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Computed Tomography Guided Stereotactic Device for the Whole Body-Technical Note

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Abstract

CT guided biopsy of extracranial lesion is a common procedure. Free hand technique is usually used for this procedure. Other methods include ultrasound guidance and the use of navigation system. In this paper the authors describe the use of stereotactic frame to perform these procedures.

The system has a base plate which attaches the system to the CT table. It has side plates and pneumatic bags to secure the patient in place. The frame is L shaped; and is fitted to the base plate. It can be adjusted in the Y axis (dorsal-ventral height). The horizontal arm has a cylindrical clamp that can slide along the X-axis (side to side). The clamp holds a cylindrical probe carrier which can slide along the Z-axis (cranial caudal) and can rotate in the coronal plane. One end of the probe carrier has a probe holder attached to it which be adjusted in the sagittal plane to any required angle. CT scans are obtained, and the target is identified. The table is moved to bring the target plane of the scan in the plane of the vertical laser positioning light on the CT gantry. The cylindrical probe carrier is the moved along the Z axis to bring the middle of the probe holder in the plane of the laser positioning light. Another set of scans are obtained. The probe holder is identified in the plane of the target. Measurements and calculations are then done to give the length of the probe needed and the angle of the trajectory in both coronal and sagittal planes. The target is then probed; and the accuracy is checked by intraoperative scans. Thirty procedures were performed using this system. Accuracy of probe placement was within ~2.95 mm along X and Y axis and ~1.5 mm along the Z axis, though the probe was always in the lesion. This accuracy can be further improved using mathematical calculation described in the paper.

This is a simple device which can set optimal trajectory of the probe holder to reach the target with good accuracy using intraoperative CT images. The system also provides stability to the probe during biopsy procedures.

Keywords: Biopsy; CT scan; Body stereotactic frame; Stereotactic surgery; Spine stereotaxis

Abbreviations: CT: Computer Tomography; mm: millimetersstereotaxis

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Introduction

Though computed tomography guided stereotactic frame for intracranial pathology has been used for a long time [1,2] no such frame currently exists for biopsy of spinal, intrathoracic and abdominal pathology. Currently these procedures are done free-handed with intraoperative CT scan or ultrasound guidance [3]. More recently different type of navigation system has been tried [4]. Another method has been to use laser pointing device mounted on the CT gantry to guide the biopsy needle [5]. Yet another method has been to use a stereo-guide and intraoperative CT scans to do vertebroplasty [6]. All these procedures are done free handed. Since the pathology in these locations is generally large, free hand procedures have worked well. However, these procedures require several scans and they do not have stabilizing system for the probe during probe passage. In this paper the authors describe a CT guided stereotactic device for the whole body with the ability to do intraoperative scans.

Materials and Methods

Description of the device

The system consists a base plate which attaches the entire system to the CT table as shown in **Figure 1**.

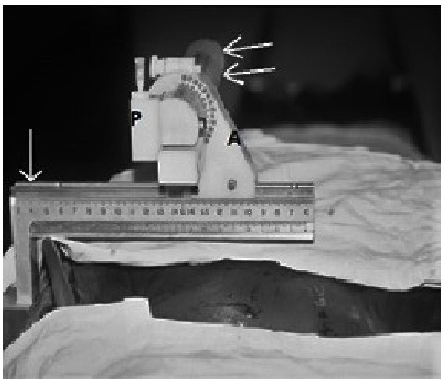

Figure 1: Shows the L shaped frame (single arrow), the cylindrical clamp (A) with angle marking, the cylindrical probe carrier (double arrows) and the probe holder (P).

It has two side plates to immobilize the patient in **Figure 2**. One side plate is fixed while the other one can be moved inwards to hold the patient tight. In addition, to get contoured firmness for immobilization each side has inflatable pneumatic bags.

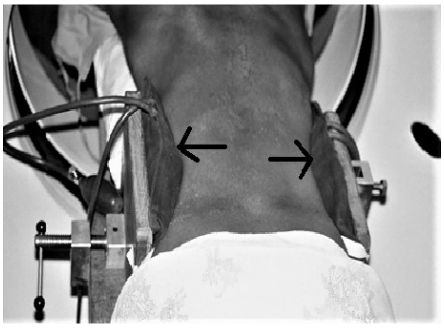

Figure 2: Shows inflatable pneumatic bags (arrows) to secure the patient in place.

