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Investigating Age-Related Changes in the Lumbar Intervertebral Disc: An MRI-Based Anatomical Analysis

Muhammad Ali, Afnan Amjad Sundal, Muhammad Shakil Sadiq, Hira Ahmed, Talat Samreen, Asma Aijaz, Farah Naz Tahir

MBBS, MCAI, FCPS (IMM), Anaesthetic Registrar, Children Health Ireland Crumlin Hospital, Ireland, Spidy0077@gmail.com
MBBS, Postgraduate Resident Neurology, Allama Iqbal Memorial Teaching Hospital, Sialkot/Khawaja Muhammad Safdar Medical College, Sialkot, afnan393@gmail.com
MBBS, MPhil (Anatomy), Associate Professor of Anatomy, Poonch Medical College, Rawalakot, AJK, mshakilsadiq@yahoo.com
Assistant Professor, Anatomy Department, KMDC, KMU, drhira_82@yahoo.com,
MBBS, MPhil (Anatomy), CHPE, Assistant Professor, Department of Anatomy, Karachi, dr.talatsamreen@gmail.com
MBBS, MPhil (Anatomy), CHPE, Assistant Professor, Department of Anatomy, Karachi Medical and Dental College, asmaaijaz56@gmail.com
MBBS, MPhil, PhD, Associate Professor of Biochemistry, Central Park Medical College, Lahore, tahirnazfarah@gmail.com

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Abstract: Advances in imaging techniques, particularly magnetic resonance imaging (MRI), have provided a non-invasive and precise method to evaluate age-related changes in the lumbar IVD. Previous studies have primarily focused on clinical findings or histological changes, leaving a gap in detailed anatomical and structural analyses through MRI imaging.**Objective:**This study aims to investigate the age-related morphological changes in the lumbar intervertebral discs using high-resolution MRI to provide an anatomical understanding of these changes over different age groups. Specifically, it seeks to explore differences in disc height, signal intensity, and structural integrity across various age categories.**Results:**It showed that MRI scans revealed statistically significant degenerative changes in lumbar IVDs with advancing age, such as reduced disc height, decreased signal intensity, and increased structural irregularities. These findings are expected to correlate with clinical symptoms of degeneration and lower back pain.**Discussion/Conclusion:**The results are anticipated to contribute valuable insights into the anatomical and structural changes in the lumbar IVD with aging. The study aims to fill gaps in the current literature by utilizing MRI to assess these changes quantitatively, providing an objective framework for future research into age-related lumbar disc degeneration and its clinical implications.

Keywords:
Lumbar intervertebral disc, age-related changes, MRI analysis.

Introduction: Intervertebral disc degeneration (IVD) is a major contributor to back pain and disability, particularly in aging populations. As the human body ages, the lumbar intervertebral discs undergo various structural and biochemical changes that contribute to functional deterioration. The lumbar spine plays a crucial role in supporting the body's weight and facilitating movement, making it particularly susceptible to wear and tear over time. The degeneration of the lumbar IVDs is characterized by a reduction in disc height, changes in water content, loss of proteoglycans, and alterations in collagen fibers, all of which can compromise the mechanical function of the spine[1-2].

MRI has revolutionized the study of IVD degeneration by providing detailed, non-invasive imaging of disc morphology and internal structure. Studies utilizing MRI have shown that age-related degeneration leads to changes in disc signal intensity, with younger discs showing high signal intensity due to the high water content, while degenerated discs display reduced signal intensity, reflecting the loss of hydration and structural integrity. Various MRI grading systems, such as the classification, have been widely adopted to assess the severity of disc degeneration. However, despite the wealth of information provided by MRI, there remains a need for comprehensive studies that not only assess degeneration but also investigate the anatomical and morphological changes associated with aging across different age groups [3-7].

Recent research has emphasized the link between lumbar disc degeneration and clinical outcomes such as lower back pain, radiculopathy, and herniated discs. While several studies have examined these clinical manifestations, few have focused on quantifying and analyzing structural changes in lumbar IVDs in a large cohort of individuals, particularly using high-resolution MRI scans. The use of such imaging technology allows for a detailed assessment of the morphology and integrity of the lumbar discs, providing a more nuanced understanding of the aging process in this region[8-9].

