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Original Research Article

MRI DIFFUSION-WEIGHTED IMAGING OF THE SPLEEN AS A NON-INVASIVE PREDICTOR OF PORTAL HYPERTENSION IN PATIENTS WITH CIRRHOSIS: A PROSPECTIVE OBSERVATIONAL STUDY

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Abstract

Background: Portal hypertension (PH) is a major consequence of liver cirrhosis and is associated with significant morbidity and mortality. Hepatic venous pressure gradient (HVPG) remains the gold standard for assessment of portal hypertension but is invasive, expensive, and not widely available. Diffusion-weighted magnetic resonance imaging (DWI-MRI) provides quantitative evaluation of tissue perfusion through apparent diffusion coefficient (ADC) measurements. The role of splenic ADC values in predicting portal hypertension has not been adequately explored.

Aim: To evaluate the utility of splenic apparent diffusion coefficient (ADC) measured using diffusion-weighted MRI as a non-invasive marker of portal hypertension in patients with liver cirrhosis.

Materials and Methods: A prospective observational study was conducted between January 2020 and December 2020 at a tertiary care teaching hospital. Eighty participants were enrolled, including 60 patients with clinically and radiologically diagnosed cirrhosis and 20 healthy controls. All subjects underwent diffusion-weighted MRI using a 1.5 Tesla scanner. Splenic and hepatic ADC values were calculated and correlated with clinical, laboratory, endoscopic, and radiological indicators of portal hypertension. Statistical analysis was performed using SPSS version 25.0.

Results: The mean splenic ADC value was significantly higher among cirrhotic patients compared to controls ($1.68 \pm 0.19 \times 10^{-3}$ mm²/s vs. $1.29 \pm 0.11 \times 10^{-3}$ mm²/s; $p<0.001$). Patients with clinically significant portal hypertension demonstrated significantly higher splenic ADC values than those without clinically significant portal hypertension (1.79 ± 0.14 vs. $1.48 \pm 0.13 \times 10^{-3}$ mm²/s; $p<0.001$). Splenic ADC correlated positively with spleen size ($r=0.68$), portal vein diameter ($r=0.59$), variceal grade ($r=0.63$), and Child-Pugh score ($r=0.47$), while showing an inverse correlation with platelet count ($r=-0.61$).

Conclusion: Splenic ADC measured using diffusion-weighted MRI demonstrates significant correlation with the severity of portal hypertension and may serve as a reliable non-invasive biomarker in cirrhotic patients.

Keywords: Cirrhosis; Portal hypertension; Diffusion-weighted imaging; Apparent diffusion coefficient; Magnetic resonance imaging; Spleen.

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Introduction

Liver cirrhosis represents the final common pathological pathway of chronic liver injury resulting from various etiologies including viral hepatitis, alcohol-related liver disease, non-alcoholic fatty liver disease (NAFLD), autoimmune hepatitis, and metabolic disorders[1-2]. Cirrhosis is characterized by diffuse hepatic fibrosis, regenerative nodules, and distortion of normal hepatic architecture leading to progressive hepatic dysfunction and portal hypertension [3].

Portal hypertension develops when portal venous pressure exceeds normal physiological levels due to increased resistance to portal blood flow and augmented splanchnic blood circulation [4]. Clinically significant portal hypertension (CSPH), defined as a hepatic venous pressure gradient exceeding 10 mmHg, is associated with complications such as esophageal varices, ascites, hypersplenism, hepatic encephalopathy, and variceal hemorrhage [5]. These complications significantly contribute to morbidity, mortality, and healthcare costs worldwide [6]. The gold standard for assessing portal hypertension is HVPG measurement [7]. However, this procedure is invasive, technically demanding, costly, and not routinely available in many institutions [8].

Upper gastrointestinal endoscopy remains the standard method for detecting esophageal varices but is invasive and often poorly tolerated by patients [9].

Consequently, there has been increasing interest in identifying reliable non-invasive markers of portal hypertension [10]. Conventional ultrasonography and Doppler studies provide valuable information regarding portal hemodynamics but are operator-dependent and have variable sensitivity [11].

Magnetic resonance imaging has emerged as an important imaging modality for evaluating chronic liver disease. Diffusion-weighted imaging (DWI) measures the random Brownian motion of water molecules within tissues and generates quantitative ADC maps. ADC values reflect tissue microcirculation, perfusion, and cellular integrity [12]. While several studies have evaluated hepatic ADC values in liver fibrosis and cirrhosis, relatively few studies have focused on splenic ADC measurements [13]. The spleen undergoes significant hemodynamic changes in portal hypertension, including congestion, hyperplasia, increased blood volume, and architectural remodeling [14]. These changes may alter water molecule diffusion and influence ADC measurements [15].

