

Novel Software for Performing Leksell Stereotactic Surgery without the Use of Printing Films: Technical Note

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Abstract

Hospitals in Japan have recently begun to employ the DICOM viewer system on desktop or laptop monitors. However, conventional embedding surgery for deep-brain stimulation with the Leksell stereotactic system (LSS) requires printed X-ray films for defining the coordination, coregistration of actual surgical films with the reference coordinates, and validation of the needle trajectories. While just performing these procedures on desktop or laptop monitors, the authors were able to develop novel software to facilitate complete digital manipulation with the Leksell frame without printing films. In this study, we validated the practical use of LSS, and benefit of this software in the Takanobashi Central Hospital and Kagoshima University Hospital.

Key words: filmless, deep brain stimulation, Leksell stereotactic surgery

Introduction

Deep-brain stimulation (DBS) is a surgical technique involving the implantation of a medical device (or brain pacemaker) into the brain. The implanted brain pacemaker then sends electrical impulses to specific brain sites, such as the subthalamic nucleus, globus pallidus interna for Parkinson's disease,^{1–3)} or the ventrointermediate nucleus for essential tremor.⁴⁾ The Leksell stereotactic system (LSS) (Elekta KK, Tokyo) is a frame-based stereotactic device for DBS, and employs the frame-based coordinate system for accurate targeting with submillimeter spatial resolution.

In actual stereotactic surgery, this system requires frequent validations of the needle position and its trajectory on printed intraoperative X-ray films by the operators. However, most hospitals tend to employ filmless environments, namely, they are abolishing conventional output on printed X-ray films and install the DICOM viewer system on desktop or laptop monitors without the use of printed films. This fact raises problems for LSS users because there is no way to define the coordinate system and check the needle position or its trajectories on printed X-ray films. Some hospitals can substitute a

mobile C-arm X-ray imaging system to check needle positions or trajectories; however, this method has the disadvantage that the viewing angle is limited to only one direction (in most cases, the lateral view), and it is difficult to check the lateral deviation of trajectories. Our hospital also has employed the filmless environment, and found that the substitute methods for printed X-ray film are inevitably desired and useful.

To resolve this issue, the authors developed novel software to facilitate complete digital manipulation with LSS without printing X-ray films. The novel software was named after the innovating institute: TaKanoBashi Coordinates (TKBC). This TKBC software may be applicable for LSS users, who are also currently laden with the problematic "film-printing" environment.

Materials and Methods

Eighteen patients were admitted to Takanobashi central hospital and performed stereotactic surgery for DBS from August 2012 to September 2015. Patients consisted of 4 men and 14 women with a mean age of 60.6 years (range: 51–74). Thirteen patients presented with Parkinson disease, three patients presented with essential tremor, and one patient presented with spasmodic torticollis.

The Ethical Committee of Takanobashi Central Hospital approved the use of TKBC, and MATLAB R2013a (The MathWorks Inc., Natick, Massachusetts, United States) was used for programming the novel software. The Ethical Committee of Kagoshima University Hospital also approved the use of TKBC for the evaluation and verification (Ethical Committee approval code No.27-98). MATLAB option, or the Image Processing Toolbox, was used for reading DICOM files, utilizing the graphical user interface for plotting and moving points on the pictorial images, and superposition of multiple images were recorded. The TKBC has three modes: (1) fiducial setting mode, (2) overlaying mode, and (3) trajectory validation mode.

Actual usage of software is as follows: in fiducial setting mode, the user marks five fiducial points on two couples of 50/150 mm ticks and tiny pores at 100-mm intervals of the horizontal bar of the Leksell frame on X-ray pictures with the indicator box taken at the beginning in the operation room. Based on the fiducial points, TKBC defines the coordinate system of the frame and draws 50–150 mm oblique lines passing through the marked fiducial points and horizontal and vertical 100–100 mm lines passing through the estimated 100-mm points.

In overlaying mode, TKBC shows the initial X-ray pictures as red images and the new X-ray pictures as blue images. The operator marks the easily discriminable feature points, such as tips of the fixation screws or the outlines of the fixation posts on both the initial and newly portrayed X-ray pictures. To obtain clear silhouettes of the feature points, we included the function of changing the magnification ratio or contrast of the images. Based on the paired marked points, TKBC overlays blue images on the red ones so that the marked points on both images match each other and complete coregistration. In the matching-point process, rotation and parallel movement of new images with the same image size are processed with a function equipped in MATLAB's image processing toolbox.

In trajectory validation mode, the user marks two points on the image corresponding to puncture needles before TKBC drawing of trajectories passing through the two marked points.

