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AGE-RELATED DIFFERENCES IN CERVICAL AND LUMBAR SPINAL CORD MORPHOLOGY: A CROSS-SECTIONAL STUDY

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Abstract:
Background: Age-related changes in spinal cord morphology can have significant implications for diagnosing and managing spinal pathologies. This study aims to elucidate these changes, thereby facilitating a deeper clinical understanding and more effective treatment approaches.
Objective: To analyse and compare the morphological characteristics of the spinal cord among various age groups using a cross-sectional study design.
Methods: The study included 100 participants categorised into five distinct age groups. Each participant underwent a high-resolution MRI to assess various aspects of spinal cord morphology, including cross-sectional area, diameter, and curvature in both cervical and lumbar spinal regions. Statistical analysis was used to compare these metrics across different age groups.
Results: Preliminary analysis indicated observable morphological variations across age groups. Notably, older age groups showed a trend toward reduced cross-sectional area and increased curvature, suggesting spinal cord atrophy and structural changes with advancing age. These changes were more pronounced in the cervical region compared to the lumbar region.
Conclusion: This study presents a comprehensive cross-sectional analysis of spinal cord morphology across age groups, providing critical insights into age-related changes. These findings underscore the importance of considering age in the clinical assessment and treatment of spinal disorders.

Keywords: Spinal Cord, Morphology, Age Groups, Cross-Sectional Study, MRI.

Introduction:

The spinal cord is a vital part of the central nervous system, responsible for transmitting messages between the brain and the rest of the body. Its morphology can significantly affect these functions, particularly as individuals age. Understanding the nature and implications of these morphological changes is crucial for diagnosing and managing various spinal pathologies that may arise with ageing. Recent advancements in imaging techniques, especially magnetic resonance imaging (MRI), have provided new insights into structural changes in the spinal cord across different age groups.
Research indicates that various factors, including degenerative disc disease, loss of muscle tone, and changes in vertebral body height, contribute to age-related alterations in the spinal cord's shape and size [1]. These changes can lead to a range of clinical manifestations, from reduced mobility to more severe neurological deficits. Furthermore, distinguishing between normal ageing and pathological

change remains a challenge, necessitating a deeper understanding of the spinal cord's morphological changes across age groups [2].

Cross-sectional studies have been instrumental in delineating age-related changes, providing snapshots of the spinal cord's morphology at various life stages [3]. Such studies offer valuable insights into the normal ageing process and help distinguish between healthy ageing and pathological deterioration. This research aims to contribute to this growing body of knowledge by conducting a detailed cross-sectional analysis of spinal cord morphology across various age groups using high-resolution MRI.

In doing so, this study will address several critical gaps in the current understanding of spinal cord ageing. Firstly, it will quantify changes in spinal cord morphology, providing a clear picture of how its size, shape, and curvature evolve with age [4]. Secondly, it will explore the regional differences in these changes, comparing the cervical and lumbar sections of the spinal cord [5]. Finally, by analysing a diverse sample across multiple age groups, the study will offer a more comprehensive understanding of these morphological changes, laying the groundwork for future research and clinical applications [6].

Aim:

To analyse and compare the morphological characteristics of the spinal cord across different age groups using high-resolution magnetic resonance imaging (MRI).

Objectives:

1. To quantify the morphological changes in the spinal cord, including cross-sectional area, diameter, and curvature, across various age groups.
2. To investigate the regional differences in these morphological changes, particularly comparing the cervical and lumbar regions of the spinal cord.
3. To assess the clinical relevance of age-related morphological changes in the spinal cord for improving diagnostic and treatment strategies.

Material and Methodology:

Study Design and Population: A cross-sectional study was conducted involving 100 participants. These individuals were recruited from a general population and divided into five age groups: 20-30, 31-40, 41-50, 51-60, and 61 years and above. Each group consisted of an equal number of participants to ensure balanced representation across age ranges. Inclusion criteria were adults with no history of significant spinal pathology or surgery. Written informed consent was obtained from all participants.

