Characterization of Liver Steatosis by Ultrasonography in Comparison to Magnetic Resonance Imaging

Esraa Gaber Eid Hammad[a*], Ahmed Okasha Muhammed[a], Hasan Sedeek Mahmoud Ali[b], Abd Al-Raheem Hussien Ali[a]

[a]Radiology and interventional Department, Faculty of Medicine, South Valley University, Qena, Egypt.

[b]Tropical Medicine & Gastroenterology Department, Faculty of Medicine, South Valley University, Qena, Egypt.

Abstract

Background: Non-alcoholic fatty liver disease affects about 10–30% of the population worldwide, with a higher incidence among obese and diabetic patients. Imaging modalities such as ultrasonography (US), magnetic resonance imaging (MRI), are preferred for hepatic fat assessment.

Objectives: To evaluate the diagnosis of liver steatosis by ultrasonography versus Magnetic resonance imaging.

Patients and methods: This was a cross sectional study that was that included all non- alcoholic fatty liver disease patients aged 18 years or older who agreed to participate. The study conducted comprehensive patient assessments, including medical history. Imaging involved pelviabdominal ultrasonography and MRI with T1/T2 weighted imaging. Laboratory investigations included liver function tests and glucose levels. BMI was calculated using standard formula. The primary focus was comparing liver steatosis diagnosis via ultrasonography and MRI, with a secondary objective to establish correlation between the two methods.

Results: The majority of patients with T1 hyperintense signals had diffuse fat infiltration on ultrasound (91 vs 9, p = .182) compared to focal fat infiltration, while the majority of patients with T2 mild hyperintense signals had diffuse fat infiltration on ultrasound (72 vs 9, p = .128) and those with hypointense signals had diffuse fat infiltration as well (19 vs 0, p = .128), but none of these results were statistically significant.

Conclusion: There is an agreement between MRI and US results in diagnosing Hepatic Steatosis, with most patients with diffuse fat infiltration on US showing T1 hyperintense signals and T2 mild hyperintense signals but none of these results were statistically significant.

Keywords: Liver Steatosis; Ultrasonography; Magnetic Resonance; Imaging.

DOI: 10.21608/SVUIJM.2024.250855.1744

***Correspondence:** esraamusa363@gmail.com

Received: 28 November,2023.

Revised: 4 January, 2024.

Accepted: 7 January, 2024.

Published: 15 June, 2025

Cite this article as Esraa Gaber Eid Hammad, Ahmed Okasha Muhammed, Hasan Sedeek Mahmoud Ali, Abd Al-Raheem Hussien Ali.(2025). Characterization of Liver Steatosis by Ultrasonography in Comparison to Magnetic Resonance Imaging. *SVU-International Journal of Medical Sciences*. Vol.8, Issue 2, pp: 10-20.

Introduction

Ultrasonography (USG) and Magnetic Resonance Imaging (MRI) are widely used non-invasive methods to detect liver fatty infiltration. USG utilizes sound waves to provide real-time liver imaging that is cost-effective and accessible. It identifies fat infiltration based on changes in tissue echogenicity due to differences in density and composition **(Makhija et al., 2021).** However, USG's accuracy may vary due to operator experience and fat accumulation levels, impacting its sensitivity for mild steatosis detection **(Qureshi et al., 2020).**

Non-alcoholic fatty liver disease (NAFLD) spans from hepatic steatosis to advanced stages like fibrosis and cirrhosis. The risk of complications like hepatocellular carcinoma (HCC) underscores the significance of early detection and management **(Papatheodoridiet al., 2018).** NAFLD is prevalent, particularly among obese and diabetic individuals. Both USG and MRI are preferred imaging methods for assessing hepatic fat content **(de Vries et al., 2020).**

MRI employs strong magnetic fields and radiofrequency pulses to generate detailed liver images, capturing tissue composition changes using T1 and T2 relaxation times. It can directly measure liver fat fraction through techniques like chemical shift imaging and Dixon-based methods, providing precise steatosis assessment **(Pasanta et al., 2021)**. Despite MRI's higher accuracy compared to USG, its limitations include cost, availability, and contraindications for certain implants **(Apostolopoulos et al., 2019).**

While USG is valuable for initial screening due to affordability and accessibility, MRI offers a thorough evaluation of liver composition and fat content. Understanding the roles of these techniques in diagnosing and monitoring liver steatosis requires further research **(Jeon et al., 2021).**

The study was aimed to evaluate the diagnosis of liver steatosis by ultrasonography versus Magnetic resonance imaging.

