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Original Article

The Role of Elastography in the Evaluation of Disease Activity in Inflammatory Bowel Diseases

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Abstract

Objective: Inflammatory bowel disease (IBD) encompasses chronic inflammation of the intestinal mucosa, including ulcerative colitis and Crohn's disease. Various parameters, scoring systems, and imaging methods are used to evaluate disease activity and treatment outcomes. Ultrasound elastography is a non-invasive, radiation-free method that assesses intestinal fibrosis and activity. This study aimed to evaluate the efficacy of ultrasound elastography in assessing disease activity in IBD patients, both in remission and active phases.

Methods: This prospective descriptive study included 38 patients with ulcerative colitis and 22 with Crohn's disease. Disease activity in ulcerative colitis patients was evaluated using the Mayo score, Truelove-Witts score, and Endoscopic Activity Index (EAI), while Crohn's disease patients were assessed using the Crohn's Disease Activity Index (CDAI) and Harvey Bradshaw Index (HBI). Patients were categorized according to disease activity. An experienced radiologist used 2D shear wave elastography (SWE) to measure intestinal stiffness in kilopascals (kPa). Statistical analysis was conducted using the Kolmogorov-Smirnov and Mann-Whitney U tests. The ROC curve and Youden Index were applied to determine the cut-off value for diagnostic accuracy.

Results: The mean age of the patients was 43.4±14.5 years. A statistically significant positive correlation was found between intestinal wall thickness and HBI, CDAI, ESR, and CRP in the Crohn's disease group (P<0.001, P<0.001, P=0.005, P=0.001, respectively). In the ulcerative colitis group, a statistically significant correlation was also observed between intestinal wall thickness and TWS, Mayo score, EAI, ESR, and CRP (P<0.001, P<0.001, P<0.001, P=0.027, P<0.001, respectively). Additionally, a statistically significant correlation was found between tissue stiffness and HBI, CDAI, and CRP in Crohn's disease, and between tissue stiffness and TWS, Mayo score, EAI, ESR, and CRP in ulcerative colitis.

Conclusion: The study revealed a statistically significant correlation between stiffness measurements (kPa) obtained through 2D-SWE, intestinal wall thickness measured by transabdominal ultrasound, and disease activity scores. 2D-SWE is a valuable tool that can complement other clinical indicators in evaluating disease activity in IBD.

Keywords: Elastography, inflammatory bowel disease, ultrasound

INTRODUCTION

Inflammatory bowel disease (IBD) refers to disorders of the intestinal mucosa characterized by chronic inflammation, marked by periods of relapse and remission. The two primary forms of IBD are ulcerative colitis (UC) and Crohn's disease (CD).[1] Diagnosis, assessment of disease activity, and evaluation of treatment outcomes are guided by the patient's symptoms, physical examination, laboratory results, radiological imaging, and endoscopic and histological findings.

The Crohn's Disease Activity Index (CDAI) and the Harvey Bradshaw Index (HBI) are the most commonly used scoring systems for assessing CD activity, while the Mayo score and the Truelove-Witts Score (TWS) are frequently used for UC.[2,3] Although ileocolonoscopy is the preferred method for diagnosing IBD due to its ability to directly examine the mucosa and obtain tissue samples for pathological analysis, its use may be limited. The invasive nature of the procedure, along with the potential for discomfort and the risk of bowel perforation, can make it unsuitable in certain situations.[4] In CD, intestinal wall thickness is a commonly used parameter in cross-sectional imaging, as it correlates well with disease activity.[5,6]

Non-invasive methods for diagnosis and monitoring are crucial for the effective evaluation and ongoing assessment of IBD. Computed tomography (CT) and magnetic resonance (MR) enterography/enteroclysis are cross-sectional imaging techniques that aid in diagnosing intestinal diseases and contribute to characterizing IBD lesions and evaluating their response to treatment.[7,8] As a non-invasive method without radiation, conventional intestinal ultrasound (US) is commonly used to detect disease activity and complications in CD. However, the information obtained from conventional US may be insufficient to distinguish between inflammatory and fibrotic strictures.[9] In IBD, intestinal wall thickness and vascularization increase with disease activity. While intestinal wall thickness can be measured using conventional US, vascularity cannot be assessed with this method.

Various US techniques, including B-mode US, color Doppler ultrasonography (CDUS), contrast US, and SE, are utilized together in clinical settings to gather comprehensive information about the affected intestinal wall. These methods provide insights into the wall's structure, thickness, layering, blood vessel patterns, and elasticity or rigidity.[10] CDUS, like other US techniques, is a non-invasive, radiation-free, and contrast-free method that provides valuable information about the vascularization of the intestinal wall. Increased blood flow in the intestinal wall, as detected by CDUS, is associated with disease activity in the intestines. A scoring system for assessing intestinal wall vascularization was developed by Limberg.[11]

Since inflammation in patients with UC is confined to the mucosa, an increase in intestinal wall thickness may not always be observed, and the wall layers are generally preserved. As a result, when patients with UC are evaluated solely using B-mode US, it may not provide sufficient information regarding disease activation.[12,13]

In recent years, UE has emerged as a non-invasive method for evaluating disease activity in IBD. Its advantages include not requiring contrast material, being radiation-free, offering good reproducibility, and providing an objective evaluation. The most commonly used UE techniques are SE and shear wave elastography (SWE). There are two methods for generating images in SE. The first method involves applying controlled pressure with a probe to the area being evaluated, and the tissue's response is assessed. In the second method, results are obtained without applying pressure by using vascular pulsations or pressure differences created by respiration within the tissues. The first method is typically used for evaluating superficial tissues such as the breast and thyroid, while the second method is preferred for deeper organs like the liver.[14]

A novel method called SWE provides a quantitative assessment of tissue stiffness in real-time, without the need for external pressure. In SWE, the driving force is generated by ultrasound, specifically through an acoustic radiation force impulse (ARFI). ARFI induces the formation of transversely propagating shear waves, and the velocity of these waves varies according to the stiffness of the tissue. By measuring this wave velocity, tissue stiffness can be quantified. Data can be collected from either a focused area or a broader region, and displayed on color-coded maps. Shear wave velocity (m/s) or Young's modulus is used to calculate tissue elasticity, with the result expressed in kilopascals (kPa). On these maps, colors range from blue to red, with blue representing soft tissues and red indicating hard tissues.[15]