In light of these considerations, this study seeks to explore the age-related anatomical changes in lumbar IVDs using MRI scans. By focusing on specific changes such as disc height, signal intensity, and the presence of structural anomalies, the study aims to establish a more complete understanding of how aging affects the lumbar discs [10]. Furthermore, the study's objective is to statistically correlate these MRI findings with clinical outcomes, such as back pain, to offer a more

comprehensive view of the relationship between age and lumbar disc health. Previous studies have often provided broad descriptions of degenerative changes, but this research aims to provide a more granular, statistically validated perspective using advanced imaging techniques.

Several studies have demonstrated the use of MRI to assess lumbar disc degeneration, but there is a notable gap in comprehensive analyses that also take into account variables such as age, gender, and clinical presentation. This gap becomes particularly significant because disc degeneration does not occur uniformly across the population. Differences in the degree of degeneration based on age, as well as regional variations within the lumbar spine, have not been fully explored. Moreover, while MRI provides high-resolution images of disc morphology, the relationship between these imaging results and clinical symptoms is often underexplored. This study seeks to address this gap by combining anatomical analyses with clinical correlations, thus providing a more holistic understanding of lumbar disc degeneration across the lifespan.

Studies have also shown that early intervention can mitigate the progression of disc degeneration, highlighting the need for early detection and prevention strategies. With advances in imaging technologies, MRI provides a valuable tool for early detection of degenerative changes in the lumbar IVDs, even before clinical symptoms arise. Therefore, this study also aims to explore the potential of MRI as a diagnostic tool for identifying individuals at risk for severe disc degeneration or associated pathologies. By creating a comprehensive database of MRI findings across different age groups, this research could contribute to the development of targeted diagnostic and therapeutic strategies aimed at preventing or delaying the onset of clinically significant lumbar disc degeneration.

Methodology

This cross-sectional design study was conducted at Allama Iqbal Memorial Teaching Hospital, to analyze MRI scans of lumbar intervertebral discs from individuals in distinct age groups. MRI scans were obtained from participants aged 20 to 80 years, grouped as follows: 20-30 years, 31-40 years, 41-50 years, 51-60 years, and 61-80 years. The sample size was calculated using Epi Info software, ensuring a power of 80% with a confidence interval of 95%. An initial sample size

estimate suggests that a minimum of 200 participants was necessary to detect significant differences in disc morphology across age groups.

Participants were recruited from a population of individuals undergoing routine MRI scans for unrelated reasons. The inclusion criteria included individuals without a history of major spinal surgery, trauma, or systemic diseases that could affect spinal health (e.g., osteoporosis, cancer). Exclusion criteria included those with severe spinal deformities, herniated discs, or other degenerative spine conditions. Informed verbal consent was obtained from all participants, and approval was sought from the local ethical committee.

High-resolution MRI scans were used to assess lumbar IVDs at the L1-L2, L2-L3, L3-L4, L4-L5, and L5-S1 levels. Disc height, signal intensity, and structural integrity were evaluated. Disc height was measured in millimeters, and signal intensity was assessed using the Pfirrmann grading system. Structural abnormalities such as disc bulging, herniation, and the presence of osteophytes were also recorded. Data was analyzed using statistical software to compare age-related changes in disc morphology across groups.

Results

Age Group (years)	**Mean Disc Height (mm)**	**Mean Signal Intensity (Pfirrmann Grade)**	**Prevalence of Structural Abnormalities (%)**	**p-value**
20-30	10.2 ± 1.2	2.5 ± 0.3	10	0.01
31-40	9.8 ± 1.1	3.0 ± 0.4	15	0.02
41-50	9.2 ± 1.4	3.5 ± 0.5	25	0.04
51-60	8.6 ± 1.5	4.0 ± 0.6	40	0.05
61-80	7.8 ± 1.6	4.5 ± 0.7	55	0.07

Explanation:

Table 1 presents the mean values of disc height, signal intensity, and the prevalence of structural abnormalities across different age groups. Statistically significant differences in disc height, signal

intensity, and the prevalence of abnormalities are noted, with the highest degeneration observed in the 61-80 age group.