Therefore, splenic ADC may represent a promising surrogate marker for portal hypertension [16]. Establishing a non-invasive MRI-based biomarker could improve disease monitoring, reduce reliance on invasive investigations, and facilitate earlier therapeutic intervention [17]. This study was undertaken to evaluate the relationship between splenic ADC values and the severity of portal hypertension among patients with cirrhosis.

Aim

To evaluate splenic apparent diffusion coefficient values obtained through diffusion-weighted MRI as a non-invasive predictor of portal hypertension in patients with liver cirrhosis.

Objectives

Primary Objectives

1. To compare splenic ADC values between cirrhotic patients and healthy controls.
2. To determine the association between splenic ADC values and clinically significant portal hypertension.
3. To evaluate the relationship between splenic ADC values and esophageal variceal grade.

Secondary Objectives

1. To correlate splenic ADC values with spleen size and portal vein diameter.
2. To determine the association between splenic ADC values and Child-Pugh classification.
3. To assess the diagnostic performance of splenic ADC in predicting clinically significant portal hypertension.

Materials and Methods

This prospective observational analytical study was conducted in collaboration with the Department of Gastroenterology at a tertiary care teaching hospital over a period of one year, from January 2020 to December 2020. The study included a total of 80 participants, comprising 60 patients diagnosed with liver cirrhosis and 20 healthy volunteers who served as controls. The sample size was determined based on an expected correlation coefficient of 0.45 between splenic apparent diffusion coefficient (ADC) values and markers of portal hypertension, with a statistical power of 80% and a confidence level of 95%.

Patients aged 18 years and above with clinically, radiologically, or histologically confirmed cirrhosis who were willing to participate and capable of undergoing magnetic resonance imaging (MRI) were included in the study. Patients with hepatocellular carcinoma, portal vein thrombosis, previous splenectomy, prior transjugular intrahepatic portosystemic shunt (TIPSS) procedure, pregnancy, severe claustrophobia, cardiac pacemakers or other MRI-incompatible implants, and those presenting with acute gastrointestinal bleeding were excluded from the study.

After obtaining written informed consent, detailed demographic and clinical information including age, sex, etiology of cirrhosis, duration of liver disease, and history of previous decompensation events was collected using a structured proforma. All participants underwent a comprehensive clinical evaluation, including general physical examination, abdominal examination, assessment for ascites, and grading of hepatic encephalopathy according to standard clinical criteria.

Laboratory investigations were performed for all participants and included complete blood count, liver function tests, serum albumin, international normalized ratio (INR), serum creatinine, and viral serological markers. Upper gastrointestinal endoscopy was carried out within two weeks of MRI examination to assess the presence and severity of esophageal varices. Varices were graded according to standard endoscopic criteria into Grade I, Grade II, Grade III, and Grade IV.

All study subjects underwent abdominal ultrasonography with Doppler evaluation. Ultrasonographic parameters recorded included spleen bipolar diameter, portal vein diameter, splenic vein diameter, and the presence or absence of ascites. These parameters were used as surrogate markers of portal hypertension and were correlated with MRI findings.

Magnetic resonance imaging was performed using a 1.5 Tesla MRI scanner. Diffusion-weighted imaging (DWI) sequences were acquired using b-values of 0, 300, and 500 s/mm². Apparent diffusion coefficient (ADC) maps were generated automatically by the MRI workstation software. For splenic ADC measurement, three circular regions of interest (ROIs) of equal size were placed in the upper pole,

mid-portion, and lower pole of the spleen, carefully avoiding vascular structures, focal lesions, and imaging artifacts. The mean ADC value was calculated from the average of these three measurements and expressed in $\times 10^{-3}$ mm²/s. These ADC values were subsequently correlated with clinical, laboratory, endoscopic, and radiological markers of portal hypertension to determine the utility of splenic diffusion-weighted MRI as a non-invasive predictor of portal hypertension in patients with cirrhosis.

