FLAWS and MP2RAGE Sequence at 3T for Surgical Localization in Pre Deep Brain Stimulator Patients

David Shipp¹; Tobias Kober, Ph.D.²

¹ Monash Medical Centre, Clayton, Victoria, Australia
² Advanced Clinical Imaging Technology, Siemens Medical Solutions-CIBM, Lausanne, Switzerland

Introduction

3D MRI sequences for pre-surgical planning are in everyday use. The newer Siemens Healthineers 3D sequences MP2RAGE¹ (Magnetisation Prepared 2 Rapidly Acquired Gradient Echo) and FLAWS¹ (FLuid And White matter Suppression) have allowed us to better visualize the deep grey matter structures required for accurate Deep Brain Stimulator (DBS) insertion in a cohort of neurology and neurosurgical patients.

Clinical applications, surgery approaches and indications

The patient cohort requiring DBS treatment contains three sub-groups of patients with movement disorders, either (1) Parkinson’s disease, (2) Parkinson’s patients with severe dyskinesia, and (3) essential tremors or dystonia.

In Parkinson’s disease, most patients have been on medication for many years, mainly L-DOPA (L-3,4-dihydroxyphenylalanine), and perhaps dopamine agonists activating signalling pathways through the dopamine receptor. The efficacy of the administered medications may however reduce after 5 to 10 years; at this stage, a patient may become a surgical candidate. The associated side effects of these drugs (dyskinesia being involuntary muscle movements, or neuropsychiatric side effects) may also have become intolerable for the patient and family by this time. Also, some form of tremor-dominant Parkinson’s disease is refractory to such treatments. DBS surgery is then an option.

The anatomical area needing accurate visualisation for these patients is the Sub-Thalamic Nucleus (STN).

See Figures 1A (coronal anatomical view) and 1B (coronal FLAIR MPR).

---

¹ WIP, the product is currently under development and is not for sale in the US and in other countries. Its future availability cannot be ensured.
For other Parkinson’s patients with substantial cognitive or psychiatric co-morbidity, or with very severe dyskinesia, the anatomical area needing accurate visualization is the **Internal segment of the Globus Pallidus (GPI)**. See Figures 2A (coronal anatomical view) and 2B (coronal FLAWS MPR).

If the treatment for essential tremor and dystonia – mainly being myosine, beta blockers and botulin toxin – have proven no longer successful, DBS surgical intervention is an option. The anatomical area needing accurate visualization for these patients is the **Ventral Intermediate Thalamus Nucleus (VIM)**, see Figures 3A (coronal anatomical view) and 3B (coronal FLAWS MPR).

### Anatomical dimensions

These three deep grey matter structures, the **Sub-Thalamic Nucleus (STN)**, the **Internal segment of the Globus Pallidus (GPI)** and the **Ventral Intermediate Thalamus Nucleus (VIM)** are typically less than 10 mm x 5 mm in dimension. See Figure 4. A dataset acquired with 0.9 mm isotropic resolution is used stereotactically to precisely ascertain the positioning of the stimulating electrodes. No fiducials are required, as facial landmarks suffice. The probes used at Monash Health are Medtronic 3389 or 3387 quadripolar electrode (Medtronic plc, Dublin, Ireland), with an electrode total diameter of 1.27 mm and total longitudinal length of 10.5 mm. They can deliver stimulation using either one polar electrode or a combination of polar electrodes along their length. So ≤ 1 mm isotropic voxel size should be the target resolution of any acquisition.
Imaging sequences

The Siemens Healthineers MP2RAGE sequence [1], featuring two gradient echo readout trains after each inversion pulse which are defined by two different inversion times ($T_{I1}$ and $T_{I2}$), yields a significant increase in grey/white matter contrast as compared to a normal MPRAGE. At Monash Health we use $T_{I1} = 700$ ms and $T_{I2} = 2200$ ms. An example of a MP2RAGE contrast can be seen in Figure 5.

However, the standard protocol of the MP2RAGE sequence is optimized for highest WM/GM contrast in the cortex. By altering the two inversion times, an increased contrast between deep grey and white matter structures can be achieved. In a special MP2RAGE variant called FLAWS [2], the $T_{I1}$ is chosen so that the WM signal decay after the inversion is around zero when the first image is sampled, i.e. at the WM null point. The second $T_{I2}$ can then be adjusted to obtain a ‘normal’ MPRAGE contrast, yielding two complementary contrasts from a single acquisition. At Monash Health, we use a first inversion time of 409 ms and a second inversion time of 1330 ms. An example of the two obtained image contrasts can be seen in Figure 6.

In a simple post-processing step which is performed directly during the image reconstruction on the scanner, a minimum-intensity projection (MIP) between the two contrasts (WM-nulled and MPRAGE) results in the so-called FLAWS contrast. An example can be seen in Figures 7A–C. (Axial FLAWS MPR) 7B (Cor FLAWS MPR) and 7C (Sag FLAWS acquisition).

Scan parameters

Protocol

- MP2RAGE with embedded FLAWS with 0.9 mm isotropic voxels
- 3D FLAIR, with 0.9 mm isotropic voxels

All sequences were acquired on a 3T MAGNETOM Verio, with a 32-channel head coil.

The referring neurosurgeon and neurologist both request the 3D FLAIR sequence as well as the 3D FLAWS / MP2RAGE sequence, as they believe the STN is still best displayed on the FLAIR acquisition. The other areas are best delineated on the FLAWS.

Even an acquisition time of 5 mins 30 secs can sometimes be problematic for this cohort of patients, with their tremors leading to motion artifacts. Preparation includes the patient taking their medication in the early morning as usual, and scheduling their MRI examination mid-morning. Intravenous Midazolam can be an option.

As a final option to obtain diagnostic images free of motion artifacts, a general anesthetic may be rarely required.

Acknowledgements

Professor Stephen Stuckey (Director Monash Imaging and Head of MRI Monash Health), Associate Professor Andrew Danks (Head of Neurosurgery, Monash Health), Professor Dominic Thyagarajan (Director of Neurology, Monash Health), Sonal Josan (Senior Scientist MRI, Siemens Healthcare Australia).

References

Figure 5: Examples of the MP2RAGE contrast. (5A) sagittal, (5B) axial, (5C) coronal.

Figure 6: Image contrasts obtained using a first inversion time of 409 ms (6A) and a second inversion time of 1330 ms (6B).

Figure 7: A minimum-intensity projection (MIP) between the two contrasts (WM-nulled and MPRAGE) results in the so-called FLAWS contrast. (7A) Axial, (7B) coronal, (7C) sagittal.

Contact
David Shipp
Monash Medical Centre
246 Clayton Rd
Clayton VIC 3168
Australia
david.shipp@monashhealth.org