Feasibility of diffusion weighted magnetic resonance imaging in evaluation of different small bowel pathology

A.H. Afifi a,*, A.M. Aboal Ela a, A. Albanna b

a Department of Radiology, Alexandria University, Egypt
b Department of Internal Medicine, Alexandria University, Egypt

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Abstract

Background: Increasing capability of MR imaging via applying DWI gives additional information about the functional state of tissues with high potentials due to lacking radiation exposure and contrast hazards. Application included evaluation of gastrointestinal tumors and follow-up to assess response to treatment. In IBD, DWI is useful in highlighting bowel segments of active disease and the purpose of this study is to evaluate role of DWI-MRI in neoplastic and inflammatory small bowel diseases.

Materials and methods: Prospective study included 50 patients subjected to MRI enterography using 1.5 T closed magnet followed with DWI and then ADC values were estimated. Ileo-colonoscopy and biopsy were done and pathological data were reviewed.

Results: Twenty-four males and 26 females with small bowel lesions were divided into two groups, 26 neoplastic (5 benign, 21 malignant) and 24 inflammatory lesions (48%). Mean ADC value of inflamed bowel was $1.59 \pm 0.45 \times 10^{-3}$ mm$^2$/s, compared to $2.74 \pm 0.68 \times 10^{-3}$ mm$^2$/s in normal bowel. ADC value of neoplastic lesions ranged from 0.6 to 1.5 and non-neoplastic lesions from 1.1 to 2. ADC value of lymphoma ranged from 0.6 to $0.7 \times 10^{-3}$ mm$^2$/s and adenocarcinomas from $0.8 \times 10^{-3}$ mm$^2$/s.

Conclusion: DWI is an important complementary sequence with the routine MRI of the small bowel helping in lesion characterization and differentiation of pathology.

1. Introduction

The process by which water molecules can move freely in different biological tissues is due to random translational “Brownian” motion, so diffusion weighted magnetic resonance imaging (DW MRI) is considered the recent imaging technique that assesses this process of diffusion in vivo. Calculating

* Corresponding author.
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ADCs “apparent diffusion coefficient” considered the quantitative way to express the degree of diffusion in biological tissues (1).

Tissue cellularity and integrity of cell membrane both estimate the degree of diffusion restriction and so pathological tissues as in case tumors or inflammation exhibited increased cell numbers that result in increased intracellular space in a given volume and consequently presented with diffusion restriction. Multiple previous studies proved also that measured ADC values decreased with increased tissue cellularity or cell density and in turn DW MRI is considered a sensitive tool in differentiating nature of histopathological tissues (2,3).

DWI in the last decade was considered an important complementary MRI technique in imaging of the abdomen and more especially the pelvis. Most malignancies affecting GIT demonstrated increased cellularity compared with normal tissues and so resulted in diffusion restriction with increased signal intensity on DWI (4). Recent previous researches showed that malignant GIT tumors have low ADC values compared with related normal tissue or benign lesions (4,5).

Recently, DWI may play a role in quantification of inflammatory process as inflamed bowel segments exhibited restricted diffusion compared with normal bowel (6,7). Also DWI can provide quantitative information about the level and activity of inflammation, whether acute or chronic inflammation, as the apparent diffusion coefficient (ADC) can be calculated from the bowel wall (8).

Practically, main indications for applying DWI are the diagnostic evaluation of neoplastic lesions regarding localization and staging in case of malignant GIT tumors. Other applications are assessing extra-intestinal spread, distant metastases and post-therapy follow-up of malignant tumors (9,10).

In application in cases with inflammatory bowel disease, DWI is useful in highlighting bowel segments of active disease and hence it is becoming a standard component of the MR enterography protocol; however, further studies are mandatory to assess the full potential of this technique and guide its clinical applications (10).

