wjpmr, 2021,7(3), 243-245

SJIF Impact Factor: 5.922

WORLD JOURNAL OF PHARMACEUTICAL AND MEDICAL RESEARCH

www.wjpmr.com

Research Article

ISSN 2455-3301

WJPMR

THE INFLUENCE OF THE IMAGING PARAMETERS OF THE CORTICOSPINAL TRACT FUNICULUS DEPICTION USING THE DIFFUSION TENSOR MR IMAGING

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DOI: https://doi.org/10.17605/OSF.IO/9TWNC

Article Received on 18/01/2021 **Article Revised on 08/02/2021** **Article Accepted on 28/02/2021**

ABSTRACT

Purpose: Fiber tracking is a method that uses diffusion tensor magnetic resonance imaging (DTI) to depict nerves by measuring the strength and anisotropic direction of each voxel. The imaging parameters used in DTI analysis are important, but the degree to which individual parameters affect nerve depiction has not been studied. The purpose of this study was to compare the depiction of nerve fibers of the corticospinal tract using different DTI parameters. Materials and Methods: DTI scans of the human brain were analyzed using four different imaging parameters: voxel size, number of excitations (NEX), number of motion probing gradient (MPG) directions, and b-values. The pyramidal depictions of tractography using these imaging parameters were compared using a 1.5 T magnetic resonance imaging device. For each image, the bilateral corticospinal tracts were modeled by fiber tractography using each of the aforementioned parameters. The resulting tractographies were assessed by physical and visual evaluation to measure the effect of the parameters under investigation. Results: The number and length of fibers increased significantly with an increase in the voxel size. However, there was no significant change in the length and number by the b-value, number of MPG axes, or NEX. The visual evaluation score also increased significantly with an increase in the voxel size. **Conclusion:** An increased voxel size significantly improved the depiction of corticospinal tract nerves in DTI tractography.

KEYWORDS: Diffusion tensor imaging, the cephalic fiber, imaging parameters.

1. INTRODUCTION

Diffusion tensor imaging (DTI) is a type of magnetic resonance imaging (MRI),[1] that captures the random motion of water molecules in the human brain. Diffusion anisotropy refers to the way in which water molecules diffuse further along the direction of a nerve fiber than across it. Fiber tracking can therefore be calculated by the maximal diffusion direction of each voxel using diffusion anisotropy of DTI.

Fiber tracking can be used to identify subtle areas of nerve damage, correlating with clinical loss of function,[2] and to identify changes in nerve function, for instance after neurosurgical intervention,[3]

The imaging parameters of DTI, which form the basis of fiber tracking, are important. DTI requires six or more directions of the motion probing gradient (MPG), but there is some evidence that 30 axes are necessary for optimal analysis of DTI by simulation.[4] However, one study showed that six gradients were adequate for optic radiation depiction and that additional gradients did not improve the outcome.[5]

However, increasing the number of directions also involves increasing the exposure time. Images using a high b-value have decreased signal-to-noise ratio (SNR) because the signal intensity of the image decreases.

In addition, it has been shown that 3 T is associated with superior depiction ability when compared to 1.5 T.[6] An image obtained using a high b-value with have a decreased SNR because the signal intensity of the image is reduced.

However, no study has been conducted on 3 T comparing 6, 12, and 40 directions with 81 directions of the MPG regarding a significant difference in the depiction ability of the optic radiation using DTI.

Therefore, the purpose of this study was to compare the depiction ability of each tractography according to changes in the imaging parameters of voxel size, MPG axes, NEX, and b-values.

2. MATERIALS AND METHODS

2-1. Imaging device, parameters and subjects

The MRI device used had a 16-channel head array coil (Ingenia 1.5 T, Philips Healthcare, Best, The

Netherlands). The recommended DTI parameters of the MRI device (NEX 2, voxel size 2.5 mm, MPG 15 axles, b-value 800s/mm^2) were used as the basic examination parameters. DTI of the human brain was performed using the above scan parameters. Details of the imaging parameters are shown in Table 1.

We obtained approval from the Ethical Review Board prior to conducting this study. Six healthy volunteers aged 20–62 were selected to participate in this study after an open call for participants and consented accordingly. Participants did not have any known brain pathology.

2-2. **Method of analysis (physical evaluation)**

Fiber tractography was performed by DTI, using the postprocessing fiber track package of advanced view attached to the Philips MRI device.

In designing the fiber tractography, regions of interest (ROIs) were set at three points: at the cerebral peduncle as a pyramidal initiation site, at the posterior limb of the internal capsule as an intermediate site, and at the precentral gyrus as the end site.

The setting positions of the three ROIs are shown in Fig. 1a-1c. An example of fiber tractography is shown in Fig. 2.

The number and length of fibers drawn under each imaging parameter were analyzed using the above software, and the differences under each condition were examined.

