The relationship between the quantitative pharmacokinetic parameters of DCE-MRI and the types of uterine fibroids based on T2WIs

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Introduction

Uterine fibroids are the most common benign tumors in women of reproductive age. Menorrhagia, dysmenorrhea, pelvic pain, and bulk-related symptoms are common symptoms [1]. Hysterectomy or myomectomy is standard treatment approach of fibroids. Magnetic resonance-guided high-intensity focused ultrasound (MRg HIFU) ablation, along with uterine fibroid embolization (UFE), is currently major nonsurgical options in the treatment of uterine fibroids [2]. The safe and effective use of MRg HIFU is affected by fibroid type in T2-weighted images (T2WIs) which were the current clinical criterion to select patients for MRg HIFU ablation [3]. The K\(\text{trans}\), K\(\text{ep}\), and V\(\text{e}\) based on Tofts model [4] of dynamic contrast-enhanced MR images (DCE-MRI) represent the process of Gd-DTPA transfer across the capillary wall, which is a surrogate of capillary permeability [5]. The aim of this study is to investigate the relationship between the quantitative pharmacokinetic parameters of DCE-MRI and the fibroid type based on T2WIs, with expectation to select suitable fibroids for MRg HIFU ablation.

Methods

This study was approved by the local institutional review board. Twenty-three fibroids in 23 females (37–53 years, mean age: 43.96±4.38 years) underwent T1 weighted images (T1WIs), T2WIs and DCE-MRI. The fibroids were divided into three types based on signal intensity in T2WIs [6]: type 1, low signal compared to skeletal muscle, 11 cases; type 2, lower signal than the myometrium and higher than skeletal muscle, 7 cases; type 3, signal equal to or higher than that of myometrium, 5 cases. In this study, the turbo field echo (TSE) T1WIs, two-dimensional TSE T2WIs and three-dimensional T1-weighted DCE-MRI were performed in a 1.5T scanner (Achieva, Philips Medical System, the Netherlands) with 16-channel XL torso coil. DCE-MRI was performed including a precontrast scan (with a flip angle of 5) and a dynamic scan (with a flip angle of 15) after a single dose injection of Gadopentetate dimeglumine (Magnevist) at a dose of 0.1 mmol/kg through a peripheral vein at a rate of 2 mL/s. Dynamic scan was performed by 60 dynamics, TR/TE=4.84/2.35ms, field of view = 200mm×200mm×96mm, matrix = 176×176, voxel size = 1.7×1.7×4mm\(^3\), NSA=2, scan duration is 330 seconds. The analysis of DCE-MRI data was performed using IDL version 6.4 Software. The process mainly included: Load the data, define the AIF, map calculation, review results, export. The quantitative parameters of K\(\text{trans}\), K\(\text{ep}\), and V\(\text{e}\) were obtained in workstation. The differences of K\(\text{trans}\), K\(\text{ep}\), and V\(\text{e}\) among the three types were determined using One-Way ANOVA. All statistical analyses were considered to be significant with P<0.05.

Results

The quantitative pharmacokinetic parameters (K\(\text{trans}\), K\(\text{ep}\), and V\(\text{e}\)) of each type were shown in Table 1 as mean±standard deviation. P-value of ANOVA analysis among the three fibroid types were shown in Table 2. The K\(\text{trans}\) of the three fibroid types is very close and there are no significant differences among them. The K\(\text{trans}\) of type 3 is higher than type 1 and type 2. The significant differences of K\(\text{ep}\) were shown between type 1 and type 3, type 2 and type 3. Moreover, there were no significant differences of V\(\text{e}\) among the three fibroid types, although average values of V\(\text{e}\) seem to be large difference among them from Table 1. The three fibroid types were shown typically with T2WIs and color maps of K\(\text{trans}\), K\(\text{ep}\), and V\(\text{e}\) in Fig 1.

Discussion & Conclusions

To our knowledge, this is the first study to compare the DCE-MRI derived contrast agent kinetic characters among the three fibroid types by using K\(\text{trans}\), K\(\text{ep}\), and V\(\text{e}\) based on Tofts model. There were no statistic differences of K\(\text{trans}\) among the three fibroid types, suggesting the similar volume transfer constant of Gd-DTPA between the capillary and extravascular extracellular space (EES). In current study, the V\(\text{e}\) representing the volume of EES per unit volume of tissue were no significant differences among the 3 fibroids types, but the V\(\text{e}\) of type 1 and type 2 were greater than 1. It indicated that the length of the dynamic scanning for this study may not be long enough to accurately estimate V\(\text{e}\) in voxels. On the other hand, it demonstrated that type 3 fibroids have the haemodynamic characters of a fast wash-out. In addition, K\(\text{trans}\) of type 3 was higher than type 1 and type 2. All of these demonstrated that the wash-out of type 3 is faster than other two types. It implied that the more heat energy may be taken away if carry out the HIFU ablation. Therefore, the patients with fibroids of type 3 may be not very suitable for MRg HIFU ablation.

In sum, the K\(\text{trans}\), K\(\text{ep}\), and V\(\text{e}\) based on Tofts model, as an objective and sensitive method for DCE-MRI data analyzing, can reveal differences of capillary permeability and blood flow among the three fibroid types, and be proposed to guide patients selection for MRg HIFU ablation.

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References


Table 1 K\(\text{trans}\), K\(\text{ep}\), and V\(\text{e}\) of three fibroid types

<table>
<thead>
<tr>
<th>Group</th>
<th>K(\text{trans}) (min(^{-1}))</th>
<th>K(\text{ep}) (min(^{-1}))</th>
<th>V(\text{e})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1 (n=11)</td>
<td>0.38±0.25</td>
<td>0.16±0.05</td>
<td>1.94±2.53</td>
</tr>
<tr>
<td>Type 2 (n=7)</td>
<td>0.47±0.30</td>
<td>0.14±0.05</td>
<td>2.27±2.55</td>
</tr>
<tr>
<td>Type 3 (n=5)</td>
<td>0.35±0.23</td>
<td>0.28±0.13</td>
<td>0.62±0.40</td>
</tr>
</tbody>
</table>

Table 2 Differences of K\(\text{trans}\), K\(\text{ep}\), and V\(\text{e}\) among 3 fibroid types

| Type 1&2 | 0.673 | 0.294 | 0.762 |
| Type 1&3 | 0.892 | 0.023* | 0.293 |
| Type 2&3 | 0.642 | 0.005* | 0.233 |

*: P<0.05

Fig.1 T2WI and color maps of K\(\text{trans}\), K\(\text{ep}\), and V\(\text{e}\) in the 3 fibroid types