Comparative study between magnetic resonance and contrast enhanced ultrasound in the assessment of the activity of Crohn's disease.

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Aims and objectives

The aim of the study is to determine in patients diagnosed with Crohn's disease (CD), the correlation between the morphological (wall thickness of pathological bowel loop) and the functional findings of inflammatory activity (pattern of contrast enhancement and diffusion restriction) in magnetic resonance images (MRI).

These findings will be compared with those obtained with contrast enhanced ultrasound (CEUS), to determine the equivalence of these two techniques.
Methods and materials

It is a non-experimental, prospective and descriptive study, started in 2011 which remains open at the present time (October, 2014).

1 DESCRIPTION OF THE SAMPLE

Inclusion criteria: - Patients with MR performed at our institution (Miguel Servet University Hospital).

- Histological diagnosis of Crohn's disease (CD).

- Clinical-analytical suspicion of inflammatory activity.

Exclusion criteria:

- No acceptance of informed consent.

- Contraindications of ultrasound contrast (sulfur hexafluoride): heart disease, pregnant women and children under 18 years.

- Studies of MR with no signs of inflammatory activity.

- Studies of MR not assessable by motion artifacts (difficulty of maintaining respiratory apnea).

Patients initially selected for performance MR-enterography (Figure 1), corresponding to a total of 32 patients, 23 men and 9 women, ranging in age from 18 to 71 years and a mean of 41 years. Once performed the MR-enterography, a specialist in abdominal radiology, only if there are findings suggestive of inflammatory activity indicates to perform an ultrasound study. In this phase, 2 patients were excluded from the study to show no signs of inflammatory activity on MR. Then, prior to the ultrasound, weight and height measurements are taken. Subsequently, a second specialist in abdominal radiology carry out an ultrasound study without prior knowledge of the MR findings. This study was performed with an interval of not more than 24 hours before the MRI. The whole study was done in 26 of the 30 patients. The reasons for ultrasound were not performed in these 4 patients were: not to localize the pathological bowel loop (1 case) and technical problems or personal motives of the remaining 3 patients.

2 TECHNICAL DESCRIPTION
2.1. Magnetic Resonance (MR).

All MR sequences (Figure 1) are evaluated to determine the presence of intestinal and extraintestinal activity. According to the literature (1-11), we evaluated its diagnostic accuracy, the following signs of activity:

- Wall thickening > 3mm.
- Submucosal edema (on T2 sequences).
- Ulcers and pseudopolyps.
- Intense parietal enhancement, compared with a normal loop, with mucosal or layered enhancement ("target sign").
- Striation of the adjacent fat (reduced fat signal in T2 sequence without fat saturation).
- Vascular congestion ("comb sign").
- Enlarged mesenteric nodes (> 1cm).
- Presence of phlegmon, abscess, sinus tract or fistula.

2.2. Contrast enhanced ultrasound (CEUS).

- Ultrasound probe: convex multifrequency probe (5-3MHz).
- Intravenous contrast: 4ml of a compound of sulfur hexafluoride and 10ml bolus of saline (0.9% sodium chloride) by peripheral vein.

3 DEFINITION OF DATA

3.1. Magnetic resonance imaging (MRI):

Retrospectively took a series of measures in the pathological bowel loop of greater wall thickness (greater than 3 mm) and increased mucosal enhancement of the coronal 3D SPGR T1 sequence with fat saturation to 70 seconds after administration of intravenous contrast (Figure 2).

We selected in the same study, a non-pathological intestinal loop (wall thickness always less than 3mm), without significant bowel wall enhancement. Similar to those measurements taken in pathological loops were carried out in non-pathological or control loops, being shown in figures 3 and 4, which is represented the method of measuring of the mucosal enhancement and noise signal, respectively.
We have also evaluated the diffusion-weighted images (Figure 5) because some authors (12) have shown its help to distinguish active from chronic-fibrotic inflammation by semiquantitatively (13,14,15) and ADC values. Measurements of ADC values are also represented in figures 6 and 7.

### 3.2. Contrast enhancement ultrasound (CEUS):

Initially, the study was performed without contrast administration (B or basal mode) to identify the inflammatory extension and the most inflamed bowel loop. Once identified the intestinal loop of greater wall thickness, the following assessments were noted:

- **Location**: terminal ileum, distal or proximal jejunum, cecum, colon (ascending, descending, transverse, sigmoid).