There are few studies on the use of UE in patients with IBD. Most research has focused on patients with CD, where the primary focus has been on evaluating fibrosis. UE, as a non-invasive and cost-effective method, assesses tissue elasticity and stiffness, with fibrosis indicating increased tissue stiffness.[16,17] UE can detect changes in tissue early, even before morphological alterations occur.[18]

MAIN POINTS

- Evaluation of disease activity in IBD using ultrasound elastography (UE), including strain elastography (SE) and SWE, has emerged as a non-invasive technique in recent years. Its advantages include not requiring contrast material, being radiation-free, offering good reproducibility, and providing objective evaluation.
- The study demonstrated a statistically significant association between disease activity scores, intestinal wall thickness measured via transabdominal ultrasound, and stiffness values (in kilopascals) obtained through 2D-SWE.
- UE is a bedside, reproducible, radiation-free, cost-effective, and easy-to-apply technique that can be more frequently utilized in daily clinical practice. It has the potential to enhance diagnostic functionality in IBD and offer clinical benefits in patient management.

The aim of this study was to compare UE findings in patients with active and remission stages of CD and UC, based on disease activity assessment scores, to determine the efficacy of UE.

MATERIAL AND METHODS

This single-center descriptive study evaluated 68 IBD patients who visited the Gastroenterology outpatient clinic at Gazi University Medical Faculty between May 1, 2021, and May 1, 2022. Patients younger than 18 years were excluded from the study. Additionally, six CD patients were excluded due to previous bowel resection, and two patients were excluded due to obesity. A total of 60 patients, consisting of 38 with UC and 22 with CD, were included in the study. The study design is summarized in Figure 1.

All patients were informed about the study, and informed consent was obtained. Exclusion criteria included patients with ascites, malignancy, prior IBD surgery, obesity (body mass index > 35 kg/m²), and those who did not voluntarily agree to participate. The study protocol was developed in accordance with the Declaration of Helsinki. Approval was granted by the Medical Ethics Committee of Gazi University Faculty of Medicine (Approval Number=795, Date: 24.10.2022), confirming that there were no ethical issues with conducting the study.

The demographic characteristics of IBD patients, including age, gender, smoking status, comorbidities, and medications used for IBD, were recorded. The Montreal classification was applied to categorize the areas of disease involvement in IBD patients. For UC patients, disease activity was assessed using the Mayo Score, TWS, and Endoscopic Activity Index (EAI). In CD patients, disease activity was evaluated using the CDAI and the HBI. Additionally, serological and biochemical tests, including hemogram, aspartate aminotransferase (AST), alanine aminotransferase (ALT), blood urea nitrogen (BUN), creatinine, ferritin, albumin levels, erythrocyte sedimentation rate (ESR), and C-reactive protein (CRP), performed on the same day, were recorded.

Patients who were in complete remission based on all scoring systems were categorized into the "remission" group, while those showing activity in at least one scoring system were placed in the "active disease" group. For patients with inflammation during an active period but currently in remission, the relevant bowel localizations were evaluated. In active patients, the active bowel segments were assessed. The intestinal segments were first examined using B-mode imaging and CDUS, and measurements of intestinal wall thickness and vascularization were recorded.

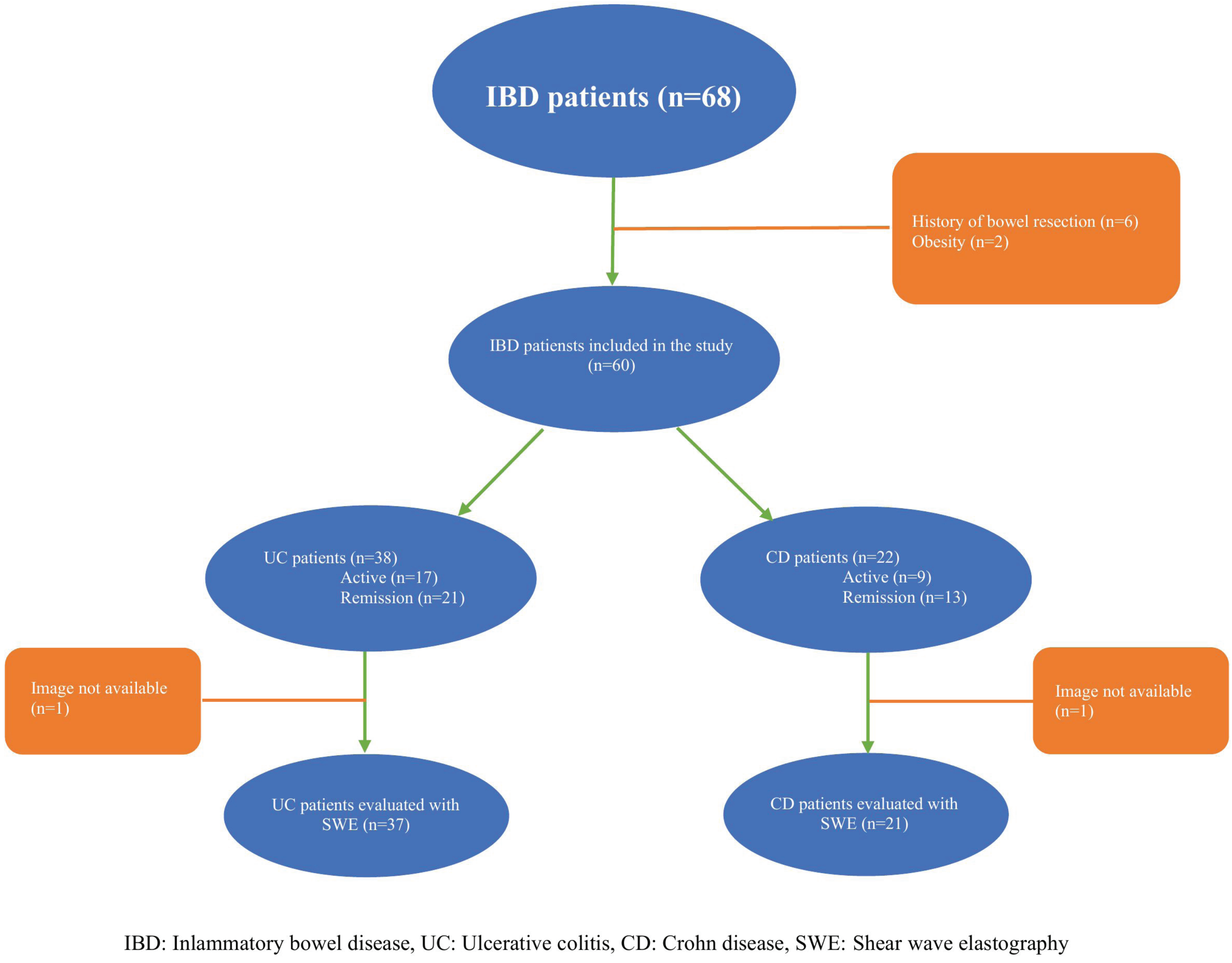

Figure 1. Study design.