Patients and methods

The investigation was a cross-sectional study conducted during the year 2022 at Qena University Hospital, Egypt under ethical code of SVU-MED-RAD028-1-22-1-308. The study took place within the Diagnostic & Interventional Radiology Department as well as the Tropical Medicine and Gastroenterology Department. The targeted population comprised individuals aged 18 years or older with non-alcoholic fatty liver disease who met specific inclusion criteria and expressed their willingness to participate. The final sample size for the study consisted of 100 patients.

Exclusion criteria were defined to encompass specific circumstances, notably contraindications to undergoing MRI scans. These contraindications encompassed factors such as the presence of metallic implants, claustrophobia, particular heart conditions, and the presence of pacemakers. Despite these exclusions, patients who fulfilled the study's inclusion criteria were included for analysis.

Each patient involved in the study underwent a comprehensive assessment that encompassed a detailed medical history review. This provided insights into factors such as the patients sex, age, family history, and past medical background. Alongside the medical history review, participants underwent imaging procedures including pelviabdominal ultrasonography **(Ferraioli and Monteiro, 2019)** and abdominal magnetic resonance imaging, utilizing T1 and T2 weighted imaging techniques **(Erden et al., 2021).**

T1-Weighted Imaging: Offering detailed anatomical information and superior tissue contrast, this sequence facilitated the characterization of liver morphology and the identification of abnormalities associated with non-alcoholic fatty liver disease (NAFLD).

T2-Weighted Imaging: This sequence enhanced sensitivity to pathological changes within the liver, aiding in the detection and characterization of liver lesions associated with NAFLD.

Imaging techniques included supine patient positioning on the MRI examination table to ensure optimal alignment for accurate abdominal imaging. Subjects were instructed to perform controlled breath-holding during image acquisition to minimize motion artifacts and enhance image quality. No contrast agents were administered for the specified MRI sequences, as the focus was on non-contrast imaging for NAFLD assessment.

We quantitatively assessed liver signal intensity and fat content through region-of-interest (ROI) analysis on T1 and T2-weighted images. Additionally, we conducted qualitative analysis, systematically reviewing images and emphasizing the identification of specific liver features.

The designed MRI protocol aimed to comprehensively assess liver morphology and composition in non-alcoholic fatty liver disease patients. The detailed imaging parameters and sequences utilized were intended to enhance diagnostic accuracy and contribute valuable data to the ongoing understanding of NAFLD through advanced imaging techniques.

Additionally, laboratory investigations were conducted, involving assessments of liver function tests and blood glucose levels. In addition to these assessments, the patients body mass index (BMI) was calculated using the standard formula of weight in kilograms divided by the square of height in meters **(Misra and Dhurandhar, 2019).**

The study primary focus centered on a comparative evaluation of liver steatosis diagnosis achieved through ultrasonography and magnetic resonance imaging. Meanwhile, a secondary objective aimed to establish a correlation between the diagnoses obtained via these two distinct imaging methods.

Statistical analysis

The statistical analyses entailed the examination of correlations between different variables, incorporating regression analyses where applicable. A statistical significance threshold of p-value less than 0.05 was employed for all tests. Notably, Pearson correlation coefficients were utilized to elucidate relationships between various parametric variables encountered within the study.

