Phantom System to quantify and map gradient induced distortions in MR images of the Pelvis

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INTRODUCTION:
Magnetic resonance (MR) imaging has been recognised as offering potential benefit in radiotherapy (RT) treatment planning (RT) of cancer as it is able to provide significantly enhanced visualisation of the lesion compared to other imaging modalities[1]. There is currently much interest in our centre in the use of MR scans to plan RT treatments for prostate cancer. A concern regarding the use of MR for RT planning is that the images are prone to geometrical distortions.

Distortion results from both deviations from the ideal homogenous magnetic field (resulting from Bo inhomogeneity, chemical shift, susceptibility differences etc.) and non-linearities in the applied magnetic field gradients. Distortion resulting from deviations from the ideal field is specific to the object being imaged and can be corrected for using a sequence involving the use of forward and reverse gradients.

Effects associated with non-linear gradients can be calculated with reference to an object of known geometry. This abstract describes the design and manufacture of a phantom system comprising a flat-topped couch insert, a reference frame and a linearity test object. The system permits system distortion to be mapped and quantified in 3 dimensions.

Phantom System Design : Both the couch insert and the reference frame contain rows of water filled marker tubes angled relative to the axis system of the scanner. This results in images in which the linearity test object is surrounded by a number of bright spots. The locations of the spots in the image uniquely define the position and orientation of the imaged slice. All three components are designed to be robust, light and of fixed geometry and are connected together using a system of simple mechanical interlocks which ensures that they are always used in an identical position with respect to each other and the scanner couch.

To map the system distortions in 3 dimensions the linearity test object consisted of three interpenetrating orthogonal arrays of water-filled, polymethylmethacrylate (PMMA) marker tubes (3mm inner diameter, 5mm outer diameter) placed at fixed, known positions and mounted perpendicularly to the principal imaging planes. The accuracy of the positioning of the tubes was checked using a laser mounted on a vernier scale. This gave a square lattice of spots separated by 30mm for each orthogonal imaging plane.

PMMA was adopted as the material of construction because of its moderate density, rigidity and transparency. Since its susceptibility is close to that of water[2] the susceptibility effects at PMMA-water boundaries are expected to be negligible. Individual tubes were linked to form a series of continuous flow paths to ease filling. To avoid tubes being deflected due to changes in temperature and hydration there are adhesive-free sliding seals at the tube-end support positions, which allow unconstrained expansion and contraction over the anticipated range of operating conditions.

METHOD:
Phantom Study : The phantom system is scanned using an acquisition sequence incorporating gradient reversal. Deviations from the ideal homogenous magnetic field are corrected for using Chang and Fitzpatrick's method[3]. The remaining distortion, associated with non-linearities of the gradients, is determined using two polynomial surface interpolations to calculate the orthogonal in-plane components of shift between the true and the distorted positions.

Patient Study : The reference frame (at the same postion relative to the isocentre as in the phantom study) is placed over the pelvis and the patient lies on the flat couch insert. The effects of the gradient non-linearities can be incorporated into the distortion correction method mentioned above[3] as the corrections associated with the gradients can be mapped in space relative to the isocentre of the magnet by the reference frame. It is necessary to use the same acquisition sequence in both the phantom and the patient study.

DISCUSSION:
The system is designed for MR imaging of the pelvis where distortion due to non-linear gradients may be significant towards the edge of the field of view. It provides a method of incorporating corrections for these errors into existing methods for correcting the effects of deviations from the ideal magnetic field. The reference frame's design allows two important quality assurance checks to be made. Because the locations of the spots in the image uniquely define the position and orientation of the imaged slice the operator is able to verify the positional information on the image header. Software can be used to compare the positions of the spots at each slice location with previous measurements. Any significant deviation in these measurements during patient imaging indicates that there has been a change in the factors contributing to MR distortion.

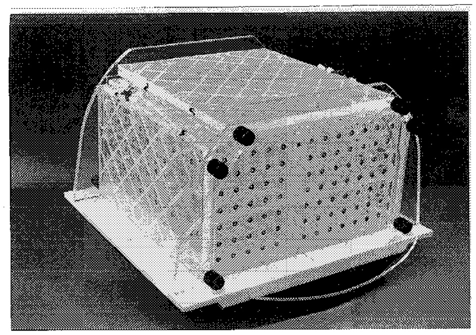

Fig 1 : The linearity test object, enclosed by the reference frame. The test object and frame are locked into place via the flat top couch insert (shown in section form).

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