The frame is L shaped. The vertical arm is fitted to the fixed sided plate of base plate. It can be adjusted in the Y axis (dorsal-ventral height). The horizontal arm is graduated in mm. On it is mounted a cylindrical clamp with angle markings, that can slide along the X-axis from one side to the other. The clamp holds a cylindrical probe carrier which can slide along the Z-axis (cranial-caudal) and rotate in the coronal plane. The probe carrier has angle markings (coronal protractor) to show the angle of rotation in coronal plane along axis of the cylindrical probe carrier. One end of the probe carrier has a probe holder attached to it. It has a vertical and a horizontal marking in the middle. It can angulate in the sagittal plane around an axis passing through the centre of the plane. There is a protractor attached to the probe carrier to show the angle in sagittal plane. The wide freedom of movement in Z axis for the cylindrical probe carrier is essential to avoid intraoperative artifact and ample room for surgical field.

Method

This is only a technical note paper and does not involve study on humans. None of the images have patient identifiers.

During the procedure Axial CT images (with the gantry perfectly vertical) at 2 mm interval and thickness are obtained over an area 2 cm cranial and 2 cm caudal to the suspected area with the pathology. The target point is identified. The table is then moved to scan position of the target. The cylindrical probe carrier is advanced so that the vertical middle line on the probe holder is aligned with the CT laser beam. The cylindrical probe carrier is then adjusted along the X-axis to a position the surgeon feels may be suitable to approach the target based on review of axial images. CT image is then obtained in the plane of the target as shown in **Figure 3**.

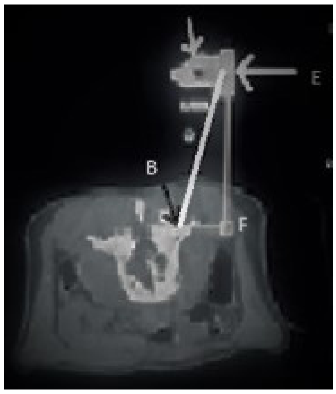

Figure 3: Intraoperative CT images show the target (black arrow), cylindrical probe carrier (short white arrow) and the probe holder (long white arrow).

On the screen of the CT console, the target (B), the axis of rotation of the cylindrical probe carrier (A) and the middle of the probe holder (E) are visible. Draw a line from E to B. EB is the length of the probe. Measure the angle BEF and make that change on the cylindrical probe carrier. The probe is then placed at the target. Intraoperative scans are obtained to confirm accuracy as shown in **Figure 4**.

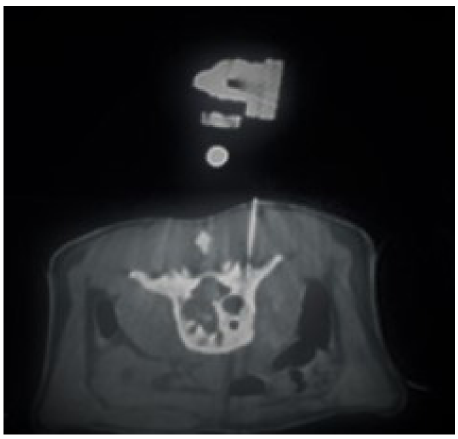

Figure 4: Shows the probe tip at the target. Pneumatic device stabilising the patient by conforming to body contour (P).

Since axis of rotation of the probe in the coronal plane is not through the axis of rotation of the probe holder, the following method can be used to increase accuracy (**Figure 3**). Lines AB and AC (a perpendicular line from A to the horizontal line BC) are drawn and measured using measure distance mode on the CT console screen. Using basic trigonometry angle BAC (angle of rotation of the probe carrier in the coronal plane)=sin-1(BC/BA); and the length of the probe from the middle of the probe to the target, BE=⍰(AB2-AE2). To make adjustment in the sagittal plane the probe carrier is moved along the Z axis for required length (ED) based on preoperative study of sagittal images. Using trigonometry, the angle on the sagittal protractor angle EBD=tan-1(ED/EB) and the length of the probe from the middle of the probe holder, BD=⍰(EB2+ED2). Alternately, the angle of the trajectory in the sagittal plane (angle EBD) can be pre-chosen based on preoperative images. The distance through which the probe carrier must be moved **Figure 3** is ED=(tan⍰EBD) X (BE) and the probe length BD= ⍰(BE2+ED2) (**Figure 5**).

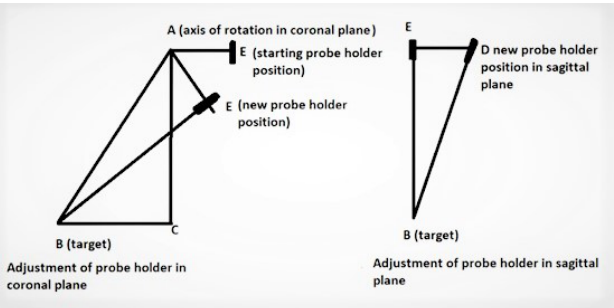

Figure 5: Geometric drawings used for calculations.

