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# THE APPARENT DIFFUSION COEFFICIENT (ADC) VALUE OF BLADDER SMOOTH MUSCLE PREDICTS BLADDER DYSFUNCTION

Hypothesis / aims of study

Lower urinary tract symptoms (LUTS), including overactive bladder, are a common condition in men and women in later life. Recent studies have indicated that chronic bladder ischemia induced by pelvic arterial occlusive disease, such as atherosclerosis, might be an important contributing factor to LUTS. Separately, magnetic resonance (MR) imaging is reportedly useful in evaluation of chronic myocardial infarction. Some studies reported a significant increase in apparent diffusion coefficient (ADC) on MR imaging in chronic myocardial infarction territories, and concluded that ADC was useful in detecting areas of infarct and that MR imaging provided clinicians with several prognostic indicators.[1)] The aim of this study was to determine whether MR imaging could be used to predict bladder dysfunction, by evaluating the association between ADC values and urodynamic findings.

Study design, materials and methods

Patients with localized prostate cancer who underwent robot-assisted radical prostatectomy (RARP) at our hospital between February 2013 and April 2014 were included in this study. Urodynamic study and MR imaging were performed before RARP. We measured the highest and lowest ADC values of the bladder smooth muscle. The relationship between the ADC value and urodynamic findings was analyzed. All values were expressed as mean ± standard deviation. An unpaired t test was used for analysis of categorical variables, and linear regression analysis was used for continuous variables. P-values of <0.05 were considered to be statistically significant.

Results

A total of 37 patients (65.1 ± 5.1 years) entered the study. The patients' characteristics are shown in Table 1. The IPSS (6.9 ± 6.3) and QOL index (2.6 ± 1.7) of patients were mild. The highest ADC value was 2.11 ± 0.27 $\times 10^{-3}mm^2$/sec and the lowest ADC value was 0.48 ± 0.22 $\times 10^{-3}mm^2$/sec. The difference between the highest and lowest ADC values (highest ADC value - lowest ADC value) was 1.63 ± 0.25 $\times 10^{-3}mm^2$/sec. Table 2 shows the correlation between ADC values and urodynamic findings. The difference between the highest and lowest ADC values was significantly associated with bladder compliance (P=0.042, C.C=0.379). The difference between the highest and lowest ADC values was significantly higher in patients with detrusor overactivity (DO) than in the other patients (DO negative vs. positive: 1.58 ± 0.21 vs. 1.98 ± 0.17, P=0.011). Figure 1 shows typical MR images. There was no significant association between the ADC value and contraction and obstruction on the Schäfer nomogram.

Interpretation of results

We demonstrated that patients with DO have a large difference between the highest and lowest ADC values. Some studies reported that the ADC value of impaired smooth muscle was different from that of normal smooth muscle.1) It is possible that the difference between the highest and lowest ADC values may reflect the degree of smooth muscle injury. The difference was not associated with Schäfer nomogram contraction. The mean post-void residual urine volume was small and the mean IPSS and QOL index were mild in this study. Hence, we believe that the bladder functions of the patients were in a compensated state. In this study, bladder compliance was significantly associated with the difference between the highest and lowest ADC values. Using a rat model, we previously reported that chronic ischemia causes bladder hyperactivity and increases bladder compliance with normal maximum pressure of the bladder.[2)] It is possible that chronic ischemia may affect the ADC value of bladder smooth muscle, the same as occurs with myocardium.

Concluding message

MR imaging may reflect bladder smooth muscle injury. MR imaging might be useful in predicting bladder dysfunction.

Table 1. Patients' characteristics

| | |
|---|---|
| Age (years) | 65.1 ± 5.1 (54 - 76) |
| IPSS | 6.9 ± 6.3 (1 - 23) |
| QOL index | 2.6 ± 1.7 (0 - 6) |
| Prostate volume (ml) | 30.2 ± 16.5 (12.4 – 85.0) |
| Highest ADC value ($\times 10^{-3}mm^2$/sec) | 2.11 ± 0.27 (1.34 – 2.71) |
| Lowest ADC value ($\times 10^{-3}mm^2$/sec) | 0.48 ± 0.22 (0.83 – 0.07) |
| Highest ADC - Lowest ADC value ($\times 10^{-3}mm^2$/sec) | 1.63 ± 0.25 (1.09 – 2.14) |

IPSS: International prostate symptom score,
ADC: Apparent diffusion coefficient

Values are presented as mean ± standard deviation (range)

