DWI before and after Gadolinium-EOB-DTPA administration: modifications of ADC maps evaluated with texture analysis.

Poster No.: C-1913
Congress: ECR 2017
Type: Scientific Exhibit
Authors: D. Cavalli¹, R. Negrelli¹, G. A. Zamboni¹, E. Boninsegna¹, A. J. Cybulski¹, S. Tambalo², R. Pozzi-Mucelli¹,¹Verona/IT, ²Rovereto/IT
Keywords: Diagnostic procedure, MR-Diffusion/Perfusion, MR, Abdomen, Image verification
DOI: 10.1594/ecr2017/C-1913

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Aims and objectives

Diffusion weighted imaging (DWI) is now part of a routine abdominal MRI examination; in fact, as demonstrated by several recent studies, detection of focal lesions is improved by DWI sequences, and the sensitivity for involved lymph nodes is increased.

It is commonly believed that the qualitative appearance of the DWI images and corresponding ADC values of splanchnic organs are identical before and after the administration of gadolinium chelates contrast media.

DWI is usually performed prior to the intravenous administration of a gadolinium chelates contrast agent. Otherwise, in some situations it would be useful to perform DWI sequences after contrast medium injection; for example, for the evaluation of focal liver lesions using Gadolinium-EOB-DTPA, multiple delayed phases are required, therefore it is desirable to administer contrast medium in the early part of the examination and after that, acquire delayed contrastographic phases.

Furthermore, it may occasionally be necessary to repeat the DWI post-contrast in the presence of motion artefacts.

Gadolinium chelates may alter the T1 and T2 relaxation times, affecting values of ADC maps. A recent and well-performed study, conducted by Wang et Al. reported that gadolinium chelates do not alter both the quantitative ADC values and the qualitative appearance of abdominal viscera except for kidneys. However it was conducted with GD-BOPTA, whose excretion is mainly renal. Only few studies were conducted on DWI examination after administration of Gd-EOB-DTPA, which is characterized by a high biliary excretion.

For the above-mentioned reasons we performed a specific evaluation of the modifications induced by Gd-EOB-DTPA in the DWI aspects and ADC values of the visceral organs, in particular liver, pancreas, spleen and kidneys.

In addition, we performed a texture analysis on the ADC maps, to depict alterations in mean values, Skeweness and Kurtosis induced by gadolinium chelates.

The aim of this study is to evaluate if Gd-EOB-DTPA modifies the apparent diffusion coefficient (ADC) map derived from Diffusion Weighted Images (DWI) on MRI, for the evaluation of splanchnic organs parenchyma and how related texture features are influenced.
Methods and materials

We reviewed the MRI examinations of 10 patients who underwent DWI before and after Gd-EOB-DTPA injection. We excluded patients who presented focal or diffuse lesions of the liver or other splanchnic organs alterations.

MR imaging was performed by means of a 1.5-T MR unit (Philips Ingenia; Eindhoven, The Netherlands) by using a phased-array coil. Patients were asked to fast for 6 hours before the MR.

Dynamic contrast-enhanced MR imaging involved a triphasic study after the injection of 0.1 mmol of a gadolinium chelates (Gadoxetic acid disodium; Gd-EOB-DTPA: Primovist, Bayer Schering Pharma AG, Berlin, Germany) per kg of body weight, administered at 2.0-2.5 ml/sec by using a power injector (Medrad, Pittsburgh, USA).

Images were obtained before contrast medium administration and during the late arterial pancreatic phase, portal venous phase (35-40 and 75-80 seconds after contrast medium administration, respectively) and a delayed hepatobiliary phase (25 minutes after contrast medium injection). The dynamic study was performed with T1-weighted volumetric sequences, with selective fat saturation acquired in the axial plane.

DWI was obtained using respiratory-triggered single-shot echo planar images, acquired at different $b$ values (0-400-800 s/mm$^2$); diffusion study was acquired before and 20 minutes after the injection of Gd-EOB-DTPA.

Qualitative image analysis was performed at a workstation by two radiologists (R.N., E.B., 6 and 4 years experience in gastrointestinal radiology, respectively). They assessed modifications of signal intensity of DWI images and corresponding ADC maps in the basal and in the late hepatobiliary phase.

A MRI technologist (D.C., 10 years experience in MR abdominal imaging) positioned 5 ROIs within the liver parenchyma, 3 in the pancreatic parenchyma, 2 in the spleen, 1 in the non declivous part of the gallbladder, 2 within the renal cortex and 2 in the medulla of each kidney, 2 in the paraspinal muscles and 2 in the subcutaneous fat, to assess quantitative modifications in ADC values before and after administration of Gd-EOB-DTPA. The mean ADC values were calculated by using ImageJ Software for Mac (version 10.2; National Institute of Health, USA). Finally, texture analysis (mean, variance, skewness and Kurtosis) of these organs was performed on ADC maps before and after contrast medium injection, by using MaZda Software for Windows.

A paired t-test was applied to evaluate quantitative image analysis of the two groups, by using Prism Software for Windows.
Results

In the qualitative image analysis, the radiologists did not depict any signal modifications in diffusion-weighted images and ADC maps of any splanchnic organs before and after Gd-EOB-DTPA administration.

Regarding quantitative image analysis, there is considerable disparity in the published apparent diffusion coefficient (ADC) values across different splanchnic organs. In our series, ADC values calculated before contrast medium injection resulted in accordance with a recent study conducted by Jafar et al., which evaluated the variability of published ADC values in normal tissues.

The quantitative values of ADC mean values before and after Gd-EOB-DTPA injection are summarized in figure 1.