All 2D SWE (shear wave elastography) measurements were performed by a single radiologist with 15 years of experience in abdominal radiology, using a LOGIQ E9 ultrasound device (General Electric Medical Systems, Wisconsin) and a 9L linear probe. The measurements were taken with the patient in the supine position, without compression, and in a neutral breathing state when patient cooperation was possible. During the elastography, three measurements were taken from different elastograms under optimal conditions for each patient, and the median value of tissue stiffness was recorded in kPa. In two patients, measurements could not be obtained due to unclear images. Additionally, eight patients could not be evaluated for vascularization because CDUS images could not be obtained.

The data obtained in the study were analyzed using SPSS version 23.0 (IBM, Chicago, USA). Descriptive statistics are presented as n(%), mean±standard deviation (SD), and median (min-max). The Pearson chi-square test or Fisher's exact test was applied to assess relationships between categorical variables. Spearman or Pearson correlation analysis was used to evaluate correlations between continuous variables. For data that did not follow a normal distribution, the Mann-Whitney U test was employed to assess differences in measurement values between two groups. The Kruskal-Wallis-H test was used to evaluate the significance of differences in means across three or more groups in non-normally distributed data. P-values less than 0.05 were considered statistically significant.

The cut-off value for diagnostic accuracy was determined using ROC curve analysis and the "Youden Index." The Hanley-McNeil test was applied to compare the areas under the curve. Following the investigation, a retrospective power analysis was conducted to ensure that the study had adequate statistical power (80%) for the variables under examination. Power calculations were performed using G*Power software (v. 3.1.9.4). No artificial intelligence was used for writing assistance.

RESULTS

Evaluation of the Clinical Characteristics of the Patients

A total of 60 patients, including 38 with UC and 22 with CD, were included in the study. The average age of the participants was 43.4±14.5 years, with UC patients averaging 42.8±15.6 years and CD patients averaging 44.5±12.7 years. Among the participants, 55% (*n*=33) were

Table 1. Demographic and Clinical Characteristics of UC and CD Patients

Characteristics	UC n (%)	CD n (%)	Total n (%)
Age, years (mean±SD)	42.8±15.6	44.5±12.7	43.4±14.5
Gender			
Male	22 (57)	11 (50)	33(55)
Female	16 (43)	11 (50)	27 (45)
Smoking			
Smokers	5 (13.1)	6 (27.3)	11 (18.3)
Non-smokers	30 (78.9)	15 (68.2)	45 (75)
Ex-smokers	3 (8)	1 (4.5)	4 (6.7)
Involvement Locations			
Proctitis	14 (37)		-
Left colitis	12 (31)		-
Extensive colitis	12 (32)		-
Ileal	-	13 (59)	-
Colonic	-	2 (9)	-
Ileocolonic	-	7 (32)	-
Disease Duration			
<5 years	11	14	25 (41.7)
>5 years	27	8	35 (58.3)
Disease Activity			
Active	17 (44.7)	9 (40.9)	26 (43.4)
In remission	21 (55.3)	13 (59.1)	34 (56.6)

UC: Ulcerative colitis, CD: Crohn disease, SD: Standard deviation

male and 45% (n=27) were female. In the CD group, 50% (n=11) were male and 50% (n=11) were female, while in the UC group, 57% (n=22) were male and 43% (n=16) were female. Both groups were evenly distributed by gender. No significant relationship was found between disease activity and demographic data.

Regarding smoking status, 75% (n=45) of the patients were non-smokers, 18.3% (n=11) were smokers, and 6.7% (n=4) were ex-smokers. Table 1 summarizes these features.

Correlation of Intestinal Wall Thickness, Tissue Stiffness, and Disease Activity

The relationship between intestinal wall thickness, tissue stiffness, and disease activity in CD was evaluated using correlation tests. Ultrasound elastography images from two patients, one with CD and the other with UC, are shown in Figures 2 and 3. A statistically significant positive correlation was found between intestinal wall thickness and several disease activity markers, including the HBI, CDAI, ESR, and CRP. The respective correlation coefficients and p-values are as follows: HBI (r=0.797, P<0.001), CDAI (r=0.786, P<0.001), ESR (r=0.594, P 0.005), and CRP (r=0.649, P=0.001) (Table 2).

A statistically significant relationship was found between tissue stiffness and HBI, CDAI, and CRP, with the following values: HBI

