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Original Article

Radiology Section

Ultrasound of Hepatic Vessels in Fatty Liver Disease

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ABSTRACT

Introduction: Fatty liver is characterised by triglyceride accumulation within the cytoplasm of hepatocytes and is graded based on degree of increased liver echotexture on ultrasonography. Various disease processes affecting liver including fatty liver have characteristic effect on haemodynamics of the liver and affect the hepatic vessels waveforms.

Aim: The purpose of the study was to investigate the effect of the fatty liver disease on hepatic artery Resistive Index (RI) and hepatic vein waveform.

Materials and Methods: Total 119 patients were examined using B-mode and Doppler sonography. Patients were divided into Grade 0 (control group) with normal liver and Grade 1, 2, 3 according to severity of fatty liver. According to the waveform patterns, the hepatic vein waveforms were classified into three groups: triphasic, biphasic and monophasic patterns. The hepatic artery was sampled at porta hepatis and RI was calculated. Statistical analysis was performed using SPSS software with application of ANOVA test and t-test.

Results: Thirty-nine patients with Grade 1, 29 patients with Grade 2, 11 patients with Grade 3 fatty liver and 40 subjects in control group were included in present study. Mean hepatic artery RI was 0.75±0.03 in control group and 0.62±0.07 in the Grade 1, 0.59±0.04 in the Grade 2 and 0.59±0.07 in the Grade 3 fatty liver groups. The difference in mean hepatic artery RI amongst the control and fatty liver groups was found to be statistically significant ($p<0.001$). Abnormal hepatic vein waveform (biphasic/ monophasic) was seen in 52 (65.8 %) out of 79 patients of fatty liver. The incidence of abnormal hepatic vein waveform increased as the ultrasound severity grade of fatty liver increased and difference between control and fatty liver groups was found to be statistically significant ($p<0.001$).

Conclusion: The hepatic artery RI decreases as the severity grades of fatty liver increases. The difference in the mean hepatic artery RI amongst various grades of fatty liver was statistically significant ($p<0.001$). The incidence of abnormal hepatic vein waveforms (biphasic/ monophasic) increases as severity of fatty liver increases and the difference between control and fatty liver groups was statistically significant ($p<0.001$).

Keywords: Biphasic, Hepatic artery resistive index, Monophasic, Triphasic

INTRODUCTION

Fatty liver is one of the commonly encountered condition in routine ultrasound practice and occurs due to an impairment of the normal processes of synthesis and elimination of fat and is characterised by triglyceride accumulation within the cytoplasm of hepatocytes [1,2]. Alcoholic liver disease and non-alcoholic fatty liver disease are the two most common conditions associated with fatty liver [3]. Alcoholic liver disease is caused by excess alcohol consumption, whereas the non-alcoholic fatty liver is related to Type II diabetes, obesity, hypertriglyceridaemia, metabolic abnormalities, dietary and nutritional abnormalities and congenital disorders.

Fatty liver or steatosis may progress to steatohepatitis with accompanying necrosis and significant inflammation in hepatocytes, cell injury leading to fibrosis and then cirrhosis [3-5]. The fatty liver has been divided into three grades according to the severity based on the degree of increased liver echotexture on ultrasonography. Major hepatic vessels show typical waveform changes in various disease processes affecting the liver due to their characteristic effect on the haemodynamic hepatic blood flow patterns [6]. The effect of intrahepatic fat deposition on the flow patterns of the hepatic vessels is not completely known [7]. However, many research studies had inferred that diffuse fatty infiltration of the liver may cause altered flow patterns in the hepatic veins and Doppler indices of hepatic artery [7-12].

The aim of the study was to evaluate the haemodynamic changes in hepatic artery and hepatic vein in patients with

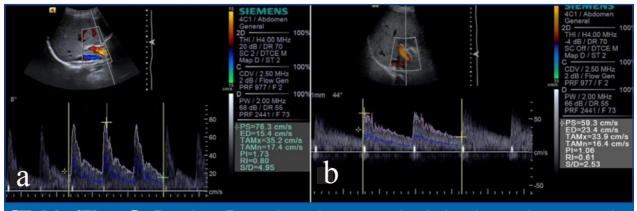
fatty liver and compare the differences between the patients with alcoholic and non-alcoholic fatty liver disease.