- **Wall thickness**: always > 3 mm.

- **Stenosis**: Yes / No.

- **Complications (phlegmon, abscess, fistula)**: Yes / No.

After contrast administration the bowel wall enhancement is monitored, recording images each 5 seconds during 120s and notice the following results:

- **Enhancement intensity**: no, probably, certain.

- **Predominant enhancement pattern**: homogeneous, irregular, no (no enhancement is identified during 120 seconds).

- **Time required for maximum bowel wall enhancement**: seconds for subsequent classification: early enhancement: <35 seconds; medium (36-59s); late (>60 s); no (not intensely enhancement for 120s of study).

The main sonographic finding in Crohn's disease activity is the wall thickening greater than 3mm. Furthermore, the loss of normal peristalsis and involvement of adjacent fat tissue usually appear. The main advantage (16-17) with CEUS over basal ultrasound, is the ability to assess the parietal microvasculature of the bowel (18) and adjacent tissues, so that you can differentiate between active inflammation (bowel wall enhancement, hypervascularity) and fibrotic state (no enhancement). We present some of the most representative cases of inflammatory activity (4 cases: figures 8-16).

### 4 DATA ANALYSIS
4.1. Descriptive study

4.1.1. Morphological MRI and CEUS findings were initially described: - Location of the inflamed bowel loop to assess the prevalence of the disease and the ability of ultrasound to detect inflammatory activity.

- Maximum wall thickness in the pathological loop determining the range and average.

- Concerning the complications, has been studied mainly in MRI to determine the signs of active inflammation. Phlegmons, abscesses, fistulas and sinus tracts are present in the active phase of CD. It also assessed the presence of complications on ultrasound, but the aim of this work is not to compare the effectiveness of the same opposite the MRI.

- Enhancement patterns in MRI (layered, homogeneous and irregular) and CEUS (homogeneous and irregular) were determined. At CEUS, we also value the time in seconds required for maximum wall bowel enhancement, determining the range and average time and the number of patients with each enhancement intensity (early, medium, late or no intense enhancement). These data are showed in figure 17.

- Range and average of noise signal and wall enhancement values in pathological and non-pathological intestinal loops, previously measured with ROI, in 3D SPGR T1 sequences prior and after contrast administration.

- Relative contrast enhancement (RCE) values of pathological and normal loops of the patients (Figure 18) was then calculated by a mathematical formula.

- Range and average of ADC values previously measured with ROI in the pathological and normal loops on each patient.

4.1.2. Body mass index (BMI) was calculated from the weight and height of each patient to determine if body weight can alter the sensitivity of ultrasound.

4.1.3. Finally, we aim to establish what are the imaging findings suggesting high probability of acute inflammation with both techniques. The extraintestinal signs of activity ("comb sign", lymphadenopathy, edema of mesenteric fat) are rated at only MR for the patients inclusion to perform CEUS.

4.2. Descriptive-analytical study

4.2.1 MRI. In a total of 30 patients with MRI performed, we have established the following analysis:
- The correlation between the wall thickness (in millimeters) and the pattern of wall enhancement by ANOVA test and secondly, we have used the T-test to evaluate the layered pattern and wall thickness.

- We have established the relationship between the wall thickness and signal intensity on diffusion images (semiquantitative) using T-test.

- The relationship between the pattern of enhancement on MRI and semiquantitative signal intensity on DWI (no / probable, certain) we have studied using $\chi^2$ test.

- To establish a correlation between RCE and ADC we used the Spearman correlation coefficient.

- Using the ROC curves we analyzed the diagnostic sensitivity and specificity of both parameters separately (RCE and ADC).

- Finally, we used the Wilcoxon test for comparison of mean values of RCE and ADC obtained in pathological and non-pathological bowel loops.

4.2.2. CEUS. We apply the T-test in 26 patients with ultrasound study performed, to establish correlation between the wall thickness and intensity of wall enhancement, unifying the "probable" and "no" patterns of enhancement (dichotomous variable: certain and probable/ no).

4.2.3. MRI and CEUS The following analysis were performed to 26 patients with the whole study:

- Analyze with $\chi^2$ test each valued enhancement patterns MR (layered, homogeneous, irregular) with the time required for maximum bowel wall enhancement in pathological loop (early, middle, late, no).