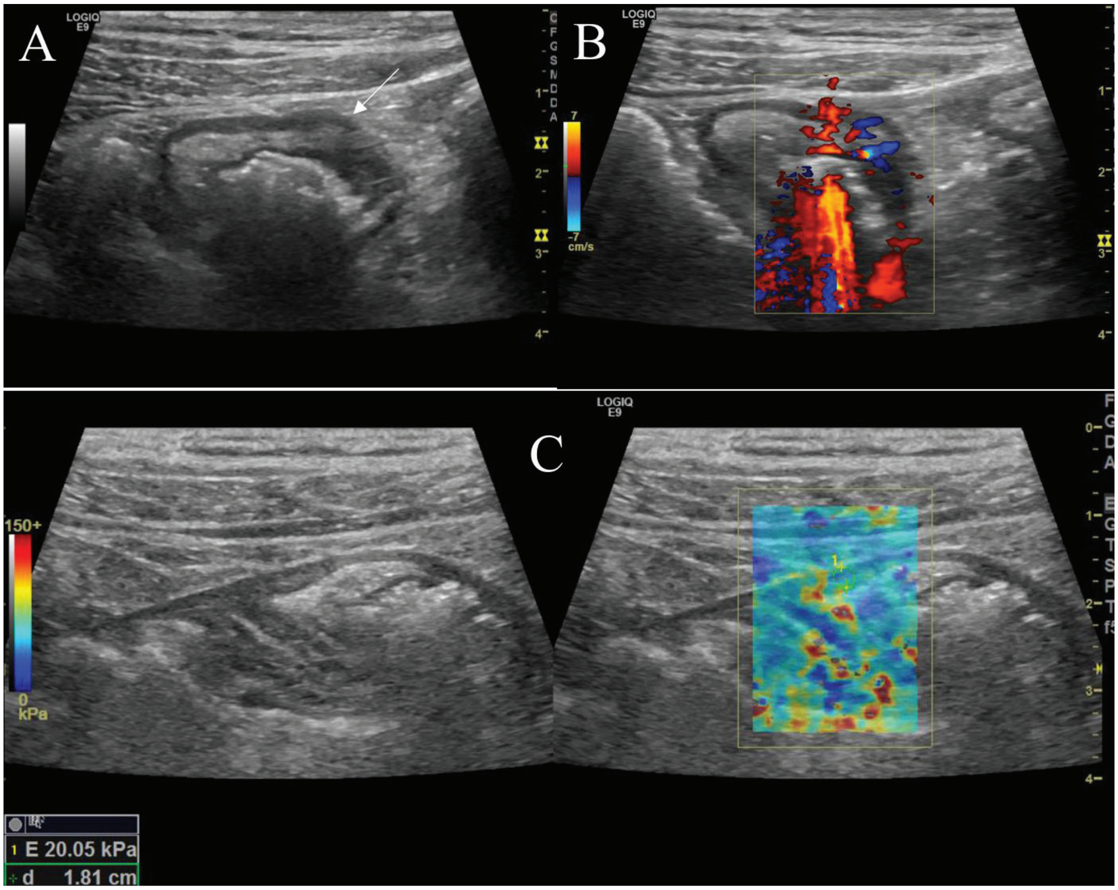

Figure 2. US image of a 48-year-old man with active Crohn's disease. (A) US image of the ascending colon showing a thickened bowel wall (arrow) and a target sign. (B) Color Doppler US image of the ascending colon showing Doppler signals in both the intestinal wall and the surrounding mesenteric fat (Limberg score: Grade 4). (C) SWE measurements of the ascending colon were obtained using a circular region of interest (ROI) placed on the bowel wall. The 2D-SWE map (right side) and grayscale image (left side) are shown. (US: Ultrasonography, SWE: Shear wave elastography).

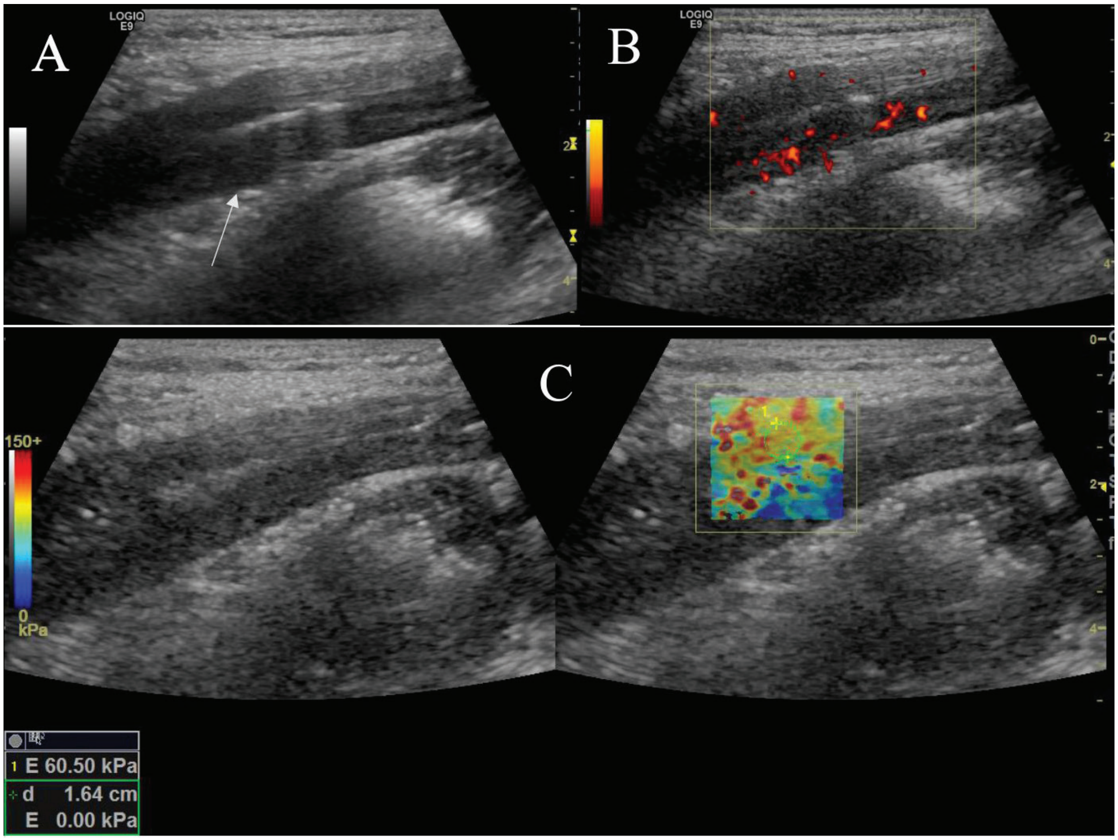

Figure 3. US image of a 22-year-old man with active ulcerative colitis. (A) US image of the rectosigmoid colon with a thickened bowel wall and loss of haustral markings (arrow). (B) Color Doppler US image of the rectosigmoid colon showing Doppler signals in both the intestinal wall and the surrounding mesenteric fat (Limberg score: Grade 3). (C) SWE measurements of the rectosigmoid colon were obtained using a circular ROI placed on the bowel wall. The 2D-SWE map (right side) and grayscale image (left side) are shown. (US: Ultrasonography, SWE: Shear wave elastography).