Results

The study involved 100 participants, with 38 males (38%) and 62 females(62%). Abdominal pain was the most common symptom, reported by 56% of patients. Fatigue and Abdominal Discomfort was observed in 12% of cases, while 38% remained asymptomatic. A significant proportion, 60%, had a history of diabetes. **(Table.1).**

Table 1. Sex & Clinical Presentation of Patients

Variables		**Patients**	**Percentage**
Sex	Male	38	38%
	Female	62	62%
Clinical Presentation	Abdominal Pain	56	56%
	Fatigue and Abdominal Discomfort	12	12%
	Asymptomatic	38	38%
Diabetics		60	60%

In patients with diffuse fat infiltration, 35 males and 56 females were observed. Similarly, focal fat infiltration had 3 males and 6 females, yielding the same non- significant p-value (.762). Abdominal pain was reported by 51 diffuse fat infiltration patients, compared to 5 with focal fat infiltration, leading to a p-value of .978. Twelve cases of diffuse fat infiltration showed Fatigue and Abdominal Discomfort, while none with focal fat infiltration did, resulting in a p-value of .246. Among asymptomatic patients, 34 had diffuse fat infiltration, and 4 had focal fat infiltration, with a p- value of .676. Diabetic patients had 55 cases of diffuse fat infiltration and 5 cases of focal fat infiltration, yielding a p-value of .775. No significant differences were found in sex, clinical presentation, age, BMI, liver enzyme levels, or bilirubin levels between the two groups. **(Table.2)**

Table 2. Data of Patients Divided by Ultrasound Finding.

Variables		**Diffuse Fat Infiltration**	**Focal Fat Infiltration**	**P. Value**
Demographics				
Age		56.5	57.2	827
BMI		29	29.7	57
Sex	Male	35	3	762
	Female	56	6	
Clinical Presentation	Abdominal Pain	51	5	.978
	Fatigue and Abdominal Discomfort	12	0	.246
	Asymptomatic	34	4	.676
Diabetics		55	5	.775
Lab investigations				
ALT		51	54	.815
AST		41	42.6	.673
Total Bilirubin		1.7	1.2	.551
Direct Bilirubin		1.1	0.8	.375
Indirect Bilirubin		0.5	0.4	.619

In **(Table.3),** in cases with mild hyperintense signals, there were 30 males and 51 females (p- value: .682). Among these, 43 experienced abdominal pain, 9 Fatigue and Abdominal Discomfort, and 34 were asymptomatic (p-values: .226, .572, .091). Diabetic patients with mild hyperintense signals were 47 (p-value: .405). In cases with hypointense signals, there were 8 males and 11 females (p-value: .682). Among these, 13 reported abdominal pain , 3 had Fatigue and Abdominal Discomfort, and 4 were asymptomatic (p-values: .226, .572, .091). Diabetic patients with hypointense signals were 13 (p-value: .405). No significant differences were observed between the groups. Patients with mild hyperintense signals had a mean age of 56.5 years, an average BMI of 29, mean ALT of 53.1 U/L, mean AST of 42.2 U/L, mean total bilirubin of 1.5 mg/dL, mean direct bilirubin of 1 mg/dL, and mean indirect bilirubin of 0.5 mg/dL. In contrast, patients with hypointense signals had a mean age of 57.2 years, an average BMI of 29.7, mean ALT of 45.4 U/L, mean AST of 37 U/L, mean total bilirubin of 1.8 mg/dL, mean direct bilirubin of 1.4 mg/dL, and mean indirect bilirubin of 0.4 mg/dL. Corresponding p-values were .827, .57, .456, .531, .678, .564, and .282. No significant differences were noted between the two groups.

Table 3. Sex & Clinical Presentation of Patients Divided by T2 MRI Findings.

Variables		**Mild Hyperintense Signals**	**Hypointense Signals**	**p Value**
Age		56.5	57.2	.827
BMI		29	29.7	.57
Sex	Male	30	8	.682
	Female	51	11	.682
Clinical Presentation	Abdominal Pain	43	13	.226
	Fatigue and Abdominal Discomfort	9	3	.572
	Asymptomatic	34	4	.091
Diabetic		47	13	.405
Lab Data				
ALT		53.1	45.4	.456
AST		42.2	37	.531
Total Bilirubin		1.5	1.8	.678
Direct Bilirubin		1	1.4	.564
Indirect Bilirubin		0.5	0.4	.282

