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*Short report*

# Accuracy of stereotaxic localisation using MRI and CT

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SUMMARY The accuracy of stereotaxic coordinates determined using the Leksell apparatus with CT and MRI was investigated using an Agar filled head phantom. Both imaging techniques were found to produce an accuracy of better than 2 mm with the exception of the Z coordinate as measured by CT (2·3 mm). This latter error is greater because of the 3 mm slice width used. Direct coronal views were used to determine Z more accurately using MRI. The measurement procedures are described and it is shown that the Leksell system of using orthogonal coordinates enables the scaling of images, which is particularly necessary with MRI, to be done easily.

The use of stereotaxic techniques for tumour biopsy and functional neurosurgery using CT for imaging is well established.[1-6] The instrument used in this study was the Leksell stereotaxic apparatus manufactured by Elekta Instrument AB, Stockholm, Sweden, which is based on the principle of positioning a circular arc-shaped probe holder such that the target is at the centre of a sphere defined by rotating the arc about a fixed axis. The arc is moved using orthogonal X-Y-Z coordinates determined from the CT scan. X and Y are determined by measuring the position of the target relative to fiducial markings on a coordinate indicator attached to the frame and Z is determined from the position on the scan of a 45° inclined marker. With the introduction of magnetic resonance imaging (MRI), modifications to the system have been introduced to enable stereotaxic measurements to be made using MRI.[7,8] The potential benefits of MRI include the improved tissue contrast compared with CT, the facility to use direct coronal imaging thereby producing equal accuracy in all three coordinate planes and the absence of any ionising radiation dose to the patient. MRI can be shown however to produce spatial distortion, particularly in the coronal and sagittal planes. This is demonstrated on an SE40/500 (that is, a spin echo sequence with echo delay of 40 ms, repetition time of 500 ms) image of a spatial linearity phantom taken on our Picker 0·15T Resistive Imager (fig 1). The phantom consists of parallel perspex planes in a paramagnetic solution.

The objectives of this study were (a) to measure the absolute accuracy of stereotaxic localisation using the

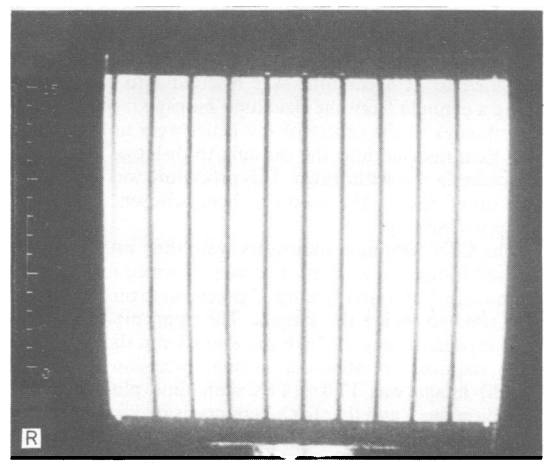


Fig 1 *An SE40 coronal image with the phantom positioned at the centre of the lead coil.*

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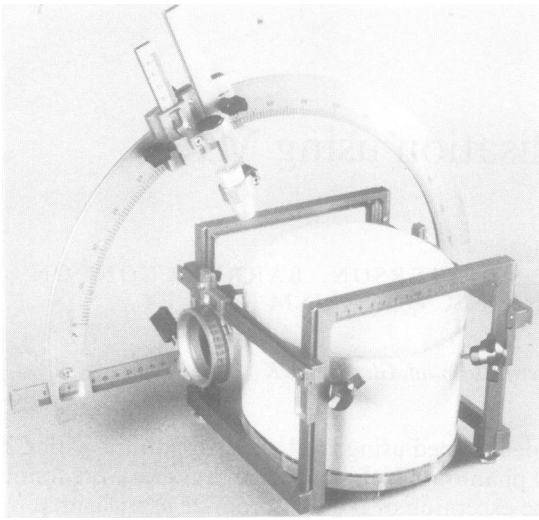

Fig 2 *An aluminium pellet being inserted into the phantom using a cannula from the Backlund biopsy kit.*

Leksell frame with CT as the imaging technique, and (b) to compare this with MRI.