- We studied the correlation between ADC values of MRI and the time required for maximum bowel wall enhancement (early, medium, late, no) by ANOVA.

- Analyze the intensity of enhancement in ultrasound (no / probable, certain) and semiquantitative signal intensity on diffusion-weighted images (no / probably, certain) by $\chi^2$ test and kappa index.

- Finally we evaluated the time required for maximum bowel wall enhancement in CEUS (early, medium, late, no) and semiquantitative signal intensity on diffusion images (no, probable, certain) by $\chi^2$ test.
Statistical power: The calculations were performed with SPSS version 17 (2008). The value was considered significant $p < 0.05$. 
## Sequences without Contrast

| SSFP (steady state free precession) T2WI with no fat suppression, in coronal planes | 3D SPGR T1WI with fat suppression (45 s delay), in coronal planes |
| 3D SSFP T2WI, in coronal planes | 3D SPGR T1WI (70 s) in coronal planes |
| SSFSE (single shot fast spin echo) T2 WI with fat suppression, in axial and coronal planes | 3D SPGR T1WI (120 s) in axial planes |
| DWI (Diffusion weighted images) GE EPI (gradient echo, echoplanar images), factors b 0 and b 600 in axial and coronal planes | |
| SPGR (spoiled gradient echo) 3D T1WI with fat suppression in coronal planes | |

**Fig. 1**

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Pathological: 3 values measured with ROI in intestinal mucosa on SPGR T1WI sequences without and 70 seconds after contrast administration (maximum signal intensity)

Fig. 2: 3 measurements with ROI in the mucosa of the intestinal loop with signs of activity and greater wall thickness on 3D SPGR T1 sequence prior and after administration of contrast to 70 seconds both in the coronal plane.

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Fig. 3: In the same way, we perform the measurements in a non-pathological bowel loop prior and after contrast administration (at 70 seconds) in coronal plane.

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Noise signal: 3 values measured with ROI in an extracorporeal area very close to abdominal wall on SPGR T1WI without and postcontrast (70 s) images.

Fig. 4: 3 measurements of noise signal with ROI in an extra-body region as close as possible to the abdominal wall, selecting the same area in SPGR T1 sequences prior and after contrast administration.

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Fig. 5

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**ADCs measurement in a pathological and a normal bowel loop**

**Pathological:** 3 values measured with ROI in intestinal mucosa with high signal intensity and calculate the arithmetic mean of these values.

**Fig. 6:** 3 measurements of ADC values on 600 b factor DWI in coronal plane in the most hyperintense bowel mucosa of the pathological bowel loop.

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Fig. 7: 3 measurements of ADC values in the same sequence in the mucosa of a non-pathological loop, subsequently the average of three measured values is calculated.

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1.5 T MR study: SSFSE T2WI in coronal plane (a), 2D SSFP T2 without fat suppression in coronal plane (b) and with fat suppression in axial plane (c), SPGR T1WI without (d) and postcontrast images (image d with 70 s delay in coronal plane) and 120 s in axial plane (f): There is a significant wall thickening and mural edema (orange arrows in a and c images) of a small bowel loop, fat striation and vascular engorgement (comb sign: yellow arrow in b). It shows a significant wall enhancement with typical target sign (green arrows in e and f), comparatively with no contrast images (green arrow in d).

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Fig. 9: 1,5 T MR study: SSFSE T2WI in coronal plane (a), 2D SSFP T2 without fat suppression in coronal plane (b) and with fat suppression in axial plane (c), SPGR T1WI without (d) and postcontrast images (image d with 70 s delay in coronal plane) and 120 s in axial plane (f): There is a significant wall thickening and mural edema (orange arrows in a and c images) of a small bowel loop, fat striation and vascular engorgement (comb sign: yellow arrow in b). It shows a significant wall enhancement with typical target sign (green arrows in e and f), comparatively with no contrast images (green arrow in d).

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Fig. 10: 1.5 T MR study: SSFP T2WI 2D in coronal plane (a), SPGR 3D T1WI without (b) and postcontrast images (70 s) in coronal plane (c and d) and axial plane (e). There are several short stenotic small bowel loops (pink arrows in a and e) with secondary pre-stenotic dilatation. These loops show irregular wall thickening and avid homogeneous wall enhancement (green arrows in c and e). Additionally, there are enlarged mesenteric lymph nodes and mild increase of mesenteric vascularity (yellow arrows in d and e).