Nephrogenic systemic fibrosis was considered as a rare but serious complication of Gadolinium-based contrast agents, that aid the direction for diminished use of intravenous contrast agents in MR imaging, and so DWI become an important alternative method to obtain information that could otherwise be obtained from extracellular contrast enhancement (11).

A new possibility to expand the capability of MR imaging was to apply new MR application, namely DWI, that could give more information about the structure and function of the involved bowel with its high potentials due to lack of exposure to radiation and contrast hazards (12).

Most of the available published descriptions of DWI for the evaluation of the bowel were focused on the detection of colorectal cancer (13).

To our knowledge, the use of DWI for evaluation of bowel wall masses and inflammation had been previously described in minor degree.

2. Purpose

The purpose of the current work is to assess the role of DW MRI sequence in diagnosis and evaluation of different inflammatory and neoplastic small bowel diseases.

3. Material and methods

Fifty patients were included in the current prospective study, during interval from December 2013 to March 2015 with suspected small bowel lesions, who were referred to multiple radiology centers, mainly for CT abdomen or CT enterocolonography “CTE” examination and consequently, they were scheduled for further assessment by complementary MRI and DW MRI in order to confirm the CT diagnosis (whether MRI and DWI would be in concordance with CTE diagnosis) or in a trial to reach the final diagnosis. Medical ethics were considered and patients were aware of the examination, and patient’s agreement was obtained with informed consent.

Only patients with positive CTE as known or suspected small bowel disease were included. Also included were group of patients in whom intravenous CT contrast injection was contraindicated due to poor renal functions (5 patients), whereas exclusion criteria included general contraindications to MRI e.g. presence of cardiac pacemakers, surgical clips in the abdomen and pelvis that can result in extensive artefacts based on their composition.

The studied patients had full history taking, thorough clinical examination. Radiological examination included routine abdominal US survey that was done for all patients to detect any other abdominal GIT abnormalities as focal hepatic lesion, lymphadenopathy or ascites.

MD CT enterography (either 16 or 64 slices) followed with abdominal MRI concerning the small bowel (i.e. MR enterography) was performed for all patients using 1.5 T superconducting closed magnet MRI followed with DWI. Ileo-colonoscopy and biopsy (endoscopic or imaging guided) were done for indicated patients, and then pathological data of all patients were reviewed.

3.1. MRI and DWI technique

Patient preparation: Patients being fasting for at least 6 h, and then were ingested with 1200–1300 mL of an iso-osmotic solution of mixed water and mannitol to produce a 3% solution (mannitol 10% diluted with water in a ratio of 1:1 in order to be iso-osmotic). This was divided into two aliquots of 600–650 mL each, and the patient drank one aliquot every 25–30 min. Another 200 mL of the solution was given just before scanning to opacify the stomach and duodenum. 10 mg of hyoscine butylbromide (Buscopan) was injected IV to eliminate peristalsis and reduce motion artifact.

MRI examination: Patients were requested to lie in the supine position, arms extended above head and phased array surface coil was used. Respiratory-gated acquisitions were used in some sequences. Typical scan time of all sequences was 20–30 min. In cases of contrast study, IV line was connected to an automated power injector filled with the appropriate dose of contrast which comprised of 0.1 mmol (0.2 mL) of gadolinium chelate per kilogram of body weight (gadopentetate dimeglumine; Magnevist, Bayer HealthCare) at rate = 3 mL/s. The importance of remaining stable during study was emphasized.

MRE scanning sequences included initial localizer T1-W GRE sequences were used, followed with single breath-hold Coronal T2-weighted sequence (HASTE), Axial and Coronal
steady-state free precession sequence (true FISP), Coronal T1-weighted 3D gradient echo (VIBE). Post-contrast VIBE sequences obtained in Coronal and Axial planes. DWI with variable $b$ values 0,400 and 800 s/mm$^2$ with TR 2000, TE 80, flip angle 90, FOV 370 mm, slice thickness 6 mm and average scan time 75 s with automatically computer-generated ADC map. We applied high $b$ values ($b > 800–1000$ s/mm$^2$) for imaging bowel segments and to suppress signals from bowel contents and contrast materials which yielded T2 shine-through artifact. Source images were transferred to a dedicated workstation for post-processing.