Table 2. Univariate analysis

a) Correlation between the ADC value and urodynamic findings using linear regression analysis

| | Mean ± SD (range) | Highest ADC ($\times 10^{-3}mm^2/sec$) | | Lowest ADC ($\times 10^{-3}mm^2/sec$) | | Highest ADC - lowest ADC ($\times 10^{-3}mm^2/sec$) | |
|---|---|---|---|---|---|---|---|
| | | *P* | *C.C* | *P* | *C.C* | *P* | *C.C* |
| First desire to void (mL) | 129 ± 61 (23-280) | 0.198 | -0.220 | 0.747 | -0.056 | 0.275 | -0.187 |
| Strong desire to void (mL) | 282 ± 113 (79-632) | 0.475 | -0.125 | 0.171 | -0.236 | 0.631 | 0.084 |
| Bladder compliance (mL/cm $H_2O$ ) | 40.8 ± 25.6 (5.5-105.3) | 0.467 | 0.141 | 0.215 | -0.237 | **0.042*** | **0.379** |
| Voided volume (mL) | 322 ± 113 (160-691) | 0.843 | -0.038 | 0.377 | -0.167 | 0.584 | 0.104 |
| Maximum flow rate (mL/sec) | 12.6 ± 5.1 (4.7-28.7) | 0.634 | 0.082 | 0.461 | -0.127 | 0.235 | 0.203 |
| Postvoid residual urine volume (mL) | 21 ± 46 (0-202) | 0.389 | -0.155 | 0.883 | 0.027 | 0.314 | -0.181 |

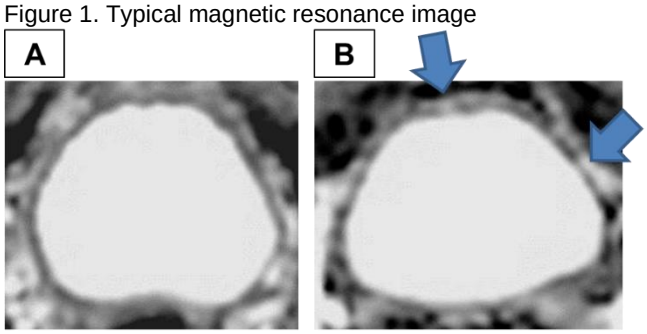
ADC: Apparent diffusion coefficient, SD: standard deviation, *C.C*: correlation coefficient
*Denotes statistical significance at p<0.05 level

b) Correlation between the ADC value and urodynamic findings using an unparied t test

| | n | Highest ADC ($\times 10^{-3}mm^2/sec$) Mean ± SD | *P* | Lowest ADC ($\times 10^{-3}mm^2/sec$) Mean ± SD | *P* | Highest ADC - Lowest ADC ($\times 10^{-3}mm^2/sec$) Mean ± SD | *P* |
|---|---|---|---|---|---|---|---|
| Detrusor overactivity | | | 0.066 | | 0.945 | | **0.011*** |
| Negative | 33 (89.2 %) | 2.06 ±0.23 | | 0.48±0.23 | | 1.58 ±0.21 | |
| Positive | 4 (10.8 %) | 2.46 ±0.29 | | 0.49±0.14 | | 1.98 ±0.17 | |
| Schäfer nomogram contraction | | | 0.577 | | 0.482 | | 0.914 |
| W-,W+,N- | 26 (70 %) | 2.09 ±0.26 | | 0.46 ±0.19 | | 1.63 ±0.25 | |
| N+, ST | 11 (30 %) | 2.15 ±0.28 | | 0.53 ±0.27 | | 1.62 ±0.26 | |
| Schäfer nomogram obstruction | | | 0.526 | | 0.836 | | 0.702 |
| 0,1,2 | 30 (81.1 %) | 2.09 ±0.28 | | 0.48 ±0.22 | | 1.62 ±0.25 | |
| 3,4,5 | 11 (18.9 %) | 2.15 ±0.20 | | 0.50 ±0.22 | | 1.66 ±0.24 | |

ADC: Apparent diffusion coefficient, n: number of patients (%), SD: standard deviation,
*Denotes statistical significance at p<0.05 level

Figure 1. Typical magnetic resonance image




A) Difference between the highest and lowest ADC values was low in this MR image.
B) Difference between the highest and lowest ADC values was high in this MR image.
The arrows indicate high ADC regions.

References

1. Nguyen C, et al: In vivo contrast free chronic myocardial infarction characterization using diffusion-weighted cardiovascular magnetic resonance. J Cardiovasc Magn Reson 2014 Sep; 16:68
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Disclosures

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