Accurate 3-dimensional Preoperative Planning and Resection in Orthopedic Oncology

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Currently, most patients with a sarcoma in an extremity are treated with a limb salvage surgery. The surgeon must determine, with the highest precision, where the bone and soft tissue should be cut to preserve as much unaffected tissue without invading tumor margins. Many times the surgeon finds, after studying the resected specimen, that margins were too wide, jeopardizing durability of the reconstruction. Other times, inaccuracy of planning or execution of the tumor resection shows violation of tumor margins, worsening patients’ life prognoses. Most preoperative plans are made using biplanes images of the lesion obtained with computed tomography or magnetic resonance imaging (MRI) studies.

In addition, intraoperatively the surgeon must rely on images hanging in the operation room, visually incorporate them, and manually perform what he or she considers appropriate margins according to a cerebral elaborated execution. This mental integration of preoperative 2-dimensional image information into a 3-dimensional intraoperative surgical situation may lead to an inaccurate execution. Many surgeons would call this experience, but it is based in a painful learning curve for patients and surgeons. Even the most experienced oncologic surgeons could find themselves in an unexpected situation when evaluating the resected specimen. This is particularly true in tumors growing in the pelvis, spine, groin, shoulder, popliteal fossae, or any other place in which the surgeon must resect as minimal an amount of tissues possible and preserve safe tumor margins. However, recent advances in computerized techniques applied to orthopedic oncology surgery may significantly influence our accuracy and predictability in tumor resections.

Computed tomography and MRI studies may be fused to determine bony cortex and intraosseous and extraosseous soft tissue tumor extension. These studies are merged to visualize the tumor and perform a virtual osteotomy, taking into account a 3-dimensional situation. The surgeon may preoperatively elaborate different resection alternatives with extreme precision. In addition, and of even more relevance, the selected cuts are viewed in a monitor in the operating room, creating a correspondence between the 3-dimensional images and real bone. Through appropriate navigation devices, a navigated pointer, an infrared camera, and tracker devices used on the patient, the surgeon is able to reproduce preoperative planned osteotomies with direct vision of the monitor with extreme accuracy in a 3-dimensional position. This is obtained by running the tracker through well-defined anatomic landmarks, shown on a monitor, which matches the real anatomy with the virtual images. No deformed or unreliable anatomic references, due to tumor growth, are needed. The previously programmed surgery is performed with high precision, without the need for the potentially inaccurate sensitive motor skills of the surgeon. Accuracy of this procedure has been recently measured in a clinical series of tumor patients to be approximately $\pm 3\text{ mm.}^{1}$

Extensive masses growing in complex anatomical areas, such as pelvic–sacral–spine tumors, in which excessive resections may originate a significant neurovascular dysfunction, have a stronger indication for navigation technologies. Even small, aggressive tumors, located purely intramedular in a long bone, make it difficult for the surgeon to determine the exact position of osteotomies intraoperatively using previous images. The use of accurate 3-dimensional preoperative planning and resection in orthopedic oncology with computer-assisted surgery...
will not diminish the need for an orthopedic oncologic surgeon to treat these patients. Preoperative virtual surgical planning, particularly the selection of osteotomy sites and the surgical procedure, is still performed by surgeons experienced with this disease.

Will these techniques be routinely applied when treating musculoskeletal tumors? Most likely yes. Currently, most surgeons must anxiously evaluate the postoperative radiographs or wait for the pathologist to verify whether oncologic margins were appropriate, but only after the resection is already performed. With current and improved computerized surgical techniques in the future, this stressful situation for the surgeon and life-threatening situation for the patient will certainly improve.

Questions arise related to clinical applications of these techniques. Equipment is costly, but is it cost effective? The surgeon and the surgical team must have training in computerized techniques that requires additional time and expenses. Surgical time, when first using this technique, may be prolonged. Some experienced surgeons may not consider these techniques necessary. Interestingly, similar arguments were raised when arthroscopy was first introduced in orthopedic surgery.

Computer-assisted orthopedic oncologic surgery means increased accuracy and precision. This is a basic need for a patient who requires a tumor resection and for the treating surgeon to perform a confident and reliable operation.

REFERENCE