# Intravoxel Incoherent Motion (IVIM) MR Imaging of Degenerated Intervertebral Lumbar disks: an initial experience

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**Target audience:** Musculoskeletal radiologist

**Introduction:**

Intervertebral disk degeneration (IVDD) is a leading cause of lumbar spine related lower-back pain[1]. Adequate nutrient supplies, which rely upon the diffusion of fluid and the maintenance of the blood supply in the margins of disk, have been regarded as essential for preventing disk degeneration and repair[2]. Further studies using diffusion-weighted imaging (DWI) have demonstrated that the decreased diffusion was associated with reduction in nutrient supply in IVDD[3,4]. Intravoxel incoher-ent motion(IVIM) based on multiple b-value DWI can reflect the microcapillary perfusion and free water diffusivity in tissue[5,6]. The purpose of this study was to assess the feasibility of using IVIM MRI to detect the pathophysiological micro-variation in IVDD.

**Methods:**

This prospective study recuited 23 patients (14 men and 9 women; mean age 40 years; median age 47; age range 21~73 years) with low back pain or sciatica. All images were obtained by using a 3.0T MR system (Signa HDxt, General Electric Medical System, Milwaukee, WI, USA) with HDCTL coil. IVDD grading was performed in the sagittal T2WIs by two experienced radiologists according to Pfirrmann grading[7]. The scanning parameters were as follows: TR/TE = 2540/125.3 ms, thickness = 4.0 mm, field of view = 320 mm, matrix = 416×320, flip angle (FA) = 90°, number of signal acquisition = 2, number of sagittal sections = 11, and acquisition time = 1 minutes16 seconds. The IVIM- DWI was acquired 3 slices passing through the middle of lumbar in the sagittal plane by spin echo-echo planar imaging (EPI). Other parameters were TR/TE = 1100/66.7 ms, thickness = 6.0 mm, field of view = 320 mm, matrix = 256×128 and number of signal acquisition = 2-5. Ten b values were used: 0, 25, 50, 75, 100, 150, 200, 300, 400 and 500 s/mm. The acquisition time was 2 minutes 1 second. All data were transferred to the imaging workstation (AW 4.2, GE Medical System) and calculated using MADC software. A radiologist with over 5-year experience delineated the region of interest (ROI) in the disks, include anterior annulus fibrosus (AF), posterior AF and nucleus pulposus (NP) based on DWIs. The standard ADC values, the true diffusion coefficient ( $ADC_{slow}$ ) and the blood pseudodiffusion coefficient ($ADC_{fast}$) were measured in mean±standard deviation (SD). To evaluate the reliability of Pfirrmann grading, intra-observer and inter-observer agreements were tested by using kappa statistics. To determine the statistical differences of ADC, $ADC_{slow}$ and $ADC_{fast}$ values between the different Pfirrmann grades, one–way analysis of variance (ANOVA) was used with Student-Newman-Keuls (SNK) test($p<0.05$ were considered significant). All statistical analyses were performed using SPSS for Windows version 13.0.0 (SPSS, Inc, Chicago, IL, USA).

**Results:**

The inter-observer and intra-observer reliability was good or excellent (kappa value ranges of 0.674 - 0.811 and 0.790 - 0.812, respectively)[8].The mean and SD of ADC, $ADC_{slow}$ and $ADC_{fast}$ values for each Pfirrmann grade were shown in Table 1 and 2. The ADC values both of NP and AF decreased with the increase of the Pfirrmann grades except ADC of NP in grade II. The $ADC_{slow}$ values of NP decreased with the increase of the grades. In contrast, the $ADC_{fast}$ values of NP and AF increased obviously in the Grade III and IV. As shown in Figure 1, significant differences in ADC of NP were observed between grade II and IV (ANOVA, $P<0.05$). However, significant differences in $ADC_{slow}$ of NP were seen between grade I and IV, II and IV, as well as in $ADC_{fast}$ of NP between grade I and IV, grade II and IV (ANOVA, $P<0.05$). Similarly, significant differences in $ADC_{fast}$ of AF were found between grade I and IV, II and IV, III and IV (ANOVA, $P<0.05$).

