AN IMAGE-GUIDED SURGICAL NAVIGATION SYSTEM FOR UROLOGY

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INTRODUCTION: Regional lymph node dissection is an integral part of disease management for patients with high grade invasive bladder cancer. The major challenge facing surgeons is ensuring that all malignant nodes have been removed. In the past, morphologic imaging using MRI or CT has not been particularly successful at detecting metastases in small nodes. As a result, imaging has played only a limited role in guiding the surgical approach. Recently, MR imaging using Ferumoxtran-10 (Combidex, Advanced Magnetics Inc., Princeton NJ), an iron oxide nanoparticle, has been shown to detect nodal metastases with an overall accuracy of 95% [1]. In theory, this high degree of accuracy should translate into a comprehensive surgical removal of metastatic nodes. In practice, this is typically not achieved, as surgeons often have difficulty physically localizing nodes that have been identified on the MR images. In this abstract, a solution to this problem is presented in the form of a navigation system, which uses previously acquired MR images to guide the surgeon to the physical location of the lymph nodes *during* the procedure.

METHODS: The general strategy behind the present navigation system is for the surgeon to identify an area of interest within the body, and then to simultaneously (and in real-time) display the corresponding area on previously acquired MR images. In this manner, the surgeon can physically localize malignant nodes in the body based on their visibility in the MR images.

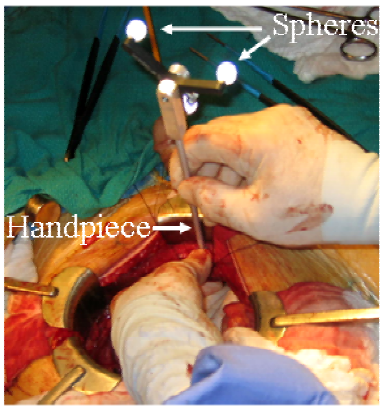

Figure 1: Handpiece, with infrared-reflective spheres, pointing at a lymph node.

The main challenge in implementing the above strategy is establishing the correspondence between MR images and the physical space inside the body. In our system, the surgeon identifies an area in the body by pointing a handpiece device at the node (Fig. 1). On top of the handpiece is a set of infrared-reflective spheres. An infrared Polaris camera (Northern Digital Inc., Waterloo, Ontario) (Fig. 2) tracks the location and orientation of the handpiece in real-time. The correspondence between the tracking system's coordinates and the MR image coordinates is established through MR-visible fiducial markers in the manner as follows: The markers are affixed to the patient prior to MR imaging, and remain in place until surgery. Immediately prior to surgery, the handpiece is placed directly on each of the fiducials, and their position recorded. This provides a set of known point-pairs in the Polaris camera and MR image coordinate systems. Using software developed in-house, the transformation between the two coordinate systems is calculated. This information is used during surgery to provide real-time annotation of the handpiece position and orientation over top of the MR images (Fig. 3).

RESULTS: The image-guided navigation system was used to guide lymph node dissection. During these procedures, the surgeon interactively used the system to physically localize the positions of lymph nodes that corresponded to metastatic lesions visualized on the Ferumoxtran-10 contrast-enhanced MR images. In all cases, the surgeon identified (and dissected) a lymph node at the position indicated by the guidance system. According to estimates given by the surgeon during the procedure, the accuracy of the navigation system was on the order of ±5mm.

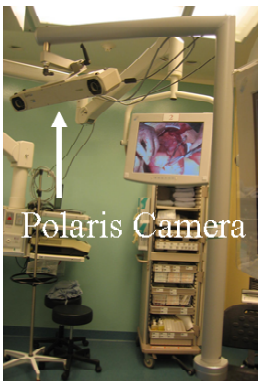

Figure 2: The infrared polaris camera.

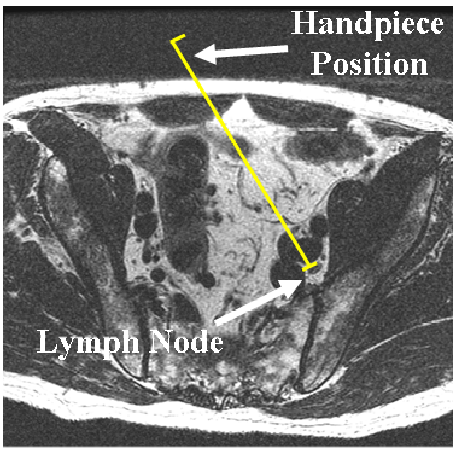

Figure 3: MR image with the position of the handpiece superimposed.

DISCUSSION: The major factor affecting the accuracy of the surgical navigation system is the occurrence of any motion between the MR scan and surgical procedure. Such motion could arise from three sources: First, the MR scan and the surgical procedure are performed on different days, and in different rooms. An attempt was made to minimize this problem by positioning the patient on the operating table as closely as possible to their orientation in the MR scanner. Additionally, a vacuum beanbag was used to minimize patient motion during surgery. A second source of motion is respiration. This effect was minimized by affixing the fiducial markers to bony landmarks along the pelvic rim – which is relatively rigid. A final source of motion is anatomic displacement caused by the surgery itself. One factor that inherently minimizes motion arising from this source is the fact that the target lymph nodes are mostly retroperitoneal. As a result, they undergo a minimal amount of displacement during surgery. In the future, it is hoped to use intra-operative re-calibration (re-registration) using fixed internal bony anatomical landmarks to further reduce the uncertainty in position introduced by the sources mentioned above.

[1] Deserno, W. M. L. L. G., *et al.*, *Radiology* 2004 233: 449-456.