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Diffusion tensor imaging with 3D-slicer for evaluating the severity of brain aging; a potential new method-severity grading for brain aging

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Abstract

Background: In modern society, the sub-health state (SHS) is becoming increasingly apparent as a result of rapid work, study, and interpersonal relationships. As a state between health and disease, it usually occurs due to long-term unhealthy habits, such as staying late, anxiety, tension, and so on. Severe SHS can lead to the occurrence of diseases and can result in sudden death. One of the familiar unhealthy habits is sleep habits, such as staying late, sleeping lightly, waking up early, etc. Long-term sleep deprivation can also increase the risk of disease, which in turn exacerbates SHS and forms a vicious cycle. Routine disease examinations are not capable of detecting SHS, which is a state of health that is easy to overlook. As a functional brain image, based on the diffusion characteristics of water molecules, Diffusion Tensor Imaging (DTI) can sensitively identify the abnormalities of brain aging at an extremely early stage. So, it has the potential to play a crucial role in assessing the severity of SHS.

Case description: A female patient was 35 years old, unmarried, and had been suffering from sleep deprivation and fatigue for 2 years. Mild depression was observed in the Self Rating Depression Scale (SDS) score. BMI was 23.3 kg/m^2. After treatment, the quality of sleep improved, and fatigue and depression ceased to exist. The BMI was 21.7 kg/m^2, and there was a mild degree of SHS in DTI contrast to moderately severe before treatment.

Conclusion: Magnetic resonance diffusion tensor imaging (DTI) can detect early abnormalities in white matter fibers of the brain and may serve as significant imaging proof for assessing and monitoring the severity of SHS.

Keywords: Case report; Sub-health status; Brain aging; Diffusion tensor imaging; Three-dimensional imaging.

Introduction

The state of sub-health status (SHS) is a distinction between normal (including psychological and/or tissue/organ function) and disease. The accelerating pace of society is causing people's mental stress to increase, which in turn leads to an increasing number of sub-healthy individuals [1,2]. If SHS isn't accurately interfered with in time, it will progress into disease, and at the same time, the disease will conversely worsen SHS [3]. Due to the lack of a clear boundary between sub-health and disease, many individuals with sub-health receive the same treatment as those with diseases, which invisibly undermines the doctor-patient relationship [4]. Therefore, early scientific evaluation of SHS is a wise choice for clinical research.

As a state between health and disease, it usually occurs for a long time due to unhealthy habits [1], such as staying late, anxiety, tension, etc. Severe SHS can lead to the occurrence of diseases and can result in sudden death [5]. One of the familiar unhealthy habits is sleep habit [6], such as staying up late, sleeping lightly, waking up early, etc. Long-term sleep deprivation can also increase the risk of disease [7], which in turn exacerbates SHS and forms a vicious cycle. Routine disease examinations are not effective in detecting SHS, which is a state of health that is easily overlooked. As a functional brain image, based on the diffusion characteristics of water molecules, DTI can sensitively identify the abnormalities in white matter fibers at an extremely early stage. Therefore, DTI's abnormal results will be significantly earlier than conventional magnetic resonance imaging to assess changes in brain tissue structure [8]. The function of the brain is to regulate the functioning of all organs and tissues in the human body, so any differences in the integrity of white matter fibers in the brain are a sensitive reflection of the body's state. In other words, by analyzing differences in DTI images, the severity of SHS could be investigated (Figure 1).