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**Fig. 11:** 1.5 T MR study: SSFP 2D T2WI in coronal plane (a), 3D SPGR T1WI without (b) and postcontrast images (70 s) in coronal plane (c and d) and axial plane (e). There are several short stenotic small bowel loops (pink arrows in a and e) with secondary pre-stenotic dilatation. These loops show irregular wall thickening and avid homogeneous wall enhancement (green arrows in c and e). Additionally, there are enlarged mesenteric lymph nodes and mild increase of mesenteric vascularity (yellow arrows in d and e).

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**Case 3**

**Fig. 12:** 1.5T MR study: SSFSE T2WI in coronal plane (a) and 3D SPGR T1 without (b) and after contrast administration (70s) in coronal and axial planes (120 s), images c and d, respectively. There is a significant wall thickening of a bowel loop with inflammatory changes in around mesenteric fat. There is also an ileo-ileal fistulous tract in between two areas of a large pathological loop of distal ileon (blue arrow in a). A significant wall enhancement of an inflamed bowel loop and a fistulous tract are showed with a opening green arrow in image b, and filled green arrows in c and d.

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Fig. 13: 1.5T MR study: SSFSE T2WI in coronal plane (a) and 3D SPGR T1 without (b) and after contrast administration (70s) in coronal and axial plane (120 s), images c and d, respectively. There is a significant wall thickening of a intestinal loop with inflammatory changes in around mesenteric fat. There is also an ileo-ileal fistulous tract in between two areas of a large pathological loop of distal ileon (blue arrow in a). A significant wall enhancement of inflamed loop and fistulous tract are showed with a opening green arrow in image b, and filled green arrows in c and d.

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Fig. 14: Ultrasound study performed initially in B mode (images a and b) with contrast administration posteriorly, evaluating the pattern of enhancement and time required for maximum bowel wall enhancement (postcontrast images at 10, 20, 35, 45, 75 and 120 s). In B mode or basal, it is showed a wall thickening of terminal ileon (yellow arrows in a), with moderate fat inflammation around it (blue arrow in a and b) and a entero-mesenteric sinus tract is also observed (pink arrows in a and b). After contrast administration, the intestinal loop shows an early intense homogeneous enhancement (green arrows) maximum at 35 s.
**Fig. 15:** Ultrasound study performed initially in B mode (images a and b) with contrast administration posteriorly, evaluating the pattern of enhancement and time required for maximum bowel wall enhancement (postcontrast images at 10, 20, 35, 45, 75 and 120 s). In B mode or basal, it is showed a wall thickening of terminal ileon (yellow arrows in a), with moderate fat inflammation around it (blue arrow in a and b) and a entero-mesenteric sinus tract is also observed (pink arrows in a and b). After contrast administration, the intestinal loop shows an early intense homogeneous enhancement (green arrows) maximum at 35 s.

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Fig. 16: Ultrasound study performed initially in B mode (images a and b) with contrast administration posteriorly, evaluating the pattern of enhancement and time required for maximum bowel wall enhancement (postcontrast images at 10, 20, 35, 45, 75 and 120 s). In B mode or basal, it is showed a wall thickening of terminal ileon (yellow arrows in a), with moderate fat inflammation around it (blue arrow in a and b) and a entero-mesenteric sinus tract is also observed (pink arrows in a and b). After contrast administration, the intestinal loop shows an early intense homogeneous enhancement (green arrows) maximum at 35 s.

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### MR and CEUS findings showed in pathological loop

<table>
<thead>
<tr>
<th>Pathological bowel loop</th>
<th>MR</th>
<th>CEUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Proximal, distal or terminal ileon, colon</td>
<td></td>
</tr>
<tr>
<td>Bowel wall thickness</td>
<td>&gt;3mm</td>
<td></td>
</tr>
<tr>
<td>Complications</td>
<td>Stenosis, abscess, phlegmon, sinus tract or fistula</td>
<td></td>
</tr>
<tr>
<td>Contrast signal intensity</td>
<td><strong>Certain</strong> (SPGR T1WI, 70s delay)</td>
<td><strong>Certain, probable, no</strong></td>
</tr>
<tr>
<td>Time required for maximum bowel wall enhancement</td>
<td><strong>No</strong></td>
<td>Early (&lt;35s), medium (36-59s), late (&gt;60s), no</td>
</tr>
<tr>
<td>Pattern of bowel wall enhancement</td>
<td><strong>Layered</strong> (mucous /stratified), homogeneuos or irregular</td>
<td>Homogeneous or irregular</td>
</tr>
</tbody>
</table>

