

Anatomical Characteristics of Thalamus-Cortical Sensory Tract in the Human Brain Using Diffusion Tensor Tractography at 3.0 Tesla Scanner

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Abstract

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BACKGROUND: Our knowledge about characteristics of the thalamocortical tract (THT) according to the cerebral origin is still few of studies about this structure on Vietnamese.

AIM: Here, we aim to characterise the morphology of the thalamocortical tract in the human brain using diffusion tensor tractography (DTT) at 3.0 tesla scanner.

METHODS: Fifty healthy subjects have enrolled in this study. Reconstructed images of the thalamocortical tract in the human brain were built using DTT at 3.0 tesla scanner.

RESULTS: The median length of the right thalamocortical tract was 130.64 mm, and the left THT was 123.14 mm, and an average of two sides was 126.34 mm. The difference between the two sides was statically significance ($p < 0.001$). The median fibre number of the right THT was 401.50, and the left THT was 315.00, and an average of two sides was 365.50. There was a diverse branch of THT: two branches (5%); three branches (25%); four branches (42%); five branches (16%); six branches (12%); in which branched contralateral for the right was 50%, and for the left was 50%.

CONCLUSION: Using the DTI and 3D image reconstruction techniques allow to build the image of sensory THT intuitively and accurately, which helps to identify the morphological characteristic of the thalamocortical tract of healthy people without invasive effects.

Introduction

Understanding the connection in a region and among regions within the brain help to know the function and coordinating activities of those regions [1]. The nervous tract within the human brain can be determined using injecting fluorescent pigments after the autopsy; however, the distance for observing only about 10 millimetres [2]. The further distance can be identified by dissection of the large conduction bundle, or determined by degradation after a local injury [3]. However, they are invasive methods and impossible for applying in the living human brain. Studies on the conduction bundle by non-invasive methods were almost handled on animals [4], [5], and researches in

the human brain using these methods are not much.

The diffusion tensor imaging (DTI) builds images based on the diffusion anisotropy of the water molecules in the axons [6], [7]. DTI is a new technique, which helps to determine the neural tracts, mostly in the living human brain. The anatomical images of sensory tract connected from the thalamus to other regions throughout the brain are important for clinical practice. However, it has not been studied well, especially in developing countries as Vietnam.

In this work, by using DTI and tractography, we studied the characteristics of somatosensory thalamocortical tract according to the cerebral origin in living subjects' brains.

Patients and Methods

Patients

This study included fifty healthy subjects, aged 18 and older. The selected subjects had no previous history of neurological, psychiatric disorders as well as physical illness.

This study was approved by the institutional review board of the 108 Military Central Hospital in Vietnam. Informed consents were obtained from the subjects included in the study. All procedures performed in studies involving human participants were in accordance with the ethical standards of the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Diffusion Tensor Image

We have employed Phillips Achieva 3.0 T using SENSE NV 16 coil channels to obtain DTI data. The sections were made from the background to the top of the skull with the basic pulse chain T1W, T2W, and FLAIR. Imaging parameters as follows: acquisition matrix 128 x 128, FOV 230 x 230 mm², TR: 10172 ms, 93 ms, EPI factor b0 and b 1000 s/mm², and 2 mm section thickness (acquired isotropic voxel size, 1.8 x 1.8 x 2 mm³).

Fibre Tracking

Diffusion-weighted image (DWI) and DTI data were analysed using software Philips Extended MR Workspace 2.6.3.1. Construction 2D colour map of fractional anisotropy (FA) was used to seed regions of interests (ROI) according to known anatomy [8]. The first ROI was placed in the commissura cerebelli, dark blue region on the FA 2D map (Figure 1A); the second ROI was located in the thalamus (Figure 1B); the third ROI was placed in the posterior limb of capsula interna, dark blue area on the FA 2D map (Figure 1C). The software was employed to reconstruct a 3D image of the sensory thalamocortical tract (THT), that was used to analyse the length, number of the tract, and the morphologies.

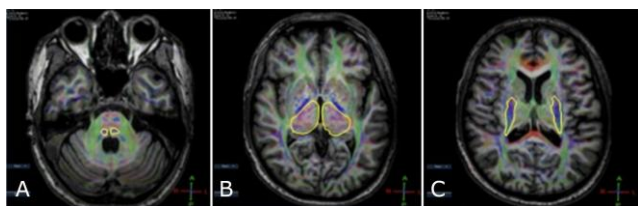


Figure 1: The seed regions of interests (ROI); The first ROI was placed in the commissura cerebelli A); The second ROI was placed in the thalamus B); The third ROI was placed in posterior of capsula interna C)

Statistical analysis

The data were statistically analysed using the SPSS software (Version 15.0; SPSS, Chicago, Illinois). The independent t-test was employed to determine the difference in length and volume of sensory THT between sexes and the two hemispheres, significant difference as $p < 0.05$. The distribution of age, sex of subjects and morphology of sensory THT was presented as the percentages.