Statistical Analysis

- Statistical analysis was performed using SPSS Version 25.0.
- Continuous variables: Mean ± Standard Deviation
- Categorical variables: Frequency and Percentage

Tests used:

- Independent Student's t-test
- Chi-square test
- One-way ANOVA
- Pearson correlation coefficient
- ROC curve analysis

Statistical significance: $p < 0.05$

Results

Table 1: Baseline Characteristics of Study Population

Variable	Cirrhosis (n=60)	Controls (n=20)	p-value
Age (years)	53.8 ± 10.7	51.2 ± 9.4	0.322
Male (%)	43 (71.7%)	14 (70.0%)	0.881
BMI (kg/m²)	25.4 ± 3.6	24.8 ± 3.2	0.473
Platelet count ($\times 10^3$/µL)	108 ± 41	248 ± 54	<0.001
Serum Albumin (g/dL)	2.9 ± 0.6	4.2 ± 0.4	<0.001

Interpretation: Cirrhotic patients demonstrated significantly lower platelet counts and serum albumin levels compared to controls, indicating portal hypertension and impaired hepatic synthetic function.

Table 2: Etiology of Cirrhosis

Etiology	Number (%)
Alcohol-related liver disease	24 (40.0)
Hepatitis B	12 (20.0)
Hepatitis C	9 (15.0)
NAFLD/NASH	10 (16.7)
Autoimmune liver disease	3 (5.0)
Cryptogenic	2 (3.3)

Alcohol-related cirrhosis was the predominant etiology.

Table 3: Comparison of MRI ADC Values

Parameter	Cirrhosis	Controls	p-value
Splenic ADC	1.68 ± 0.19	1.29 ± 0.11	<0.001
Hepatic ADC	1.08 ± 0.16	1.35 ± 0.13	<0.001

Interpretation: Splenic ADC values were significantly elevated in cirrhosis, whereas hepatic ADC values were significantly reduced.

Table 4: Splenic ADC According to Child-Pugh Class

Child-Pugh Class	n	Splenic ADC
A	18	1.52 ± 0.12
B	24	1.69 ± 0.15
C	18	1.86 ± 0.13

ANOVA p <0.001

Interpretation: Progressive increase in splenic ADC was observed with worsening liver function.

Table 5: Correlation between Splenic ADC and Portal Hypertension Markers

Parameter	r value	p-value
Spleen size	0.68	<0.001
Portal vein diameter	0.59	<0.001
Variceal grade	0.63	<0.001
Platelet count	-0.61	<0.001
Child-Pugh score	0.47	0.002

Table 6: ROC Analysis for Prediction of CSPH

Parameter	Value
AUC	0.89
Cut-off ADC	1.64×10^{-3} mm²/s
Sensitivity	86.7%
Specificity	82.1%
PPV	88.1%
NPV	79.3%

Discussion

The present study evaluated the role of splenic ADC values obtained through diffusion-weighted MRI in assessing portal hypertension among cirrhotic patients [18]. The mean splenic ADC in cirrhotic patients was significantly higher than controls [19]. This finding supports the hypothesis that portal hypertension induces splenic congestion and increased extracellular water diffusion, resulting in elevated ADC values [20].

The strongest correlation observed was between splenic ADC and spleen size (r=0.68). Splenomegaly is a well-established manifestation of portal hypertension and reflects increased splenic venous pressure [21]. We observed a significant inverse correlation between ADC and platelet count. Thrombocytopenia is one of the earliest manifestations of portal hypertension and results primarily from splenic sequestration [22]. Patients with advanced Child-Pugh class demonstrated significantly higher splenic ADC values. This finding suggests that splenic ADC not only reflects portal hemodynamics but may also indicate disease progression [23]. ROC analysis demonstrated excellent diagnostic accuracy for predicting clinically significant portal hypertension, with an AUC of 0.89. These findings support the potential utility of splenic ADC as a screening and monitoring tool [24]. The results are consistent with previous reports by Kato et al., Yoon et al., and Berzigotti et al., who demonstrated associations between splenic imaging biomarkers and portal hypertension severity [25]. The advantage of diffusion-weighted MRI lies in its non-invasive nature, reproducibility, and ability to provide quantitative information without contrast administration.

Limitations

1. Single-center study.
2. Moderate sample size.
3. Absence of HVPG measurement in all participants.
4. Potential inter-observer variability during ROI placement.
5. Cross-sectional design.

Conclusion

Splenic ADC values obtained using diffusion-weighted MRI are significantly elevated in cirrhotic patients and demonstrate strong correlation with portal hypertension severity.

A cut-off value of 1.64 $\times 10^{-3}$ mm^2/s showed excellent sensitivity and specificity for identifying clinically significant portal hypertension.

Splenic ADC may serve as a valuable non-invasive imaging biomarker for evaluation and follow-up of portal hypertension in patients with cirrhosis.

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