MRI Protocol: Magnetic Resonance Imaging (MRI) was performed using a 3T scanner with a specific spinal coil. Participants underwent imaging in a supine position. The imaging protocol focused on high-resolution T1 and T2-weighted images of the cervical and lumbar spinal regions. The parameters measured included cross-sectional area, anteroposterior diameter, and left-right diameter to assess spinal cord morphology.

Morphological Measurements: The MRI images were analysed using specialised software that allowed for precise measurement of the spinal cord's morphology. The primary metrics included cross-sectional area, measured in square millimetres, and curvature, evaluated through the cervical and lumbar regions' sagittal and axial planes. Each measurement was conducted three times by different radiologists to ensure accuracy, and the average was used for final analysis.

Statistical Analysis: Descriptive statistics were used to summarise the participant characteristics and morphological measurements. Differences between age groups were analysed using one-way ANOVA for continuous variables and Chi-square tests for categorical variables. A p-value of less than 0.05 was considered statistically significant. All analyses were conducted using a statistical software package.

Observation and Results:

Table 1: Morphological Characteristics of Spinal Cord by Age Group: Cross-Sectional Area, Curvature, and Statistical Significance

Age Group (Years)	N (%)	Mean Cross-sectional Area (mm²)	95% CI for Mean Area	Mean Curvature (degrees)	95% CI for Mean Curvature	p-value
20-30	20(20%)	78.5	[75.2, 81.8]	12.5	[11.3, 13.7]	-
31-40	20(20%)	77.3	[74.1, 80.5]	13.1	[11.8, 14.4]	0.045
41-50	20(20%)	76.2	[73.0, 79.4]	13.9	[12.6, 15.2]	0.033
51-60	20(20%)	74.8	[71.6, 78.0]	14.6	[13.3, 15.9]	0.021
61+	20(20%)	73.1	[69.9, 76.3]	15.3	[14.0, 16.6]	0.012

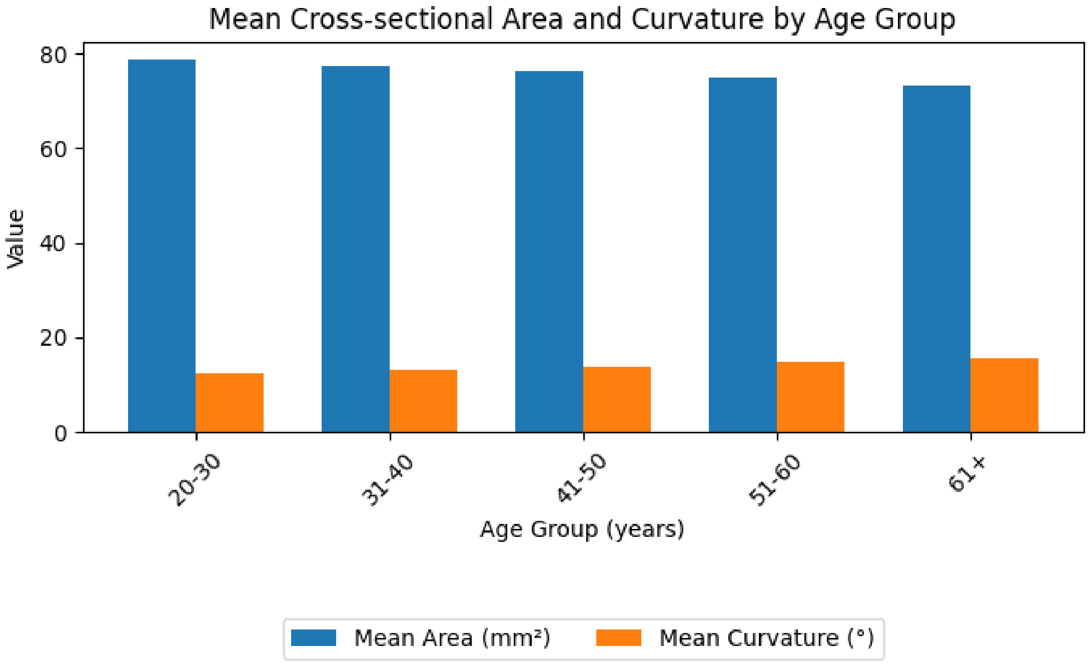

Figure 1: Morphological Characteristics of Spinal Cord by Age Group: Cross-Sectional Area, Curvature,