Among the patients, 86 individuals had Ultrasound Grade I findings, representing 86% of the total. The remaining 14% (14 patients) had Ultrasound Grade II findings. All 100 patients exhibited T1 hyperintense signals (100% of cases). For T2 signals, 81 patients displayed mild hyperintense signals, making up 81% of the total, while the remaining 19% (19 patients) showed hypointense signals. **(Table .4)**

Table 4. US and MRI data of included subjects

Variables		**Patients**	**Percentages**
US Grading			
Ultrasound Grade I		86	86%
Ultrasound Grade II		14	14%
MRI Evaluation			
T1 Hyperintense Signals		100	100%
T2	**Mild Hyperintense Signals**	81	81%
	Hypointense Signals	19	19%

For Us evaluations taking MRI as gold standard, sensitivity reached 98.9%, specificity was 40%, PPV was 96.9% and NPV was 66.7% with accuracy of 961%. **(Table 5).**

Table 5. Sensitivity of US based on MRI.

US	MRI		Total	Sensitivity	Specificity	PPV	NPV	Accuracy
	Yes	**No**						
Yes		3	97	98.9%	40%	96.9%	66.7%	96%
No		2	3					
		5	100					

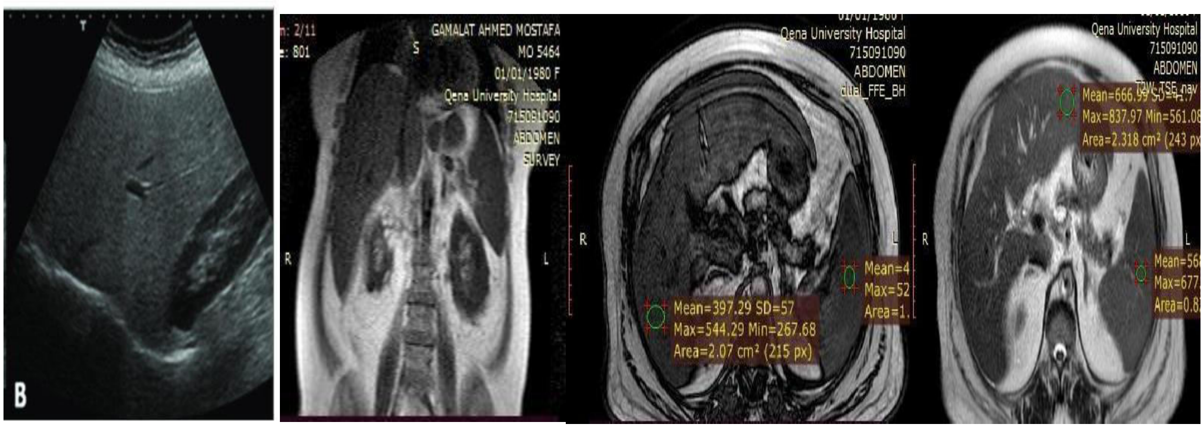

Fig.1. A 40-year-old male diabetic patient whose BMI was 30 kg/m2 presented with right hypochondrial pain. Liver enzymes were normal., SGPT=30 U/L,SGOT 25 U/L, total bilirubin 0.55 mg/dl, abdominal ultrasound showed mildly enlarged diffuse fatty liver grade I, MRI shows Mildly hyper intense signals on T1, Hypo intense signals on both T2, and out phase With Liver Steatosis ± 21.8