MATERIALS AND METHODS

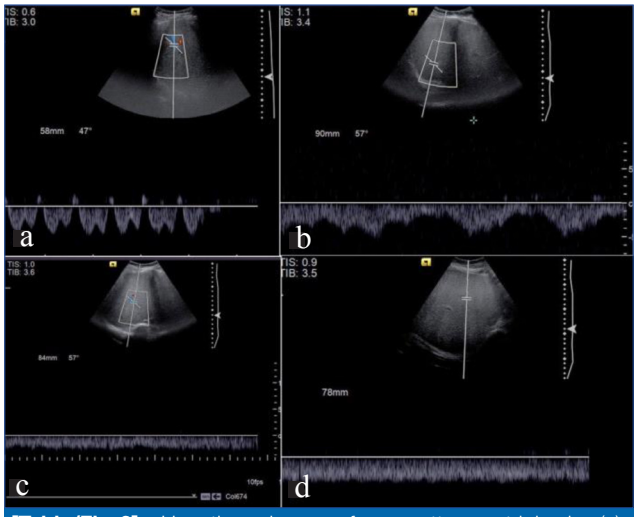
This hospital based prospective case-control study was carried out in the Department of Radiodiagnosis of Medical College and tertiary Hospital.

Written informed consent was obtained from all patients. The college ethics committee approved the study. The patients who were referred for ultrasound abdomen and found to have fatty liver disease were included in the study. Total 119 patients (68 males and 51 females) were studied from July 2014 to June 2017 over the duration of 3 years. The patients were evaluated for liver size, liver echotexture, grade of fatty liver, hepatic artery RI and hepatic vein waveform pattern. Patients who had liver mass, liver cirrhosis, congestive changes in liver, portal vein pathology, hepatitis, Wilson's disease, haemochromatosis and heart failure were excluded from the study. The detailed history of patients was documented at the time of initial visit with liver specific history including history of alcoholism, storage disorders, obesity and metabolic diseases. B-mode ultrasonography of liver and color and spectral Doppler of hepatic artery and vein were performed with SIEMENS ACUSON S2000 machine using 3.5 MHz convex array transducer. Patients were examined in supine and left lateral decubitus position and intercostal and subcostal approach were used for the assessment of the liver. Image optimisation with appropriate depth and enhancement was done. The maximum craniocaudal dimension of the liver was obtained in midclavicular line and hepatomegaly was defined as the mid clavicular long axis dimension of the liver being longer than 155 mm [13]. The four groups were defined as normal (Grade 0) with normal liver echotexture; and Mild (Grade 1); Moderate (Grade 2); and Severe (Grade 3) fatty liver, according to the degree of diffuse fatty infiltration of the liver seen in terms of mild, moderate and marked increase of liver parenchymal echotexture on ultrasound respectively. The patients were asked to hold breath for a moment in shallow inspiration for the Doppler study of hepatic vessels. Average 3 to 4 cycles of spectral waveform were obtained and analysed. The Doppler angle was maintained between 30 to 60 degrees.

The hepatic artery was sampled at porta hepatis area where hepatic artery passes anterior to the portal vein and hepatic artery RI was measured [Table/Fig-1a,b]. The hepatic veins were evaluated through right lateral intercostal approach with patient in left lateral decubitus position and right or middle hepatic veins were sampled 3-5 cm away from inferior vena cava. The hepatic vein spectral waveform patterns were classified into three groups: Group 1-regular triphasic waveform, Group 2-biphasic waveform with loss of reverse flow, and Group 3-monophasic or flat waveform [Table/Fig-2a-d].



[Table/Fig-1]: Duplex Doppler ultrasound of the hepatic artery in normal patient (a) and fatty liver patient (b).



[Table/Fig-2]: Hepatic vein waveform patterns: triphasic (a), biphasic without a reverse flow (b) and monophasic or flat waveform (c,d).

STATISTICAL ANALYSIS

Statistical analysis was performed using SPSS software, Version 20.0 with application of ANOVA test and sample t-test. The quantitative data variables were expressed in mean±standard deviation and in percentage (%). One-way ANOVA test was used to compare the mean liver size and mean values of hepatic artery RI for various grades of fatty liver. Chi-square test/Fisher's exact test was used to find the significant association between grades with various qualitative data variables. Two independent sample t-test was used for intergroup comparison of averages. p-values <0.05 were considered statistically significant.

