Supplementary Materials & Methods

Electrode information

Electrodes manufactured at the MNH had a diameter of 0.4 mm (0.8 mm including the cannula) and comprised nine contacts separated by 5 mm (contact surface area 0.8 mm$^2$). The deepest contact consisted of the tip of the steel core stripped of insulation. This contact had a length of 1 mm, while all other contacts were formed from stripped sections of the marginal wire to create 0.5 mm long coils. DIXI electrodes had a diameter of 0.8 mm and comprised ten contacts separated by 3.5 mm (contact surface area 5 mm$^2$). Bone pegs enable fixation of the electrode to the skull ensuring that the same position is kept during the chronic investigation [S1]. Pegs were 2.5 mm height with a diameter of 1.3 mm. We modeled the corresponding electrode and peg for each case.

Image acquisition protocol

Anatomical MR imaging acquisition consisted of T1-Weighted Spoiled Gradient-Echo (SPGR) 3D axial-planar with an 8-channel head coil (TR= 23 ms, TE= 8 ms, flip angle=20°). CT consisted of a single-rotation volume (3D CT) without contrast medium (0.75s/r gantry rotation speed; 80 kVp tube voltage; 300 mAs tube current, 240 mm collector diameter; 512x512 matrix; 0.25 mm reconstruction interval). CTA consisted of dynamic four-dimensional whole-brain CT arteriography and venography (80 kVp tube voltage, 150 mAs tube current; detector width of 160 mm). It was performed to provide vascular contrast beginning at the peak of the arterial phase until the end of the venous phase. Acquired images were reconstructed to yield 3D volumes of 1mm axial slices at a 512x512 image matrix with a resolution of 0.55x0.55 mm$^2$ for MR and 0.43x0.43 mm$^2$ for CT/A.
**Image pre-processing**

For each patient, MRI intensity was corrected [S2] and normalized. CTA was resampled to 0.5 mm isotropic voxel-size. MR and CTA images were denoised [S3]. The denoised MR image was linearly transformed to the ICBM152 stereotaxic model, obtained from the unbiased average of 152 subjects [S4]. These registration parameters were obtained using a hierarchical 3D cross-correlation maximization [S5]. The goal of the linear registration is to normalize for head size, position, and orientation, which is required to obtain patient-specific brain masks [S6]. More detail is available in [S7-S9]. The patient's CT and MRI data were registered together using a rigid transformation (six parameters; normalized mutual information). A rigid transformation is sufficient, since these datasets were acquired within the same week. In those cases where the available CT was obtained separately from CTA, the CT and CTA volumes were registered using a rigid transform (six parameters; mutual information). CTA was then registered to MRI by concatenating CTA to CT and CT to MRI transforms.

**Integration with clinical software**

The best electrode set and the list of ordered trajectories were presented to the surgeon in IBIS [S10] to visualize trajectories overlaid on MR, CT, and CTA images. Segmented structures and estimated vesselness were included. Navigation included a 3D view of reconstructed anatomical volumes and surfaces; 2D axial, coronal, and sagittal views; probe’s eye view; and trajectory view. To allow greater clinical flexibility, trajectories in the list can be selected and weights can be modified in the IBIS GUI. Changing weights updates scores, trajectory order, and re-computes the best set of electrodes in less than a second. Results of this study only considered the best automatic electrode sets.
Figure 4 shows some of the visualization capabilities. Figure 4.A shows a set of electrodes overlaid on the 2D planes as well as their entry points on the skull in 3D; Figure 4.B shows the same electrodes with overlaid distance map of the AG in 2D and on the brain surface with 3D vessels rendering; Figure 4.C shows the relation to sulci and 3D vessels rendering; and Figure 4.D the location of each contact within the target volumes.
References