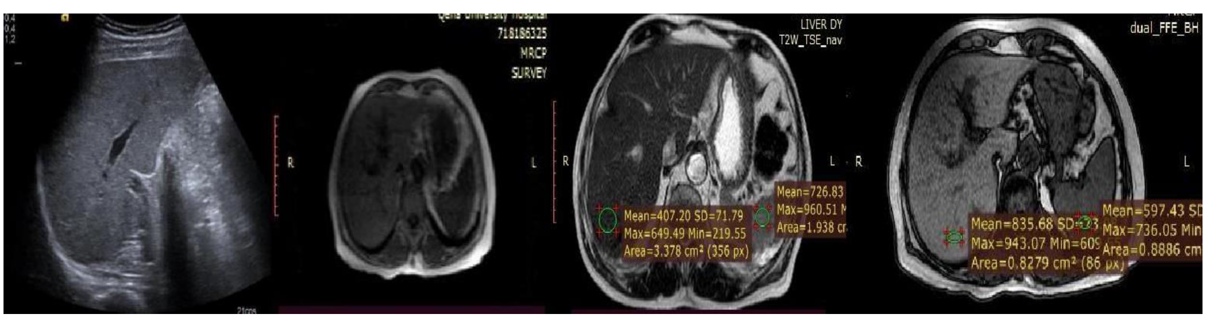

Fig.2. A 40-year-old non-diabetic female patient whose BMI was 24.7 kg/m2 presented with upper abdominal pain.. Her liver enzymes were normal , SGPT= 22 U/L, SGOT=21 U/L,total bilirubin 0.38 mg/dl. Abdominal ultrasound showed diffuse fatty liver infiltration grade II.MRI showed Mildly hyper intense signals on T1, Hypo intense signals on both T2, and out phase With Liver Steatosis ± 23.4

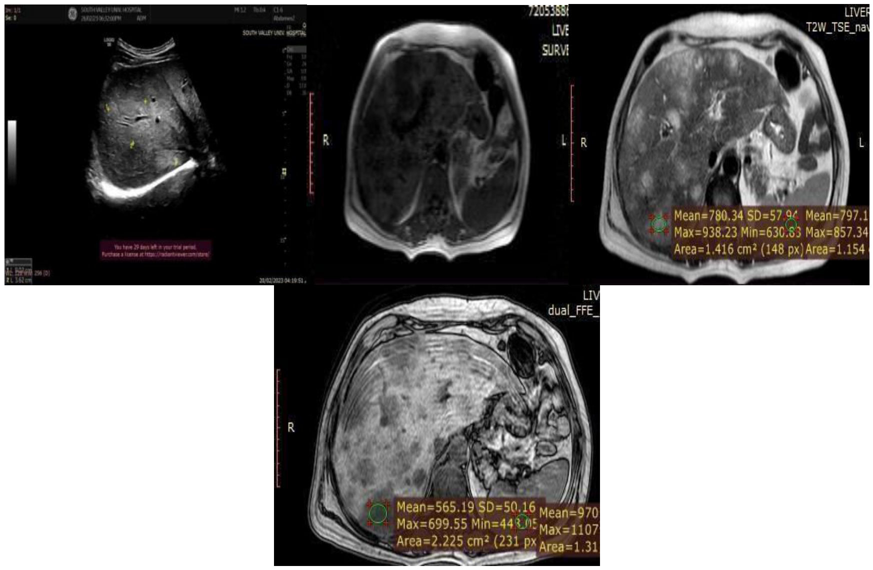

Fig. 3. A 50-year-old non-diabetic female patient whose BMI was 19 kg/m2 presented with upper abdominal pain.. liver enzymes were mildly elevated, SGPT= 117U/L , SGOT =500U/L , total bilirubin =0.38 mg/d Abdominal ultrasound showed focal fatty liver infiltration MRI showed focal fatty infiltration with MRI Liver Steatosis ± 26.9

Discussion

To avoid severe liver disorders like NAFLD and NASH, hepatic steatosis, a major consequence of metabolic dysfunction, must be accurately diagnose and monitored. Ultrasonography and MRI are promising non-invasive imaging technologies **(Muthiah et al., 2022).** Ultrasonography uses sound waves for real- time liver imaging and is affordable. It can detect mild to severe steatosis, although operator competence, body type, and fat buildup may reduce its accuracy **(Seneviratne et al., 2023).** Instead, MRI uses magnetic fields and radiofrequency to provide precise liver pictures, especially T2-weighted fat images. MRI has superior specificity and sensitivity than ultrasonography despite its higher cost and restricted availability **(Bachtiar et al., 2019; Ma et al., 2022).** Ultrasonography is useful for early evaluation, but MRI's detailed liver composition and fat accumulation assessment suggests future investigation on their complimentary diagnostic functions **(Tamaki et al., 2022; Ballestri et al., 2019).**

In our study, ultrasound diagnoses indicated that 91% of patients had Diffuse Fat Infiltration, while 9% displayed Focal Fat Infiltration. Ultrasound grading revealed that 86% were categorized as Grade I, and the remaining 14% as Grade II. In MRI analysis, all patients exhibited Hyperintense signals on T1, with 81% showing Mild Hyperintense Signals and 19% displaying hypointense signals on T2 imaging. The mean In & Out Phase was 30.3%, varying from 5% to 88%.