RESULTS

The study included 119 subjects out of which 68 (57.14 %) were males and 51 (42.86 %) were females. On gray-scale ultrasound examination, there was no evidence of raised echogenicity in liver parenchyma in the control group and the degree of fatty infiltration was graded as Grade 0. Diffuse fatty liver was sonologically graded in mild (Grade 1), moderate (Grade 2) and severe (Grade 3) grades based on mild, moderate and marked diffuse increase in hepatic echogenicity respectively.

Thirty-nine patients with Grade 1 fatty liver, 29 patients with Grade 2 fatty liver, 11 patients with Grade 3 fatty liver and

USG Fatty Liver Grading	No. of Patient (n)	Hepatic Artery RI						
		Mean	Std. Deviation	Std. Error	95% CI for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Grade 0	40	0.7548	0.03544	0.00560	0.7434	0.7661	0.69	0.81
Grade 1	39	0.6292	0.07098	0.01137	0.6062	0.6522	0.36	0.71
Grade 2	29	0.5938	0.04887	0.00908	0.5752	0.6124	0.45	0.68
Grade 3	11	0.5991	0.07382	0.02226	0.5495	0.6487	0.49	0.69

[Table/Fig-3]: Hepatic artery resistive index according to ultrasound grading of the fatty liver.
* ANOVA test was used; CI-Confidence interval

40 subjects in the control grade 0 group were included in present study. The Grade 1 fatty liver group mean age was 45.00±12.34 years (range 24-68 years), Grade 2 fatty liver group mean age was 40.90±14.26 years (range 23-78 years), Grade 3 fatty liver group mean age was 45.82±11.81 years (range 31-64 years), and the control group mean age was 41.88±14.52 years (range 21-75 years). The mean age of fatty liver patients and control groups was not statistically different (p =0.515). The patients were further divided into alcoholic (Grade 0-4, Grade 1-18, Grade 2-15, Grade 3-6) and non-alcoholic (Grade 0-36, Grade 1-21, Grade 2-14, Grade 3-5) groups.

Mean craniocaudal dimension of liver in midclavicular line was 13.25±1.08 cm in the control group and 14.13±1.73 in Grade 1 fatty liver, 14.72±1.46 in Grade 2 and 15.55±1.63 in Grade 3 patients. Out of 79 patients of fatty liver, hepatomegaly was seen in 21 (26.5) patients while liver size was normal in 58 (73.4) patients. The liver size increased with the degree of fatty infiltration and the difference between mean liver size in control group (Grade 0) and fatty liver group (Grade 1,2,3) was statistically significant (p<0.001).

Mean hepatic artery RI was 0.75±0.03 in control group and 0.62±0.07 in the Grade 1 fatty liver group, 0.59±0.04 in the Grade 2 fatty liver group and 0.59±0.07 in the Grade 3 fatty liver group [Table/Fig-3]. The patients with a higher grade of fatty liver showed relatively lower hepatic artery RI in our study. The difference in the mean hepatic artery RI amongst the control group (grade 0) and fatty liver groups (grade 1,2,3) was found to be statistically significant (p<0.001). The difference between Mean hepatic artery RI in alcoholic and non-alcoholic fatty liver patients were not statistically significant [Table/Fig-4].

Hepatic vein flow patterns according to fatty liver grades are shown in [Table/Fig-5]. Out of 40 patients in the control group,

USG Fatty Liver Grading	Alcoholic/ Non Alcoholic Fatty Liver	No. of Patients (N)	Hepatic artery RI		p-value
			Mean	SD	
Grade 1	Alcoholic	18	0.61	0.09	0.159
	Non-alcoholic	21	0.64	0.05	
Grade 2	Alcoholic	15	0.59	0.04	0.902
	Non-alcoholic	14	0.60	0.06	
Grade 3	Alcoholic	6	0.62	0.07	0.418
	Non-alcoholic	5	0.58	0.08	

[Table/Fig-4]: Hepatic artery RI in alcoholic and non-alcoholic fatty liver patients.
*Two independent sample t-test was used to calculate difference in mean between the two groups

