Image Fusion of 3T and 1.5 T MRI for Parkinson’s Disease Surgery: a New Method
Fusão de Imagem de RM de 3 Tesla com 1,5 Tesla para Cirurgia de Parkinson: Descrição de um Novo Método

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ABSTRACT
Introduction. Anatomical landmarks for stereotactic surgical procedures like deep brain electrodes implantation for Parkinson’s Disease has been performed since a long time ago through low-field magnetic resonance image (MRI) such as 1.5 Tesla (T) apparatus. Methods: We describe a direct method of visualization of subthalamic nucleus. For this purpose, a routine 1.5T MRI images are taken, and undergoes further fusion with 3T MRI pictures. Results. The result of image fusion allows tridimensional reconstructions, and a better differentiation between white matter and gray matter of the brain. A higher resolution also gives better identification of subthalamic nucleus, skull base nucleus, red nucleus, as well as other anatomical landmarks, resulting in higher accuracy of the procedure. Conclusion. A computational platform combining these two MRIs (3T and 1.5T) has reached more accuracy for surgical implantation of electrodes in Deep Brain Stimulation for subthalamic nucleus.

Key words: Stereotactic, Parkinson’s disease, Magnetic resonance, Subthalamic nucleus

INTRODUCTION

Deep brain stimulation (DBS) has been proven to be an efficient and safe option for selected cases of Parkinson disease (PD), which can result in a better quality of life. Subthalamic nucleus (STN) DBS has also showed superior results than pallidotomy and thalamotomy procedures for PD¹². Yet, success rate depends on the accuracy to reach the stereotactic coordinates on the target³.

STN is a small and oblique structure, in relation to the three planes. These features can difficult electrode positioning. For this reason, the target is based on coordinates, which can be set through indirect or direct methods. The indirect method is mostly defined based on the intercommissural line and red nucleus (RN) location. On the other hand, a direct method consists in STN image from magnetic resonance (MR) sequences with good contrast between white and gray matters. However, the substantia nigra pars reticulata can be difficult to be distinguished from the nucleus⁴. The 1.5 T MRI cannot define targets as the 3T MRI, which has a better definition of basal ganglia structures functioning as the ideal tool for a direct visualization.

A detailed image obtained from 3T equipment, with better resolution, allows a better visualization of the subthalamic nucleus, skull base nucleus, red nucleus, and other anatomical landmarks, resulting in higher accuracy of the procedure.
definition of the subcortical structures, is important for surgical planning. When using a stereotactic apparatus, however, this can generate higher inaccuracy, being preferable an equipment with lower field of magnetic strength.

We describe a pioneer method of image fusion of pre-operative 3T MRI with 1.5T MRI obtained on the surgery day generating a better setting of anatomical landmarks.

**METHODS**

**3T MRI on the day before surgery**

Protocol consists on 3T MRI obtained on the day before surgical procedure, with the presence of the surgeon to visualize volumetric slices on T2 sequence. During the exam main structures are identified, such as red nucleus, STN, and the midline, including anterior commissure and posterior commissure.

Images from 3T MRI obtained a day before the surgery were fusioned with 1.5T on the day of surgical procedure.

![Figure 1. A,B,C. MRI depicting red nucleus (arrows) (sagittal, axial and coronal slices data, respectively). D,E,F. MRI showing STN (arrows) (axial, sagittal and coronal slices data, respectively).](image)

**Stereotactic frame implant and 1.5T MRI on the day of surgery**

On the day of the surgery, the stereotactic frame is adapted at the operating room, and the patient is forwarded to obtain a 1.5T MRI in order to acquire the stereotactic coordinates. Brain MRI of high resolution is obtained to visualize stereotactic landmarks. On T1 weighted images, the anterior commissure (AC) and posterior commissure (PC) are localized, using sagittal reconstruction, including confirmation in the axial plane, calculating the commissure midpoint, and further acquisition of stereotactic coordinates on three planes (x, y, and z) for anatomical points.

![Figure 2. 1.5T MRI for targeting left STN.](image)

After acquiring both MR images, 1.5T MRI (with stereotactic frame) is fusioned to the 3T MRI. The fused images are checked in order to verify anatomical accuracy, especially of vascular structures, fissure of Sylvius, crystalline, pineal region, skull, and soft tissues.

![Figure 3. Images fusioned of 3T and 1.5T MRIs showing with more accuracy, and delimiting better the right STN target.](image)

Additionally, anatomical localization of the target is confirmed through digitized stereotactic maps of Schaltenbrand-Wahren and Talairach. Reformattting MRI images in the coronal plane, with T2 and T1 weighted sequences help in localizing basal nuclei.
Implantation of intracerebral electrodes and pulse generator

DBS implantation is done in a two-step procedure. First, DBS electrodes are implanted by target nuclei stereotactic coordinates. Next, DBS electrodes are connected under the skin to an implantable pulse generator (IPG), in the subcutaneous tissue, through infraclavicular incision.

