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A Quick and Universal Method for Stereotactic Visualization of the Subthalamic Nucleus before and after Implantation of Deep Brain Stimulation Electrodes

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Key Words

Abstract

For deep brain stimulation (DBS) of the subthalamic nucleus (STN), it would be an advantage if the STN could be visualized with fast acquisition of MR images, allowing direct and individual targeting. We present a protocol for T2-weighted, nonvolumetric fast-acquisition MRI, implemented at 8 centers in 6 countries. Acquisition time varied between 3 min 5 s and 7 min 48 s according to the center, and imaging often provided visualization of the STN on axial and coronal scans. Postoperatively, the same imaging proto-

col permitted visualization of the target area and DBS electrodes with minimum artifacts. This imaging technique may contribute to a decrease in the number of electrode passes at surgery.

Introduction

Benabid et al. [1] were the first to describe parameters of 'fat-shift' T2-weighted MRI for direct visualization of the subthalamic nucleus (STN). However, for surgical targeting, they use ventriculography. Most workers who rely on MRI for targeting the STN determine its position on T1-weighted images, in relation to third ventricle landmarks and brain atlases. The few publications reporting the use of MRI for direct visualization of the STN describe volumetric T2-weighted sequences with a long acquisition time [2–5], sometimes requiring reformating of images and/or additional T1-weighted sequences that are used for targeting [2, 6], and often necessitating general anesthesia during imaging. Postoperative imaging, as described in the literature, shows with very few exceptions [4, 6] that the quality of the images does not allow location of the electrode contacts in the target structure [2, 7, 8]. In this paper, we present the preliminary experience from different centers in which the T2-weighted, fast-acquisition nonvolumetric MRI protocol, described only for postoperative imaging by the German group from Kiel [4], was implemented both preoperatively for direct targeting of the STN and postoperatively for verification of electrode location.

Table 1. Some of the parameters of MRI (axial scanning) used in the various centers

	London	Trondheim	Enschede	Nara	Cape Town	Stockholm	Umeå/Uppsala
Frame	Leksell	Leksell	no frame	CRW	Laitinen	Laitinen	Laitinen/Leksell
Scanner	GE	Siemens	Philips	Siemens	Siemens	Siemens	Philips
TR	3,500	3,000	3,000	4,000	3,000	6,200	3,000
TE	90.9	82	85	17	96	112	84
Thickness of slice/gap, mm	2/0.2	2/0	2/0	2/0	2/0	2/0	2/1
Excitations, n	4	3	3	3	3	5	4
Field of view, mm	250 × 250	250 × 250	220 × 220	256 × 256	230 × 230	250 × 220	230 × 250
Slices, n	22	19	variable	variable	15	17	22
Acquisition time	7 min 7 s	7 min 48 s	6 min 42 s	5 min 30 s	5 min 37 s	7 min 20 s	3 min 5 s

TR = Time of repetition; TE = time of echo; CRW = Cosman Roberts Wells; GE = General Electric.
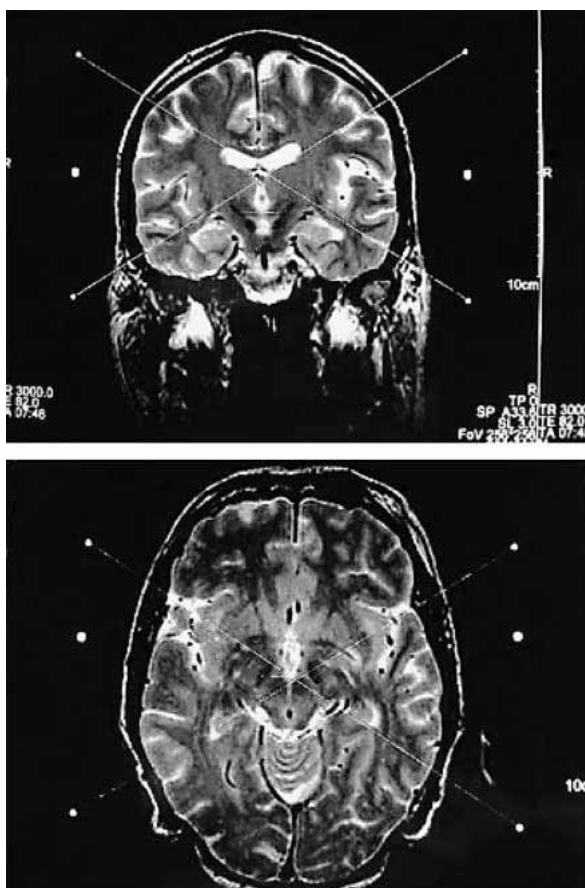
Fig. 1. The STN and surrounding structures are shown on 2-mm-thick axial and 3-mm-thick coronal scans, with a time of acquisition for each sequence of 7 min 48 s (Siemens scanner).