Operators can define the position of the intended target such as the subthalamic nucleus for Parkinson disease in any mode. The operator can also validate the spatial relationship of the trajectory and the target in trajectory mode. These programs are compiled as stand-alone software without requiring installation of MATLAB.

Results

In all cases, we confirmed that TKBC can be substituted for a series of the surgical procedures on printed films. In addition to Takanobashi Central Hospital we installed TKBC compiled for 64-bit Microsoft Windows 7 at Kagoshima University Hospital on August 2014 and confirmed that TKBC worked successfully for the evaluation and verification in DBS surgery of a 66-year-old male presenting with Parkinson disease.

A Representative Case

A 57-year-old female who was presenting with intractable Parkinson disease for 9 years underwent stereotactic surgery. TKBC compiled for 32-bit Microsoft Windows XP was installed in DICOM viewer system in our operation room. After frame fixation, computed tomography (CT) and magnetic resonance imaging (MRI) examination were undertaken, and Leksell SurgiPlan (Elekta KK, Tokyo)⁵⁾ was used for determining the designated tentative target position. The location was 85.7, 95.5, and 121.5 mm on the x-, y-, and z-axes in Leksell frame coordinates. We entered the coordinate information of the intended target in the TKBC. Moreover, we undertook stereotactic implantation surgery on printed X-ray films in a conventional manner while manipulating the TKBC (Fig. 1). We drew two pairs of 50–150 mm oblique lines and 100–100 mm horizontal and vertical lines on printed X-ray pictures, and checked if the lines pass through the same crossing point. On desktop of the viewer system, we marked five fiducial points consisting of two pairs of 50-mm and 150-mm ticks and the tiny pore at 100-mm tick. TKBC automatically drew two pairs of 50–150 mm oblique lines passing through the marked 50-mm ticks and 150-mm ticks, and estimated 100–100 mm horizontal and vertical lines, which were validated by operators' visual inspection. We continued the conventional stereotactic surgical operation, penetrating the cortices with the dull puncture needles through burr holes before taking X-ray pictures (Fig. 2). We overlaid the latest films on the initial films in the conventional manner by manipulating the TKBC. In overlaying mode, we marked three blue plus symbols at the screw tips on the new images, and three red plus symbols at the corresponding screw tips on the initial images. TKBC superposed the blue images on the red ones and we validated if the three-paired points coincided. In trajectory validation mode, we marked two cross points on the puncture needles of the new images. TKBC drew lines passing through