Table 2. Correlation of Intestinal Wall Thickness, Tissue Stiffness, and Disease Activity

CD	**HBI**		**CDAI**		**ESR**		**CRP**	
	r	**p**	**r**	**p**	**r**	**p**	**r**	**p**
Intestinal Wall Thickness (mm)	0.797	**<0.001**	0.786	**<0.001**	0.594	**0.005**	0.649	**0.001**
Tissue stiffness (kpa)	0.772	**<0.001**	0.817	**<0.001**	0.335	0.138	0.503	**0.02**

UC	**TWS**		**Mayo Score**		**EAI**		**ESR**		**CRP**	
	r	**p**	**r**	**p**	**r**	**p**	**r**	**p**	**r**	**p**
Intestinal Wall Thickness (mm)	0.619	**<0.001**	0.630	**<0.001**	0.551	**<0.001**	0.364	**0.027**	0.589	**<0.001**
Tissue stiffness (kpa)	0.546	**<0.001**	0.491	**0.002**	0.481	**0.003**	0.407	**0.012**	0.423	**0.009**

CD: Crohn disease, HBI: Harvey bradshaw index, CDAI: Crohn's disease activity index, ESR=Erythrocyte sedimentation rate, CRP: C-reactive protein, UC: Ulcerative colitis, TWS: Truelove witts score, EAI: Endoscopic activity index.

(r=0.772, P<0.001), CDAI (r=0.817, P<0.001), and CRP (r=0.503, P=0.02) (Table 2).

The relationship between intestinal wall thickness, tissue stiffness, and disease activity in UC was evaluated using correlation tests. A statistically significant correlation was found between intestinal wall thickness and TWS, Mayo score, EAI, ESR, and CRP, with the following values: TWS (r=0.619, P<0.001), Mayo score (r=0.630, P<0.001), EAI (r=0.551, P<0.001), ESR (r=0.364, P=0.027), and CRP (r=0.589, P<0.001) (Table 2).

A statistically significant correlation was also found between tissue stiffness and TWS, Mayo score, EAI, ESR, and CRP, with the following values: TWS (r=0.546, P<0.001), Mayo score (r=0.491, P=0.002), EAI (r=0.481, P=0.003), ESR (r=0.407, P=0.012), and CRP (r=0.423, P=0.009) (Table 2).

Correlation tests showed a statistically significant relationship between tissue stiffness and intestinal wall thickness in both CD and UC, with values of r=0.797, P<0.001 for CD and r=0.628, P<0.001 for UC.

Tissue Stiffness and Intestinal Wall Thickness ROC Analysis

In active IBD patients, the relationship between intestinal wall thickness and tissue stiffness was assessed using ROC analysis. The area under the curve (AUC) was found to be 0.900 (P<0.001) for tissue stiff-

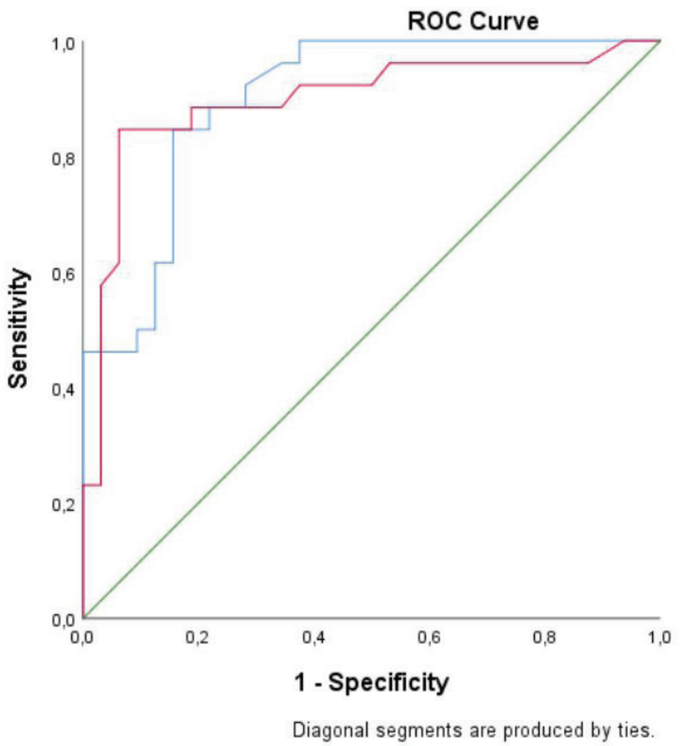

Figure 4. ROC analysis of tissue stiffness and intestinal wall thickness data in active IBD.

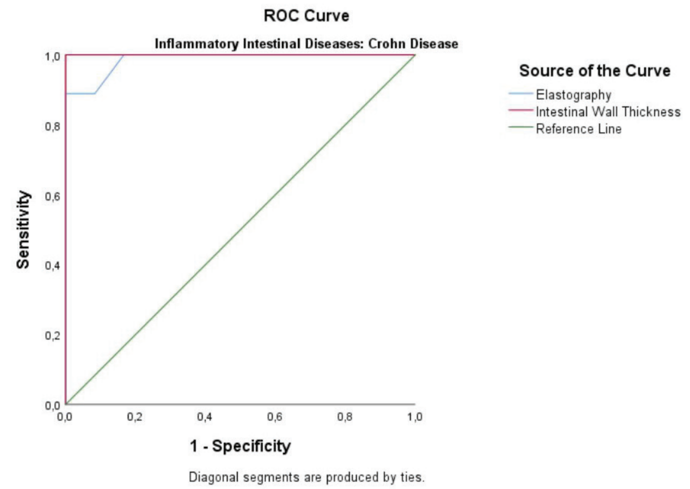

Figure 5. ROC analysis of tissue stiffness and intestinal wall thickness data in active CD.

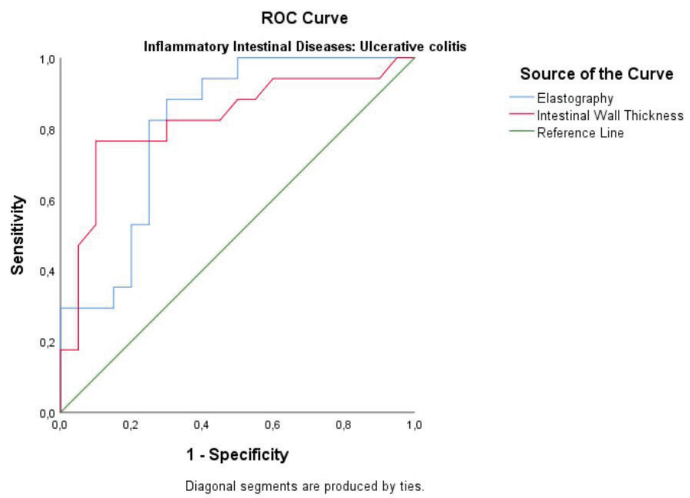

Figure 6. ROC analysis of tissue stiffness and intestinal wall thickness data in active UC.

ness and 0.897 ($P<0.001$) for intestinal wall thickness, indicating both parameters were effective in determining disease activity.