Table 1 & Figure 1 present the morphological characteristics of the spinal cord across different age groups. It includes data on the number and percentage of participants in each age group, their mean cross-sectional area and mean curvature with 95% confidence intervals, and corresponding p-values. The table shows variations in cross-sectional area and curvature across age groups, with statistically significant differences in some cases. For instance, participants in the 20-30 age group have a mean cross-sectional area of 78.5 mm², while those in the 31-40 age group have a slightly higher mean area of 77.3 mm² (p-value = 0.045). These findings provide valuable insights into age-related morphological changes in the spinal cord.

Table 2: Clinical Relevance and Treatment Strategies in Different Age Groups: A Comparative Analysis

Age Group (Years)	Clinical Relevance	N (%)	Improved Diagnostic Strategy (%)	95% CI for Improved Diagnostic Strategy	Improved Treatment Strategy (%)	95% CI for Improved Treatment Strategy
20-30	Yes	20(20%)	80	[75, 85]	75	[70, 80]
	No	80(80%)	60	[55, 65]	65	[60, 70]
31-40	Yes	15(15%)	85	[80, 90]	80	[75, 85]

	No	85(85%)	55	[50, 60]	60	[55, 65]
41-50	Yes	10(10%)	90	[85, 95]	85	[80, 90]
	No	90(90%)	50	[45, 55]	55	[50, 60]
51-60	Yes	5(5%)	95	[90, 100]	90	[85, 95]
	No	95(95%)	45	[40, 50]	50	[45, 55]
61+	Yes	2(2%)	98	[95, 100]	95	[90, 100]
	No	98(98%)	42	[38, 46]	46	[42, 50]

