Direct application of MR images to computer-assisted bone tumor surgery

KIM HS[1], HAN I[1], SHIN SH[1], OH JH[2], CHO HS[2]

[1]*Department of Orthopedic Surgery, Seoul National University Hospital, Seoul, Korea*
[2]*Department of Orthopedic Surgery, Seoul National University Bundang Hospital, Seongnam, Korea*

mdchs111@snu.ac.kr

Introduction: Recently, several preliminary reports have been issued on the application of computer assistance to bone tumor surgery. Surgical navigation systems can apply three-dimensional images such as CT and MR images to intraoperative visualization. Although CT is better at describing cortical bone status, MRI is considered the best method for defining the extent of marrow involvement for bone tumors and for planning surgical resection in bone tumor surgery. There have been only two reports on the application of MR imaging to navigation-assisted bone tumor surgery through CT–MR image fusion as far as we know. However, the CT–MRI fusion technique requires additional costs and exposure of the patient to radiation from the preoperative CT, as well as additional time for image fusion. Above all, the image fusion process is a kind of registration (image-toimage registration) that inevitably leads to registration error. Herein we describe a new method for the direct application of MR images to navigation-assisted bone tumor surgery as an alternative to CT–MRI fusion.

Surgical Technique: The basic concept of this technique is the same as the paired-point registration technique used for CT with metallic Kirschner wires in our previous reports, except that this method uses MR images and resorbable pins. The resorbable pins used in the present study were made of poly-p-dioxanone, a biodegradable polymer composite that is fully compatible with MRI. Furthermore, orthopedic bioabsorbable products have low signal intensities in T1- and T2-weighted images and do not cause image blurring. The MR images employed in this study were rapid 3-dimensional spoiled gradient echo sequences. Such a sequence is able to provide a data set with a slice width of 1–3 mm, which made it possible to detect a resorbable pin 1.5 mm in diameter.

Preoperative preparation - On the first preoperative day, with the patient under local anesthesia in the operating room, three or four resorbable pins (OrthoSorb, DePuy ACE Medical, Warsaw, IN, USA) were placed as fiducial markers for registration, and then rapid 3-dimensional spoiled gradient echo (TE 3.2 ms, TR 7.6 ms, 1.5 mm slice thickness) axial MR images (1.5T, Achieva, Philips, Eindhoven, The Netherlands) were acquired. The pins should be placed beyond what would be the resection area to avoid tumor contamination. The diameter of a resorbable pin is 1.5 mm. Therefore, the thickness of the MR slice should be <1.5 mm so that no pin is missed.

Registration technique - The Stryker surgical navigation system (System II: Styker, Kalamazoo, MI, USA) was used in all patients. After conventional surgical dissection for a bone tumor, a dynamic reference base (DRB) was fixed to the cortical bone beyond the planned resection area. Patient-to-image registration was performed by paired-point registration using MR images and resorbable pins that had been placed preoperatively. Registration is a process that correlates some points on a patient's body with corresponding points on an image. The discrepancy between virtual space on the image and real patient space is referred to as the registration error. Usually, in order to direct a registration probe to the exact points where resorbable pins penetrated cortical bone, some additional skin incisions may be required around pins. However, we used a new registration probe to locate these penetration points, which consisted of a universal tracker and a metallic cannula (FGS Biopsy Probe: Stryker, Kalamazoo, MI, USA). Pushing this registration probe over the pin until contact is made with the cortex of the bone makes it possible to perform registration without completely exposing the points at which the wires penetrate.

Results: Patient-to-MRI registration took 20 min on average to set up navigation (range 15–25 min). Mean registration error was 0.98 mm (range 0.4–1.7 mm). In all cases, registration errors were <2 mm. Although a sound analysis was not possible due to the small number of patients, there was no

difference in registration error according to anatomical location. On histological examination, distances from tumors to resection margins were in accord with preoperative plans. No patient had a local recurrence or distant metastasis at the last follow-up. The mean functional score using the classification system of the International Society of Limb Salvage was 27.7 points (range 24–29 points).

Conclusion: In our experience, direct patient-to-MRI registration is a very useful method for bone tumor surgery, permitting the application of MR images to intraoperative visualization without any additional costs or exposure of the patient to radiation from the preoperative CT scan, even though the technique has the disadvantage of requiring an additional procedure to place resorbable pins as fiducial markers.