3.2. Interpreting diffusion-weighted images

(1) **Qualitative analysis:** DWI were viewed to assess signal intensity whether there is diffusion restriction in abnormal tissue (e.g. inflammatory, abscess or tumor) resulting in hyper-intensity on DWI and of low signals on ADC maps.

(2) **Quantitative analysis:** Mean ADC values of different tissues were calculated. Areas of most restricted diffusion (ROI i.e. region of interest) have low ADC values. DWI was interpreted in correlation with ADC map and then ADC values were calculated in $10^{-3}$ mm$^2$/s.

4. Results

Current study included 50 cases divided as 24 males (48%) and 26 females (52%). Small bowel lesions were subdivided based upon the final diagnoses into two groups, 26 small bowel neoplastic lesions (52%) (including 5 benign and 21 malignant tumors) and 24 inflammatory lesions (48%) with different stages of chronicity. Renal insufficiency was found in five patients where CT and MRI were done without contrast administration.

Malignant lesions included 9 lymphoma, 8 adenocarcinoma, 3 gastrointestinal stromal tumors GIST and one carcinoid tumor. Benign lesions (5 patients) were benign adenomatous polyps. Neurofibromatosis type I was found in one case presented with terminal ileum GIST and “Café-au-lait” flat and pigmented skin spots “hallmark of NF”. Inflammatory group included inflammatory bowel diseases (active Crohn’s disease 15 cases, chronic non-active Crohn’s 5 cases), 3 cases were non-specific inflammation and one case was T.B ileitis.

The mean age was 54.7 ± 12.9 years ranging from 24 to 78 years in neoplastic lesions and was 33.4 ± 10.6 years ranging from 18 to 55 years in non-neoplastic lesions. The main patients’ presentations included abdominal pain in 40 patients (80%); followed by chronic diarrhea in 12 patients (24%); weight loss in 6 patients (12%); hematochezia in 3 patients (6%); constipation in 3 patients (6%); jaundice in 2 patients (4%) and one patient presented with melena (2%).

The final diagnosis had been confirmed by ileo-colonoscopy and biopsy in 29 lesions (58%), Upper GI endoscopy and biopsy in 7 lesions (14%), ultrasound guided biopsy in 3 lesions (6%), ERCP in 2 lesions (4%), surgical exploration in 2 lesions (4%) and the remaining in 7 lesions (12%), and the final diagnosis was achieved with radiological findings and supported by clinical data.

4.1. MRE and DWI findings

Group A patients include 26 (52%) neoplastic lesions.

*MRI and DWI of small bowel lymphoma:* This was diagnosed in 9 patients (one duodenal, two jejunal, three ileal and three in terminal ileum and ileo-cecal). Gross patterns included polypoid (five lesions), infiltrating (two lesions), and diffuse wall thickening with lost parietal folds (two lesions).

Radiological features were aneurysmal dilation of the lumen “due to local neuropathy” in eight lesions (as in Case 1), large exo-enteric mass extending beyond bowel wall (two lesions) and circumferential infiltration was eccentric, with the absence of a distinct mesenteric or anti-mesenteric distribution in 5 lesions. Lymphoma typically demonstrated
homogenous mild enhancement in seven lesions and moderate heterogeneous enhancement in two lesions. Lymphomatous infiltrations in liver (two lesions), lung, kidney and spleen (one lesion) and mesenteric lymph nodes (5 lesions). All lymphoma cases showed avid diffusion restriction and ADC value ranging from 0.6 to $0.7 \times 10^{-3}$ mm$^2$/s.