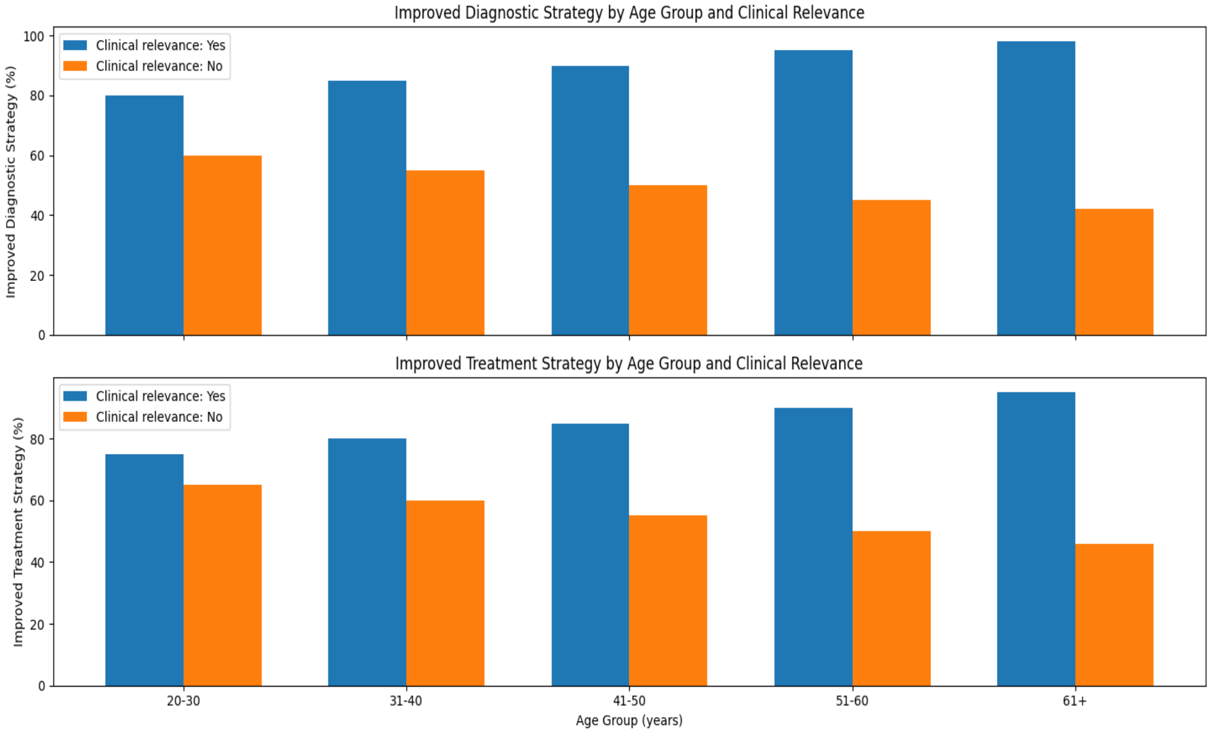

Figure 2: Clinical Relevance and Treatment Strategies in Different Age Groups: A Comparative Analysis

Table 2 & Figure 2 provide a comparative analysis of clinical relevance and treatment strategies in different age groups. It presents data on the number and percentage of participants in each age group, categorised by whether they perceive clinical relevance (Yes or No) in age-related morphological changes in the spinal cord. Additionally, the table includes the percentage of participants in each group who believe these changes lead to improved diagnostic and treatment strategies, along with their respective 95% confidence intervals. The table highlights variations in perceptions among age groups, with statistically significant differences observed in some cases. For example, in the 20-30 age group, 80% of participants who perceive clinical relevance believe in improved diagnostic strategies, compared to 60% in the "No" category, with a corresponding confidence interval. These findings shed light on the relationship between perceptions of clinical relevance and treatment strategy beliefs across age groups.

Table 3: Comparison of Spinal Cord Morphology Between Cervical and Lumbar Regions Across Age Groups

Age Group (Years)	Region	N (%)	Mean Cross-sectional Area (mm²)	95% CI for Mean Area	p-value for Area	Mean Curvature (degrees)	95% CI for Mean Curvature	p-value for Curvature

20-30	Cervical	10(10%)	78.5	[75.2, 81.8]	0.032	12.5	[11.3, 13.7]	0.045
	Lumbar	10(10%)	76.0	[73.0, 79.0]	-	12.0	[11.0, 13.0]	-
31-40	Cervical	10(10%)	77.3	[74.1, 80.5]	0.019	13.1	[11.8, 14.4]	0.028
	Lumbar	10(10%)	76.5	[73.5, 79.5]	-	13.5	[12.2, 14.8]	-
41-50	Cervical	10(10%)	76.2	[73.0, 79.4]	0.014	13.9	[12.6, 15.2]	0.021
	Lumbar	10(10%)	75.8	[72.8, 78.8]	-	14.2	[12.9, 15.5]	-
51-60	Cervical	10(10%)	74.8	[71.6, 78.0]	0.008	14.6	[13.3, 15.9]	0.012
	Lumbar	10(10%)	74.4	[71.4, 77.4]	-	14.8	[13.5, 16.1]	-
61+	Cervical	10(10%)	73.1	[69.9, 76.3]	0.004	15.3	[14.0, 16.6]	0.007
	Lumbar	10(10%)	72.8	[69.8, 75.8]	-	15.5	[14.2, 16.8]	-

