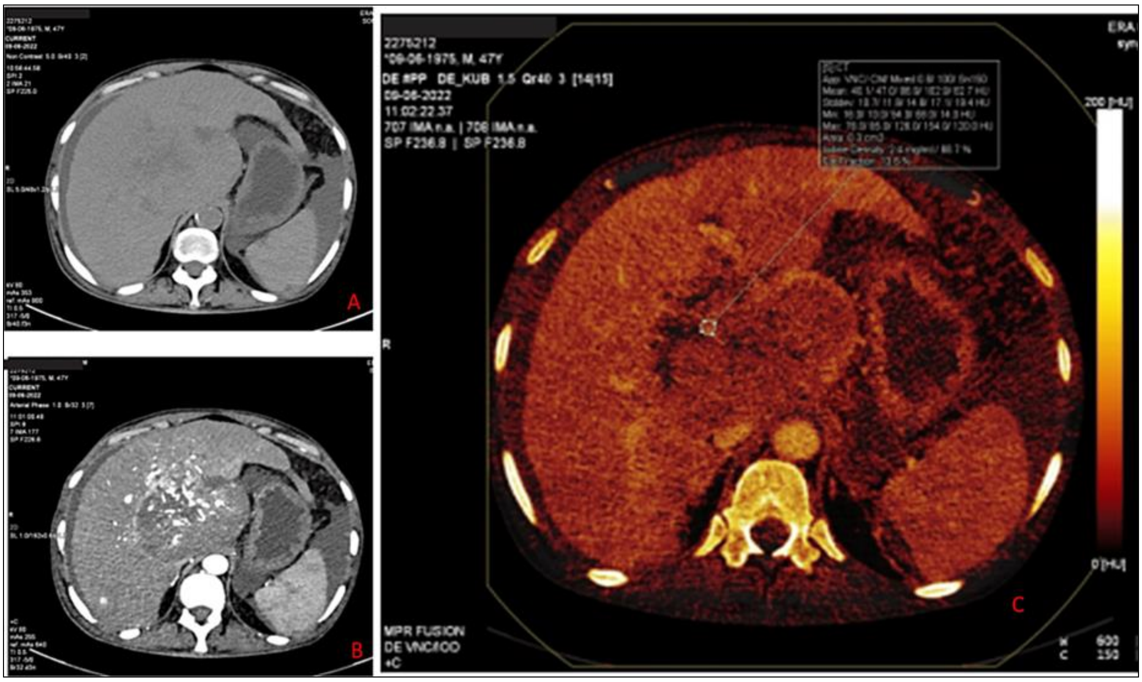

Fig 1: A. NCCT showing ill-defined hypodense lesion; B. CECT demonstrates showing heterogenous enhancement; C. Iodine overlay DECT image showing quantification of contrast uptake in Hepatocellular carcinoma

