Journal of Neuroradiology xxx (2017) xxx–xxx

Available online at
ScienceDirect
www.sciencedirect.com

Elsevier Masson France
EM|consulte
www.em-consulte.com

Technical Note

Newly observed anterior thalamocortical fiber of the thalamus using 7.0 T super-resolution magnetic resonance tractography and its implications for the classical Papez circuit

Sang-Han Choi [a], Young-Bo Kim [b,*], Zang-Hee Cho [a,**]

[a] Neuroscience Research Institute, Suwon University, 17, Wauangil, Bongdam-eup, Hwaseong-si, Gyeonggi-do, South Korea
[b] Neuroscience Research Institute, Gachon University, 1198 Kuwol-dong, Namdong-gu, Incheon, South Korea

ARTICLE INFO

Article history:
Available online xxx

Keywords:
Anterior thalamocortical fiber of the thalamus
Cingulate cortex
7 T MRI
Track density imaging
Papez circuit

ABSTRACT

Here, we have employed recently developed super-resolution tractography using 7.0 T-MRI to analyze the fine structures involved in thalamocortical connections, something that has proved difficult using conventional techniques. We detail a newly observed thalamocortical pathway connecting the anterior nucleus of the thalamus and the cingulate cortex not via the internal capsule but via the septal area. The observed pathway is believed to be a classical pathway of the Papez circuit but had not been previously identified.

Introduction

Using track density imaging (TDI) with super resolution tractography, the sensitivity of visualizing white matter structures has improved drastically [1]. The sensitivity of TDI is further increased when TDI is combined with ultra-high field 7.0 T magnetic resonance imaging (MRI) [1–3], which facilitates the study of functional connectivity [4]. The present paper describes how super-resolution TDI can be used to analyze many delicate fibers, such as those involved in anterior thalamocortical connections [3,4].

Thalamocortical fibers are a group of ascending projection fibers arising from the nuclei of the thalamus that project to the cerebral cortex via the internal capsule (IC) [5]. The thalamocortical fiber of the anterior nucleus of the thalamus (ANTCF) connects the anterior nucleus of the thalamus (AN) to the cingulate cortex (CgC). The ANTCF is known to be one of the major pathways of the classical Papez circuit that is considered an important memory circuit believed to be the anatomical substrate of emotional experience, as proposed by Papez in 1937 [5–10].

However, the detailed pathway of the ANTCF has not been fully described in previous neuroanatomy literature [5–7]. We also found that in most fiber-tracking studies of thalamocortical fibers using diffusion tensor imaging (DTI), the ANTCF has not been mentioned [8–10] or the connection between the CgC and the AN has been missed [11]. This is likely due to the inability to observe the ANTCF using conventional low-field MR DTI or tractography. Some neuroanatomical reports suggest that the AN and CgC may be connected via the temporal path through the anterior limb of the IC (ALIC) [12–14]. One DTI study reconstructs the ANTCF based on this temporal path using compulsory seed tracking method [15]. However, the existence of the temporal path of the putative ANTCF (pANTCF) connection is questionable, as there is a massive blockage by the commissural fibers [16]. Fig. 1 illustrates the pANTCF temporal path, a putative ANTCF. Because the subgenual anterior cingulate cortex (sgACC) is close to the AN, we suggest that instead of the ALIC, fibers from the AN are directly connected to the sgACC through the septal area (SA), as shown in Fig. 2. We have therefore coined the term ANTCF to denote this new fiber track and have demonstrated the existence of the ANTCF with super-resolution tractography using 7.0 T MRI.

Materials and methods

There are three steps in the acquisition and processing of fiber tracking information: diffusion weighted imaging (DWI) data acquisition, TDI data processing, and seed tracking analysis. The experiment was performed using a 7.0 T MRI scanner (Magnetom 7.0T, Siemens, Erlangen, Germany) following the guidelines of the institutional review board. Three healthy, young male subjects

* Corresponding author.
** Co-corresponding author.
E-mail addresses: sanghanchoi@gmail.com (S.-H. Choi), neurokim@gilhospital.com (Y.-B. Kim), zhcho36@gmail.com (Z.-H. Cho).