Results

Clinical use

Thirty procedures were performed using this system. The trigonometric methods described in the method section to overcome the inaccuracy that may result due to the off-centred axis of rotation of the probe holder was not used. The procedures included 16 spinal biopsies, 2 percutaneous pedicle needle placements for vertebroplasty, 2 sacral fixations, 6 intrathoracic biopsies, 2 liver biopsies and 2 kidney biopsies in **Figure 6**. There was no complication from the procedure.

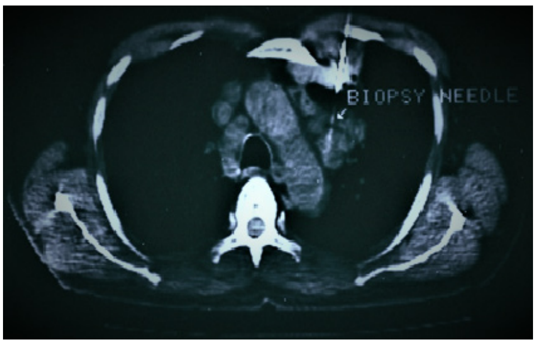

Figure 6: Parasternal approach to para-aortic lymph node.

Accuracy of probe placement was within ~2.95 mm along X and Y axis and ~1.5 mm along the Z axis, though the probe was always in the lesion.

Mathematical study was done to determine the degree of inaccuracy that would result with use of off-axis rotation of the probe holder. This showed error of ~2.9 mm in X and Y axis.

Discussion

There are several stereotactic systems for brain surgery. Most of them are centre of the arc based [1,2]. The arc is moved in all 3 planes to put its centre on the target. This enables the operator to reach the target from limitless trajectories. Frame based stereotactic framed has been used reach target in the upper cervical targets [7]; however, it not practical to use such a system for whole body because it will require an arc that wound be larger than the diameter of the CT gantry, and stabilization the body is difficult. The authors therefore invented the present system.

This system is based on using the laser positioning light to align the Z plane, do direct measurements of certain key distances on the images and then calculate distances and angles to positions the probe to the target. Since the procedure is done in the scanner, it becomes accurate and safe, because it gives the operator opportunity to make corrections. The ability to change the trajectory in both, coronal and sagittal plane helps the operator to avoid critical structures. Unlike stereotactic systems for brain lesions in which the head can be totally immobilized by skeletal fixation, the present system will have some patient movement and respiratory movement. This problem was partly overcome by inflatable pneumatic bags which are contoured to irregular body anatomy. Another method is to use vacuum device [8]. If the procedure is done under general anaesthesia respiratory movement can be reduced to improve accuracy.

Since this system is designed for the whole body and the size of pathology is large, the probe can still reach the pathology if there was a small inaccuracy. In cases reported in this paper inaccuracy of probe placement was within 2.95 mm for X and Y axis. This could be due to small patient movement, respiratory movement, deflection of the probe by firm structures along the trajectory and off-axis location of the probe holder. In the methods section, the authors therefore have described a geometric method to correct error encountered by off axis location of the probe holder.

Since all the components of the system are fixed during the passage of the probe the probe has a stable and steady approach to the target. Though there can be minor deflection of the probe due to firm structures along the trajectory this can be detected on intraoperative images. Furthermore, since the trajectory is pre-determined prior to the passage of the needle the operator does not have to image at every stage of the needle advancement. This reduces the radiation to the patient. In addition, CT images obtained for trajectory planning are obtained over a limited segment of the body. This further reduces the radiation delivered to the patient.

Conclusion

This is a simple device which can help the operator to accurately target intra-thoracic, intra-abdominal and spinal pathology using intraoperative CT images. The system also provides stability to the probe during biopsy and enables the operator set trajectory to avoid critical structures. This can be a good tool for surgeons and interventional radiologists.

Availability of Data and Material

This only a technical note. Images available to author are in paper.

Authors' Contributions

AAP designed the frame and the methodology and wrote the paper together with AKC AC and approved the paper.

AKC designed the frame and wrote the paper together with AAP and used the system and approved the paper.

AC helped in the collect the data, used the system with AKC, helped in the writing of the paper and approved the paper.

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Conflicts of Interests

The authors declare no conflicts of interests.

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