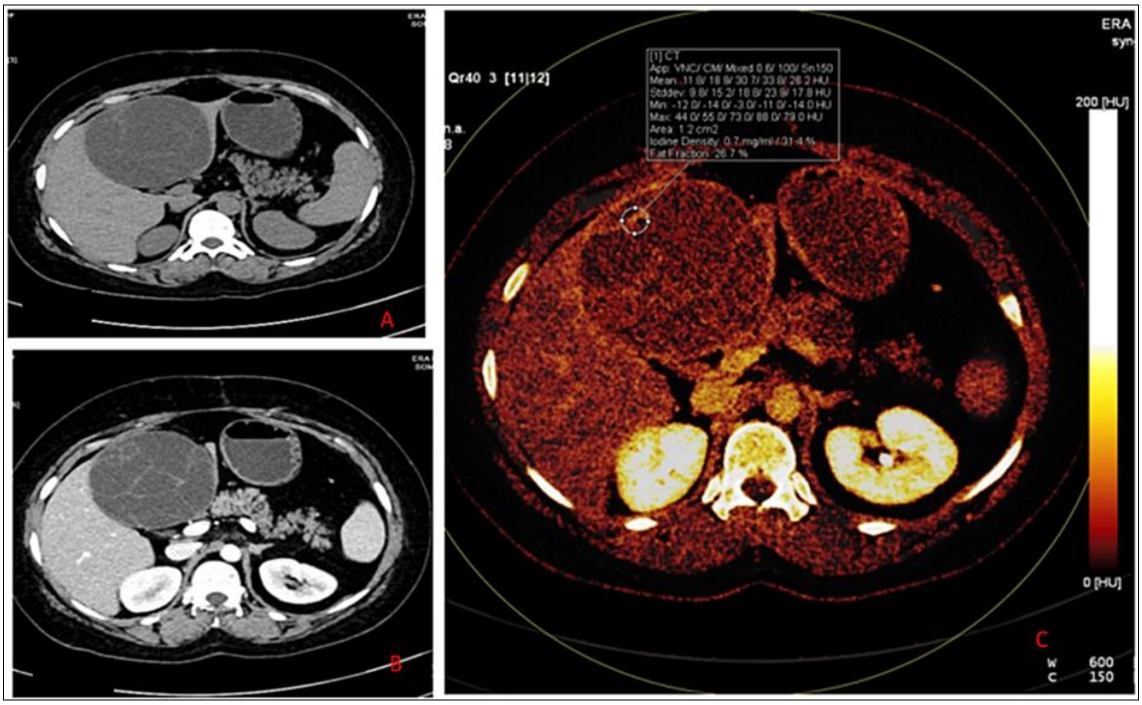

Fig 2: A. NCCT showing well defined lesion with thin septas; B. CECT image showing enhancement in septa. C. Iodine overlay DECT image showing quantification of contrast uptake in Hydatid cyst

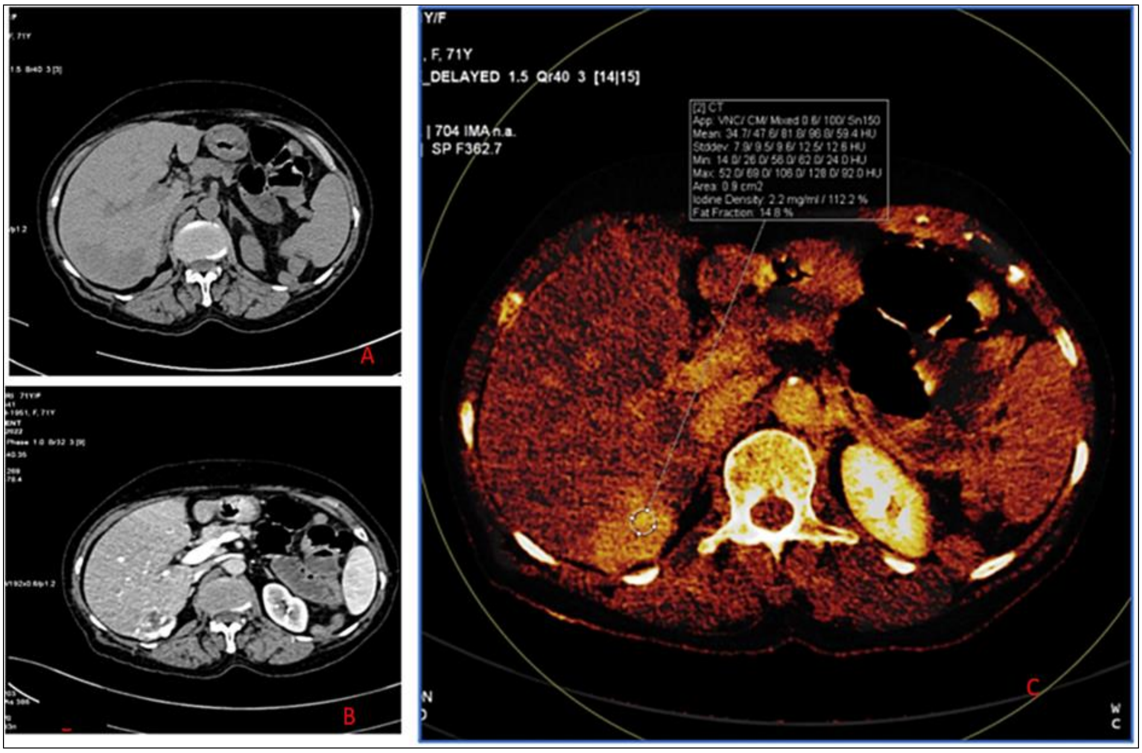

Fig 3: A. NCCT showing a lobulated hypodense lesion; B. CECT image showing peripheral nodular enhancement; C. Iodine overlay DECT image showing quantification of contrast uptake in Haemangioma