Hepatic Waveform	Grade 0 n=40 (%)	Grade 1 n=39 (%)	Grade 2 n=29 (%)	Grade 3 n=11 (%)
Triphasic	35 (87.5)	17 (43.5)	9 (31)	1 (9.1)
Biphasic	5 (12.5)	16 (41)	2 (6.9)	2 (18.2)
Monophasic	0 (0)	6 (15.4)	18 (62.1)	8 (72.7)

[Table/Fig-5]: Hepatic vein flow pattern according to fatty liver grades.
*Fisher's exact test was used to determine associations between categorical variables

hepatic vein waveform was triphasic in 35 (87.5%) patients and biphasic in 5 (12.5%) patients. Out of these 5 patients with biphasic waveform, only one had history of alcoholism. In 39 patients with Grade 1 fatty liver, hepatic vein waveform was triphasic in 17 (43.5 %) patients, biphasic in 16 (41 %) patients and monophasic in 6 (15.4%) patients. Out of 29 patients of the Grade 2 fatty liver, hepatic vein waveform was triphasic in 9 (31%) patients, biphasic in 2 (6.9%) patients and monophasic in 18 (62.1%) patients. In 11 patients with Grade 3 fatty liver, hepatic vein waveform was triphasic in 1(9.1%)

Hepatic Vein Waveform Pattern	Control	Fatty Liver Group				p-value
	Grade 0 n=40 (%)	Grade 1 n=39 (%)	Grade 2 n=29 (%)	Grade 3 n=11 (%)	Total n=79 (%)	
Normal (Triphasic)	35 (87.5)	17 (43.9)	9 (31)	1 (9.1)	27 (34.2)	< 0.001
Abnormal (Bi/Monophasic)	5 (12.5)	22 (56.4)	20 (69)	10 (90.9)	52 (65.8)	

[Table/Fig-6]: Analysis of hepatic vein waveform pattern in control and fatty liver groups.
*Fisher's exact test was used

patient, biphasic in 2 (18.2 %) patients and monophasic in 8 (72.7%) patients. Abnormal hepatic vein waveform (biphasic and monophasic) was seen in 52 (65.8 %) out of 79 patients of fatty liver [Table/Fig-6]. The abnormal hepatic vein waveform (biphasic/ monophasic) incidence was 22 (56.4 %) for Grade 1, 20 (69 %) for Grade 2, 10 (90.9 %) for Grade 3 and 5 (12.5 %) for Grade 0 or control group patients. The incidence of abnormal hepatic vein waveform increased as the ultrasound severity grade of fatty liver increased. The distribution of normal and abnormal hepatic vein waveform pattern between patients of control group (Grade 0) and fatty liver group (Grade 1, 2, 3) was statistically significant (p<0.001). Out of total 57 patients (control group-5, Fatty liver group-52) with abnormal hepatic vien waveform, 28 patients were alcoholic and 29 were non-alcoholic patients. The difference between abnormal hepatic vein waveform in alcoholic versus non-alcoholic patients was not significant (p=0.535).

DISCUSSION

Fatty liver or steatosis occurs due to impairment of the normal processes of synthesis and elimination of fat resulting in loss of balance between the processes of delivery and removal of lipids [1,2]. Fatty liver is characterised by triglyceride accumulation within the cytoplasm of hepatocytes. Alcoholic liver disease and non-alcoholic fatty liver disease are the two most common conditions associated with fatty liver [3]. Alcoholic liver disease is caused by excess alcohol consumption, whereas the non-alcoholic fatty liver is related to Type II diabetes, obesity, hypertriglyceridaemia, metabolic abnormalities like galactosaemia, glycogen storage diseases, homocystinuria, and tyrosinaemia, dietary and nutritional abnormalities and congenital disorders. Lipid is also present in normal liver and liver is defined as fatty whenever the amount of lipid in liver, mostly in a form of triacylglycerol, is more than 5% [14,15]. Based on the amount of lipids in liver, fatty liver is further divided into mild (accounting 5%-10% of liver), moderate (accounting for 10%-25% of liver), and severe (accounting for over 25% of liver). Fatty liver or steatosis may progress to steatohepatitis with accompanying necrosis and significant inflammation in hepatocytes, cell injury leading to fibrosis and then cirrhosis resulting in liver related morbidity and mortality [3-5].