Results

Characteristics of the subjects

In this study, subjects distributed mostly in young and middle-age with 18-39 age group accounted for 42%, the 40 – 49 age group accounted for 46%, and fewer in elder subjects with ≥ 60 age group accounted for 15%. The percentage of two genders were similar to male (52%) and female (48%) (Table 1).

Table 1: Age and genders of the subjects

| | Age groups: numbers (%) | | | Sum |
|--------------|-------------------------|----------|-----------|-----------|
| | 18 – 39 | 40 – 59 | ≥ 60 | |
| Male | 9 (18%) | 14 (28%) | 3 (6%) | 26 (52%) |
| Female | 12 (24%) | 9 (18%) | 3 (6%) | 24 (48%) |
| Both genders | 21 (42%) | 23 (46%) | 6 (12%) | 50 (100%) |

Characteristics of somatosensory thalamocortical tract

The 3D reconstructed images of the somatosensory thalamocortical tract were built successfully based on diffusion tensor image and fibre tracking using the dedicated software. Then, we measured the length and counted the number of branches in each hemisphere separately (Figure 2).

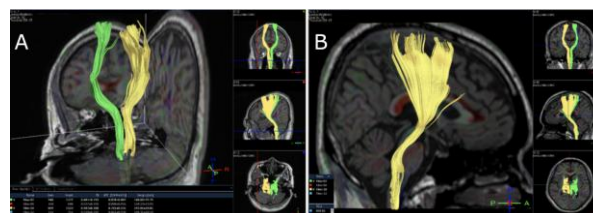


Figure 2: The 3D reconstructed images of the sensory thalamocortical tract; Green showed the tract on the right hemisphere A) and the yellow illustrated for the tract of the left hemisphere B)

The results showed that the mean length of the somatosensory thalamocortical tract on the right hemisphere (130.17 ± 11.44 mm) was statistical significance longer than the left one (121 ± 13.49 mm) ($P < 0.005$). This suggests that there were differences in the anatomical characteristics of sensory thalamocortical tract length between the right and the

left (Table 2).

Table 2: The length of the sensory of the thalamocortical tract in study subjects

| The length of the sensory of the thalamocortical tract (mm) | | | | | | P |
|---|----------|----|------------------|----------|----|--------|
| Left hemisphere | | | Right hemisphere | | | |
| Mean (mm) | SD (mm) | N | Mean (mm) | SD (mm) | n | < 0.05 |
| 121.21 mm | 13.49 mm | 50 | 130.17 mm | 11.44 mm | 50 | |

We also investigated the influence of gender on the length of sensory of the thalamocortical tract by comparing between the sexes. Data showed that the length bunch of males tended to be longer than that of females; however, there were no significant differences between the sexes ($P > 0.05$) (Table 3).

Table 3: Length comparison of right and left of the sensory of the thalamocortical tract between the sexes

| The length of the sensory of the thalamocortical tract (mm) | | | | | | | p |
|---|-----------|----------|----|-----------|----------|----|--------|
| | Males | | | Females | | | |
| | Mean (mm) | SD (mm) | n | Mean (mm) | SD (mm) | n | |
| Left hemisphere | 123.32 mm | 13.22 mm | 26 | 118.94 mm | 13.70 mm | 24 | > 0.05 |
| Right hemisphere | 132.32 mm | 12.88 mm | 26 | 127.85 mm | 9.37 mm | 24 | > 0.05 |

We counted the number of lines of the somatosensory thalamocortical tract on both sides of the hemisphere. The statistical analysis showed that the median number of the right side (401.5) tend to be higher than that of the left side (315). However, the difference was not statistically significant ($P > 0.05$) (Figure 3D).