We observed a significant increase of mean ADC values of liver parenchyma (p<0.001), pancreatic parenchyma (p=0.02) and renal medulla (p<0.01) 25 minutes after gadolinium-EOB-DTPA administration (Figures 2-7). There was no statistical difference of ADC values measured before and after Gd-EOB-DTPA administration in the spleen, gallbladder, renal cortex, paraspinal muscles and subcutaneous fat (Figure 2). A plausible explanation of these quantitative changes should be related to the pharmacokinetics of Gd-EOB-DTPA, which alter ADC values of the organs which discharge these gadolinium chelates, such as liver and renal medulla. However, a statistically significant difference was observed also within the pancreatic parenchyma.

Concerning texture analysis, we did not observe statistical difference in terms of mean values, variance, skewness and kurtosis before and after Gd-EOB-DTPA administration, except for liver skewness values (p=0.001) (Figure 8-10).
Table 1 Quantitative mean ADC values ($x \times 10^{-3}$ mm$^2$/s) before and 25 minutes after Gd-EOB-DTPA administration.

<table>
<thead>
<tr>
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<th>Pre-contrast</th>
<th>Gd-EOB-DTPA</th>
<th>$p$-value</th>
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<tbody>
<tr>
<td>Liver</td>
<td>1020.099 ± 69</td>
<td>1138.681 ± 81.3</td>
<td>$&lt;$0.001</td>
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<tr>
<td>Pancreas</td>
<td>1156.103 ± 87.8</td>
<td>1288.233 ± 127</td>
<td>0.02</td>
</tr>
<tr>
<td>Spleen</td>
<td>778.723 ± 44.7</td>
<td>749.687 ± 51.6</td>
<td>NS</td>
</tr>
<tr>
<td>Renal cortex</td>
<td>1746.148 ± 66.5</td>
<td>1791.255 ± 58.1</td>
<td>NS</td>
</tr>
<tr>
<td>Renal medulla</td>
<td>1579.487 ± 65.8</td>
<td>1726.244 ± 76</td>
<td>$&lt;$0.001</td>
</tr>
<tr>
<td>Gallbladder</td>
<td>2759.742 ± 132.5</td>
<td>2803.280 ± 154.2</td>
<td>NS</td>
</tr>
<tr>
<td>Muscle</td>
<td>1339.112 ± 72.5</td>
<td>1377.131 ± 78.9</td>
<td>NS</td>
</tr>
<tr>
<td>Fat</td>
<td>272.670 ± 135.8</td>
<td>348.428 ± 147.6</td>
<td>NS</td>
</tr>
</tbody>
</table>

Fig. 1: Quantitative mean ADC values ($x \times 10^{-3}$ mm$^2$/s) before and 25 minutes after Gd-EOB-DTPA administration.

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Fig. 2: The graph shows mean ADC values of splanchnic organs before and after Gd-EOB-DTPA administration.

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Fig. 3: Box plot of ADC values of the liver parenchyma before and after Gd-EOB-DTPA administration (p<0.01).

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**Fig. 4:** Box plot of ADC values of the pancreatic parenchyma before and after Gd-EOB-DTPA administration ($p=0.02$).

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Fig. 5: Box plot of ADC values of the spleen before and after Gd-EOB-DTPA administration (p=NS).

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Fig. 6: Box plot of ADC values of the renal cortex before and after Gd-EOB-DTPA administration (p=NS).

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Fig. 7: Box plot of ADC values of the renal medulla before and after Gd-EOB-DTPA administration (p<0.01).

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Table 2: Texture analysis (mean values, variance, skewness and kurtosis) before and 25 minutes after Gd-EOB-DTPA administration.

<table>
<thead>
<tr>
<th></th>
<th>PRE-CONTRAST</th>
<th>GD-EOB-DTPA</th>
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<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Variance</td>
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<tr>
<td>Liver</td>
<td>1285,87</td>
<td>13346,40</td>
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<tr>
<td>Pancreas</td>
<td>1426,08</td>
<td>20133,83</td>
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<td>Spleen</td>
<td>898,30</td>
<td>3940,92</td>
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<td>Renal cortex</td>
<td>2009,75</td>
<td>23277,79</td>
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<td>Renal medulla</td>
<td>1895,58</td>
<td>13708,64</td>
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<tr>
<td>Gallbladder</td>
<td>3146,83</td>
<td>26647,50</td>
</tr>
<tr>
<td>Muscle</td>
<td>1501,39</td>
<td>12220,07</td>
</tr>
<tr>
<td>Fat</td>
<td>521,66</td>
<td>27139,56</td>
</tr>
</tbody>
</table>

Fig. 8: Texture analysis (mean values, variance, skewness and kurtosis) before and 25 minutes after Gd-EOB-DTPA administration.

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Fig. 9: Texture analysis: axial ADC map with multiple ROIs positioned within the liver parenchyma, the pancreatic parenchyma and the spleen (MaZda Software).

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Fig. 10: Texture analysis: histograms derived from the liver parenchyma before and after Gd-EOB-DTPA administration.

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Conclusion

Diffusion weighted images and related ADC maps are not qualitatively influenced by Gd-EOB-DTPA. However, in our series Gd-EOB-DTPA significantly increases quantitative ADC values of liver, pancreas and renal medulla. These quantitative alterations should be considered when using numeric data calculated in the ADC maps.

Finally, Gd-EOB-DTPA does not modify the texture analysis of the normal tissues of splanchnic organs, except for an isolated increase of the liver skewness.
References