**MRI and DWI of small bowel adenocarcinoma:** This was diagnosed in eight patients where MRI showed heterogeneous enhancing luminal duodenal cauliflower mass (in two patients), diffuse trans-mural infiltration of jejunal wall with exophytic growth and accompanied with eccentric bowel wall thickening in two patients (Case 2), and terminal ileal lesions appeared as infiltrative lesions, causing luminal stenosis and obstruction with pre-stenotic dilatation in three patients (Case 3). Two lesions in terminal ileum and ileo-cecal valve involvement showed a local soft tissue mass (one with omental,
Case 2 56 years female patient had pathologically proven jejunal adenocarcinoma with ulceration and perforation (A) Coronal, (B) Axial true-FISP and (C) Coronal post-contrast VIBE fat sat with enhanced circumferential irregular mural annular thickening of the proximal jejunum with mild localized free fluid collection (arrow in B) related to its medial aspect. (D) and (E) DWI and ADC showed diffusion restriction with ADC value averaging $0.8 \times 10^{-3}$ mm$^2$/s.
one with liver metastasis). General MRE features as sharply demarcated, circumferential luminal narrowing, with shoulder- ing of the margins and mucosal destruction. Post-gadolinium MRE demonstrated mildly enhancing heterogeneous eight lesions. All cases showed diffusion restriction and ADC values ranging from 0.8 to $1 \times 10^{-3}$ mm$^2$/s.

**MRI and DWI of small bowel GIST:** This was diagnosed in three patients: two at terminal ileum and one at distal jejunum. Hallmarks of diagnosis is the exophytic growth nature due to serosal origin with significant mass effect (Case 4). The boundary of the lesion was more distinct after contrast. Malignant GISTs are predominantly extra-luminal, eccentric and frequently develop necrosis and hemorrhage. One of these cases was associated with Neurofibromatosis type I (NF1) (Case 5), and showed diffusion restrictions with ADC value averaging $0.83 \times 10^{-3}$ mm$^2$/s. The other two cases showed diffusion restriction with ADC value averaging $0.8 \times 10^{-3}$ mm$^2$/s and $0.88 \times 10^{-3}$ mm$^2$/s.

**MRI and DWI of small bowel carcinoid:** This was diagnosed in one case with no specific MRI features as CT enterography was superior in detecting the primary lesion, desmoplastic reaction and calcification rather than MRI. DWI shows mild restriction as well as comparatively high ADC compared with other lesions ADC value $1 \times 10^{-3}$ mm$^2$/s.

**Group B patients:** This group included IBD that was diagnosed in 20 patients (12 confined to the small bowel and 8 had ileo-colonic disease). Seventeen had specific inflammatory disease (16 Crohn's disease and one TB) and three with non-specific inflammatory diseases.

**Features of active Crohn's disease:** Case 6 showed uniform mural thickening more than 3 mm, high T2-signals (due to edema), and engorged related vasa recta (Comb's sign) in 11 patients. Post-contrast enhancement of the bowel wall (stratification with target pattern) was found with enhanced local mesenteric adenopathy. Luminal affection was found either as non-constricted bowel lumen in 11 patients, or stenosis with pre-stenotic dilatation in 4 patients in the terminal ileum (namely fibro-stenotic type). Features of chronic Crohn's disease were creeping fat and fibro-fatty proliferation (4 patients with skip lesions). Complications are ileo-ileal and ileo-colic fistula (in 2 patients) and peri-anal fistula in one patient (penetrating type). Pelvic abscess occurred in two lesions. Bowel segments with active inflammation showed more diffusion restriction in comparison with normal bowel segments, which

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**Case 3** 28 years male had pathologically proven ileal adenocarcinoma (A) HASTE Coronal, (B) Axial true FISP showed irregular short- segmental tumifactive circumferential thickening resulting in manifest luminal stenosis (straight arrow), (C) and (D) DWI showed diffusion restriction (red arrow in C) with ADC value averaging $0.82 \times 10^{-3}$ mm$^2$/s.
could be assessed in both qualitative (as increased signal intensity on DWI) and quantitative manners (as decreased ADC values).