Liver biopsy and histologic analysis is considered the diagnostic gold standard for the assessment of fatty liver. However, fatty liver also can be diagnosed with USG and use of cross-sectional imaging like Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) [3]. Imaging in fatty liver disease is needed to confirm the diagnosis, exclude other unsuspected causes of liver disease, assess the degree of involvement and to define the prognosis. Ultrasonography is the most preferable initial diagnostic method for fatty liver as it is quick, readily available, cost effective with no radiation risk. However, ultrasound has limitations which include interobserver variation and lack of objectivity [3,16].

The fatty liver has been divided into three grades according to the severity based on the degree of increased liver echotexture on ultrasonography depending on the amount of fat deposition in liver. Diffuse fatty liver [11,16-18] can be sonologically graded in mild (Grade 1), moderate (Grade 2) and severe (Grade 3) fatty liver. Mild (Grade 1) fatty liver shows mild diffuse increase in hepatic echogenicity with normal visualisation of diaphragm and intrahepatic vessel borders. Moderate (Grade 2) fatty liver has moderate diffuse increase in hepatic echogenicity with slightly impaired visualisation of intrahepatic vessels and diaphragm. Severe (Grade 3) fatty liver shows noticeable increase in hepatic echogenicity and poor penetration of the posterior segment of the right diaphragm.

Every disease process that affects the liver has its own characteristic effect on the hemodynamic blood flow patterns of the liver, causing unique waveforms changes in major hepatic vessels [6]. The effect of intrahepatic fat deposition on the flow patterns of the hepatic vessels is not completely known [7]. Many research studies had inferred that diffuse fatty infiltration of the liver may cause altered flow patterns in the hepatic veins and doppler indices of hepatic artery [7-11].

The hepatic artery is a low-resistance vessel and wider normal ranges of 0.55-0.81 RI have been reported for this vessel [6]. Low hepatic arterial resistance is more specific for disease and has been associated with proximal arterial narrowing, celiac or hepatic atherosclerotic disease, arcuate ligament syndrome and distal vascular shunts, arteriovenous fistulas, cirrhosis with portal hypertension, arteriovenous or arterioportal shunts and Osler-Weber-Rendu syndrome with arteriovenous fistulas. Mihmanli et al., found that RI of hepatic artery decreases gradually as severity of fatty infiltration increases [10]. Mohammadi A et al., in a similar study also reported decrease in the hepatic artery RI as the grade of fatty liver increased. They found hepatic artery RI of 0.81 (+ or-0.02), 0.78 (+ or-0.03), 0.73 (+ or-0.03), and 0.68 (+ or-0.05), respectively, in normal patients (group A), patients with mild (group B), moderate (group C), and severe (group D) fatty liver respectively which was significantly different between groups (p < 0.001) [11]. In our study, we found that the hepatic artery RI showed significant reduction as the grades of fatty liver increased. Mean hepatic artery RI was 0.75±0.03 in control group and 0.62±0.07 in the Grade 1 fatty liver group, 0.59±0.04 in the Grade 2 fatty liver group and 0.59±0.07 in the Grade 3 fatty liver group in present study [Table/Fig-3]. The difference in the mean hepatic artery RI amongst the various groups was found to be statistically significant (p<0.001). The patients with a higher grade of fatty liver showed relatively lower hepatic artery RI in our study and the hepatic artery RI decreased as the grade of fatty liver increased which was also reported by Mohammadi A et al.,

[11]. Balasubramanian P et al., [19] also reported significantly less hepatic artery RI in patients with non-alcoholic fatty liver disease with better correlation with the severity of disease when compared to controls due to an increased hepatic arterial flow. The difference between mean hepatic artery RI in alcoholic and non-alcoholic fatty liver patients in our study were not statistically significant [Table/Fig-4].

The hepatic veins have characteristic triphasic waveform pattern, which consists of three peaks; antegrade systolic and diastolic flow, and a short retrograde flow by right atrial systole [8]. An alteration in hepatic parenchymal compliance, pressure of the right atrium or pressure differences during respiration in the thoracoabdominal cavity affects the triphasic waveform pattern [6, 20]. It has been demonstrated that decreased phasicity of hepatic veins with biphasic or monophasic waveform is associated with cirrhosis, fibrosis, hepatitis, transplant rejection, hepatic vein thrombosis (Budd-Chiari syndrome), hepatic veno-occlusive disease, and fatty liver [6-9,20-22].