In active IBD patients, when the tissue stiffness threshold value was set at 11.435 in the ROC analysis, the sensitivity was 84.6% and the specificity was 84.4%. Similarly, when the intestinal wall thickness threshold value was set at 3.40, the sensitivity was 84.6% and the specificity was 93.7% (Figure 4).

ROC Analysis of Tissue Stiffness and Intestinal Wall Thickness in CD

In active CD patients, the ROC analysis revealed that AUC for tissue stiffness was 0.986 ($P<0.001$) and 1.0 ($P<0.001$) for intestinal wall thickness, indicating both parameters were highly effective in determining disease activity.

When the tissue stiffness value was set at 11.50 kPa in the ROC analysis, the sensitivity was 88.9% and the specificity was 100%. For intestinal wall thickness, with a threshold value of 3.35 mm, both sensitivity and specificity were 100% (Figure 5).

ROC Analysis of Tissue Stiffness and Intestinal Wall Thickness in UC

In active UC patients, the ROC analysis revealed that AUC for tissue stiffness was 0.812 ($P<0.001$) and 0.824 ($P<0.001$) for intestinal wall thickness, indicating that both parameters were effective in determining disease activity.

When the tissue stiffness value was set at 9.53 in the ROC analysis, the sensitivity was 88.2% and the specificity was 70%. For intestinal wall thickness, with a threshold value of 3.40, the sensitivity was 76.5% and the specificity was 90% (Figure 6).

Comparison of Tissue Stiffness by Disease Duration and Activity

Tissue stiffness measurements showed no significant differences between patients with IBD duration of less than five years and those with more than five years, regardless of whether they were in remission or had active IBD ($P=0.458$ and $P=0.206$, respectively).

There was no statistically significant difference in tissue stiffness between patients with UC and CD in remission ($P=0.059$). However, the analysis revealed a statistically significant difference in tissue stiffness between patients with active UC and those with active CD ($P=0.025$). Additionally, a statistically significant difference was observed when comparing tissue stiffness values between IBD patients in remission and those with active disease ($P<0.001$).

The Relationship Between TWS Score with Limberg Score and Vascularization Status in UC Patients

Thirty UC patients were grouped as mild and moderate/severe according to their TWS. Vascularization and wall thickness were evaluated.

Table 3. The Relationship Between TWS Score with Limberg Score and Vascularization Status of UC Patients

Category	Limberg Score 0-1	Limberg Score 2-3-4	Total	P	Vascularization +	Vascularization -	Total	P
TWS Mild	83.3% (n=10)	16.7% (n=2)	100% (n=12)	**0.003**	83.3% (n=10)	16.7% (n=2)	100% (n=12)	**0.001**
TWS Moderate/Severe	27.8% (n=5)	72.2% (n=13)	100% (n=18)		22.2% (n=4)	77.8% (n=14)	100% (n=18)	

UC: Ulcerative colitis, TWS: Truelove witts score

Table 4. Relationship Between Disease Activity with Limberg Score and Vascularization Status

mean±SD (min-max)	Limberg score grade 0-1	Limberg score grade 2-3-4	P	Vascularization -	Vascularization +	P
ESR	16.18±13.15 (4- 48)	32.78±18.22 (13-73)	**<0.001**	16.19±13.41	32.08±18.14	**<0.001**
CRP	5.69±10.84 (1-56)	18.30±30.2 (1.5-126)	**0.001**	5.79±11.04	17.67±29.71	**0.002**
Ferritin	45.3±42.3 (5-159)	50.7±84.03 (2-294)	0.115	46.88±42.38	48.87±82.71	**0.045**
HBI	1.91±1.31 (0-4)	8.50±2.20 (6-13)	**<0.001**	1.91±1.31	8.50±2.20	**<0.001**
CDAI	61.16±31.21 (15-123)	230.25±40.4 (179-287)	**<0.001**	61.16±31.21	230.25±40.45	**<0.001**
EAI	140±2.16 (0-8)	7.13±4.80 (0-12)	**0.004**	0.92±1.20	7.18±4.65	**0.001**
Mayo Score	1.73±1.53 (0-6)	6.80±3.38 (1-12)	**<0.001**	1.42±1.01	6.75±3.27	**<0.001**

Mann-Whitney U test was used. ESR: Erythrocyte sedimentation rate, CRP: C-reactive protein, HBI: Harvey bradshaw index, CDAI: Crohn's disease activity index, EAI: Endoscopic activity index, SD: Standard deviation.

In the mild group, based on the TWS score, 83.3% (*n*=10) had a Limberg score of 0-1, and 16.7% (*n*=2) had a Limberg score of 2-3-4. In the moderate/severe group, 27.8% (*n*=5) had a Limberg score of 0-1, and 72.2% (*n*=13) had a Limberg score of 2-3-4. A significant relationship was found between the TWS and Limberg score (*P*=0.003) (Table 3).

According to the TWS score, 83.3% (*n*=10) of the mild group showed no vascularization, while 16.7% (*n*=2) had vascularization. In the moderate/severe group, 22.2% (*n*=4) had no vascularization, while 77.8% (*n*=14) exhibited vascularization. A significant difference was found between the TWS score and vascularization status (*P*=0.001) (Table 3).

Relationship Between Disease Activity with Limberg Score and Vascularization Status

Twenty CD patients and thirty UC patients were compared based on their Limberg scores, with patients grouped into grade 0-1 and grade 2-3-4. Ten patients were not evaluated due to the inability to obtain images with CDUS. Figure 7 shows the vascularization status and elastography images of a patient with UC.

In 50 IBD patients, the mean ESR and CRP values were significantly different between the group with Limberg grades 0-1 and the group with grades 2-3-4 (*P*<0.001 and *P*=0.001, respectively). Among 20 CD patients, the mean HBI and CDAI scores were also statistically significantly different between the grade 0-1 group and the grade 2-3-4 group (both *P*<0.001). In 30 UC patients, the mean EAI and Mayo scores showed statistically significant differences between the grade 0-1 group and the grade 2-3-4 group (*P*=0.004 and *P*<0.001, respectively) (Table 4).

In 20 CD and 30 UC patients, vascularization status was compared by dividing them into two groups: present and absent.