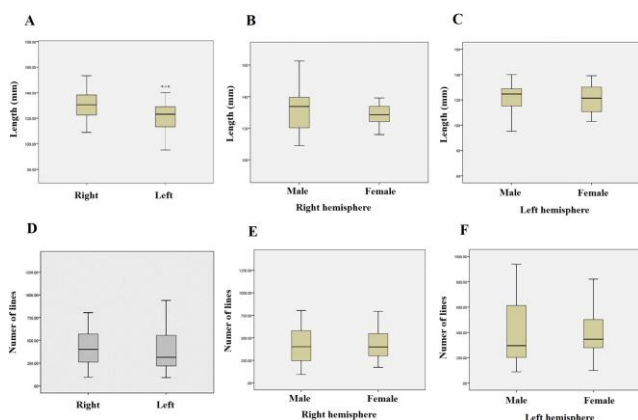


Figure 3: The length and the number of lines of the sensory of thalamocortical tract in study subjects; Comparison of sensory thalamocortical tract length between right and left hemisphere, mean \pm SD; $n = 50$ for each side; * $P < 0.001$ left side versus right side A); Length comparison of right B) and left C) of the sensory of thalamocortical tract between the sexes, mean \pm SD, males ($n = 26$), females ($n = 24$); Comparison the number of sensory thalamocortical tract lines between right and left hemisphere, mean \pm SD, $n = 50$ for each side D); Comparison on the number of lines of right E) and left F) of the sensory of thalamocortical tract between two genders, mean \pm SD, males ($n = 26$), females ($n = 24$)**

Comparison of the number of somatosensory thalamocortical tract lines between two genders showed that the lines of the right side were equivalent in the two sexes, in the left side the lines of males tend to lower than females, but no statistically significant difference ($P > 0.05$) (Figure 3E and 3F).

Based on the 3D reconstructed images of the

somatosensory thalamocortical tract and the number of branches, we classified the branching morphology as following: 2, 3, 4, 5, 6 or contralateral branches (Figure 4 and Table 4).

Table 4: The branch morphology distribution of the sensory thalamocortical tract

| | Branch morphology (%) | | Sum |
|------------------------|-----------------------|-----------------|-----------|
| | Right hemisphere | Left hemisphere | |
| 2 branches | 3 (3%) | 2 (2%) | 5 (5%) |
| 3 branches | 14 (14%) | 11 (11%) | 25 (25%) |
| 4 branches | 22 (22%) | 20 (20%) | 42 (42%) |
| 5 branches | 6 (6%) | 10 (10%) | 16 (16%) |
| 6 branches | 5 (5%) | 7 (7%) | 12 (12%) |
| Contralateral branches | 6 (50%) | 6 (50%) | 12 (100%) |

The data showed that somatosensory thalamocortical tract was the polymorphic branch. Most abundance was four-branches-morphology (42%); other morphologies were found including three branches (25%), five branches (16%), six branches (12%), and the two branches (5%). Obtained images showed that the appearance of the branch was into the contralateral hemispheres, with the left and right ratio equal on each side.

Discussion

Our data showed that the length of the somatosensory thalamocortical tract on the right hemisphere (130.17 ± 11.44 mm) was statistically significantly longer than that on the left hemisphere (121 ± 13.49 mm). But, the study done by Kamali et al., on the sensations in the brain stem showed that there was similar in length between the right and the left sides [9]. The differences between our and Kamali's results can be explained by the fact that the different anatomical locations can lead to differences over the structure. Moreover, there are always differences in general function and sensory conduction, in particular, between two sides of the brain [10], which may lead to changes along the length of the somatosensory thalamocortical tract between the two sides. The length of the somatosensory thalamocortical tract in males tend to be longer than in females in this study, and this may be due to the brain of male larger than female [11]. However, the difference was not statistically significant, and this may be due to not large enough in the size of the subjects in our study.

The number of the somatosensory thalamocortical tract lines was higher in the right hemisphere (401.5) than that in the left hemisphere (315.0), but the difference was not statistically significant. This result may be due to the majority of subjects in this study were right-handed persons, which can make the sensory transduction differences between the right and left side of the body [12], [13]. In order to clarify this, extensive research with a larger number of subjects are needed. In the relationship

between gender and number of the somatosensory thalamocortical tract lines, notably the number on the left side in males (295.5) was much lower than that in females (347.0), while the number on the right side was almost equivalent between males (401.5) and females (398.5). These differences are quite interesting, but larger studies are required to clarify these phenomena.

Our data showed that the somatosensory thalamocortical tract was the polymorphic branch. The diversity of morphology may be related to the function, distribution of nerve conduction bundles, and the diversity of subjects (gender, age, etc.).

Using the diffusion tensor imaging for studying the anatomical characteristics of the somatosensory thalamocortical tract is a new advanced technique not only in Vietnam but also in the world. So far, this is the ideal method which allows studying the white matter, designated the nerves and neurotransmitters on the non-invasive living body [14], [15].

In conclusion, the data in this study can be used as anatomical reference parameters for the understanding function of the brain in sensory transduction from the thalamus to the cortex. Our finding is also the basis for the assessment and detection of function area in the brain, and for understanding the mechanics of some diseases related to brain injury and nerve conduction clinically such as stroke, degenerative myelin, diffuse axonal injury, and Wallerian degeneration. The results of the study also open up the new directions for DTI application to study neurotransmitter activity under physiological conditions and diseases for understanding the function of neural activity in clinical applications.

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