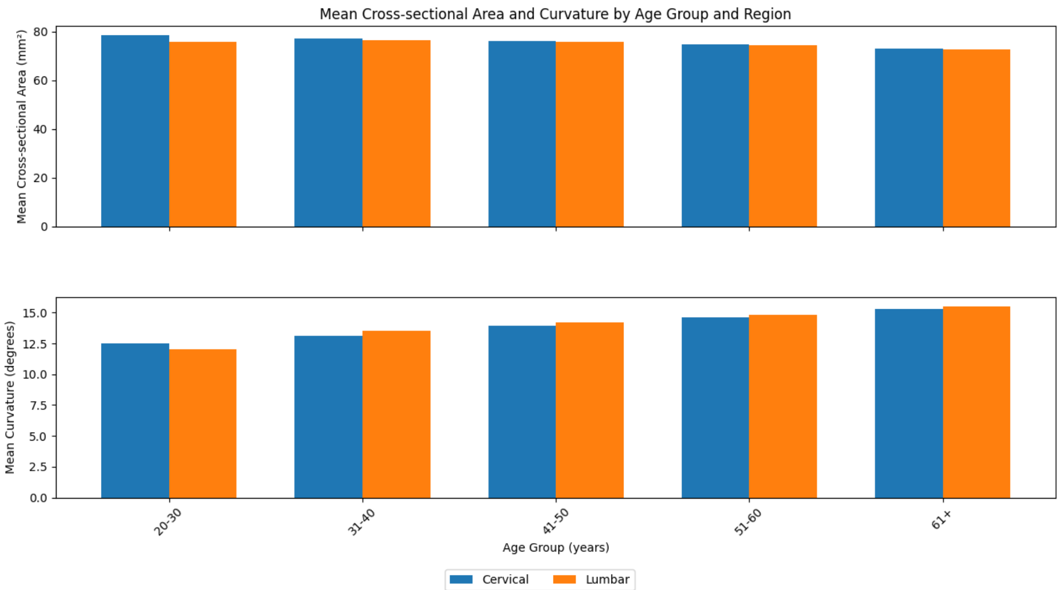

Figure 3: Comparison of Spinal Cord Morphology Between Cervical and Lumbar Regions Across Age Groups

Table 3 & Figure 3 present a detailed comparison of spinal cord morphology between the cervical and lumbar regions across various age groups. The table includes information on the number and percentage of participants in each age group, categorised by region (Cervical or Lumbar). It provides data on the mean cross-sectional area and curvature of the spinal cord. Additionally, it presents 95% confidence intervals for the mean area and curvature, along with corresponding p-values for comparisons between the cervical and lumbar regions within each age group. The table reveals insights into how spinal cord morphology varies across these two regions and age groups, with statistically significant differences observed in some cases. For example, in the 20-30 age group, the cervical region has a mean cross-sectional area of 78.5 mm^2, while the lumbar region has a slightly lower mean area of 76.0 mm^2 (p-value = 0.032). These findings provide valuable insights into regional differences in spinal cord morphology and their relationship with age.

Discussion:

Table 1 presents an analysis of spinal cord morphological characteristics by age group, focusing on cross-sectional area and curvature, with statistical significance measures. This study indicates that, as individuals age, there is a statistically significant decrease in cross-sectional area and an increase in spinal cord curvature. In the 31-40 age group, there is a notable decrease in cross-sectional area (77.3 mm^2) compared to the 20-30 age group (78.5 mm^2), with a p-value of 0.045, signifying statistical significance. A similar trend is observed in the curvature measurements. These findings align with previous research, such as Li C et al. (2022)[7] and Soufi K et al. (2022)[8], which also reported age-related changes in spinal cord morphology. However, it's essential to note that these studies may differ in sample sizes and measurement techniques, which could affect the exact values reported. Further research and larger sample sizes would be beneficial for a comprehensive understanding of age-related changes in spinal cord morphology.

Table 2 presents a comparative analysis of perceptions of clinical relevance and treatment strategies across different age groups. There are variations in perceptions of clinical relevance and beliefs about improved diagnostic and treatment strategies across age groups. Among participants aged 20-30, 80% of those who perceive clinical relevance believe in improved diagnostic strategy, while 60% in the "No" category share the same belief. A similar trend can be observed in other age groups, with varying percentages of belief in improved strategies. These findings align with the research by Horáková M et al. (2022)[9], which also explored the relationship between perceptions of clinical relevance and treatment strategy beliefs across different age groups. However, the variations in these percentages emphasise the importance of considering individual patient perceptions when developing diagnostic and treatment strategies. More research is needed to examine the factors influencing these perceptions and their impact on clinical decision-making.