Among the 50 IBD patients, the mean ESR, CRP, and ferritin values in the group without vascularization were statistically significantly lower than those in the group with vascularization (*P*<0.001, *P*=0.002, and *P*=0.045, respectively). In 20 CD patients, the mean HBI and CDAI values in the group without vascularization were statistically significantly lower than in the group with vascularization (*P*<0.001 and *P*=0.015, respectively). In 30 UC patients, the mean EAI and Mayo scores in the group without vascularization were found to be statistically significantly lower than in the group with vascularization (*P*=0.001 and *P*<0.001, respectively) (Table 4).

DISCUSSION

Many radiological methods are utilized for the diagnosis and follow-up of IBD, with US, CT, and magnetic resonance imaging (MRI) being the most commonly employed techniques.[19] UE is a non-invasive technique that assesses tissue stiffness and elasticity. It is easily applicable, radiation-free, and cost-effective. However, there are few studies in the literature that evaluate the efficacy of UE in determining disease activity in IBD patients.

Fraquelli et al.[20] evaluated the effectiveness of ultrasound in patients with CD and established a threshold value for colonic wall thickness at 3-4 mm. When the threshold was set at 4 mm, the test's sensitivity was 75%, and the specificity was 97%. In another study, Allacco et al.[21] determined the threshold value for increased intestinal wall thickness in 53 UC patients to be 4.43 mm, with a sensitivity of 76% and a specificity of 100%. In our study, when the threshold value for intestinal wall thickness in patients with active CD was set at 3.35 mm in the ROC analysis, both sensitivity and specificity were 100%. For patients with active UC, the threshold value for intestinal wall thickness was 3.40 mm, with a sensitivity of 76.5% and a

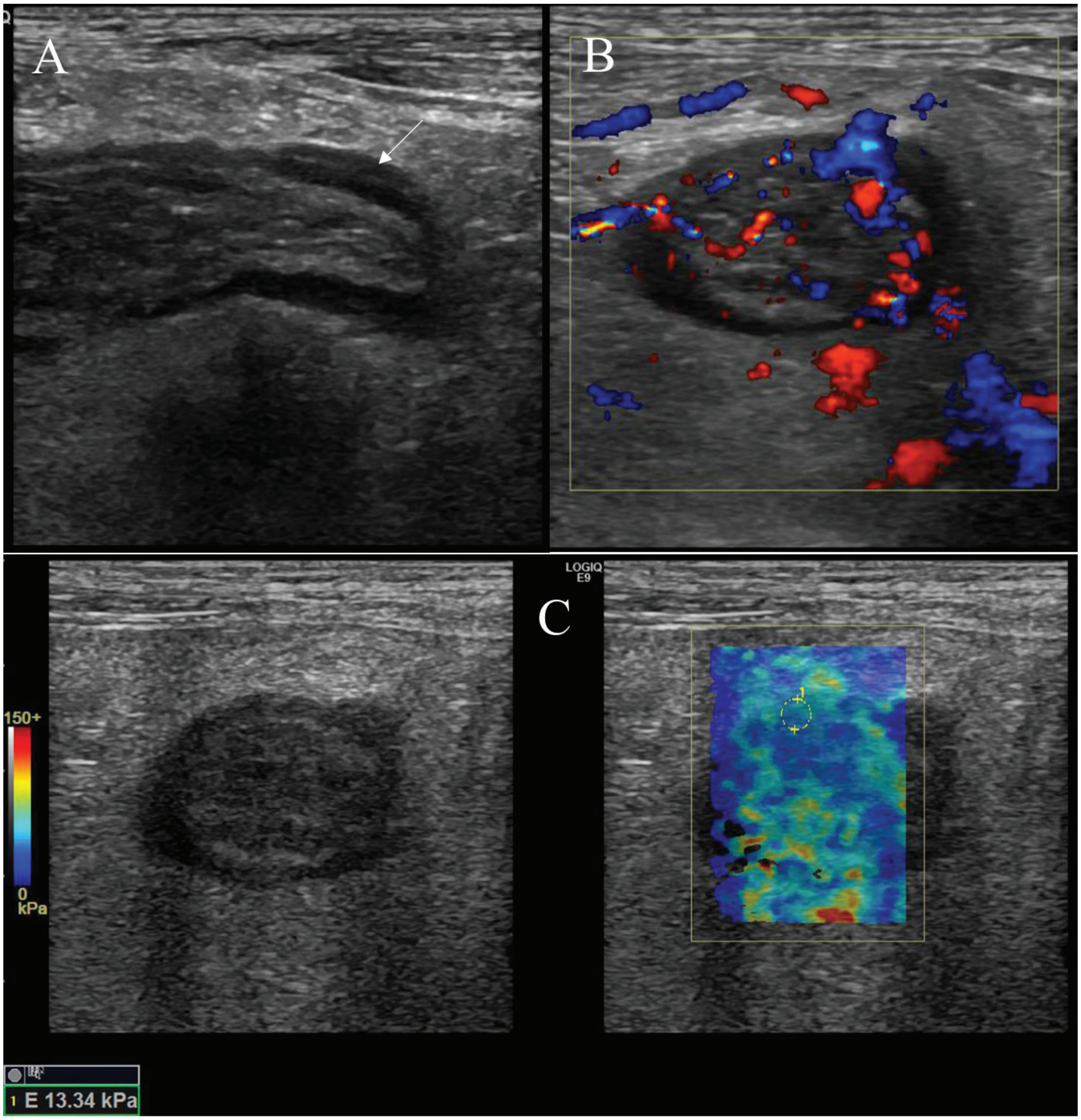

Figure 7. US image of a 38-year-old woman with active ulcerative colitis. (A) US image of the rectosigmoid colon showing a thickened bowel wall (arrow). (B) Color Doppler US image of the rectosigmoid colon showing Doppler signals in both the intestinal wall and the surrounding mesenteric fat (Limberg score: Grade 4). (C) SWE measurements of the rectosigmoid colon were obtained using a circular ROI placed on the bowel wall. The 2D-SWE map (right side) and grayscale image (left side) are shown. (US: Ultrasonography, SWE: Shear wave elastography).

specificity of 90%. These findings align with the results reported in the literature.

Quaia et al.[22] evaluated the terminal ileum using US in 15 CD patients with a CDAI > 150, finding a statistically significant correlation between CDAI and intestinal wall thickness. Similarly, in our study, a significant correlation was observed between intestinal wall thickness and disease activity scores in both UC and CD. This data suggests that to determine whether the disease is active and gauge its severity in patients with IBD, a more practical approach like US can be utilized. This method could expedite treatment and follow-up processes, offering an alternative to colonoscopy, which requires a more involved preparation process.