Ultrasound imaging uses sound waves but may not identify fat infiltration, particularly diffuse accumulation **(Seneviratne et al., 2022; Ferraioli et al., 2022).** This may explain why diffuse fat infiltration (91%) outnumbers focal fat infiltration (9%) in our study. Ultrasonography's greater sensitivity to wide tissue echogenicity alterations may explain this occurrence. T1-weighted MRI showed hyperintense signals in all cases, suggesting consistent hepatocyte lipid content. Mild hyperintense T2 MRI signals may indicate lipid-rich hepatocytes owing to increased water content, whereas hypointense signals may indicate tissue composition. These results demonstrate the techniques' ability to detect liver tissue lipid content changes **(Zhen et al., 2020; Zech et al., 2020; Watanabe et al., 2015).**

Our findings align with previous studies. **Ibacahe et al. (2020)** demonstrated ultrasound's dependability for assessing liver fat infiltration compared to magnetic resonance spectroscopy (MRS), particularly in adults, suggesting ultrasound's viability as an alternative when MRS is inaccessible. **Paige et al.** meta-analysis **(Paige et al., 2017)** involving 2815 patients showed ultrasound's sensitivity and specificity for distinguishing moderate to severe fat infiltration from none to be 85% (80–90%) and 93% (87–97%), respectively, in adult patients. **Ahmed et al. (2017)** Egyptian study indicated 100% sensitivity and 10% specificity for ultrasound in detecting histologically confirmed NAFLD, implying its role in ruling out histology or preventing biopsy in grade "A" hepatic infiltration cases. Similarly, Hernaez et al. (2011) affirmed ultrasound's accuracy in detecting moderate and severe NAFLD with an area under the summary receiving operating characteristics curve of 0.93 (0.91–0.95). These studies collectively support ultrasound's practicality and reliability for liver fat assessment and NAFLD detection.

In our study, asymptomatic individuals with specific ultrasound findings displayed intriguing correlations with T2 MRI signals. Asymptomatic patients with Focal Fat Infiltration showed hypointense T2 MRI signals, while those with Diffuse Fat Infiltration exhibited moderate hyperintense signals. However, statistical significance was not reached for ultrasound findings and T2 MRI results (p-value = 0.091). Ultrasound Grade I corresponded to higher In & Out Phase MRI values, while Ultrasound Grade II was linked to lower percentages. These data suggest an impact of ultrasound-detected fat infiltration on magnetic resonance properties **(Zhang et al., 2018; Rajamani et al., 2022). Bohte et al.'s study (2012),** however, indicated limited accuracy of ultrasound alone in predicting steatosis presence or severity, especially in severely obese adults, highlighting the need for additional MRI usage. Notably, their use of a different MRI technique prevents direct comparison to our results.

In the **Stahlschmidt et al. (2023)** study, ultrasound accuracy was compared with MRS for detecting and grading hepatic steatosis in NAFLD patients. High sensitivity (100%) was observed for moderate to severe HS detection and satisfactory sensitivity (97.2%) for slight HS. Moderate specificity (60%) was reported in ultrasound grading, with challenges in certain cases. Weak to moderate agreement between ultrasound and MRS HS grading was noted, with ultrasound sometimes indicating greater severity.

Similarly, **Kromrey et al. study (2019)** assessed ultrasound accuracy for ruling out hepatic steatosis using MRI as the reference standard. B-mode sonography exhibited 74.5% sensitivity and 86.6% specificity for detecting HS, with a conclusion that ultrasound is an effective tool for assessing HS in a clinical setting, albeit with limitations in low liver fat content patients.

