MR enterography in pediatric Crohn's disease: Analyzing the apparent diffusion coefficient to assess active bowel wall inflammation

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Purpose

Crohn's disease (CD) is a chronic idiopathic inflammatory condition potentially affecting any portion of the alimentary tract. It is characterized by a relapsing-remitting clinical behavior and typically the inflammation along the intestine is segmental and transmural. A key issue in the management of patients with CD concerns how best to assess the disease's extent and inflammatory activity.

Magnetic resonance enterography (MRE) is the first-line imaging modality for assessing pediatric patients with CD. Besides the advantages of avoiding any ionizing radiation and obtaining a better soft tissue contrast resolution than with computed tomography, MRE has the ability to investigate disease activity, differentiating between active inflammation and fibrosis, with important implications for disease management [1-6].

Diffusion-weighted imaging (DWI) has been studied in conjunction with MRE with a view to improving the accuracy of disease activity assessments.

The DWI technique uses the diffusion of water molecules in biological tissue to create images that reflect changes in water motility caused by interactions with cell membranes, macromolecules, and tissue alterations. In addition to provide images, DWI intrinsically provides quantitative parameters through the apparent diffusion coefficient (ADC) values, helping to quantify the restriction of the water molecules' diffusion [7, 8] (Fig. 1).

While numerous published studies have demonstrated the association between active bowel inflammation in CD and restricted mural diffusion on DWI in adult patients [9-13], literature in pediatric patients is limited [14-17].

Aims of the study were to compare DWI findings with morphological MRE sequences in cohorts of pediatric patients with CD, and to quantify the mean ADC for inflamed intestinal segments and areas of inactive disease.

Images for this section:

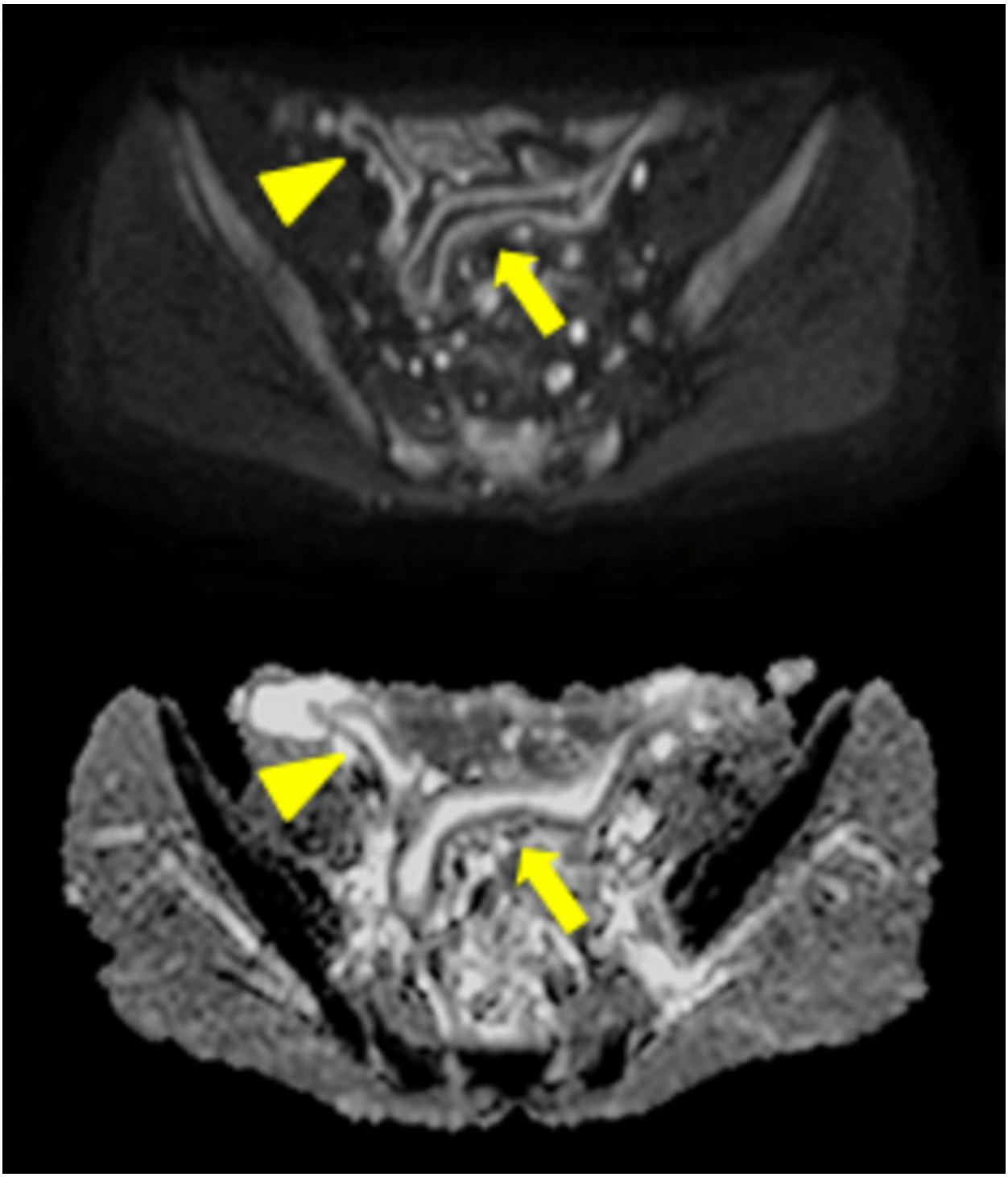

Fig. 1: Sigmoid loop (arrow) and terminal ileum (arrowhead) characterized by diffusivity restriction: DWI (above) and relative ADC map (below).

Methods and materials

A single-center retrospective study was conducted over the years 2013-2016 at the Pediatric Radiology Department of the University of Padua. 50 patients (25 M; 25 F; mean age: 12,7 years), with histopatologically confirmed CD, were included in the study. All patients' parents were informed about the examination and gave their written consent to it. Patients underwent MRE (Siemens Avanto, Germany, 1.5 T) using a standardized protocol.

From four days before the procedure, patients were asked to adopt a low-fiber diet. On the day before the examination, they drank an age-related quantity (maximum: 2 liters) of a water solution containing 4 sachets (17,4 g) of PEG (polyethylene glycol) 4000. Patients fasted for 6 hours before the procedure, and 40 minutes beforehand they were given oral PEG 4000 (17.4 g) dissolved in 20 ml of water per kilogram of body weight. Patients were placed in the supine position, head first. After performing localizer sequences, the following were obtained: T2 True-FISP sequences on the coronal and axial planes, with a thickness of 3 mm; T2 HASTE sequences with the same planes and thicknesses; T2 HASTE sequences with fat saturation (FS) on the coronal plane (3 mm thickness); T1 VIBE FS sequences on the coronal plane (3 mm thickness); T1 VIBE FS sequences with contrast medium on the coronal and axial planes 30 seconds (arterial phase), 70 seconds (portal phase), and 150 seconds (late phase) after administering the contrast agent, on the coronal and axial planes (3 mm thickness). The contrast medium was gadolinium chelate (Dotarem, Guerbet, France) 0.01 mmol/kg.

Free-breathing DWI sequences were obtained with b=0, 400, 800 s/mm² on the axial plane (6 mm thickness). The mean duration of DWI sequences was approximately 4 minutes. Subtraction sequences of the various dynamic phases were also recorded. ADC maps were generated from the DWI sequences. The ADC was measured by placing specific regions of interest (ROI; area <10 mm²) in appropriately selected segments of ileum and colon with active and inactive disease.

Images were evaluated by two radiologists.

Results

Diffusivity was always restricted in inflamed bowel walls, identified on morphological MRE sequences by recognizing the typical signs (mural thickening, enhancement etc.). In particular, at higher b values (b=800), the difference in mean ADC values between inflamed loops and uninflamed loops was found statistically significant. Mean ADC values of inflamed loops was 1.08±0.29 $x10^{-3}mm^2/s$ (Fig. 2); mean ADC values of uninflamed loops was 3.10±0.33 $x\ 10^{-3}mm^2/s$ (Fig. 3) (p=0.003). It was demonstrated that these

values were independent by patients' gender (males: 1.06±0.30 vs 3.07±0.33 x $10^{-3}$$mm^2$/s; females: 1.10±0.29 vs 3.12±0.30 x $10^{-3}$$mm^2$/s). Values and their distribution are represented in Fig.4. We found no overlapping between ADC values in inflamed and uninflamed loops, meaning that the sensibility and the specificity in detecting bowel walls with different characteristics is very high.

