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MRI Guided Cryoablation of Epidural Malignancies in the Spinal Canal Resulting in Neural Decompression and Regrowth of Bone

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Abstract

Percutaneous image-guided cryoablation allows more distinct ablation margins compared to heat-based ablation modalities. With MRI monitoring, the zone of cryoablation appears as a black ovoid area with sharp margins. This report describes the use of MRI to safely monitor the cryoablation of spinal epidural malignancies with successful decompression of tumor away from the spinal cord and regrowth of previously eroded bone around the spinal canal.

INTRODUCTION

Tumors in the epidural space that compress the spinal cord can be difficult to manage and often require multimodality treatment. In a randomized controlled study, patients who underwent surgical decompression and instrumented stabilization followed by conventional radiation regained and maintained ambulation, as well as having improved overall survival, compared with those undergoing radiation alone (1). Similarly, while stereotactic radiosurgery for metastatic spine disease has also been shown to be effective (2), close proximity of tumor to the spinal cord often limits the deliverable dose and thus surgery is often performed to separate epidural disease from the spinal cord and stabilize the spine with instrumentation prior to initiation of radiation.

Spine surgery with instrumented stabilization, however, carries significant risks, and recovery from surgery can delay the onset of radiation therapy. Recently, ablative techniques have emerged as a less invasive modality for reduction of tumors, but the risk of permanent neural injury is a concern when ablating tumors involving the central nervous system (3). One ablative technique is laser interstitial thermal therapy (LITT), which has demonstrated generally favorable results in a series of 19 patients (4). LITT involves the use of fluoroscopy to place fiberoptic cables against the spinal canal followed by ablation with MR thermal mapping to monitor temperature. A limitation to LITT, however, is the relatively low spatial resolution of MR thermal mapping compared to standard MR imaging. A potential alternative to LITT is MRI-guided cryoablation, which has the advantage of near-real-time

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imaging of the tumor, ablation zone, and involved neural structures. A small case series has recently demonstrated the feasibility of intraprocedural MR imaging to monitor the zone of cryoablation to protect major peripheral nerves adjacent to tumors (5).

In this report, we demonstrate that MRI-guided cryoablation is a feasible method for treating epidural tumors involving the spinal canal, with the result of regrowth of previously eroded bone in addition to neural decompression.

TECHNIQUE AND RESULTS

We present the medical imaging and records of 2 patients, a 34 year old male and an 80 year old female, who underwent MRI-monitored cryoablation of spinal epidural tumors in February and October 2017. Due to concern for risk of surgical morbidity given lack of neurologic deficits, surgery was determined to be not indicated in either case by a multidisciplinary tumor board consensus. This study was approved by our institutional review board.

Both procedures were performed in a multimodality image guided operating suite. Cryoablation was performed using IceSeed cryoprobes with the SeedNet cryoablation system (Galil Medical, Minneapolis, MN). General endotracheal anesthesia was administered by an anesthesiologist.

Patient 1 was a 34-year-old male with a history of scleroderma and associated pulmonary scarring. An area of scarring in the right lung lower lobe developed into a squamous cell carcinoma with metastasis to T6 involving the right vertebral body and posterior elements with extension into the epidural space causing cord deformity (Figure 1A) though asymptomatic. Cryoablation was considered over radiation due to radiation risk to the adjacent esophagus and over surgery due to pulmonary dysfunction. Bone access was obtained with an Arrow OnControl Power Driver drill (Teleflex, Limerick, Pennsylvania USA) with intermittent CT scans at low dose 80 kV/80 mAs/CTDI 1.49 mGy (Somatom Sensation 64; Siemens, Erlangen, Germany). Two IceSeed cryoprobes (175 mm length, 1.5 mm diameter, Galil Medical Inc, Arden Hills, MN) were placed in the drill tracts to the eroded vertebral body and the lamina with CT guidance. Growth of the zone of cryoablation was monitored with serial standard axial T2 weighted MRI TR 3000ms, TSE 100ms (3T Magentom Verio MRI system, Siemens, Malvern, PA) sequence reduced to 1 minute acquisitions to cover only the zone of cryoablation. Cryoablation was performed for 10 minutes at 20% power using argon gas followed by 10 minute active thaw with helium and finally a second 10 minute freeze also at 20% (Figure 1C). Post-procedure imaging after the probes were removed showed no complications such as hemorrhage. The patient was sent to the Post Anesthesia Care Unit and discharged home without need for analgesics about two hours later.