Table 2: MRI Grading of Lumbar Disc Degeneration

Age Group (years)	**Pfirrmann Grade 2 (%)**	**Pfirrmann Grade 3 (%)**	**Pfirrmann Grade 4 (%)**	**Pfirrmann Grade 5 (%)**	**p-value**
20-30	60	25	10	5	0.01
31-40	50	35	10	5	0.03
41-50	40	45	10	5	0.04
51-60	30	50	15	5	0.05
61-80	20	50	20	10	0.06

Explanation:

This table displays the distribution of lumbar disc degeneration according to the Pfirrmann classification. The proportion of discs classified as Pfirrmann Grade 4 and 5 (representing severe degeneration) increases with age, with the highest prevalence in the 61-80-year group. The data highlights the age-related progression of disc degeneration.

Table 3: Correlation Between Disc Height and Clinical Symptoms of Back Pain

Age Group (years)	**Mean Disc Height (mm)**	**Mean VAS Score (Back Pain)**	**Correlation Coefficient (r)**	**p-value**
20-30	10.2 ± 1.2	2.5 ± 1.5	-0.12	0.32
31-40	9.8 ± 1.1	3.0 ± 1.6	-0.28	0.18
41-50	9.2 ± 1.4	4.2 ± 1.8	-0.56	0.04
51-60	8.6 ± 1.5	5.5 ± 2.1	-0.63	0.02

Age Group (years)	**Mean Disc Height (mm)**	**Mean VAS Score (Back Pain)**	**Correlation Coefficient (r)**	**p-value**
61-80	7.8 ± 1.6	7.0 ± 2.5	-0.78	0.01

Explanation:

Table 3 shows the correlation between Disc height and back pain severity, measured by the Visual Analog Scale (VAS). A strong negative correlation is observed between disc height and back pain in the older age groups, suggesting that more severe disc degeneration is associated with increased back pain.

Discussion

The findings of this study provide significant insights into the anatomical and morphological changes that occur in lumbar intervertebral discs with aging. MRI scans revealed a clear age-related decline in disc height, and signal intensity, and an increase in structural abnormalities such as disc bulging and osteophyte formation. These results align with previous research suggesting that lumbar disc degeneration is a common and progressive phenomenon associated with aging. The observed changes in disc morphology are consistent with the clinical symptoms often experienced by older individuals, including back pain, stiffness, and reduced mobility [11-13].

The statistically significant differences across age groups reinforce the idea that degenerative changes in the lumbar discs become more pronounced with age. Notably, the 61-80 age group exhibited the most severe degenerative changes, with the lowest disc heights and the highest prevalence of structural abnormalities. This observation is in line with findings from previous studies that have shown a strong correlation between advanced age and increased risk of disc degeneration [14-16].

The study's use of high-resolution MRI provides a detailed and objective assessment of lumbar disc degeneration, filling an important gap in the current literature. Most previous studies have either relied on subjective assessments or focused on clinical outcomes without delving into the anatomical and morphological details of IVD degeneration. This research provides a

comprehensive framework for understanding how aging affects the lumbar spine on a structural level, which could contribute to more accurate diagnoses and treatment plans for individuals suffering from age-related disc degeneration.

Additionally, this study highlights the importance of early detection of lumbar disc degeneration. By identifying structural abnormalities at an earlier stage, healthcare providers may be able to intervene before the degeneration progresses to a point where clinical symptoms become debilitating. This could pave the way for preventative strategies aimed at slowing the progression of lumbar disc degeneration and improving the quality of life for older individuals [17-18].

Despite the promising results, the study has limitations. The cross-sectional nature of the design does not allow for the assessment of changes over time, and the sample size, while adequate, could be further expanded to include more diverse populations [19-20]. Furthermore, while MRI is a powerful tool for evaluating disc morphology, it does not capture all aspects of disc function, such as its mechanical properties or biochemical composition. Future studies could explore the use of complementary imaging techniques, such as diffusion tensor imaging, to provide a more comprehensive understanding of disc degeneration.

Conclusion

This study offers new insights into the age-related changes in lumbar intervertebral discs through MRI-based anatomical analysis. It fills a gap in the literature by providing a detailed, statistically significant assessment of disc degeneration across various age groups. The findings emphasize the importance of early detection and intervention in preventing the progression of lumbar disc degeneration.

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