Images for this section:

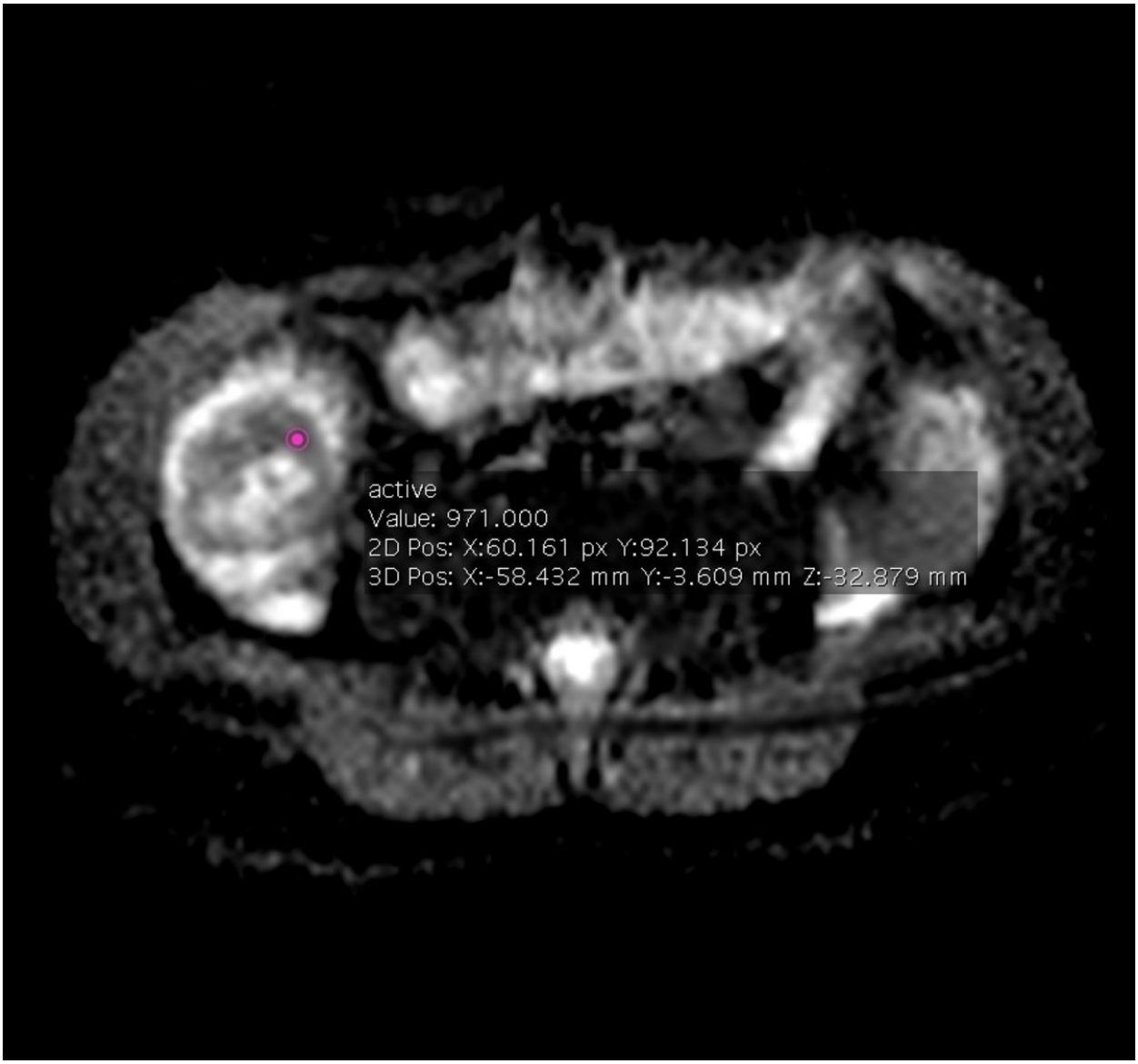

Fig. 2: ROI on a inflamed bowel wall (M; 15 y.). Medium ADC value is 0,97 x 10(-3) mm(2)/s.