Patients and Methods

Eight centers in six countries participated in this study (three centers in Sweden and one center each in the United Kingdom, Norway, the Netherlands, Japan and South Africa). MRI was performed on commercial machines of 1.5 tesla (Siemens, Philips and General Electric), except in one case in which a 1.0-tesla machine was used. The stereotactic frames used were the Leksell, Laitinen or Cosman Roberts Wells. A total of more than 85 patients undergoing STN deep brain stimulation (DBS) were imaged with axial and coronal scans using the parameters shown in table 1. At surgery, macrostimulation was used in all centers.
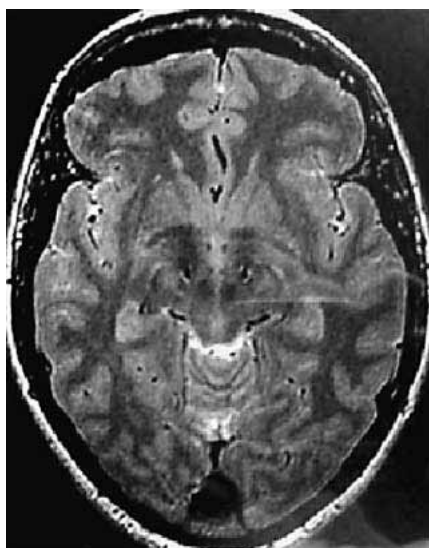
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Fig. 2. Bilateral DBS electrodes in the STN are shown on a 2-mm-thick axial scan, with an acquisition time of 7 min 7 s (General Electric scanner).

In all but one center (where local regulations prohibit MRI of implanted DBS electrodes), a postoperative MRI using the same parameters as preoperatively was performed occasionally, sometimes with the stereotactic frame still on the patient's head.

Results

Table 1 provides some details of the scanning parameters used in the various centers. The acquisition time varied between 3 min 5 s and 7 min 48 s for each scanning orientation. In most cases, the STN could be visualized on axial and coronal scans. Upon manipulating the contrast of the image on the screen after completion of the scanning, it was often possible to discriminate between the STN proper and the nigra on axial scans located ventrally in the target area. Figure 1 shows the STN and surrounding structures on axial and coronal scans. Figure 2 shows the location of bilateral DBS electrodes on an axial scan. Figure 3 shows one coronal and one axial scan with a unilateral left-sided STN DBS electrode.
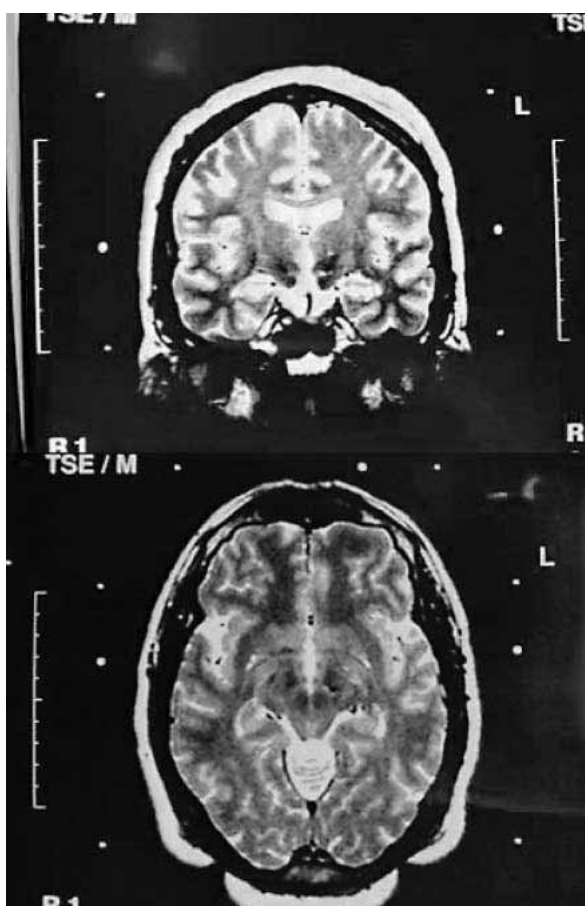
Fig. 3. A 3-mm-thick coronal and a 2-mm-thick axial scan showing a unilateral left-sided DBS electrode. Acquisition time was 4 min 3 s (Philips scanner).

Discussion

Given that access to MRI scanners in most centers is limited, it would be an advantage if the scanning time could be shortened as much as possible, while at the same time not compromising the quality of the images. The results presented here reflect an experience that is still evolving, especially when it comes to shortening the time of acquisition even more. As shown in table 1, there was still a wide range between the shortest and the longest times of acquisition obtained in the various centers in this study. However, our acquisition time was far below the

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20–25 min or more reported by most other workers [2–6]. In our multicenter experience, there was difficulty obtaining homogeneous parameters across the different MRI scanners, which was related to difficulties in translating the setting and parameter information from one scanner to another. Additionally, there was an interindividual variability, in that in some patients, the STN was more clearly visible than in other patients, although they were scanned on the same scanner with the same parameters. We do not have an explanation for this; it may be due to differences in the ages and disease duration of the patients, or may reflect the difference in the iron content in the basal ganglia including the STN. With respect to postoperative scanning, especially in the coronal plane, it was still difficult to obtain a nice visualization of both the target structure and electrode contacts. However, on axial scans, this was often easier, as shown in figures 2 and 3. It must be stressed that notwithstanding the precision of imaging, there is always an imperative need to check the accuracy of reaching the target at surgery with either macrostimulation or microelectrode recording and stimulation. Whether the imaging technique described here decreases the number of electrode passes at surgery, and/or provides better results compared with indirect targeting techniques, remains to be analyzed.

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