Stereotactic MRI for Functional Neurosurgery in Parkinson's Disease

A Simmons [1,2,3], J Dawson [2,3], E Moore [2,3,4], M Hu [5], R Chaudhuri [5], CE Polkey [6]

[1] Clinical Neurosciences, Institute of Psychiatry , [2] Neuroimaging, Maudsley Hospital, UK

[3] Neuroimaging, [4] Medical Physics, [5] Neurology and [6] Neurosurgery, Kings College Hospital, UK

Introduction

Surgical interventions to control Parkinson's disease (PD) have a long history. Pallidotomy, for example, was performed in the 1950s for treatment of the motor symptoms of PD (1) but dissatisfaction with the long term results of surgery led to a decrease in popularity and its replacement to a large degree by thalamotomy. More recently a resurgence of interest in surgical intervention for PD has taken place including pallidotomy (2,3), thalamotomy, thalamic stimulation, subthalamic nuclei stimulation and fetal tissue transplantation (4). Stereotactic MRI has a valuable role to play in such procedures. We have developed and tested a suite of protocols for stereotactic imaging for a range of functional neurosurgery operations which we describe here.

Methods

A 1.5T General Electric Signa Horizon Echospeed MR system (Milwaukee, WI, USA) fitted with actively shielded gradients was used for all studies. To ensure accurate stereotactic localisation, a stereotactic MRI quality assurance protocol was carried out on a monthly basis, using a custom designed phantom and a series of comparisons to CT measurements (5). The phantom comprises a perspex cube of length 150 mm filled with copper sulphate solution. Attached to opposite corners of the cube and running diagonally through its centre are four nylon wires on to which are threaded small perspex spheres which act as the stereotactic targets. The targets may be moved in position by a special tool but otherwise remain firmly in place.

Clinical imaging takes place on several occasions for each subject (i) As a screening procedure to ensure the absence of any other pathology (ii) Using the stereotactic head frame immediately prior to surgery for stereotactic target identification (iii) One to two days post-surgery to evaluate the orientation of tracts and accuracy of targeting (iv) 3-6 months post-surgery as a follow up.

A series of conventional anatomical images are acquired for screening. These comprise axial fast spin echo proton density and T_2-weighted images (TR=3000ms, TE_1=20ms, TE_2=80ms, echo train length=8, 1 data average) and coronal T_1-weighted spin echo images (TR=600ms, TE=20ms, slice thickness=5mm, slice gap=2mm, 256x192 acquisition matrix, 2 data averages).

Deep grey structures are visualised in the coronal plane, perpendicular to the AC-PC plane using two acquisition protocols. (a) Coronal fast inversion recovery protocol for visualising the thalamus and different parts of the globus pallidus - TR=3000ms, TI=200ms, TE=15ms, echo train=8, 2.5 mm slices, 0 mm gap, 256x256 matrix, 1 data average. (b) High signal to noise ratio coronal dual echo spin echo protocol for visualising the subthalamic nuclei - TR=2200ms, TE1=60ms, TE2 = 120ms, bandwidth1 = 15.62kHz, bandwidth2 = 4.46kHz, 256x256 matrix, 4mm slice, 0.4 mm gap, 1 data average. Acquisition (b) is repeated twice with a 2 mm difference in slice position to ensure the STN is not missed due to partial volume effect.

A Leksell stereotactic head frame is used for all surgical procedures and head movement limited at other scanning sessions by foam padding within the head coil and a restraining band across the forehead.

The imaging protocol has been applied to over twenty patients. Each set of images were reviewed by two experienced observers (JD, AS) to rate whether the different components of the globus pallidus, the thalamus and the subthalamic nuclei could be confidently identified. Post-surgical images were assessed to determine tract topography and targeting accuracy.

Results

Previously we reported initial experience with our stereotactic MRI quality assurance programme (1). We now have >18 months experience with the protocol. In general the stability of the stereotactic measures has proved to be very good. One exception has been due to a fault with the cold head of the MR system when distortions at the periphery of the images of up to 4 mm was determined, requiring corrective intervention by service personnel. This reinforces the need for a specific stereotactic MR protocol.

The screening assessment identified two patients with unrelated pathology who were excluded from the surgery programme. For all other subjects visualisation was good either at the time of screening or under anaesthetic with the stereotactic head frame in place. In a number of cases screening images were adversely affected by patient movement however. Tract topography post-surgery was very good in all but two pallidotomy cases where the tracts were seen to deviate from the intended target - one due to a bend in the electrode and the other due to conflicting information from electrophysiology which had resulted in a second alternative approach angle being taken.

Discussion

Stereotactic MRI is a critical component of a successful functional neurosurgery programme which may also include intraoperative cell recordings and electrical stimulation prior to lesioning. We have developed a protocol for quality assurance and imaging of deep grey structures. The protocol has proved successful in identifying the targets of interest.

REFERENCES

(1) Cooper AS, *Psychiatr Q,* 27, 317-319, 1953
(2) Dogali M et al, *Neurology*, 45 : 753-761, 1995
(3) Lozaro AM et al, *Lancet*, 346, 1383-1387, 1995
(4) Starr PA et al, *Neurosurgery*, 43, 989-1015, 1998
(5) E Moore et al, *Proc ISMRM*, 2155, 1998