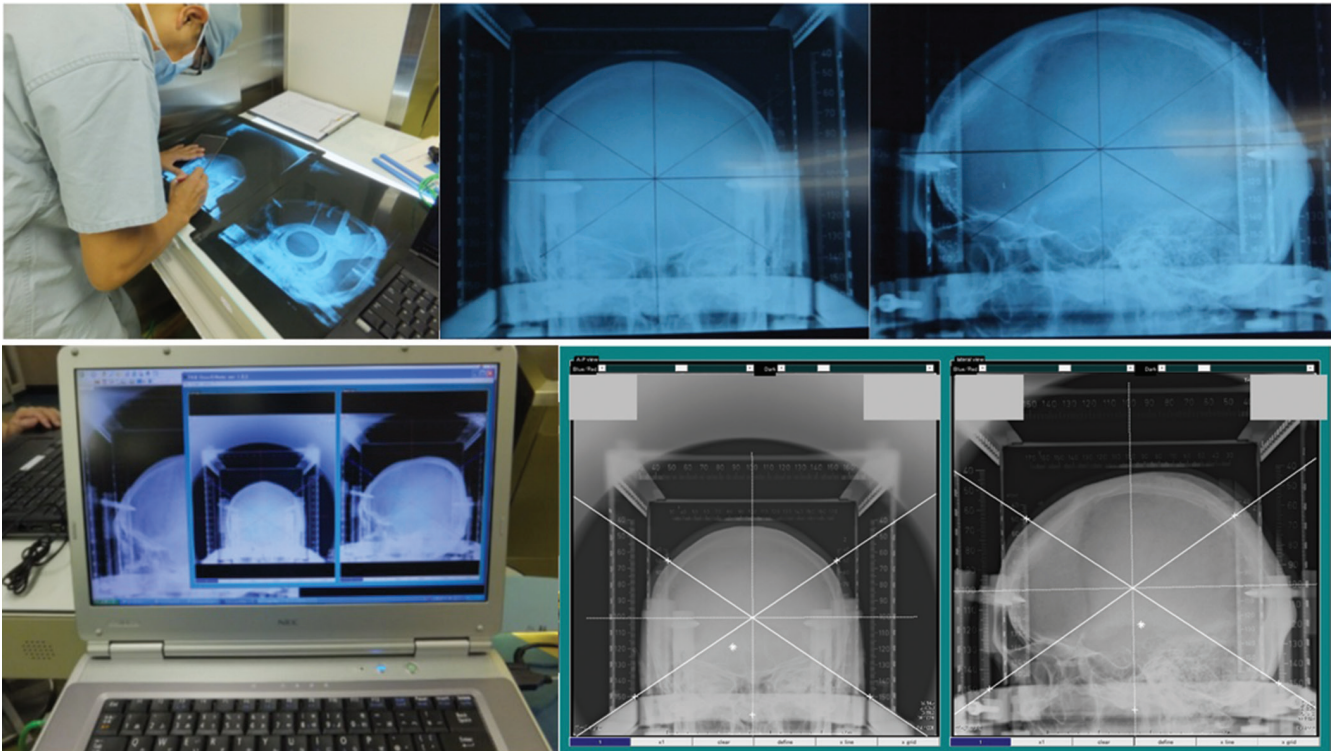


Fig. 1 Upper column: Conventional coordinates definition on printed X-ray films with a pencil. Lower column: Coordinates definition with the software, TaKanoBashi Coordinate (TKBC). Eight pointed *asterisks* denote the tentative target points. Five *white plus symbols* denote marked fiducial points of 50 mm, 150 mm ticks, or the tiny pore at 100 mm point. *White solid lines* denote 50–150 mm oblique lines and *white dotted lines* denote 100–100 mm horizontal and vertical lines estimated by TKBC, respectively.

the marked points, and we validated if spatial relationships between the trajectories and intended target-positions had been established (Fig. 3). After insertion of the recording microelectrode, we took X-ray pictures and overlaid them on the initial pictures and validated if the microelectrode was located at the intended target point as described above (Fig. 4). We then searched for the optimal stimulus points for embedding the stimulus lead. We finally took X-ray pictures, validated the lead position, plugged the burr hole, made subscapular pockets to store the opposite side of the lead, and closed the skin incision.

Discussion

It would save time and costs of printing many X-ray films if operators used only TKBC and did not refer to printed X-ray films. Furthermore, it is not necessary to install the X-ray film illuminator screen or desk in the operation room, thus saving space in the operating room as well. While the accuracy of conventional manipulation on printed

films depends on the line width of the pencil that of TKBC depends on the spatial resolution of original DICOM images. TKBC has a function for magnifying images; thus, the spatial resolution of the monitor can be displayed without constraint (vs. X-ray film).

The advantages of digital manipulation over conventional manipulation on printed films are as follows: (i) easy modification of the magnification ratio with contrast of X-ray pictures and (ii) the use of numerous digital filters in the fields of photo-retouch software to establish more accurate superposition and validation.

To overlay two images, MATLAB's `cp2tform` function has routinely been used. This function executes two-dimensional affine transformation with arbitrary length of paired points. If the number of feature points is increased, more precise coregistration is expected. Detailed algorithms and examples are shown in MATLAB's kit documents. However, if a pattern-matching algorithm including automatic extraction of feature points were to be implemented, the overlaying mode could be abbreviated. X-ray

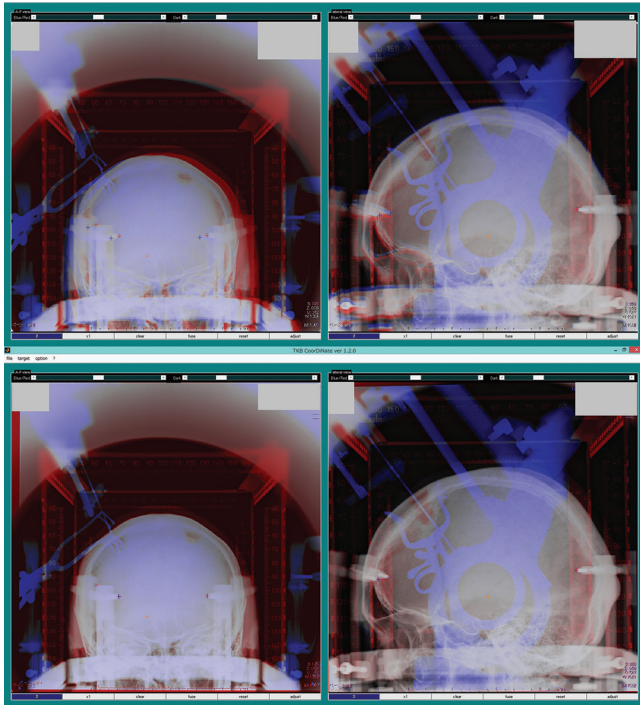


Fig. 2 Upper column: Before superposition. *Red images* denote the initial X-ray pictures and *blue images* denote the latest X-ray pictures. *Red plus symbols* denote marked feature points and *blue ones* denote marked feature points. Lower column: After superposition. *Blue images* are overlaid so that *red and blue points* matched each other.