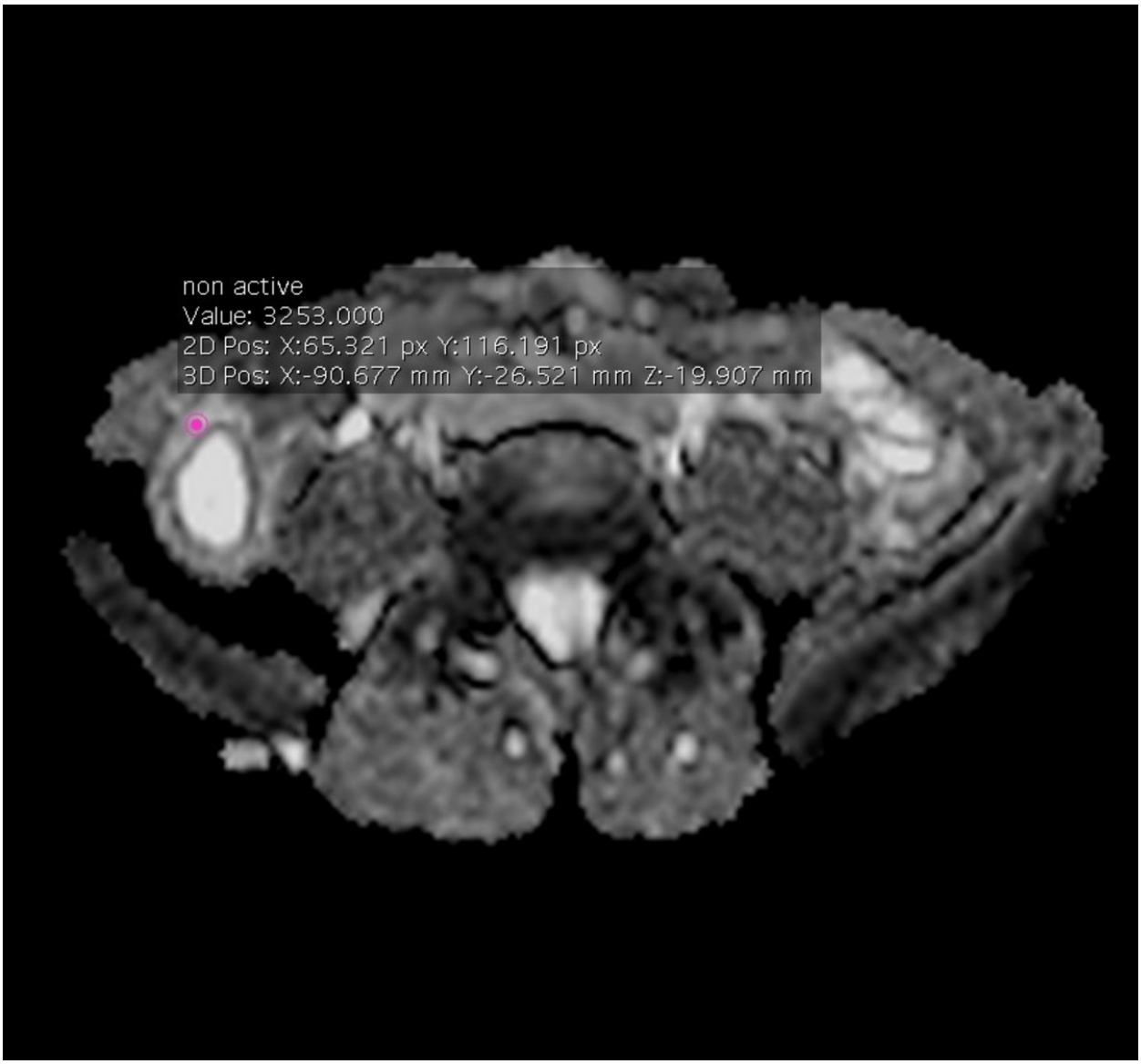

Fig. 3: ROI on a inactive bowel wall (M; 11 y.). Medium ADC value is 3,25 x 10(-3) mm(2)/s.