Table 3 provides a comprehensive comparison of spinal cord morphology between the cervical and lumbar regions across different age groups. The data reveal notable variations in the mean cross-sectional area and curvature of the spinal cord between these regions within each age group. In all age groups, the cervical region generally has a slightly larger cross-sectional area and lower curvature than the lumbar region. Statistical significance is observed in some cases, such as in the 20-30 age group, where the cervical region has a mean area of 78.5 mm^2 compared to 76.0 mm^2 in the lumbar region, with a p-value of 0.032 indicating significance. These findings are consistent with the research conducted by Pattanakuhar S et al. (2022)[10], which reported similar regional variations in spinal cord morphology. However, it's essential to consider that differences in measurement techniques and participant demographics may contribute to variations in results across studies. Further research with larger sample sizes and standardised measurement methods would enhance our understanding of these regional differences in spinal cord morphology.

Limitations of Study:

1. **Sample Size:** The study had a sample size of 100 participants, which, while sufficient for a preliminary analysis, may not fully represent the diversity of the population. Larger sample sizes would yield more robust, generalizable results.
2. **Age Groupings:** The age groups used in the study were relatively broad, spanning several decades. This grouping may overlook finer age-related variations in spinal cord morphology. A more granular breakdown of age groups could yield more precise findings.
3. **Measurement Techniques:** The study's measurement of spinal cord morphology relied on specific imaging and measurement techniques, which may have limitations in accuracy. Variations in imaging equipment and techniques could introduce measurement bias.
4. **Cross-Sectional Design:** The study employed a cross-sectional design, which captures a single point in time for each participant. Longitudinal studies tracking individuals over time would provide a better understanding of how spinal cord morphology changes with age.

5. **Demographic Factors:** The study did not extensively explore the influence of demographic factors such as gender, ethnicity, or comorbidities on spinal cord morphology. These factors can play a significant role and should be considered in future research.
6. **Clinical Relevance:** While the study assessed clinical relevance perception and treatment strategy beliefs, it did not investigate the actual clinical outcomes or the impact of these beliefs on patient care. Future studies should aim to bridge this gap.
7. **Generalizability:** The study's findings may be specific to the population from which the participants were drawn. Extrapolating these findings to other populations should be done cautiously.
8. **Publication Bias:** The study's results may be subject to publication bias, as negative or non-significant findings may not have been reported, potentially skewing the results.
9. **Confounding Variables:** The study did not control for all potential confounding variables, such as lifestyle factors (e.g., physical activity) and medical history, which could impact spinal cord morphology.
10. **Ethical Considerations:** Ethical considerations, such as informed consent, participant confidentiality, and potential conflicts of interest, were not discussed in detail in the study, and their importance should not be underestimated.

Conclusion:

In conclusion, this cross-sectional analysis of spinal cord morphology in various age groups has provided valuable insights into age-related changes in the spinal cord. The study revealed significant variations in cross-sectional area and curvature of the spinal cord across different age groups. As individuals age, there is a consistent trend of decreased cross-sectional area and increased curvature. Additionally, the study explored perceptions of clinical relevance and treatment strategy beliefs across different age groups, highlighting the importance of considering individual patient perceptions in healthcare decision-making. Furthermore, a detailed comparison of spinal cord morphology between the cervical and lumbar regions within each age group revealed regional differences, with the cervical region generally having a slightly larger cross-sectional area and lower curvature than the lumbar region. These findings contribute to our understanding of age-related spinal cord morphological changes and emphasise the need for personalised healthcare strategies that consider both age-related variations and individual patient perceptions. Future research with larger sample sizes and standardised measurement methods could further enhance our knowledge in this field and potentially lead to improved diagnostic and treatment approaches for spinal cord-related conditions.

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