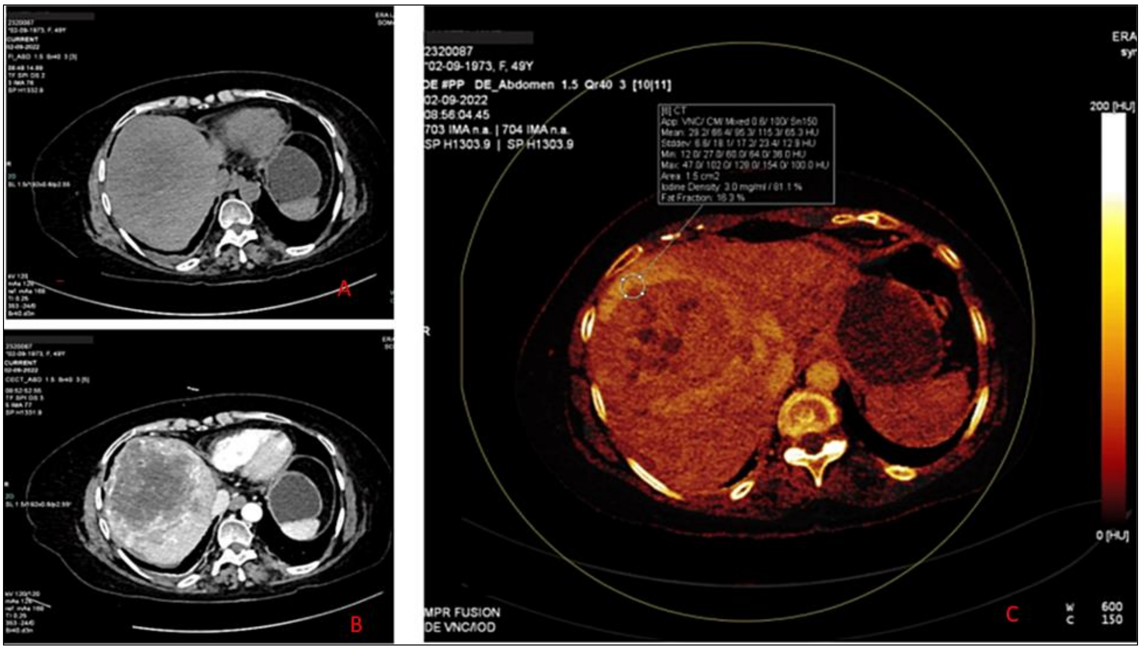

Fig 4: A. NCCT showing an ill defined hypodense lesion; B. CECT image showing heterogenous enhancement; C. Iodine overlay DECT image showing quantification of contrast uptake in a Metastatic lesion

Discussion

"Liver lesions are a prevalent finding in modern medical setup, largely due to advances in imaging technology and an increase in liver-related health issues linked to sedentary lifestyles and poor dietary habits. However, accurate diagnosis of liver lesions remains challenging due to their heterogeneous nature and potential etiologies. The search for reliable diagnostic tools to provide useful information is an ongoing and dynamic process. This study suggests that Dual-energy CT (DECT) is a superior alternative to Multi-detector CT (MDCT) or Ultrasound (USG) for cases with severe symptoms and those at risk for malignancies, such as patients who have had cancer-related surgeries or have not responded to medication for liver-related diseases. In contrast, MDCT and USG can be used interchangeably for patients with less severe symptoms, allergies to contrast medium, or technical difficulties. It is worth noting that DECT availability is still evolving, and this study adds to the understanding of lesion appearance on DECT.

Diagnostic efficacy of MDCT with a sensitivity and specificity of 100% and 80%, respectively. They reported a positive predictive value (PPV) of 94.6% and a negative predictive value (NPV) of 100%, with an overall accuracy of 95.6%. While these values are similar to those reported in this study, the superiority of MDCT in detecting malignancies may be attributable to the different phases based on the vascular nature of the masses. The limited number of malignant cases in this study may also have contributed to the high specificity, as compared to the study by Hafeez *et al*. [14] where there were two misdiagnoses, leading to a loss of specificity by 20%.

In a study from India with an adequate number of benign and malignant cases, Goel *et al* [15] found the sensitivity and specificity of triphasic MDCT to be 96.2% and 100%, respectively, similar to the present study. Their study also demonstrates that the number of cases in some series can affect specificity alarmingly.

Investigators have found CT and MDCT to be good non-invasive tools in characterizing the lesions. An iodine map can be subsequently isolated from the mixed images, giving information about the distribution of iodinated contrast media in the target organ. As a result, it directly reflects the degree of enhancement at the lesion and gives information about the tumors' blood supply [16]. One of the advantages of computed tomography is that it outperforms USG and MRI for evaluating the extra-hepatic abdomen [17].

Limitations

We failed to find any previous study that has been done to report the findings of DECT by using iodine concentration for focal and malignant liver lesions. Though DECT design proposal dates back to late 20th century, the technology is still in early days of adaptation. Most of the studies that have been done on liver imaging using DECT, have been limited to measuring the radiation that the patient might be subjected to or measured that noise and methods to keep them to a minimum. Keeping in view the small sample size in present study, further studies on a larger sample size with relaxed sampling criteria are recommended to validate the findings of the present study.

Conclusions

In this study, we have concluded that iodine quantification using dual-energy computed tomography is helpful in the characterization and follow-up after treatment of liver lesions. However, few malignant masses are hard to differentiate from benign lesions because of low contrast enhancement and improper washout. With the help of iodine quantification using DECT all the cases with malignancy were accurately detected as malignant lesions show higher degree of enhancement. The findings of the present study concur that DECT can be used as a highly specific and sensitive imaging modality for malignant and benign liver lesions as compared to MDCT and USG.

Conflict of Interest

Not available

Financial Support

Not available

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