https://doi.org/10.1016/j.neurad.2018.01.054
0150-9861/

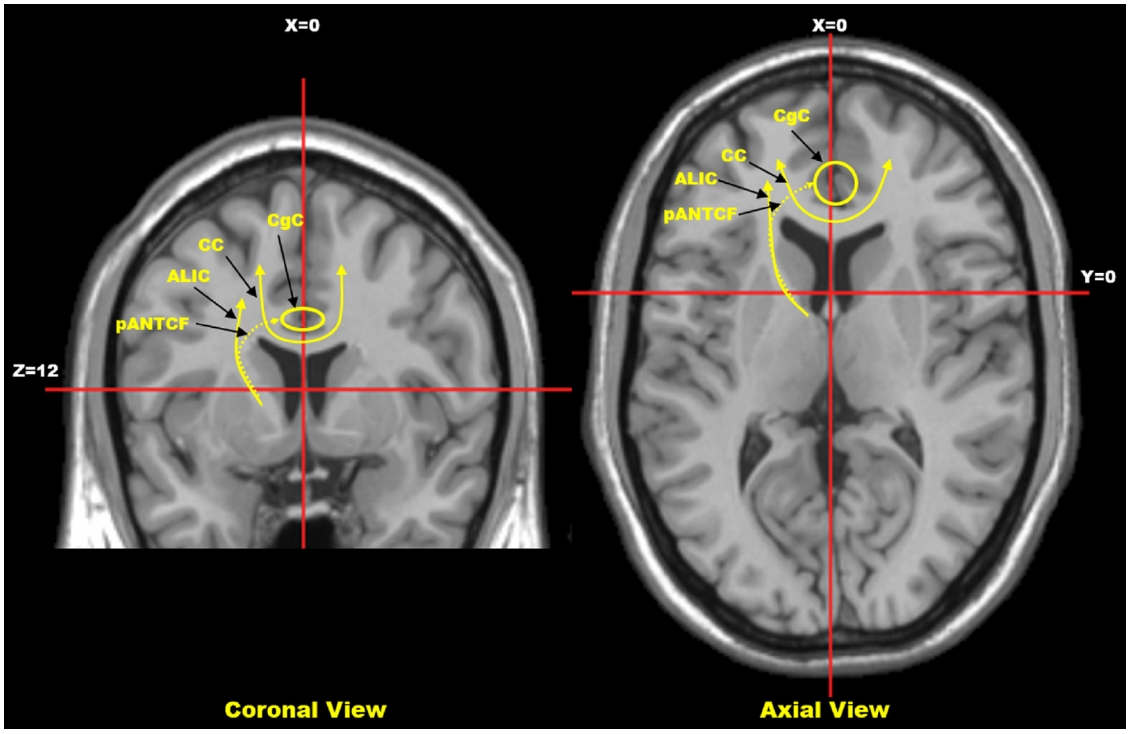

Fig. 1. Classical view of the pANTCF (yellow dotted lines) originating from the ALIC in the MRI image of the coronal and axial view. CC: corpus callosum.

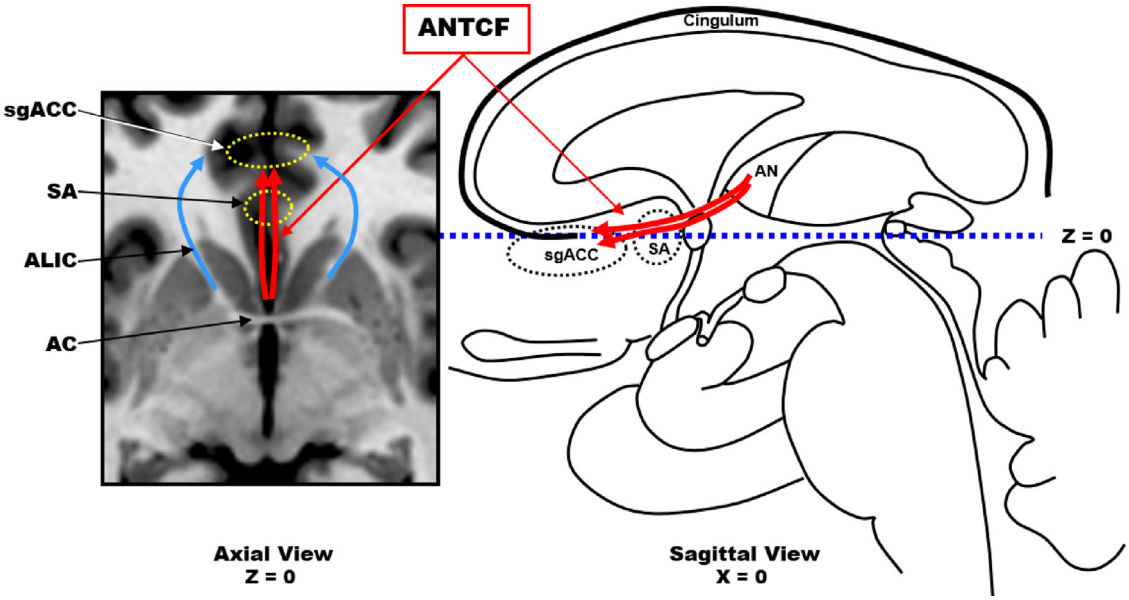

Fig. 2. The proposed new ANTCF (red lines) in an MRI image of the axial view (left) together with a diagram of a sagittal view (right). The blue lines indicate the classical pANTCF and the red lines indicate the new proposed ANTCF. In the diagram on the right, the dotted blue line indicates the cut level of the axial image shown on the left. AC: anterior commissure.

(aged 30, 34, and 35) were recruited as volunteers. DWI data was acquired using a single-shot echo-planar imaging sequence with the following parameters: repetition time/echo time = 6000/83 ms; matrix size = 128 × 128 (FOV 230 mm × 45 slices); 1.8 mm isotropic resolution; 64 DW directions; *b*-value = 2000 s/mm^2, with a *b* = 0 image; GRAPPA with factor 3; and bandwidth of 1562 Hz/px. There were three repeats scanning with a total acquisition time of 19 min and 5 s.

DWI data were then processed using the TDI image processing technique [1]. TDI analysis was carried out using the MRtrix (Brain Research Institute, Florey Neuroscience Institutes, Melbourne, Australia) [17]. Relevant tracking parameters were: tracking type = SD_PROB; track minimum length = 20 mm; step-size = 0.02 mm; curvature radius constraint = 0.04 mm; fiber orientation distribution (FOD) cutoff for track termination = 0.3; and number of tracks = 6,000,000 [17]. The final TDI image was generated with a nominal isotropic resolution of 0.18 mm.

Seed tracking analysis was performed to confirm the pathway of the ANTCF and to identify the connection between the sgACC and the AN. Three seed points were selected with a single voxel in the pregenual ACC (pgACC), sgACC, and the AN in the sagittal view

Please cite this article in press as: Choi S-H, et al. Newly observed anterior thalamocortical fiber of the thalamus using 7.0 T super-resolution magnetic resonance tractography and its implications for the classical Papez circuit. J Neuroradiol (2017), https://doi.org/10.1016/j.neurad.2018.01.054