Multiple comparisons of Tukey and ANOVA tests were used to test for a statistically significant difference.

2-3. Method of analysis (visual evaluation)

Sight evaluation of the fiber image was carried out in five phases, by 10 observers. The observers were radiologists with 10 years' experience or more.

The evaluation criteria were as follows:
Point 1: The number and length of nerve fibers are insufficient.
Point 2: The number and length of nerve fibers are moderately insufficient.
Point 3: The number and length of nerve fibers are moderate.
Point 4: The number and length of nerve fibers are sufficient.
Point 5: The number and length of nerve fibers are completely depicted.

Fiber tractography images at points 1 and 5 on this scale are shown in Fig. 3.
For the visual evaluation score, significant difference authorization was practiced, similar to method 2-2.

Multiple comparisons of the Dunn and Friedman tests were used to test for a significant difference.

3. RESULTS

3-1. Physical evaluation

The number and length of nerve fibers depicted using different voxel sizes are shown in Fig. 4a and 4b. The number of fibers increased significantly with an increase in voxel size, as shown in Fig. 4a. In addition, the fiber length significantly increased using the 3.5 mm voxel when compared with the 2.5 mm and 1.25 mm voxels, as shown in Fig.4b. The number and length of nerve fibers using different b-values, NEX, and MPG axes are shown in Fig. 5a and 5b, Fig. 6a and 6b, and Fig. 7a and 7b, respectively. There was no significant difference in length or number of fibers with changes in b-values, NEX, or MPG axes.

3-2. Visual evaluation

The visual scores using a different voxel size, b-values, NEX, and MPG axes are shown in Fig. 8a-8d. With an increase in the voxel size, the score of the visual evaluation increased significantly, as shown in Fig. 8a. The visual evaluation score did not change significantly with changes in the b-value, NEX, or MPG axes as shown in Fig. 8b, Fig. 8c, and Fig. 8d, respectively.

4. DISCUSSION

In this study, both physical and visual evaluation showed excellent results with an increase in the voxel size. For this reason, it is thought that information on the diffusion anisotropy in one voxel is improved by the expansion of voxel size, and the signal-to-noise ratio (SNR) of the original image is increased. It has been reported that DTI can more accurately express molecular diffusion by increasing the SNR.[7] It was thought that it was obtained by enough diffusion that a significant difference did not occur in the number and the length of the fiber in different b-values, although a condition of b-value was used to evaluate a corticospinal tract with 500s/mm^2. In this study, the visual evaluation score increased significantly with an increase in voxel size. In contrast to this, the visual evaluation scores decreased significantly when the number of MPG axes increased from 6 to 15, and when the NEX increased from 1 to 2. We think that a visual evaluation intends for overall vanity, not nervous number and length. The physical evaluation scores did not increase significantly with an increase in MPG axes.

In preliminary research, it has been reported that the ability to depict the optic radiations does not increase significantly with an increase in the number of MPG axes in 3.0 T MRI devices,[8] we obtained similar results in this study using a 1.5 T MRI device.

6. CONCLUSION

The number and length of nerve fibers depicted increased significantly with an increase in voxel size, as did the visual appearance of the tractography. Nerve fiber depiction did not change significantly with changes in the numbers of MPG axes, NEX, or b-values.

In conclusion, an increase in voxel size was effective in improving the depiction of corticospinal tract nerves.

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Figure legends

1. 1a. Setting initiation site region of interest (ROI) at the position of the midbrain cerebral peduncle for right corticospinal tract fiber depiction.
2. 1b. Setting intermediate site ROI at the position of the posterior limb of internal capsule for right corticospinal tract fiber depiction
3. 1c. Setting end site ROI at the position of the whole brain cortex for right corticospinal tract fiber depiction.
4. Images of pyramidal tractography.
5. Examples of tractographies scoring 1 and 5 on the visual evaluation score.
6. 4a. Comparison of the number of fibers for different voxel sizes in physical evaluations.
7. 4b. Comparison of the length of fiber for different voxel sizes in physical evaluations.
8. 5a. Comparison of the number of fibers for different b-values in physical evaluations.
9. 5b. Comparison of the length of fibers for different b-values in physical evaluations.
10. 6a. Comparison of the number of fibers for different number of excitations (NEX) in physical evaluations.
11. 6b. Comparison of the length of fibers for different NEX in physical evaluations.
12. 7a. Comparison of the number of fibers for different number of directions of motion probing gradient (MPG) in physical evaluations.
13. 7b. Comparison of the length of fibers for different number of directions of MPG in physical evaluations.
14. 8a. Visual evaluation scores for different voxel sizes.
15. 8b. Visual evaluation scores for different b-values.
16. 8c. Visual evaluation scores for different NEX.
17. 8d. Visual evaluation for different numbers of MPG axes.