**Method**

A perspex head sized phantom was filled with a newly mixed 1·5% aqueous solution of agar which was allowed to set overnight. This mixture has been shown to give a physiologically realistic MR signal.[9] The gel used here produced a $T_1$ of 226 ms and a $T_2$ of 91 ms at 6 MHz and 21°C and gave a CT attenuation of 14·2 Hounsfield units at 120 kV.

The procedure adopted to check the localisation was the reverse of a normal stereotaxic biopsy. The Leksell frame was fitted to the phantom (fig 2) and the probe holder arc attached. A specially constructed aluminium pellet, 2 mm in diameter and 4 mm in length with a small tapered end designed to fit a cannula, was inserted into the phantom using a cannula from the Backlund biopsy kit (fig 2) and the coordinates of the centre of the pellet were noted. A stylet was then inserted into the cannula to dislodge the pellet as the cannula was withdrawn. This procedure was repeated for two other pellets, the positions being chosen to provide a variety of settings.

The CT coordinate indicators were then attached to the Leksell frame and a series of scans performed on the Philips Tomoscan 310. Initially normal precision (6 mm slice width) was used to locate the targets. The appropriate cuts were then repeated using the high precision 3 mm slice mode. The time required to obtain a normal precision (6 mm slice width) image was 17·8 s (4·8 s scan time plus 13 s reconstruction time) and that for a high precision image was 32·6 s (9·6 s scan time plus 23 s reconstruction time). The total imaging time depends on the number of scans required to locate the target.

The CT coordinate indicators were then replaced by MRI coordinate indicators in which the metal strips are replaced by hollow channels which are filled with a vegetable oil. The liquid used has a $T_1$ of 302 ms and a $T_2$ of 209 ms at 6 MHz and 20°C. It produces bright spots on the SE80/1597 images and dark spots on the IR400/3198 images of the phantom. Both transverse and coronal images were acquired. The imager was a Picker resistive 0·15 T Vistaview. The imaging times were 6·7 minutes for a 16 slice SE80 and 13·6 minutes for a 16 slice IR400.

*Measurement of coordinates*

Coordinates were measured relative to the fiducial markings. Figure 3 shows these markings on a transverse SE40/800 MR image. Measurements can be made directly from the viewing console or by measuring distances on radiographs.

AD and CB (fig 3) should measure 19·0 cm on MRI and 18·0 cm on CT, whilst AC and BD should measure 12·0 cm. It was found to be advisable to ignore the preprogrammed scaling on the MRI and CT computer viewing consoles and on the Leksell coordinate scales[7] and to scale all X measurements relative to the measured values of AD or CB and all Y measurements relative to measured values of AC and AD. This was particularly important with MRI where AD could vary from 186 mm to 192 mm when comparing a transverse slice at the bottom of the frame with one at the top. There was no difference between AD and CB on transverse MR images but there was a difference of 3 or 4 mm in the coronal plane. There was, however, no difference between AC and BD in either transverse or coronal images. With MRI it is recommended therefore that transverse images be used for X and Y determination and coronal images for Z determination.

