REPLY:

We thank Treuer et al for their interest in our article “Determining the Orientation of Directional Deep Brain Stimulation Electrodes Using 3D Rotational Fluoroscopy.” The coordinates (x, y, z) and 2 angles (pitch and yaw angles) are required to define the orientation of a nondonical deep brain stimulation (DBS) lead, and determining these is routine clinically. In directional leads, a third angle (roll) needs to be considered. We investigated the “iron sights method” to additionally determine this angle because there was no known imaging technique allowing us to do so precisely. We could demonstrate that this method allows determining a lead orientation angle with high interrater reliability. We are aware that this angle is determined in a plane defined by 3D rotational fluoroscopy. As used in CT scans, the rotational fluoroscopy should be aligned to the tuberculum sellae–occipital protuberance line, and head tilt must be excluded by aligning both external acoustic meatus. This line closely correlates to the anterior/posterior commissure line, which defines the relevant plane in clinical DBS practice. In publications, typically the orientation of directional leads is described and depicted in this plane.

3D rotational fluoroscopy allows reconstructing a volumetric dataset that can be fused with the preoperative, stereotactic CT or MR imaging scan as shown in Fig 1. Thus, after fusion with these images, the stereotactic coordinates together with the pitch and yaw angles can be determined in a stereotactic planning setting, allowing the roll angle to be calculated for any desired plane. In addition, the surrounding anatomic structures can be visualized (eg, in the preoperative MR imaging).

To address the authors’ comment (additionally using ground truth and to further investigate the influence of different implantation angles on the iron sights method), we embedded a directional lead in an acrylic glass cylinder. This model was fixed in a stereotactic frame (Leksell G frame; Elekta Instruments, Stockholm, Sweden) and oriented visually with the marker exactly facing anteriorly. This orientation was confirmed by a strictly lateral fluoroscopy plane with an oblique scan is necessary. However, this can be precisely predicted from the stereotactic planning of the DBS procedure.

REFERENCES

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FIG 1. A, Visualization of 3D directional electrode models in a 3D reconstruction of rotational fluoroscopy imaging. The blue line (in-plane) indicates the detected orientation in the axial plane based on the iron sights method. The orange line originating out of the marker indicates the lead orientation. B, The same scene from a lateral view. The in-plane orientation and marker orientation form a rectangular triangle (red transparent) with the right angle at the marker. C, Fusion of rotational fluoroscopy 3D reconstruction and the CT scan in Brainlab Elements (Brainlab, Munich, Germany).
FIG 2. A, A directional lead embedded in an acrylic glass cylinder (ground truth). This model was fixed in a stereotactic Leksell G frame (Elekta Instruments) and oriented visually and with stereotactic fluoroscopy with the marker exactly facing anteriorly. B, Fluoroscopy was aligned with the stereotactic frame. C, The arc angle (lead rotation in the coronal plane) was changed to polar angles of 0°–60° in steps of 10°. D, The ring angle (lead rotation in the sagittal plane) was changed, resulting in polar angles of 0°–90° in steps of 10°. Digital x-ray and 3D fluoroscopy were performed for each setting to investigate in which angles the overlap of the gaps between the electrode segments (iron sights) is visible.