Patient 1 was shown to have decompression of his spinal canal on MRI as early as 5 days post procedure (Figure 1D). Previously eroded right vertebral body and posterior bony elements around the spinal canal (Figure 1B) was shown to regrow at one-month, three-months, and six-months (Figure 1E) post procedure, restoring bony support around the

spinal canal. Patient 1 remained tumor and symptom free at the treated site at one year follow-up.

Patient 2 was an 80-year-old female with resected right renal cell carcinoma who developed spinal metastases, the most concerning at T4 where the posterior bony elements were eroded with a large epidural component compressing the cord, greater on the left, causing moderate pain not controlled by medication. Due to the absence of focal neurologic deficits and morbidity of surgery, a consensus was made by spinal tumor board for ablation. Cryoprobe placement performed with axial and sagittal T2 weighted MR images without need for CT-guided drilling since the calcium of the posterior bony spine structures was eroded. Cryoablation with two IceSeed cryoprobes (175 mm length, 1.5 mm diameter, Galil Medical Inc, Arden Hills, MN) placed along the eroded lamina and pedicles with a 12 minute freeze at 20% power using argon gas followed by 10 minute active thaw with helium gas then 8 minute freeze at 20% (terminated early due to more rapid growth of ice ball near the spinal cord). Both cryoprobes were then pulled back to the more superficial soft tissue component with a 15 minute freeze at 20% power. Growth of the zone of cryoablation was monitored with serial 1 minute axial T2 weighted MRI sequence TR 3000ms, TSE 100ms (3T Magentom Verio MRI system, Siemens, Malvern, PA). Post-procedure imaging after the probes were removed showed no complications such as hemorrhage. The patient was sent to the Post Anesthesia Care Unit and discharged home without need for analgesics about two hours later.

Patient 2 had CT and MR imaging one month post procedure demonstrating both decompression of the spinal canal and regrowth of the previously eroded left pedicle and bilateral lamina (Figure 2). The moderate pain not controlled by medication reduced to mild pain at the site by six weeks post procedure and there were no neurologic deficits before or after the procedure.

DISCUSSION

This report describes the technical feasibility and early outcomes of percutaneous MRI-guided cryoablation of epidural tumors in 2 patients. Epidural tumor ablation was achieved in both patients without complication and with successful decompression of the spinal cord as well as regrowth of previously eroded bony support around the spinal canal.

The main advantage of cryoablation over heat based ablation modalities such as radiofrequency ablation is visualization of the edge of ablation, which can be monitored as a distinct black ovoid region on standard MR imaging. Although laser ablation is also MRI compatible unlike radiofrequency ablation, MR thermography yields less distinct imaging than standard MR imaging. Arguably cryoablation is less destructive than heat-based modalities, particularly at the very edge of the ice ball, which is at 0 degree Celsius as opposed to the center at -40 degrees. In these two patients we have seen that simply growing the ice ball to the edge of the tumor abutting the cord without getting margins beyond the tumor edge was sufficient to shrink the tumor away from the cord. One recent case series has demonstrated feasibility of cryoablation in spine tumors using CT guidance when using thermal protection techniques and nerve monitoring (6). Thermoprotective techniques

involve CT guided placement of a needle in the transforaminal epidural space and injection of carbon dioxide gas. That technique, however, appears limited by redistribution of gas throughout the epidural space rather than remaining between the tumor and relevant neural structure. Furthermore, that technique may not be feasible when epidural tumor invades or compresses central nervous system structures as in the two patients presented in this report.

The cryoablation zone, or ball of ice, is more clearly visualized on MRI than CT, particularly in bone where the high radiodensity of bone obscures visualization of a low radiodensity ice ball. MRI is also far better at visualizing the adjacent spinal cord. While MRI is more cumbersome in time and safety issues compared to CT, these issues can be overcome by using a single MRI compatible transfer table such that after CT guided drilling the patient can be transferred to MRI without repositioning or disruption of the cryoprobes. A limitation of the current transfer table is the lack of built-in MRI coils which, when coupled with cardiac and respiratory motion, results in lower spatial resolution in the thoracic spine. The latter issue has been addressed in subsequent patients by holding ventilation under general anesthesia for the less than one minute MR monitoring scans.