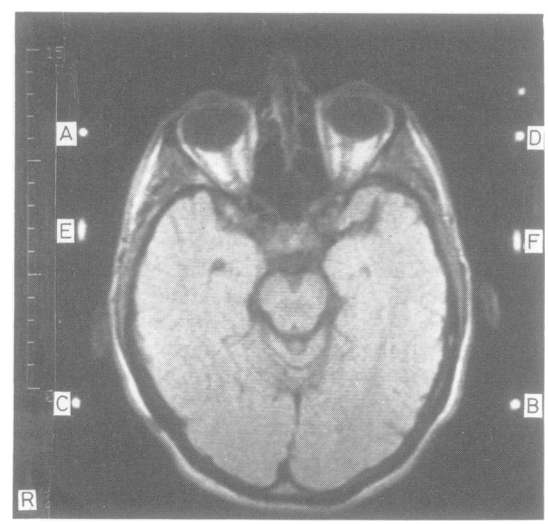


Fig 3 *A transverse SE40/800 image showing the fiducial markings A, B, C and D. The diagonals E and F are used to determine an approximate value for Z which is obtained more accurately from the coronal image.*

Table *Deviation from target position (mm)*

| | *Object 1* | | | *Object 2* | | | *Object 3* | | |
|---|---|---|---|---|---|---|---|---|---|
| | *X* | *Y* | *Z* | *X* | *Y* | *Z* | *X* | *Y* | *Z* |
| $CT_1$ | +2·0 | 0 | +2·0 | −1·0 | −1·0 | +2·5 | +1·0 | −1·5 | +0·5 |
| $CT_2$ | +1·0 | −1·5 | +2·5 | −1·5 | −1·0 | +2·5 | 0 | −1·5 | −0·5 |
| MRI | +1·0 | −0·5 | +1·0 | −0·5 | −1·5 | 0 | +1·5 | 0 | +1·5 |

$CT_1$—measurement from viewing console, $CT_2$—measurement from film, MRI—SE80/1597 sequence measurement from film.

## Results and Discussion

The targets were inserted at positions chosen to cover the range of coordinates likely to be encountered in practice. Deviations from these coordinates on the MRI and CT measurements are listed in the table.

The greatest error was in the Z coordinate as measured by CT. This is not surprising as the accuracy of measurement of Z is limited by the slice width selected; in this case it was 3 mm.

Measurements on the viewing console are limited by the pixel size of the display (in this case 1 mm). The marker on the screen cannot always be positioned as accurately as the eye demands.

The matrix camera which produces radiographs has the drawback in theory of introducing geometric distortion but this did not appear to introduce any significant errors in the measurements.

The results presented do not demonstrate a significant difference between measurements from the console or from film. There was no difference between the IR and SE MRI measurements.

The three primary sources of error in the experiment were:

1 Inaccuracy in positioning the pellets, especially when dislodging them from the cannulla where an error (mainly in Z) of the order of 1 mm was possible.
2 The limitation in measuring the coordinate from the consoles or film where the accuracy cannot be much better than 0·5 mm.
3 The geometric distortion of the imaging device which would appear to be less than 0·5 mm if the appropriate scaling is done on the measurements.
4 The error introduced by inaccuracies in the frame. Our results indicated that these are less than 0·5 mm.

The errors found here in coordinate determination using MRI do not differ significantly from those of CT and are comparable with those found by others using CT. Thomson *et al*[5] obtained mean errors in X and Y coordinates of 1·59 mm and 1·49 mm and Brown *et al*[1] obtained a mean error of 1·0 mm.

The sagittal view on MRI is not recommended as only the upper fiducials are present and so no scaling can be applied.

It is well known that the presence of metal objects can significantly distort MR images. In such situations the spacing of the corner fiducials will be appreciably altered on the image compared with the values normally obtained. These spacings should always be checked before accepting an image for stereotaxic measurements.

The Leksell principle of stereotaxic coordinate determination using three orthogonal axes is particularly well suited to magnetic resonance imaging as the X, Y and Z axes of MRI correspond with the X, Y and Z axes of the frame and so scaling can be applied in a straightforward way.

## Conclusions

1 The error in determining X, Y and Z stereotaxic coordinates using MRI should be less than 2·0 mm.
2 The error in determing X and Y coordinates using CT should be less than 2·0 mm. The accuracy of the Z determination is limited by the slice width which is selected.
3 Scaling has to be applied using MRI.

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