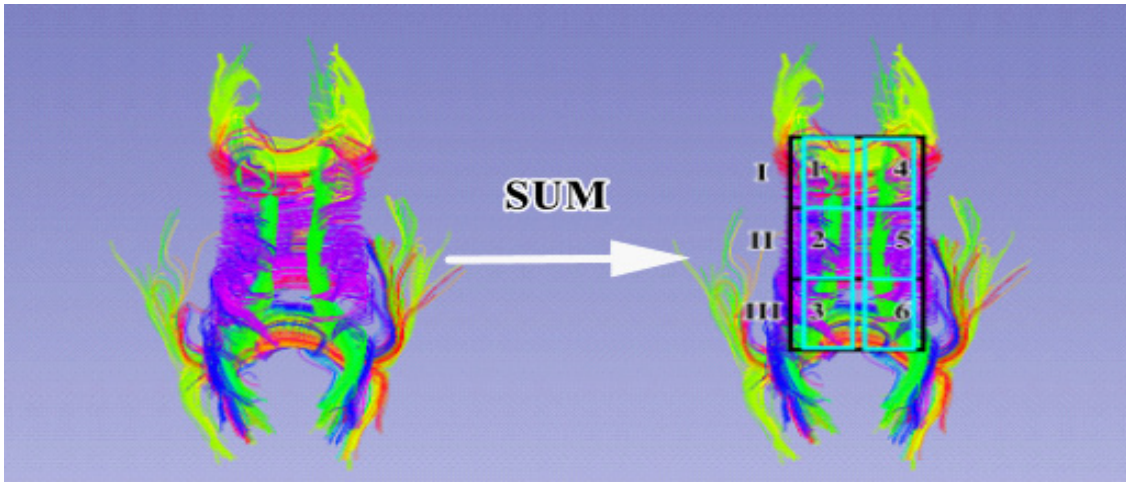

Figure 1: A method to evaluate the severity of brain aging grading. The corpus callosum and cingulate gyrus need to be represented in DTI images. In the first step, the corpus callosum was divided into three parts and scored 1 to 3 based on the degree of luxurious white matter fiber (mild, moderate, and severe). Then, there was a weight value of 1, 2, and 3, respectively, based on local white matter fiber for each part. Each part scored 6 points, resulting in a total score of 18 for all three parts. In the subsequent phase, the bilateral cingulate gyruses were subdivided into three parts and scored 1, 2, and 3 according to how much luxuriant white matter fiber was present (mild, moderate, and severe). Then, each part was assigned a weight value of 1, 2, and 3, respectively, based on local white matter fiber. The total score for each section was 6 points, and the total score for all six sections was 36. At the end, the total score was 54.

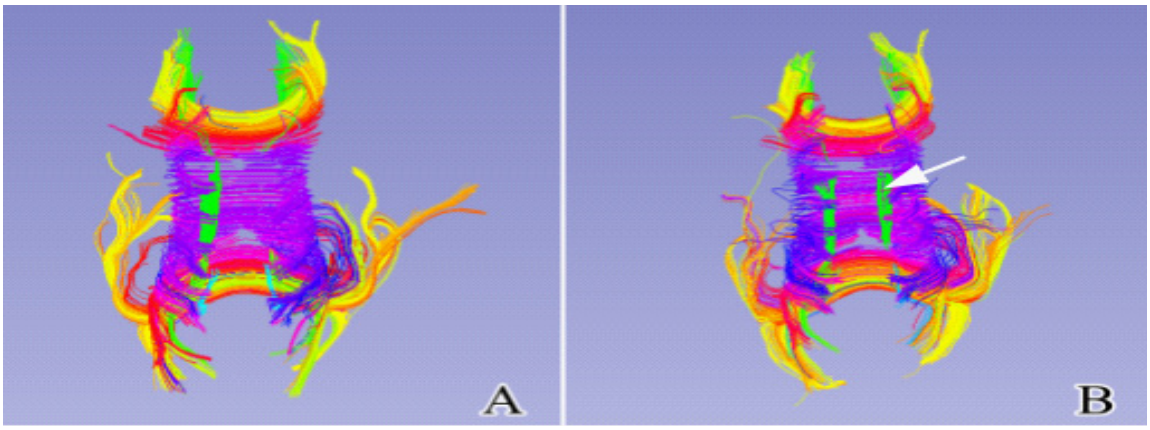

Figure 2: The scoring system for corpus callosum (CC) and cingulate gyrus (CG). The right CG was more intact after treatment compared before (arrow). The total scores before and after the intervention were 23 **(A)** and 15 **(B)**, respectively, which were associated with moderate and mild SHS (A) respectively.

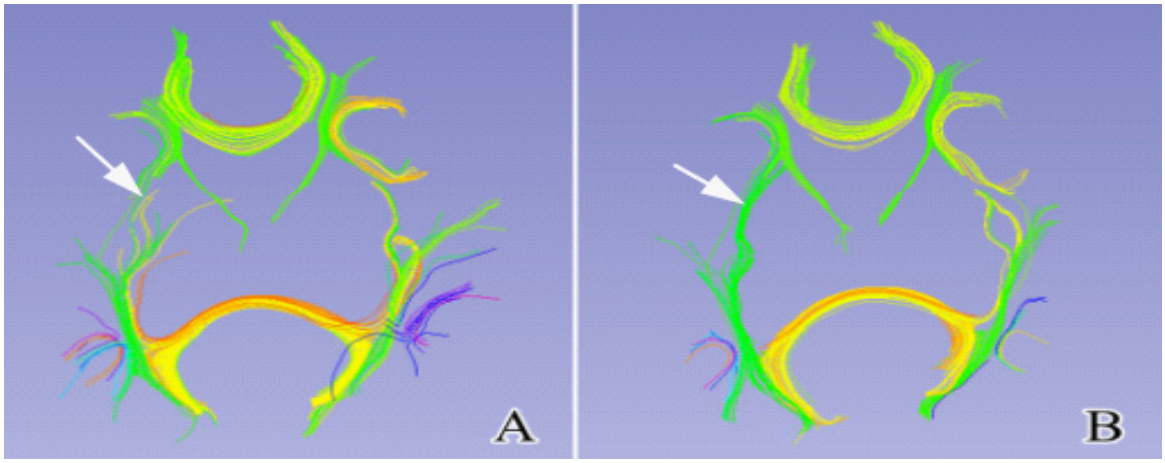

Figure 3: The inferior frontal occipital tract (IFOT). The IFOT showed finer continuity and integrity after treatment **(B)** compared to before **(A)** (arrow).