Goertz et al.[23] evaluated 77 CD patients retrospectively and 21 CD patients prospectively. Using the ARFI technique, they found that the tissue stiffness of the normal stomach, ileum, and sigmoid colon was lower compared to the involved ileum and sigmoid. In retrospectively analyzed patients, tissue stiffness values from UE were correlated with intestinal wall thickness and the Limberg vascularization score. However, no significant correlation was found between stiffness values detected by UE and intestinal wall thickness, the Limberg score, clinical activity, or CRP levels in the prospectively examined patients. In contrast, our prospective study found a statistically significant correlation between tissue stiffness and HBI, CDAI, and CRP in CD patients. These findings indicate that more comprehensive studies involving a larger number of patients are needed.

In another study by Goertz et al.,[24] which included 20 UC patients and 13 healthy controls, ARFI tissue stiffness, intestinal wall thickness, and the Limberg score were evaluated. The UC group consisted of individuals with moderate disease activity. Tissue stiffness values and wall thickness were found to be significantly higher in the UC group compared to the control group. No significant correlation was observed between BMI, age, or intestinal wall thickness in the UE tissue stiffness measurements in the control group, and there was no correlation between the Limberg score and ARFI measurements. Although our study did not include a control group, it utilized the SWE elastography technique, which provides more quantitative results. A statistically significant correlation was found between tissue stiffness and the TWS, Mayo score, and intestinal wall thickness in UC patients. Additionally, our study revealed a significant correlation between the Limberg score and all disease activity scores (TWS, Mayo score, EAI) in 30 UC patients. It is well-known that the inflamed intestinal wall forms new vessels through angiogenesis, and previous studies have found a correlation between the severity of IBD and intramural vascularization.[25] Our findings further support this information.

Marin et al.[26] examined 59 patients (21 with CD involving only the colon and 38 with UC). They found that intestinal wall thickness correlated significantly with the HBI in patients with colonic CD (r=0.81, P<0.0001) and with the Mayo score (r=0.72, P<0.0001) and CRP (r=0.52, P<0.0001) in UC patients. In addition to CRP, the Limberg score was also well correlated with the HBI in CD and the Mayo score in UC. Similarly, Fufezan et al.,[27] in their study of 14 pediatric CD patients, evaluated intestinal segments using CDUS and SE, finding a statistically significant correlation between disease activation, intestinal wall thickness, and vascularization. In our study, we also found correlations between CRP, disease activity scores, Limberg scores, intestinal wall thickness, and tissue stiffness values, which align with the findings in the literature. These results underscore the effectiveness of US and UE in determining disease activity. They further highlight the importance of using non-invasive, cost-effective, easily accessible, and objective methods when evaluating IBD patients, suggesting the need for new approaches and the selection of appropriate techniques based on individual patient needs.

Yamada et al.[28] evaluated bowel activity using UE performed within two days of colonoscopy in 26 UC patients. They compared the results with the modified TWS, the Lichtiger index, and the EAI. A negative correlation was observed between tissue stiffness values measured by SWE and disease activation scores, while a moderately positive correlation was found between the Lichtiger index and EAI scores. However, no correlation was found between intestinal wall thickness, SWE stiffness values, the Lichtiger index, or EAI scores. In their ROC analysis, a tissue stiffness value of 2.20 kPa showed 86.4% sensitivity and 75% specificity in detecting disease activity (AUROC 0.909). In our study, when the threshold value for tissue stiffness was set at 11.435 kPa in the ROC analysis for active IBD patients, the sensitivity was 84.6% and the specificity was 84.4%. A moderate but statistically significant correlation was found between tissue stiffness and TWS and EAI in UC patients. Although Yamada et al.'s[28] findings are not fully consistent with other studies in the literature, including ours, these results indicate that further research with larger sample sizes is needed to clarify the relationship between tissue stiffness and disease activity.

Studies have demonstrated that MR and US can accurately diagnose moderate to severe disease activity in UC.[29] This suggests that, in the future, when evaluating disease activity in IBD, invasive methods involving radiation and contrast agents may be replaced by techniques that prioritize patient comfort, deliver rapid results, and offer similar efficacy. With conventional US, intestinal wall thickness can be measured, providing insight into disease activity. However, conventional US does not offer information about vascularization or tissue stiffness, and it is also operator-dependent, which is a notable limitation. In contrast, our study utilized SWE, which, unlike other ultrasound elastography techniques, is the least operator-dependent and provides quantitative results. This makes it a valuable tool for assessing tissue stiffness and improving the overall evaluation of disease activity in IBD.

Since frequent evaluations through multiple examinations are necessary in the diagnosis and treatment of IBD, it is crucial to use high-tolerance techniques that are rapid and minimally impact patients' quality of life. IBD primarily affects a young population, and by selecting appropriate techniques, the loss of workforce can be minimized while enhancing patient comfort. Thus, there is a strong need for easy-to-apply, reproducible, quantitative, and cost-effective methods to assess disease activity. UE is one such technique, offering promise for this purpose. UE has become increasingly used across a range of conditions, and with further large-scale studies, it is expected to become one of the primary imaging methods for IBD. Moreover, UE could serve as a valuable tool in assessing disease activity, guiding diagnosis and treatment when endoscopic examinations are not tolerated or when patients are unsuitable for endoscopic procedures. This potential makes UE an important option in the management of IBD.

Although UE is a relatively new technique, it has been used in only a limited number of studies in IBD. The variation in techniques used across studies in the literature presents a challenge, as it complicates direct comparisons. However, despite this limitation, these studies are valuable as they help guide more comprehensive research on the subject and highlight the potential of UE as an important tool in IBD evaluation.

Our study has some limitations. Firstly, the difficulty in recruiting a sufficient number of IBD patients for routine control during the pandemic period led to a smaller sample size, which stands out as a limiting factor. Additionally, the absence of a healthy control group and the variability in affected intestinal segments among patients are further limitations. Another constraint was the inability to use the fecal calprotectin test, which is a reliable indicator of IBD activity, due to its high cost.

In conclusion, UE offers several advantages: it can be applied bedside, is reproducible, radiation-free, cost-effective, and easy to implement. These qualities suggest that UE could be more widely adopted in daily clinical practice, improving diagnostic functionality in IBD and providing clinical benefits for patient management.

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