Abnormal hepatic vein waveform pattern was seen in 52 (65.8 %) out of 79 patients of fatty liver disease in the present study. This finding matches with the study by Tunçyürek O et al., who reported abnormal HV Doppler waveform in 119 (65%) of 181 cases of diffuse fatty liver and reported correlation between fatty liver grade and HV Doppler waveforms (p=0.03) [23]. We also found that the incidence of abnormal hepatic vein waveforms (biphasic and monophasic) increased as the ultrasound severity grade of fatty liver increased and was 22 (56.4 %) for grade 1, 20 (69 %) for grade 2, 10 (90.9 %) for grade 3 fatty liver patients. The difference in presence of abnormal hepatic vein waveform pattern (biphasic or monophasic) between patients of control group (Grade 0) and fatty liver group (grade 1, 2, 3) was statistically significant (p<0.001). Mohammadinia AR et al., in their study reported the incidence of monophasic and biphasic hepatic vein waveform as 2 (10%) for mild fatty liver group, 11 (55%) for moderate fatty live group, 16 (80%) for severe fatty liver group and none for control group [25]. They reported significant difference (p < 0.001) in the distribution of hepatic vein triphasic Doppler waveform pattern between the patients and the control group [24]. Alizadeh A et al., found significant association of triphasic and monophasic pattern of hepatic veins with fatty liver grade on sonography evaluation [25]. Oguzkurt L et al., reported abnormal HV Doppler waveform in 43% patients with fatty infiltration of liver and only 2% of healthy subjects had an abnormal waveform. They also found that difference in the distribution of Doppler waveform pattern between the patients and the control group was significant (p < 0.001) [8]. However, Oguzkurt L et al., did not find any relation between the degree of fat infiltration and the hepatic vein waveform pattern [8]. Oguzkurt L et al., also found no difference in behaviours of hepatic vein doppler waveform in relation to the different etiological factors for fatty liver [8]. The difference between abnormal hepatic vein waveform in alcoholic versus non-alcoholic fatty liver patients was also not significant (p=0.535) in our study.

The volume of the hepatocytes increases due to accumulation of fat in fatty liver producing reduced liver parenchymal compliance. This causes reduction in size of the hepatic sinusoids with decreased hepatic microcirculation and vascular compliance, leading to ischaemia and in long term to fibrosis [11,23,26]. The decreased liver parenchyma compliance in diffuse liver disease like fatty liver with progression of fibrosis causes reduced phasicity in hepatic vein waveforms [11]. Liver fibrosis can cause further damage to the sinusoids and increased resistance to the portal vein flow with decrease in flow velocity of the portal vein. This results in compensatory increase in the hepatic artery diastolic flow with reduction in the RI of hepatic artery [11,12]. Various studies in literature including the present study have reported abnormal hepatic vein waveform and reduction in hepatic artery RI in fatty liver [7-12,19,23-26] irrespective of etiology [8] and liver size [23]. The studies have also found correlation of decreased hepatic artery RI [10,11] and abnormal hepatic vein waveform [24-26] with the grades of fatty liver. Abnormal hepatic Vein Doppler waveform have also been reported in patients with cirrhosis [6,21,22,27] with positive correlation between Child-Pugh score and flat waveform [22]. Therefore, it is important to diagnose and characterize flow abnormalities in hepatic vessels in fatty liver and evaluate the liver for associated focal or diffuse liver fibrosis [11,12].

LIMITATION

The limitation of our study was that the biopsy was not performed to confirm the diagnosis of fatty liver and also presence or absence any other coexisting liver disease. However, strict sonography criteria were applied for diagnosis and grading of the fatty liver in all patients.

CONCLUSION

In conclusion, the hepatic artery RI decreases significantly as the severity grades of fatty liver increases and shows statistically significant difference amongst the various grades of fatty liver. The incidence of abnormal hepatic vein waveforms (biphasic and monophasic) increases as the ultrasound severity grade of fatty liver increases and is statistically significant between patients of control group and fatty liver group. The difference between abnormal hepatic vein waveform and reduction in hepatic artery RI in alcoholic versus non-alcoholic fatty liver patients is not significant.

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