Conclusion

In conclusion, our study highlights a noteworthy alignment between MRI and ultrasound results in diagnosing Hepatic Steatosis, particularly among patients with diffuse fat infiltration exhibiting corresponding T1 hyperintense and T2 mild hyperintense signals.

References

- **Ahmed MH, Noor SK, Bushara SO, Husain NE, Elmadhoun WM, Ginawi IA et al .(2017).** Non-alcoholic fatty liver disease in Africa and Middle East: an attempt to predict the present and future implications on the healthcare system. Gastroenterology research, 10(5): 271.
- **Apostolopoulos AP, Angelis S, Yallapragada RK, Khan S, Nadjafi J, Balfousias T et al. (2019).** The sensitivity of magnetic resonance imaging and ultrasonography in detecting rotator cuff tears, Cureus, 11(5): e4581.
- **Bachtiar V, Kelly MD, Wilman HR, Jacobs J, Newbould R, Kelly CJ et al .(2019).** Repeatability and reproducibility of multiparametric magnetic resonance imaging of the liver. PloS one, 14(4): e0214921.
- **Ballestri S, Nascimbeni F, Lugari S, Lonardo A, Francica G.(2019).** A critical appraisal of the use of ultrasound in hepatic steatosis. Expert review of gastroenterology & hepatology, 13(7): 667-681.
- **Bohte AE, Koot BG, van der Baan-Slootweg OH, Rijcken THP, van Werven JR, Bipat S et al. (2012).** US cannot be used to predict the presence or severity of hepatic steatosis in severely obese adolescents. Radiology, 262(1): 327-334.
- **Bril F, Ortiz- Lopez C, Lomonaco R, Orsak B, Freckleton M, Chintapalli K et al. (2015).** Clinical value of liver ultrasound for the diagnosis of nonalcoholic fatty liver disease in overweight and obese patients. Liver International, 35(9): 2139-2146.
- **de Vries M, Westerink J, Kaasjager KH, de Valk HW. (2020).** Prevalence of nonalcoholic fatty liver disease (NAFLD) in patients with type 1 diabetes mellitus: a systematic review and meta-analysis. The Journal of Clinical Endocrinology & Metabolism, 105(12): 3842-3853.
- **Erden A, Öz DK, Peker E, Kul M, Ateş FSÖ, Erden İ, İdilman R. (2021).** MRI quantification techniques in fatty liver: the diagnostic performance of hepatic T1, T2, and stiffness measurements in relation to the proton density fat fraction. Diagnostic and Interventional Radiology, 27(1): 7.
- **Ferraioli G, Kumar V, Ozturk A, Nam K, de Korte CL, Barr RG et al. (2022).** US attenuation for liver fat quantification: an AIUM-RSNA QIBA pulse-echo quantitative ultrasound initiative. Radiology, 302(3): 495-506.