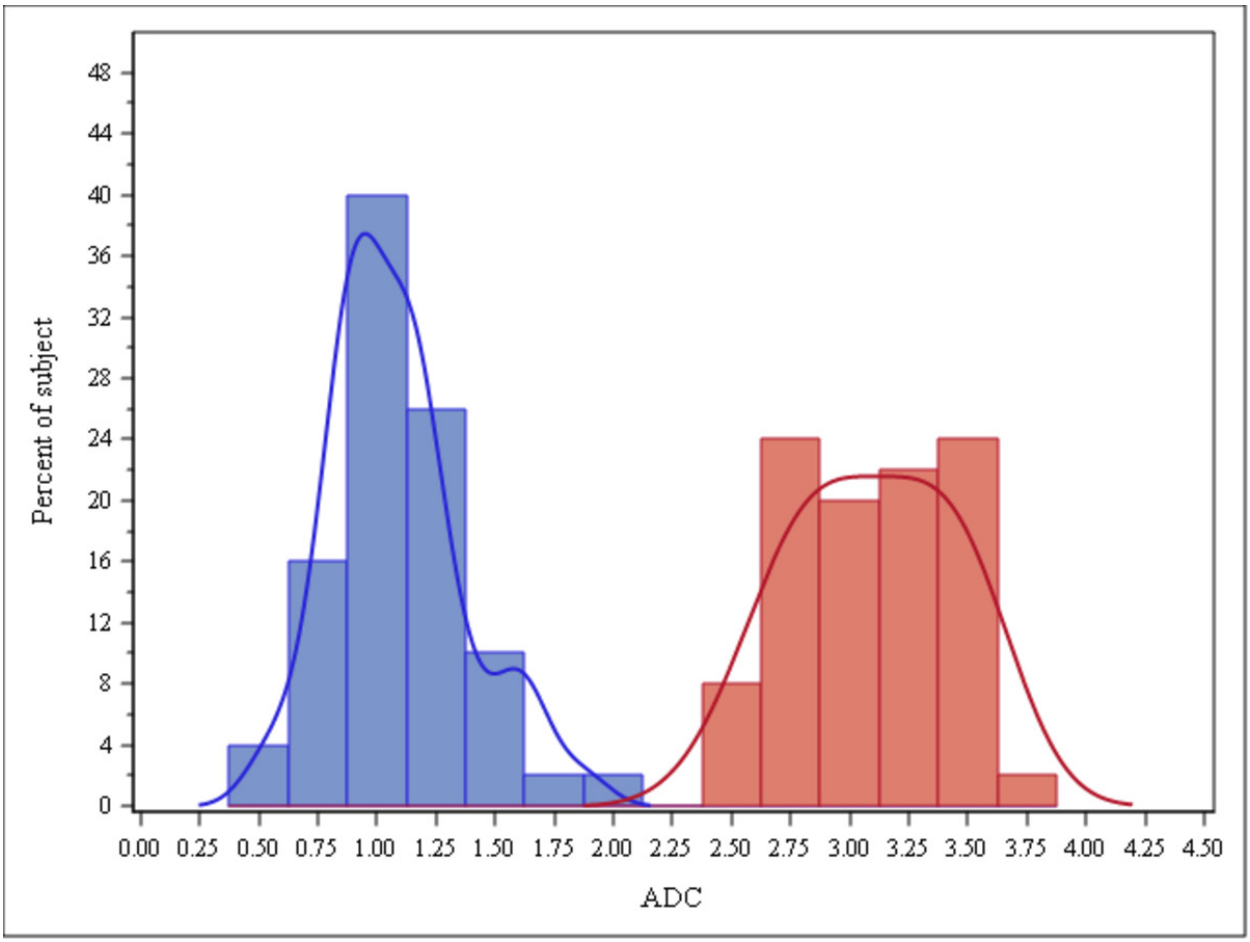

Fig. 4: ADC values with relative distribution calculated placing a ROI in inflamed bowel loops (blue boxes and line) and in uninflamed loops (red boxes and line).

Conclusion

In pediatric Crohn's disease, the mean ADC was found significantly higher in bowel segments with active as opposed to inactive disease. DWI sequences and ADC maps might be used alongside traditional MRE sequences to facilitate a quantitative analysis of disease activity and to improve accuracy in determining the extent of disease activity. DWI should always be included in pediatric study protocols, considering that these sequences are short lasting and free breathing. The ADC obtained from DWI sequences could serve as an effective alternative to post-contrast study.

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