Use of intraoperative 3D volume visualization for navigated bone tumor resection: a report of two cases

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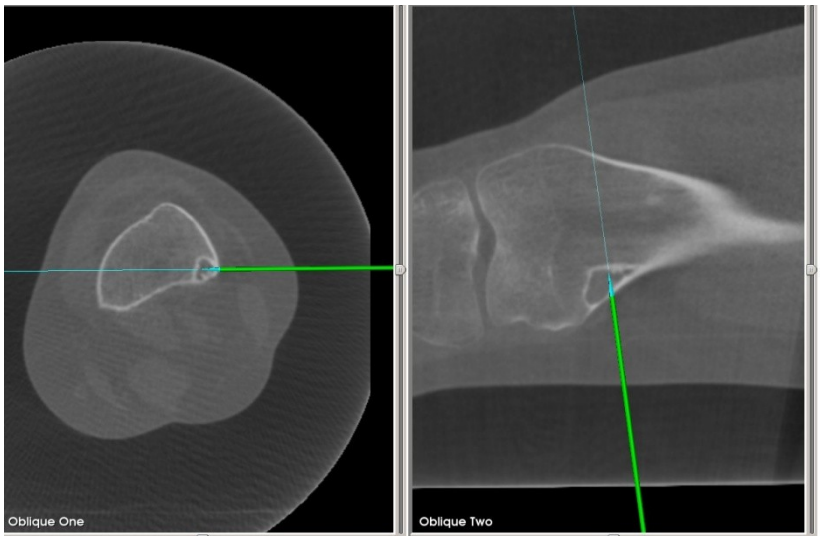
Introduction: Osteoma and non-ossifying fibroma are two types of benign, but painful, bone tumors. Surgical resection is traditionally the technique of choice following a failure to respond to primary non-operative treatments. Complete excision of all reactive bone is essential to minimize the likelihood of recurrence; conversely, excessive resection of normal bone can increase recovery time and the risk of complications. Thus, proper localization of the tumor is critical to the success of these procedures.

Although, CT-based navigation has been employed for excision of tibial osteoid osteomas [1], its routine use may be dissuaded because of longer operative times, high cost, and radiation exposure. Here, we report two clinical cases of bone tumor excision using an alternative navigation approach which used intraoperative 3d fluoroscopy and a novel room calibration such that no patient-based registration was required.

Technical Details: Case 1 was an 18-year-old female with an osteoid osteoma on the mid-shaft of the right tibia. Case 2 was a 20-year-old female with a right distal femur non-ossifying fibroma.

Both tumor excisions were performed by senior orthopaedic surgeons (DDB and JFR) in a contemporary operating room at Kingston General Hospital (Kingston, Canada). This high-tech operating room features an optical tracking system (Optotrak Certus, NDI, Canada) and an Innova 3D cone-beam computed tomography (CBCT) C-arm (GE Healthcare, France). At the onset of each procedure, a calibration was performed to register the imaging space of the C-arm to the tracking system. This calibration has been previously described and shown to have a mean error of 0.3mm [1].

For patient tracking, an optical local coordinate reference (LCR) body was attached to the bone with the tumor using percutaneously-placed pins, such that the LCR remained within the field of view of tracking system during imaging and navigation. The Innova C-arm was used to acquire an intraoperative 3D CBCT image of the tumor region (40 degree/sec rotation, 40cm FOV). Using custom navigation software (iGO technologies, Canada) the 3D image was volume-rendered and sliced to produce images similar to a CT-series, but with the ability to control the viewing orientation for enhanced visualization.



For both cases, two perpendicular oblique views in predominately axial and sagittal directions were displayed on computer monitors in the operating room for navigation (Figure 1). The entire process from imaging to intraoperative display was approximately seven minutes. An optically-tracked drill

guide was used to navigate a guide-pin into the tumor by displaying the real-time orientation of the drill guide relative to the anatomy. As the drill guide was moved, the viewing orientation was updated to center the oblique views at the guide tip.

With guide pin in place, cannulated drills and reamers were used to expose the tumor. The tumor was excised with the help of an optically-tracked probe to palpate the excision and validate the tumor margins. Again, the views were reconfigured to center the oblique views at the probe tip.

Following excision, the vacant cavity was filled with graft material. Closure was achieved with sutures for subcutaneous tissue and either nylon sutures or staples for skin and LCR pins removed. The excised reamings and direct scraping were sent to pathology and both patients were followed up in clinic.

Discussion: In contrast to conventional image-guided navigation, the navigated technique presented here uses intraoperative 3D CBCT imaging for navigation, such that no preoperative CT imaging or tumor segmentation was required. This approach reduces the need for technical staff, and minimizes the time associated with planning image-navigated procedures. Significantly, this also avoids segmentation errors that may result in ill-defined tumor margins.

In both cases, diagnosis was made from preoperative X-ray, and all imaging required for navigation was collected intraoperatively. No additional intraoperative imaging was collected to verify LCR placement or registration, thereby hypothetically reducing radiation exposure for both the patient and surgical team.

Preoperative image-to-tracking registration likely led to reduced operative time by circumventing the need for standard patient-based registration. Moreover, errors associated with this process, such as those incurred when registering surface points collected from a near-cylindrical bone shaft, were avoided.

These two cases represent the first clinical application of our novel navigation system. These were relatively simple excisions, but allowed us to gain invaluable experience with the navigation system. Both excisions were deemed to be successful, with no recurrence of the tumor, and both patients reported improved symptoms. The treating surgeons, DDB and JFR, were pleased with the easy workflow of the system, compared to conventionally-navigated procedures.

References

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