

A comparison of three approaches for defining nucleus pulposus and annulus fibrosus on sagittal MR images.

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Introduction: Quantitative MR T2 and T1rho relaxation time measurements of the disc reflect the intrinsic material properties of disc tissues. For MRI image analysis, a number of methods have been described to define nucleus pulposus (NP) and annulus fibrosus (AF), including manual region-of-interest (ROI) method based on radiologists' experience, or uniform methods based on equal areas of square or circular ROIs placed horizontally across the disc, with or without a gap between them. For the later method, the central three ROIs were usually defined as NP while the anterior/posterior ROIs were defined as the anterior AF or posterior AF respectively. While there is yet not a consistent way to define NP and AF in disc studies currently, the goals of this work are to evaluate the agreements among different ROI methods, and to provide potential guidelines of ROI definition for further quantitative disc analysis.

Materials and methods: There were 52 subjects in this study: 12 subjects without low back pain (9 male and 3 female; mean age: 32.1 years; age range: 23–42 years), and 40 subjects who had low back pain (17 male and 23 female; mean age: 54.1 years; age range: 28–76 years). All subjects were confirmed to have no other spine diseases except disc degeneration. The study was approved by the local human research ethics committee with written informed consents obtained from all subjects. All subjects underwent imaging in the morning using a 3-T clinical MRI system (Achieva, Philips Healthcare, Best, The Netherlands).

T1rho and T2 data acquisitions were according to previous reports. The mid-sagittal images of the lumbar spine were analysed. The corresponding T2-weighted image was used as the reference for drawing the ROIs. For manual ROI based method (M-ROI) [1–3], ROIs were manually drawn over the T2 maps and T1rho maps of the discs by a radiologist with 5 years of experience in reading spine MR images. Three ROIs including NP, anterior AF and posterior AF were drawn (Fig. 1a). For the uniform methods, we evaluated (i) 5-ROI method where each of the 5 equal squares measured 20% of the midline disc diameter in the sagittal plane (Fig. 1b) [4–6] (ii) 7-ROI method where 7 equal squares of 6.5 mm² ROI with equal spacing between the ROIs were placed horizontally from anterior to posterior (Fig. 1c) [7]. For both 5-ROI and 7-ROI methods, the average of the central 3 ROIs was defined as NP, i.e., 2nd, 3rd, 4th ROI for 5-ROI and 3rd, 4th, 5th ROI for 7-ROI method respectively. Different choices of ROIs were evaluated for defining AF in 5-ROI method, including: (i) first ROI was defined as the anterior AF and the last ROI was defined as the posterior AF; (ii) average of the first and last ROIs was defined as AF. For the 7-ROI method, the definition of AF includes: (i) first ROI represents anterior AF and the last ROI represents posterior AF; (ii) average of the 1st and 2nd ROI represents anterior AF while the average of the 6th and 7th ROI represents the posterior AF; (iii) average of the first 2 and last 2 ROIs represents AF. The 5-/7- ROI methods were performed using an open source image processing software (Image J), while the M-ROI method was performed on a radiological workstation (Viewforum, Philips Medical System). Agreement of M-ROI, 5-ROI and 7-ROI methods was assessed, using intra-class correlation coefficient (ICC) on absolute agreement, as well as Bland-Altman plot. According to Fleiss, ICC values > 0.75 represent a good agreement, and values between 0.4 and 0.75 represent fair to moderate agreement.

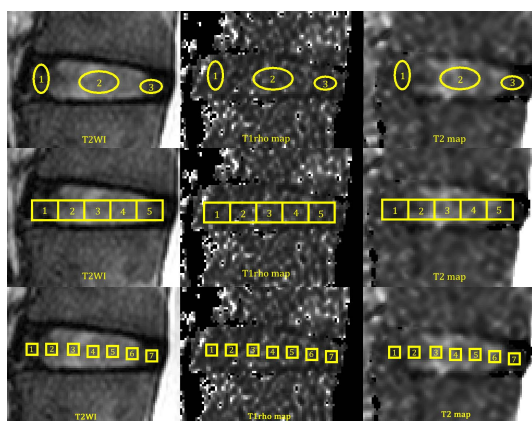


Fig. 1. Three ROI drawing methods used in this study: (a) M-ROI where ROI₁ represents anterior AF, ROI₂ represents NP and ROI₃ represents posterior AF; (b) 5-ROI and (c) 7-ROI.

Results: The ICC values were all >0.75 when comparing 5-/7-ROI with M-ROI methods for NP, suggesting a good agreement. However, the agreement for assessing AF was only moderate or poor. Compared with the 7-ROI method, the results were slightly in favor of the 5-ROI method. Selecting the 1st and the 7th ROI as the anterior and posterior AF did not improve the agreement of 7-ROI method with the M-ROI method as compared to using the average of 2 ROIs to represent anterior/posterior AF. Comparable results were obtained with Bland-Altman plots.

Discussion: Both NP and inner AF show nearly the same level of high signal intensity, and the boundary between inner AF and NP is often indistinct on T2 weighted images. The common 5-ROI method cannot exclude annular tears. Actually there is a high possibility that a portion of inner AF is included as NP. The 5-/7-ROI methods may include the anterior longitudinal ligament and posterior longitudinal ligament as AF. The border between the AF and NP is also unlikely to be completely vertical as delineated in the 5-/7- ROI methods and the shape of NP and AF will change according to ageing and degeneration. It has been noted that in the lumbar spine, the AF tends to be thicker ventrally than dorsally. The M-ROI method is more likely to select the 'pure' NA and AF components, allowing more accurate degeneration-related mechanism studies of these components. On the other hand, the 5- or 7-ROI methods may help towards automatic or semi-automatic image analysis, potentially reducing the radiologists' workload. With the 7-ROI method, we initially hypothesized that, while the 2nd and 6th ROI may include some of the NP component, the 1st and 7th ROI would better represent AF. However, our results did not show that the 1st and the 7th ROI had a good agreement with M-ROI measurement for AF either. Due to the imprecision as described above and the moderate to poor agreement with M-ROI method for defining of AF as shown in this study, better automatic or semi-automatic image analysis methods of disc components remain to be further developed. We showed that both 5-ROI and 7-ROI methods can be used to select NP. However, variation occurred for AF selection, and the agreement cannot be significantly improved by changing the number of ROIs counted for AF in both methods.

This study is partially supported by a grant from the Research Grants Council of the Hong Kong SAR (No.SEG CUHK02) and a research grant from University of Macau (MYRG185(Y3-L3)-FST11-MSP).

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