**Fig. 17**

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### Calculation of RCE (relative contrast enhancement) in pathological and normal bowel loops

<table>
<thead>
<tr>
<th>SEQUENCES</th>
<th>NOISE SIGNAL</th>
<th>INFLAMMATORY bowel loop</th>
<th>CONTROL bowel loop</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SPGR T₁WI without contrast, in coronal plane</strong></td>
<td>3 values measured with ROI in an extracorporeal area very close to abdominal wall (1) and calculate the arithmetic mean of these values</td>
<td>3 values (with ROI) in intestinal mucosa and calculate the arithmetic mean</td>
<td>3 values (with ROI) in normal mucosa and calculate the arithmetic mean</td>
</tr>
<tr>
<td><strong>SPGR T₁WI with contrast (70 s delay), in coronal plane</strong></td>
<td>3 values measured with ROI in the same area (1) and calculate the arithmetic mean of these values</td>
<td>3 values (with ROI) in intestinal mucosa with the highest enhancement and calculate the arithmetic mean</td>
<td>3 Values in normal mucosa and calculate the arithmetic mean</td>
</tr>
</tbody>
</table>

\[
RCE = \frac{(\text{Wall signal intensity postgadolinium} - \text{signal intensity pregadolinium})}{\text{signal intensity pregadolinium}} \times 100\% \times \frac{\text{Noise signal pregadolinium}}{\text{postgadolinium}}
\]

---

**Fig. 18**

Results

1 Descriptive Analysis
Pathological bowel segments most affected:
- Terminal ileon (16 patients), distal ileon (11), distal and terminal ileon (1), ileo-colic surgical anastomosis (1 patient).
Range and average of wall thickness at MR: 3.5 - 17mm, mean 8.64mm.
Range and average of wall thickness in ultrasound: 3.3 - 9mm, mean 5.94mm.
Complications in MR: stenosis (16 patients); fistula (10); abscess (2).
Complications in CEUS: stenosis (7 patients), fistula (2).
Pattern of enhancement in MR in order of frequency:
- Layered (23 patients); homogeneous (5); irregular (2).
Pattern of enhancement in CEUS:
- Homogeneous (22 patients); irregular (3); absence of enhancement (1).

We did not find the pathological loop in B-mode ultrasound in one patient due to an intestinal occlusion, therefore we did not administer contrast material.

No ultrasound study was performed by personal or technical reasons: 3 patients.
Time required for maximum wall bowel enhancement in CEUS: 10-60 seconds; mean 31.48s.

Ultrasound enhancement in seconds:
- Early (18 patients); medium (3) and late (2); no intense enhancement (3 patients).

Noise signal range on 3D T1 SPGR sequences without contrast: 19 - 100.67; mean 45.35.
- Noise signal range on 3D T1 SPGR postcontrast sequences: 19.67 - 109.67; mean 52.58.

Range of parietal signal intensity measured at the pathological loop on 3D T1 SPGR sequences without contrast: 214.67 - 605.67; mean 417.40. Range of parietal signal intensity measured at the pathological loop on 3D T1 SPGR postcontrast sequences: 659 - 1639.67; mean 1014.82.

Range of parietal signal intensity measured at the non-pathological loop on 3D T1 SPGR sequences without contrast: 235.67 - 807; mean 391.71.
Range of parietal signal intensity measured at the no-pathological loop on 3D T1 SPGR postcontrast sequences: 319-1109; mean 641.904.

RCE range and average in normal loop: 0 - 267.43; mean 63.76.
RCE range and average in pathological loop: 39.99 - 343.94; mean 139.95.
ADC range in normal loop: 1.92-4.07x10^{-3} mm^2 / s; mean 3.07x10^{-3} mm^2 / s.
ADC range in pathological loop: 0.78-3.36x10^{-3} mm^2 / s; mean 1.60x10^{-3} mm^2 / s.
Body mass index (BMI) range: 15.59-42.72; mean 24.67. No difficulties in ultrasound evaluation were determined in any of the patients studied.