In the first step the patient is awoken to allow monitoring of neurological conditions. In the operating room, under local anesthesia, two bifrontal incisions are performed with subjacent trepanation. After dura mater incision and cerebral cortex coagulation, the electrode is inserted in each STN according to the stereotactic coordinates set on MRI for a physiological confirmation.

In our experience with this case, significant difference was observed in STN visualization using 3T MRI, compared to 1.5T. The possibility of direct visualization of this anatomical structure, previously just “visualized” through indirect methods, based on neighbouring structures, allows more safety to perform electrode implantation, and turns this into a more accurate method. Inadequate positioning of the electrode can have serious consequences, as may occur when a stimulus deviation is done more inferior or medial regions. In the limbic territory of STN, this error of coordinates increases the risk of post-operative acute depression and suicidal attempts.

Surgical procedure had no complications, and the patient was discharged after control brain CT-scan to confirm the fusion location on Schaltenbrand-Wahren and Tailarach atlas. No signs of intracranial bleeding were found. On the seventh postoperative day, the pulse generator was turned on. Patient showed rigidity and bradykinesia improvement.

Since patients who underwent STN stimulation are known to have L-DOPA doses reduction of 70-100%\(^2\), the dyskinesia triggered by medication use also showed clinical improvement. After 30 days, antiparkinsonian drugs were reduced by half and the patient showed a remarkable symptom improvement.

Intracranial hematomas can occur in 2% of the patients, and

**DISCUSSION**

Stereotactic implant of DBS is widely performed in selected cases of PD patients, with good results for tremor, bradykinesia and rigidity. The indirect method calculates the coordinates based on MRI identification of the intercommissural line, between anterior and posterior commissures\(^5\). Alternatively, stereotactic location of STN can be presumed from its relationship with RN, a subjacent landmark which would offer higher precision\(^6\).

A number of different techniques of images were employed in the anatomical study for these patients’ treatment. Two exams to determine stereotactic coordinates, ventriculography and cerebral angiography, were replaced by computed tomography (CT)\(^4\) and MR\(^7\), which are less aggressive, with lower risks related to contrast injection, and more accurate. Since several years ago, in our hospital, the Neurological Institute of Curitiba (INC), 1.5T MRI has been used for anatomical location of stereotactic coordinates. Our choice for MRI is due to its capacity to obtain direct images in different planes, with a better resolution and clear visualization of deep brain structures\(^8\). STN is more difficult to be visualized; however, according to a recent anatomic study it has uniform anatomic relationships with RN, which enable the stereotactic coordinate to be calculated\(^8\). MRI can result in excellent image resolution in all three planes. In spite of that, some smaller targets are not always visualized, and this exam can suffer some image distortion. Even though these distortions are generally small and peripheral, they can jeopardize the precision of functional neurosurgery. Due to this probability, some kind of intra-operative neurophysiological confirmation is mandatory for the targets during the procedure\(^6\)\(^9\).

In our experience with this case, significant difference was observed in STN visualization using 3T MRI, compared to 1.5T. The possibility of direct visualization of this anatomical structure, previously just “visualized” through indirect methods, based on neighbouring structures, allows more safety to perform electrode implantation, and turns this into a more accurate method. Inadequate positioning of the electrode can have serious consequences, as may occur when a stimulus deviation is done more inferior or medial regions. In the limbic territory of STN, this error of coordinates increases the risk of post-operative acute depression and suicidal attempts\(^10\)\(^11\).

Surgical procedure had no complications, and the patient was discharged after control brain CT-scan to confirm the fusion location on Schaltenbrand-Wahren and Tailarach atlas. No signs of intracranial bleeding were found. On the seventh postoperative day, the pulse generator was turned on. Patient showed rigidity and bradykinesia improvement.

Since patients who underwent STN stimulation are known to have L-DOPA doses reduction of 70-100%\(^12\), the dyskinesia triggered by medication use also showed clinical improvement. After 30 days, antiparkinsonian drugs were reduced by half and the patient showed a remarkable symptom improvement. On control CT-scan, a small late cortical hematoma was observed at the electrode entry point on the right side. Intracranial hematomas can occur in 2% of the patients, and

![CT-scan depicting proper positioning of electrodes.](Image)
mental confusion may be present for a couple of days in 15%. A conservative treatment was chosen since no sign of neurological deterioration was seen. Further exams showed total resolution of the hematoma.

CONCLUSION

Computational platform made possible an integration of two modalities of MRI, 3T and 1.5T. Preoperative images were obtained on pre-neurosurgical routine, depicting functional and structural aspects of patients’ brain, making this method more accurate for DBS implantation within the STN.

In our opinion, a lower rate of error in electrode positioning could be possible, with subsequent better clinical results. Further studies with larger number of cases would be warranted to better show this potential.

REFERENCES


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