Mean ADC value of proven inflamed bowel segments was $1.59 \pm 0.45 \times 10^{-3} \text{mm}^2/\text{s}$ (range, $1.1-2.0 \times 10^{-3} \text{mm}^2/\text{s}$), compared to $2.74 \pm 0.68 \times 10^{-3} \text{mm}^2/\text{s}$ (range, $2.03-4.03 \times 10^{-3} \text{mm}^2/\text{s}$) in normal bowel segments. On the other hand, ADC value of neoplastic lesions ranged from 0.6 to $1.5 \times 10^{-3} \text{mm}^2/\text{s}$ while that of the non-neoplastic lesions from $1.1$ to $2.0 \times 10^{-3} \text{mm}^2/\text{s}$. Low ADC value in non-neoplastic lesions was due to pelvic abscess with increased viscosity which decreases the diffusibility rather than cellularity.

Statistical analysis of ADC value in diffusion MRI among the studied neoplastic and non-neoplastic patients was presented in Table 1. The cutoff value of ADC for non-neoplastic lesion was $1.05 \times 10^{-3} \text{mm}^2/\text{s}$, so lesions with ADC less than $1.05 \times 10^{-3} \text{mm}^2/\text{s}$ are neoplastic while lesions with ADC value more than $1.05 \times 10^{-3} \text{mm}^2/\text{s}$ are non-neoplastic with a sensitivity of 100%, specificity = 88.5%, area under the curve (AUC) = 0.963 (Fig. 1).

ADC value of lymphoma ranged from 0.6 to $0.7 \times 10^{-3} \text{mm}^2/\text{s}$ while that of the adenocarcinomas lesions ranged from $0.8$ to $1.0 \times 10^{-3} \text{mm}^2/\text{s}$. Statistical analysis of ADC value in diffusion MRI among the studied patients with lymphoma and adenocarcinoma lesions was presented in Table 2.

Receiver operating characteristic (ROC) curve of the cutoff ADC value used for differentiating adenocarcinoma from lymphoma lesions of small bowel disease = $0.75 \times 10^{-3} \text{mm}^2/\text{s}$, sensitivity = 100%, specificity = 100%, area under the curve (AUC) = 1 (Fig. 2).

The cutoff value of ADC for adenocarcinoma is $0.75 \times 10^{-3} \text{mm}^2/\text{s}$, so lesions with ADC less than $0.75 \times 10^{-3} \text{mm}^2/\text{s}$ are lymphoma while lesions with ADC value more than $0.75 \times 10^{-3} \text{mm}^2/\text{s}$ are adenocarcinomas with

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**Case 4** 70 years male patient had pathologically proven ileal and ileo-cecal adenocarcinoma. (A) and (B) Coronal true-FISP with fat sat showed uniform mural thickening of the terminal ileum (curved white arrow in A) with exophytic soft tissue mass (star in B) associated with multiple omental deposits (straight white arrows in A). (C) and (B) DWI and ADC showed diffusion restriction of the omental deposits (red arrows).
a sensitivity of 100%; specificity of 100% and PPV = 100%, NPV = 100%. Area under curve = 1.0.

5. Discussion

DWI of the small bowel used in evaluation of primary GIT neoplasms as detection, assessment of extra-intestinal spread and detection of distant metastases, also in identifying actively inflamed loops of bowel in cases of inflammatory bowel diseases; this was approached by the presence of restricted diffusion within the tumor lesion or active inflammation in the affected bowel wall. It gives both qualitative and quantitative information about tissue cellularity as well as integrity of cell membranes (14).

Ichikawa et al. (14) stated that DWI with high $b$ value of 1000 s/mm² provided 90.9% sensitivity and 100% specificity for detecting colorectal cancers. In this series of 42 patients with sigmoid and rectal carcinoma, all tumors were clearly demarcated from both normal bowel wall and bowel lumen, which were always hypo-intense on DWI.