- **Ferraioli G, Monteiro LBS. (2019).** Ultrasound-based techniques for the diagnosis of liver steatosis. World journal of gastroenterology, 25(40): 6053.
- **Hernaez R, Lazo M, Bonekamp S, Kamel I, Brancati FL, Guallar E, Clark JM et al. (2011).** Diagnostic accuracy and reliability of ultrasonography for the detection of fatty liver: a meta- analysis. Hepatology, 54(3): 1082-1090.
- **Ibacahe C, Correa-Burrows P, Burrows R, Barrera G, Kim E, Hirsch S et al. (2020).** Accuracy of a semi-quantitative ultrasound method to determine liver fat infiltration in early adulthood. Diagnostics, 10(6): 431.
- **Jeon SK, Lee JM, Joo I, Park SJ. (2021).** Quantitative ultrasound radiofrequency data analysis for the assessment of hepatic steatosis in nonalcoholic fatty liver disease using magnetic resonance imaging proton density fat fraction as the reference standard. Korean journal of radiology, 22(7): 1077.
- **Kromrey ML, Ittermann T, Berning M, Kolb C, Hoffmann RT, Lerch MM et al. (2019).** Accuracy of ultrasonography in the assessment of liver fat compared with MRI. Clinical radiology, 74(7): 539-546.
- **Ma Y, Jang H, Jerban S, Chang EY, Chung CB, Bydder GM et al. (2022).** Making the invisible visible—ultrashort echo time magnetic resonance imaging: Technical developments and applications. Applied Physics Reviews, 9(4), e 111825.
- **Makhija N, Vikram NK, Srivastava DN, Madhusudhan KS. (2021).** Role of diffusion-weighted magnetic resonance imaging in the diagnosis and grading of hepatic steatosis in patients with non-alcoholic fatty liver disease: comparison with ultrasonography and magnetic resonance spectroscopy. Journal of Clinical and Experimental Hepatology, 11(6): 654-660.
- **Misra A, Dhurandhar NV. (2019).** Current formula for calculating body mass index is applicable to Asian populations. Nutrition & diabetes, 9(1): 3.
- **Muthiah MD, Cheng Han N, Sanyal AJ. (2022).** A clinical overview of non- alcoholic fatty liver disease: a guide to diagnosis, the clinical features, and complications—what the non- specialist needs to know. Diabetes, Obesity and Metabolism, 24(1), 3-14.
- **Paige JS, Bernstein GS, Heba E, Costa EA, Fereira M, Wolfson T et al. (2017).** A pilot comparative study of quantitative ultrasound, conventional ultrasonography, and magnetic resonance imaging for predicting histology- determined steatosis grade in adult nonalcoholic fatty liver disease. Am J Roentgenol, 208(1), W1-W10.
- **Papatheodoridi M, Cholongitas E. (2018).** Diagnosis of non-alcoholic fatty liver disease (NAFLD): current concepts. Current pharmaceutical design, 24(38): 4574- 4586.
- **Pasanta D, Htun KT, Pan J, Tungjai M, Kaewjaeng S, Kim H et al. (2021).** Magnetic resonance spectroscopy of hepatic fat from fundamental to clinical applications. Diagnostics, 11(5): 842.
- **Qureshi MM, Saleem H, Bacha R, Shah RA. (2020).** Comparison of Ultrasonography with Magnetic Resonance Imaging for the Diagnosis of Liver Steatosis, 6(2): 121-133.

- **Rajamani AS, Rammohan A, Sai VR, Rela M. (2022).** Current techniques and future trends in the diagnosis of hepatic steatosis in liver donors: A review. Journal of Liver Transplantation, 7(1): 100091.
- **Seneviratne N, Fang C, Sidhu PS. (2023).** Ultrasound-based hepatic fat quantification: current status and future directions. Clinical Radiology, 78(3): 187-200.
- **Stahlschmidt FL, Weber IL, Ludwig MV, Feuerschuette LM. (2023).** Steatosis Grading Comparison Between Qualitative Ultrasonography and Magnetic Resonance Spectroscopy in Patients With Nonalcoholic Fatty Liver Disease. Journal of Diagnostic Medical Sonography, 39(1): 33-41.
- **Tamaki N, Ajmera V, Loomba R. (2022).** Non-invasive methods for imaging hepatic steatosis and their clinical importance in NAFLD. Nature Reviews Endocrinology, 18(1): 55-66.
- **Watanabe A, Ramalho M. AlObaidy M, Kim HJ, Velloni FG, Semelka RC et al. (2015).** Magnetic resonance imaging of the cirrhotic liver: An update. World journal of hepatology, 7(3): 468.
- **Zech CJ, Ba-Ssalamah A, Berg T, Chandarana H, Chau GY, Grazioli L et al. (2020).** Consensus report from the 8th international forum for liver magnetic resonance imaging. European radiology, 30(1): 370-382.
- **Zhang YN, Fowler KJ, Hamilton G, Cui JY, Sy EZ, Balanay M et al. (2018).** Liver fat imaging—a clinical overview of ultrasound, CT, and MR imaging. The British journal of radiology, 91(1089): 20170959.
- **Zhen SH, Cheng M, Tao YB, Wang YF, Juengpanich S, Jiang ZY et al .(2020).** Deep learning for accurate diagnosis of liver tumor based on magnetic resonance imaging and clinical data. Frontiers in oncology, 10(1): 680.