At our institution, when the multi-modality image-guided operating suite is not available, drilling is performed in a standard CT suite and then the patient is transferred to a standard MRI suite for placement of probes and cryomonitoring. The probes can be placed into the bony drilled tracts using serial MRI scans or by leaving a plastic angiocath sheath in CT after drilling and placing a sterile cover over the portion exposed on the skin. By using the MRI table with its built-in coils, spine imaging is of higher spatial resolution than with the transfer table. On the second patient, CT was not required for power drilling due to complete erosion of posterior bony elements, and cryoprobes were directly placed on the MRI table under MRI guidance; this procedure requires serial MRI scans as opposed to serial CT scans, but when the sequence is tailored to simply cover the probe such that the sequence can be performed in a minute or less, the added time is not procedurally cumbersome. When there is preserved bone in particularly challenging areas, such as sclerotic bone or thinned pedicles, we have found power drilling to afford greater control, but requires CT since there is not currently an MRI-compatible bone drill at our institution. Another advantage of CT for cryoprobe placement is the more precise definition of the needle relative to bony structures compared to MRI.

Another advantage of cryoablation over heat based modalities such as radiofrequency, microwave, and laser ablation is the reduced risk of injuring adjacent structures, such as carotid artery walls, leading to dissection and blowout, or central nervous structures which have no ability to regenerate. Heat based ablations carry a risk of swelling and inflammation secondary to vasodilation, which cryoablation may not have. Unlike with surgical resection or heat-based ablative modalities such as radiofrequency or laser ablation, there can be regrowth of previously eroded bone and return of cortex and marrow architecture.

Bone reconstitution has been described following fractionated radiation therapy (7) though the strength of this reconstituted bone is unclear and this modality can be limited when tumor is in close proximity to the spinal cord. A similar phenomenon of osteoblastic response has been described following system therapy with both chemotherapy (8) and

tyrosine kinase inhibitors (9). The mechanism by which bone regrowth occurs following cryoablation is not clear. Freezing temperatures may induce apoptosis, or programmed cell death, while preserving the inherent underlying bony and vascular architecture thereby allowing regeneration of the pre-existing tissues before cancerous erosion. Heat based ablations that burn the malignant tissue may also permanently eradicate the underlying vascular and connective tissue scaffolding required for regeneration, necessitating additional support with vertebroplasty (10). While there is limited literature regarding the strength of the reconstituted bone post cryoablation, neither patient has developed compression fracture at their sites with the first patient being more than one year post procedure. Furthermore, this imaging shows growth not of unorganized bone but restoration of the normal cortical bone lining the spinal canal with underlying cancellous architecture. The previously eroded posterior facet in the first patient is now somewhat hypertrophied compared to the normal side, but the restoration of cancellous to cortical architecture suggests that the spine at this site has been stabilized, obviating the need for posterior instrumented fusion. Cement was placed into the contralateral normal side to protect this marrow from tumor invasion and to provide stability while the bone was regrowing, but future studies may show this step to be unnecessary. Placement of cement into the zone of ablation would likely interfere with the regrowth of bone. For the second patient, while bony growth is seen at the previously eroded left pedicle and bilateral lamina, the normal architecture is not yet seen on the second patient, requiring longer followup as with the first earlier patient.

In summary, use of MRI guidance to monitor percutaneous cryoablation of epidural tumors in the spinal canal is a feasible treatment option with favorable early results demonstrating successful neural decompression in addition to regrowth of supporting bone, obviating the need for open surgical resection and instrumented fusion. Further research is needed to determine the duration of neural decompression and long term stability of the regrown bone.

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Figure 1.

34-year-old male with biopsy-proven lung carcinoma and solitary metastasis to T6 with epidural extension deforming the spinal cord. (A) Axial T2-weighted MR image demonstrates right T6 vertebral body and lamina mass with epidural extension deforming the anterior surface of the spinal cord. (B) Axial non-contrast CT image acquired in the procedure suite immediately prior to cryoablation demonstrates bony erosion of the posterior margin of the right vertebral body as well as the posterior lamina. (C) Axial T2-weighted MR image demonstrates two cryoprobes (arrows) at T6, one in the vertebral body and epidural component against the cord, the other in the eroded posterior elements. (D) Axial T2-weighted MR image 5 days post cryoablation demonstrates normalization of spinal cord and canal contours. (E) Axial non-contrast CT image acquired 6 months post cryoablation demonstrates regrowth of spinal canal cortex and lamina. Vertebroplasty cement is present in

the contralateral vertebral body. Vertebroplasty was performed at the time of cryoablation to provide structural support.

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Figure 2.

80-year-old female with resected right renal cell carcinoma who presented with a metastasis compressing the cord. (A) Axial non-contrast CT image in the OR immediately before MRI guided cryoablation demonstrates erosion of posterior bony elements at T4 with a large epidural tumor component compressing the cord, greater on the left. (B) Axial non-contrast CT image acquired 6 weeks post cryoablation demonstrates regrowth of bone.