Current study demonstrated that on DW images with high $b$ value, malignant lesions exhibited high signal intensity with low ADC values due to high cellular contents, diminished extracellular space, and tissue disorganization resulting in restricted diffusion. The cutoff value of ADC for non-neoplastic lesion was $1.05 \times 10^{-3}$ mm²/s, so lesions with ADC less than this value were considered neoplastic while lesions more than $1.05 \times 10^{-3}$ mm²/s were non-neoplastic with a sensitivity of 100%; specificity of 88.5% and PPV = 100%, NPV = 100%.

For further specification, also noted that cutoff value of ADC for differentiating lymphoma from adenocarcinoma was $0.75 \times 10^{-3}$ mm²/s, where cases with ADC less than $0.75 \times 10^{-3}$ mm²/s were lymphoma while those with ADC value more than $0.75 \times 10^{-3}$ mm²/s were adenocarcinoma with a sensitivity of 100%; specificity of 88.5% and PPV = 100%, NPV = 100%.

We were in agreement with the results of new study performed by Feuerlein et al. (4) who stated that majority of GIT malignancies demonstrated high cellularity than normal tissues and hence showed restricted diffusion than normal tissues.

Also, DWI can help in differentiation between recurrent cancer and secondary post-radiotherapy changes, by estimating related ADC values, where high ADC and no diffusion restriction matching with tissue edema 2ry to post-radiation therapy and low ADC indicating recurrent tumor. Here, DWI technique will be advantageous over PET as the later will be of limited use after short time of radiation therapy due to increased uptake due to inflammation and edema (12).

Regarding Crohn’s disease and ulcerative colitis, the active bowel inflammation showed infiltrated lamina propria and submucosa by inflammatory and lymphocytic cells resulting in increased cellularity, viscosity and granulation tissue leading to restricted diffusion (6,13).

Complications of inflammatory bowel disease as abscess formation as well as fistula, and sinus formation could be traced at DWI, leading to high accuracy for diagnosing intra-abdominal abscesses (15).
In the current study, abscesses expressed diffusion restriction as a result of its high viscid fluid contents rich in bacteria, inflammatory cells, and cellular debris. Also fistulas and sinus tracks expressed high signals on DWI, again, because of pus, inflammatory cells, and debris in and around the fistula tract.

Table 1  Diffusion MRI among the studied patients with neoplastic and non-neoplastic lesions.

<table>
<thead>
<tr>
<th>Diffusion of MRI</th>
<th>Non-neoplastic lesion (n = 24)</th>
<th>Neoplastic lesion (n = 26)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restricted DWI</td>
<td>No restriction 2 8.3</td>
<td>0 0.0</td>
<td>FE $P = 0.103$</td>
</tr>
<tr>
<td></td>
<td>Restriction 22 91.7</td>
<td>26 100.0</td>
<td></td>
</tr>
<tr>
<td>ADC value</td>
<td>Min-max 1.1–2.0</td>
<td>0.6–1.5</td>
<td>$t = 8.427$</td>
</tr>
<tr>
<td></td>
<td>Mean ± SD 1.5 ± 0.3</td>
<td>0.9 ± 0.2</td>
<td>$P &lt; 0.0001^*$</td>
</tr>
</tbody>
</table>

$FE$: Fisher’s exact test.
$t$: $t$-test.
* Significant at $P \leq 0.05$.

In the current study, abscesses expressed diffusion restriction as a result of its high viscid fluid contents rich in bacteria, inflammatory cells, and cellular debris. Also fistulas and sinus tracks expressed high signals on DWI, again, because of pus, inflammatory cells, and debris in and around the fistula tract.

Pus contents showed high viscosity with packed inflammatory cells, both were resulted in diffusion restriction which appears as increased signal intensity on DWI.