2.-Descriptive Statistical Analysis

2.1. MRI

2.1.1. We studied the relationship between the wall thickness measured in millimeters with the pattern of wall enhancement in MR by ANOVA test, with no statistically significant differences for homogeneous and irregular patterns (p>0.05). However, performing a secondary analysis between the layered pattern and wall thickness (Figure 19) using T-test, we can conclude that the layered pattern is associated with a greater wall thickness (9.330mm), reaching statistical significance (p <0.05).

2.1.2. The correlation between wall thickness and semiquantitative signal intensity on diffusion images (DWI), concluded statistically significant results (p = 0.005) between the two variables (Figure 20).

2.1.3. The analysis between enhancement pattern on MR and semiquantitative signal intensity on DWI, were not statistically significant. The layered pattern, observed in 18 patients (78.3%) a "certain" restriction, without statistical significance (p=0.136). Their irregular and homogeneous patterns were further to rise significant results (p> 0.05).

2.1.4. Spearman test demonstrated a moderate negative correlation (-0.454) between the relative contrast enhancement (RCE) and ADC values jointly analyzing pathological and normal loops values, determining that the higher the contrast enhancement values the ADC values were lower, and consequently the diffusion restriction is greater (Figure 21). We observed a discordant case with the other cases (points) that are represented in the graph, which may correspond to determining the presence of very high values of mean bowel wall enhancement (1262.666), without significant restriction on diffusion sequence (mean ADC 2.663x10^-3mm2/s), both measured in the pathological loop, consequently altering the result of the formula of RCE and correlation.

- Using the ROC curves, we evaluated these two parameters separately, we observed a higher diagnostic yield for the ADC (Figure 22 includes both graphs, ADC and RCE) than for the RCE.

- Wicoxon test demonstrated a statistically significant difference (p <0.001) in ADC values and RCE analyzed in pathological loops respect to non-pathological loops (Figure 23).

2.2. CEUS

2.2.1. Wall thickness and ultrasound enhancement intensity. We determined that the "certain" semiquantitative enhancement (observed in 17 patients) presented a higher mean wall thickness (6,600mm) than those patients with probable wall enhancement (8
patients) or not present (1 patient), although the results are not statistically significant (p = 0.053).

2.3. MRI and CEUS
2.3.1. We analyze each valued enhancement patterns on MR with the time required for bowel wall enhancement intensely in CEUS (early, middle, late or not) using \( \chi^2 \) test for each type of enhancement. None of these patterns of enhancement allowed the use of the \( p \) probably due to the insufficient sample. The homogeneous and irregular patterns showed no correlation with the presence of early enhancement, being objectified in 3 (16.7% of the total with early enhancement) and in 1 patient (5.5%) respectively. The layered pattern, observed in 20 patients presented an early ultrasound enhancement in 14 patients (70%), with not statistically significant results, although it seems to have some correlation between both of them.

2.3.2. ADC values and the time required for maximum wall bowel enhancement in CEUS was evaluated by test ANOVA. Los patients with early ultrasound enhancement had higher ADC values than in the remaining patients, with a non-statistically significant result (p = 0.737).

2.3.3. Intensity of wall enhancement in CEUS in correlation with semiquantitative signal intensity on DWI, we found a concordance in 16 patients, 3 probable (50% of probable signal) and 13 with "certain" signal intensity (68.4% of "certain" high signal) without obtaining a kappa index of statistically significant agreement (kappa 0.145, p = 0.396).

2.3.4. Analysis between the time required for maximum bowel wall enhancement in CEUS and semiquantitative signal intensity on DWI, it was observed that of 18 patients who showed an early ultrasound enhancement, 12 had a semiquantitative signal intensity "certain" in diffusion sequences (66.66%), 5 patients an intensity of "probable" sign and one showed no diffusion restriction, with no statistically significant results (p = 0.31). The summary of the comparative results between MRI and ultrasound are shown in Figure 24.

2.3.5. Finally, the results of our study, we can define the high probability of acute intestinal inflammation criteria in MR and CEUS (Figure 25), regardless of extraintestinal findings, which are not studied in this work.
Images for this section:

<table>
<thead>
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<th>LAYERED PATTERN</th>
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<th>STANDARD DEVIATION</th>
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Fig. 19

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<td>Probable / No</td>
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<td>6,333</td>
<td>2,4367</td>
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</table>

Fig. 20

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Spearman Coefficient
- We demonstrated a significant negative moderate correlation between RCE and ADC values
- Rho \(-0.454\); \(p<0.001\)

Graphic 1: the higher values of contrast enhancement (RCE) are correlated with lower ADC values (more diffusion restriction).