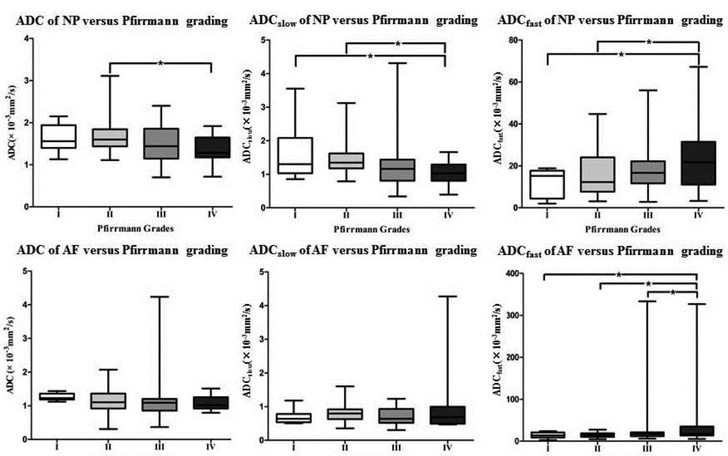


Figure 1. The ADC, $ADC_{slow}$ and $ADC_{fast}$ measurements versus Pfirrmann grading. *$p<0.05$

**Discussion and conclusion:**

In current study，the $ADC_{slow}$ values, reflecting pure diffusion in tissue of NP and AF, decreased with the increased grading of IVDD，which were consistent with the previous studies using apparent diffusion coefficient. On the other hand, the blood supply derives from the vertebral arteries that give rise to two capillary plexuses. One plexus penetrates a small distance (1–2 mm) into the outer AF, and the other penetrates the subchondral bone into the core of disk from the vertebral body. Previous studies demonstrated that the calcified cartilaginous endplate can occlude blood vessels, thus the proliferative vascular can invade into the AF in severely IVDD[9]. In this study, $ADC_{fast}$ values of AF were slight higher than NP except in grade II and the $ADC_{fast}$ values of disk increased with the increase of Pfirrmann grades, which suggested an increasing microcapillary perfusion in IVDD, especially in the portion of AF. In conclusion, IVIM MR imaging may provide an objective and non-invasive biomarker for estimating diffusivity and microcapillary perfusion in IVDD.

**Table 1: The mean of ADC and IVIM values of NP in the different Pfirrmann grades**

| Grade | N | ADC | $ADC_{slow}$ | $ADC_{fast}$ |
|---|---|---|---|---|
| | | Mean ± SD ($\times10^{-3}mm^2/s$) | | |
| I | 6 | 1.63±0.35 | 1.61±0.98 | 12.28±7.00 |
| II | 42 | 1.66±0.37 | 1.40±0.38 | 16.24±10.11 |
| III | 44 | 1.50±0.43 | 1.20±0.60 | 18.21±10.43 |
| IV | 22 | 1.35±0.31 | 1.04±0.31 | 23.37±17.28 |
| Total | 114 | 1.54±0.40 | 1.26±0.52 | 18.17±11.99 |

**Table 2: The mean of ADC and IVIM values of AF in the different Pfirrmann grades**

| Grade | N | ADC | $ADC_{slow}$ | $ADC_{fast}$ |
|---|---|---|---|---|
| | | Mean ± SD ($\times10^{-3}mm^2/s$) | | |
| I | 6 | 1.26±0.11 | 0.69±0.25 | 14.20±7.37 |
| II | 42 | 1.13±0.35 | 0.80±0.27 | 14.37±5.38 |
| III | 44 | 1.12±0.58 | 0.71±0.26 | 23.59±48.14 |
| IV | 22 | 1.08±0.24 | 0.90±0.80 | 67.73±108.09 |
| Total | 114 | 1.12±0.43 | 0.78±0.42 | 28.22±58.82 |

**Acknowledgements:** The authors would like to thank Drs. Dandan Zheng, Zhenyu Zhou and Guang Cao from Applied Science Lab, GE Healthcare for their technical assistance.

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