film has its own magnification distortion with the peripheral magnification larger than central magnification.⁶⁾ Although the image processing toolbox has a function for adjusting this distortion, we did not implement this function in order to replicate the conditions in printed X-ray films faithfully. TKBC does not have a function for connecting to the network or server system of DICOM in hospitals, and operators must prepare picture files formatted as DICOM, BMP, PNG, or JPG by themselves. As TKBC has yet to be approved by the Pharmaceutical Act in Japan, operators employ it at their own risk. Although intraoperative CT or MRI⁷⁾ might be solution with the same purpose in stereotactic surgery without printed films; however, TKBC is more practical and convenient to use.

Conflicts of Interest Disclosure

There were no conflicts of interest. All authors who are members of The Japan Neurosurgical Society (JNS) have registered online self-COI Disclosure Statement Forms through the website for JNS members.

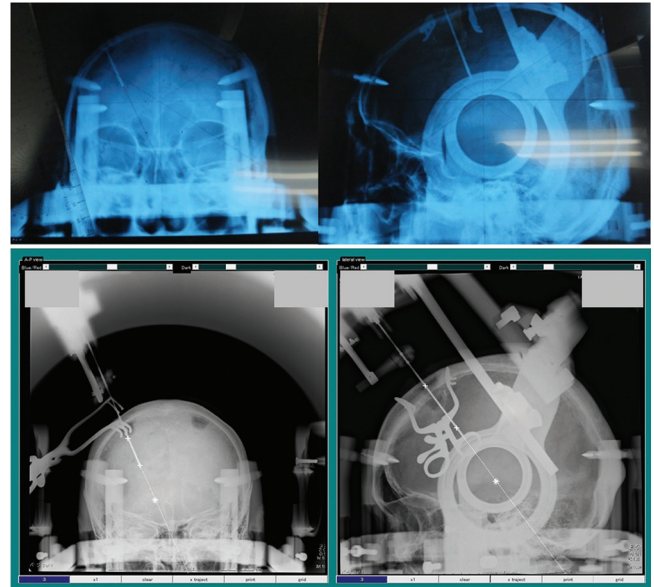


Fig. 3 Upper column: Validation of the needle trajectories on the printed films in a conventional manner. Lower column: Validation of the needle trajectories on TKBC. *White plus symbols* denote points marked on the needles and *white lines* denote the trajectories passing through the two points. *White eight pointed asterisks* denote tentative target points.

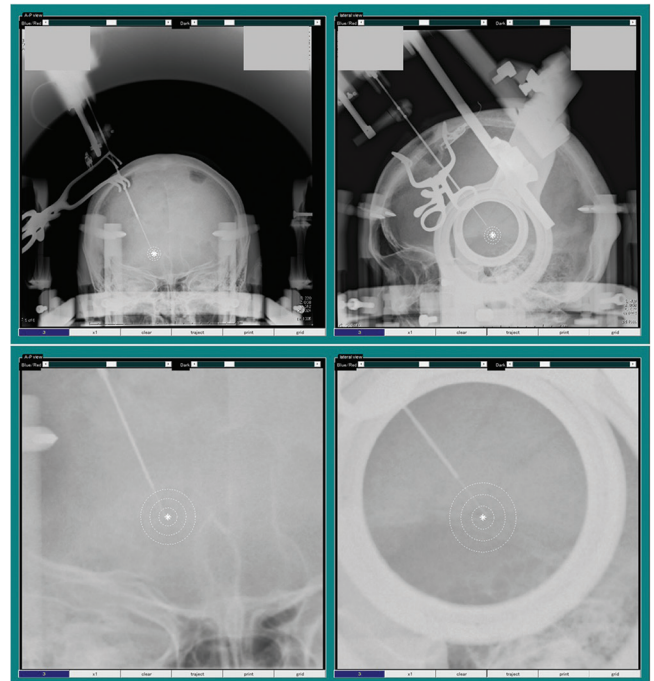


Fig. 4 Upper column: Validation of the position of the recording microelectrode. *White asterisks* denote the tentative target points. *White dotted circle* denote circles with 2 mm, 4 mm, and 6 mm radius from the target. Lower column: Magnified images.

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