Fig. 21
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**ROC curves**

- ADC is a parameter more accurate than RCE to determine inflammatory activity \((p<0.001)\)

<table>
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<th>Area under curve</th>
<th>Statistical Significance</th>
<th>CI (95%)</th>
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<td>0.936</td>
<td>0.000</td>
<td>0.865-1</td>
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<tr>
<th>Area under curve</th>
<th>Statistical Significance</th>
<th>CI (95%)</th>
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<td>0.865</td>
<td>0.000</td>
<td>0.766-0.964</td>
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**Fig. 22**

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Wilcoxon Test

- RCE y ADC values in pathological and normal bowel loops ($p<0.001$)

<table>
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<th>RCE</th>
<th>ADC</th>
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<td>[39.9-343.9]</td>
<td>[0.78-3.36x10^{-3}mm^2/s]</td>
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<td>Average</td>
<td>139.95</td>
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<tr>
<td>Normal</td>
<td>[0-267.4]</td>
<td>[1.92-4.07x10^{-3}mm^2/s]</td>
</tr>
<tr>
<td>Average</td>
<td>63.7</td>
<td>3.07 x 10^{-3}mm^2/s</td>
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</table>

Table: It is showed significant higher RCE values and lower ADC values in a pathological loop respect to a normal loop

Fig. 23

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- MR and CEUS

<table>
<thead>
<tr>
<th></th>
<th>CEUS</th>
<th>Time required for maximum bowel wall enhancement (early, medium, late, no)</th>
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<tbody>
<tr>
<td>Pattern of enhancement</td>
<td></td>
<td>No statistically significant *</td>
</tr>
<tr>
<td>Signal intensity on DWI (semiquantitative)</td>
<td>No statistically significant ($p&gt;0.05$)</td>
<td>No statistically significant *</td>
</tr>
<tr>
<td>ADCs (quantitative)</td>
<td></td>
<td>No statistically significant</td>
</tr>
</tbody>
</table>

* We observed a relation between the layered pattern and “certain” signal intensity on DWI (78.3%) and the early homogeneous pattern showed by CEUS (70%)
<table>
<thead>
<tr>
<th></th>
<th>MR</th>
<th>CEUS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Significant bowel wall thickness</strong></td>
<td>&gt;9mm</td>
<td>&gt;6mm</td>
</tr>
<tr>
<td><strong>Wall enhancement (semiquantitative)</strong></td>
<td><strong>Layered or mucous</strong>, specially if it is intense and early</td>
<td><strong>Intense and homogeneous specially if it is early</strong> (≤35s)</td>
</tr>
</tbody>
</table>
| **Wall enhancement (MR sequences SPGR T1WI with and without contrast)** | **Without contrast**: average 417.40  
**Postcontrast**: average 1014.82 | **Software to quantify is not available in our institution** |
| **Signal intensity on DWI (semiquantitative)** | **Significant increased of signal intensity** in pathological bowel loop | **No** |
| **CDA values (quantitative)** | Average 1.6 x 10⁻³ mm²/s | **No** |
Conclusion

MRI is the gold standard technique to detect signs of bowel acute inflammation in patients with CD.

In our study, we conclude that the most accurate signs of activity in MRI are wall thickness and layered pattern, with good correlation between them. However, although the layered pattern most frequently presents a "certain" semiquantitative signal intensity we could not conclude statistically significant results. A moderate statistically significant negative correlation between the relative contrast enhancement (RCE) and the ADC values, being ADC more accurate than RCE for the presence of inflammatory activity. However, both assessments are complementary to the morphological sequences, but DWI could be considered in those patients who have a contraindication to intravenous contrast injection.

In CEUS we observed a relation between "certain" wall intense enhancement and a greater wall thickness and the appreciation of "certain" high signal intensity on DWI, although without statistical significance. CEUS does not have a significant correlation with the functional MRI findings, although we have observed that early homogeneous enhancement has been linked most often to layered pattern in RM and a "certain" signal intensity on DWI (66.6% of cases with "certain" signal intensity showed an early ultrasound enhancement). CEUS, therefore, may be useful in monitoring patients with CD and suspected active inflammation, localized mainly in distal or terminal ileum, in case of problems of availability or contraindications to MRI studies.
References