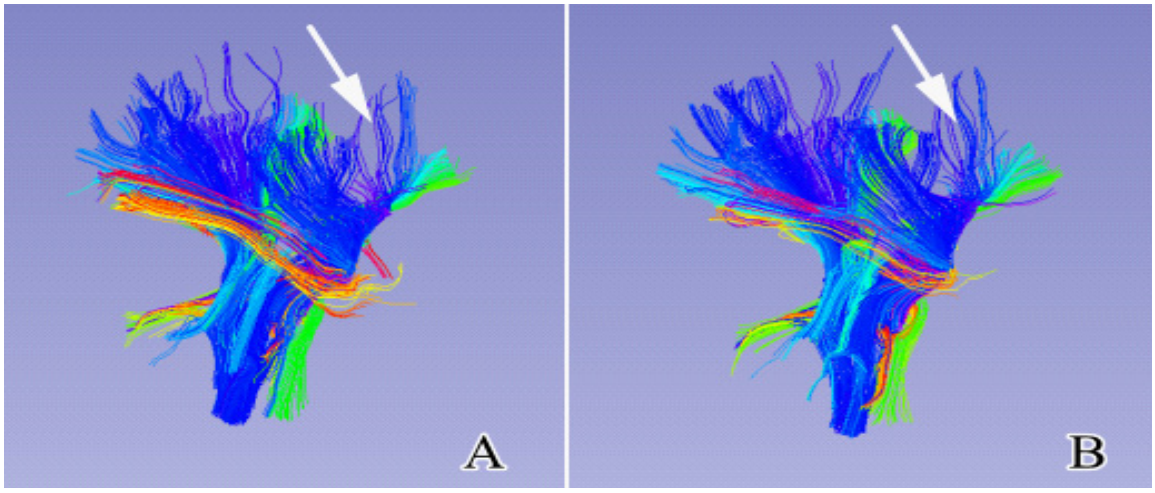

Figure 4: The pyramidal tract (PT). The right PT after intervention **(B)** had a greater amount of integrity than the previous one before intervention **(A)** (arrow).

Case description

Unmarried female 35 years old with sleep deprivation and fatigue for 2 years. Routine physical examination showed no abnormalities, and the Self Rating Depression Scale (SDS) score was 58 points, which belongs to mild depression. BMI was 23.3 kg/m^2. Moderate sub-health severity assessment is achieved by Diffusion Tensor Imaging (DTI). With the assistance of active learning, exercise (walking 8000 steps daily), and nutritional support, the quality of sleep has improved, leading to an 8-hour daily sleep time and the disappearance of fatigue. The depression score is 46 points, which is normal, and the BMI is 21.7 kg/m^2. DTI SHS severity assessment is mild (Figures 2-4).

Discussion/conclusion

SHS refers to the intermediate state between health and disease, which does not belong to any particular disease but not to a healthy state. In terms of SHS of the brain, it shows a premature reduction in its functionality. The severity grading can be utilized to predict prognosis, develop personalized treatment plans, monitor disease progression, effectively manage patients, improve their quality of life, and promote scientific research and public health work.

In this report, the sparsity of the corpus callosum and cingulate gyrus, closely related to health [9-10], was used for grading. The total score was 54 with a median value of 27. The grading was including slight (0<~≤ 10), mild (10<~≤ 20), moderate (20<~≤ 30), and severe (>30). The validation of a large sample is currently being carried out. In this case, the severity score was 23 before interference, which is considered moderate SHS and indicates premature brain aging. With a comprehensive intervention, including adjustments in sleep time, improvement of sleep environment, and nutritional support, after a 3-month follow-up, the severity score of premature brain aging was 15 points, which is considered mild. The depression self-assessment score is 46 points, which is a normal value. The patient's sleep quality has improved compared to before, and fatigue has disappeared.

Therefore, extracting DTI corpus callosum and cingulate nerve fibers for grading the severity of premature brain aging may lead to more efficient evaluation of SHS, personalized intervention measures, and improved patient quality of life.

Data availability statement: The original contributions presented in the study are included in the article. Further inquiries can be directed to the corresponding authors.

Declarations

Ethics statement: The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions: QX was responsible for the first draft of the manuscript. LW was responsible for checking the manuscript and collecting clinical information. QX, HP and MC managed the method and image processing.

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Conflict of interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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