Even pattern of restriction helped in differentiating abscess from necrotic neoplasm as in cases of GIST, where restriction
Table 2 MRI Diffusion among studied patients with lymphoma and adenocarcinoma.

<table>
<thead>
<tr>
<th>ADC value</th>
<th>Lymphoma (n = 9)</th>
<th>Adenocarcinoma (n = 8)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min–max</td>
<td>0.6–0.7</td>
<td>0.8–1.0</td>
<td>Z = 3.527</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>0.7 ± 0.05</td>
<td>0.9 ± 0.08</td>
<td>P &lt; 0.0001*</td>
</tr>
</tbody>
</table>

Z: Mann Whitney test.
* Significant at P < 0.05.

in abscess was in the central trapped pus while in necrotic neoplasm it shows restriction along the residual peripheral solid portion, which was in agreement with Schmid-Tannwald et al. (16).

Kiryu et al. (17) and Oto et al. (13) stated that DWI expressed high sensitivity (86–94%) and specificity (81.4–84.8%) for diagnosing active inflammatory bowel disease.

Applying ADC threshold of 2.4 × 10⁻³ mm²/s, Oto et al. (6) reported that DWI presented 94% sensitivity and 88% specificity in distinguishing normal and inflamed bowel and this value concomitantly was agreed with our results that added that inflamed bowel segments showed more diffusion restriction in comparison with normal bowel segments.

Low et al. (18) added the high diagnostic accuracy of DWI for detecting early peritoneal deposits especially when combined with dedicated MRI study using oral and IV contrast. In the current study, this was significantly noted in limited number of cases and we recommend to apply it in special separate study using wider scale of patients having different malignant abdominal primaries that suspected to have peritoneal deposits.

Regarding characterization of metastatic lymphadenopathy in the current study, pelvi-abdominal lymph nodal deposit showed high signals on DWI with low ADC values. Considerable overlap existed between ADC values between benign and malignant lymph nodes; however, Feuerlein et al. (4) and Kyriazi et al. (19) stated that nodal metastasis had lower ADC values as compared to benign ones.

Vandecaveye et al. (20) presented ADC threshold value of 1.0–1.38 × 10⁻³ s/mm² with more than 90% sensitivity and specificity to differentiate metastatic from normal lymph nodes in the primary malignancies of head and neck.

We were in agreement with Sinha et al. (21) who stated that DW MRI considered powerful tool to increase the diagnostic accuracy as it can depict abnormality of the gastrointestinal tract, and so it could help in the diagnosis of the primary lesion and depict distant metastases in patients with known GIT malignancies.

The advantages of MRI over CT in general included the elimination of ionizing radiation and hence the only tool in pregnant patients and the preferred tool in children, it has the high diagnostic performance in patients with impaired renal function. If necessary, the non-contrast MR examination could be performed, with high accuracy for patients with a contrast allergy or low glomerular filtration rate who were at risk for nephrogenic systemic fibrosis.

In the described cases, DWI helped in quantification of inflammatory changes as well as the related complications with no need of contrast material administration. This qualitative information helped to assess response to treatment in patients with malignant small bowel lesion. DWI helped to assess degree and activity of bowel inflammation as well as estimated response as regards inflammatory bowel disease (IBD). Multiple studies discussed its help in predicting treatment response by estimating ADC values before management of tumors. Complications of inflammation, such as malignant changes, abscess, and fistula might also be depicted (22).

Considering DWI as a part of standard MR imaging, no additional technique or machine is needed as it can be added to the routine MR protocol, but common limitations of both MRI and DWI take long time of the study performance and interpretation as compared with CT enterography (11).

6. Conclusion

DWI is an important complementary sequence with the routine MRI of the small bowel that helps in lesion quantification and characterization in a hope to reach final confident diagnosis and in order to reduce the rate of biopsy. Also DWI may be used as a monitoring tool in follow-up for the response to therapy.

Conflict of interest

The authors declared that there is no conflict of interest.

References

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