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CORR Insights®: Is Limb Salvage With Microwave-induced Hyperthermia Better Than Amputation for Osteosarcoma of the Distal Tibia?

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Where Are We Now?

Osteosarcomas at the distal tibia pose considerable challenges to limb salvage surgery. Any soft-tissue mass in the distal leg lies in close proximity to the important tendons and neuromuscular structures narrowing the sought-after

wide margin for limb salvage. Though osteosarcomas at the distal tibia are rare (< 4% of all osteosarcomas), several forms of reconstruction have been described, and there are problems with each. Prosthetic reconstruction is associated with frequent complications [1, 9, 14], and allografts have high rates of nonunions and delayed unions [2, 13]. Vascularized fibular autografts (either pedicled or free) are technically demanding, lengthy procedures associated with a protracted convalescence during which weight bearing is limited [4, 8, 15, 16]. Nonvascularized fibular grafts carry the risk of stress fracture, particularly with longer segments and also take time to hypertrophy. Bone transport is satisfactory for shorter

lengths but also risks junctional non-unions [8]. External fixation wires and pins can be a problem for those on chemotherapy. These complications can undermine the benefits associated with limb salvage, which has been shown to provide superior function compared to amputation [13], the historical surgical treatment for osteosarcoma.

Hyperthermia has long been used to ablate tumors. But unlike radiofrequency ablation, which requires a conductive field for heating, microwaves can heat tissues by transmitting kinetic energy to polar molecules like water. Microwaves can transfer heat through charred tissue. Tissues, like bones and lungs, are better treated with microwaves than radiofrequency ablation [12, 17] because microwaves, by using multiple antennae, can heat larger tumor volumes faster and at higher temperatures than radiofrequency ablation. Therefore, microwaves are the ideal way to generate heat for larger volumes of tumors in bone tissues.

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The development of needle-like, internally-cooled antennae allows for more energy to dissipate with more uniform heating. Placing multiple antennae in specific configurations can rapidly achieve the temperatures required for tumor ablation. Monitoring the temperature within the tumor, and in vital areas like joint cartilage or neuromuscular bundles, help limit potential damage.

Building off of the results from previous studies [5, 6], Han and colleagues use an unconventional approach for limb salvage in distal tibial tumors. In order to avoid a complete bony osteotomy at the proximal site, the authors used microwave-generated hyperthermia to ablate the tumor after dissecting and isolated the tumor with margin from the surrounding tissues.

Where Do We Need To Go?

Despite the available data, I believe there is still considerable apprehension about using this technique. Our use of microwave technology must improve so that the heating can be done uniformly, quickly, and precisely in a predictable way without putting surrounding tissues at risk.

We need robust evidence to prove that microwave ablation completely kills the tumor. While one study

showed bone viability and no loss of mechanical strength after microwaving [11], no studies have demonstrated that microwaves can kill tumors without harming surrounding tissues, and such studies—perhaps in animal models—are called for before the technique should be widely adopted.

Microwave technology is still evolving, and should become more surgeon-friendly with better control over the way energy is transferred to the tissues. Simulation studies, like one recently performed on the liver [3], are needed for bone. A customized construct of antennae should be developed that can predict when the heating will allow a precisely targeted ablation with minimum risk. We also need a better understanding about healing after this after a limb salvage procedure.

Several other questions remain: Does the heat-treated bone ever completely revascularize? How long does it take to regain sufficient strength in bone to allow unassisted weight bearing ambulation?

How Do We Get There?

Randomized studies with a group treated with microwave technology and one treated with conventional resection and reconstruction would yield the best data. But because

osteosarcomas of the distal tibia are rare, it is unlikely that a study can gather enough patients. In that case, the best group for comparison would be patients who were offered the microwave technology, but opted for conventional surgery. The authors had 13 such patients, which should have been included in this study. Subsequent studies can include these patients. Comparison studies at the same center would be ideal, but proper case-matched studies can be done across different centers. Assurance of local control would be the first step towards more widespread use of this technology.

Surgeons and engineers can work together to improve the equipment for better tumor ablation in vivo. A virtual simulation of tumor heating would provide proper planning and potentially better antennae placement for more uniform heat distribution. The focus, as always, should be on safety as well as ease of use.

Retrieval studies can shed light on the healing process following limb salvage with microwave-induced hyperthermia. Canine models of osteosarcoma would be a great way to simulate the human tumors and study the microwave technology in situ, as well as the biology of healing after microwaving.

Limb salvage is moving towards closer resection margins [10], allowing

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for more biological reconstruction. For this technology to realize its full potential, however, more surgeons and centers outside of China need take an interest in the approach. New clinical trials backed by good research studies should be the first step.

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