Percutaneous Cryoablation of Chest Wall and Pleural Masses

- Percutaneous cryoablation is performed by freezing tissue with probes inserted under imaging guidance.
- Cryoablation is a minimally invasive, repeatable, and relatively pain-free procedure that can destroy malignant tissue and nerves and reduce pain.
- It is a treatment option for pain control for thoracic tumors including metastases, mesothelioma, recurrent thymoma, and schwannoma.
- It is most commonly used in poor surgical candidates who have metastatic, recurrent, or refractory tumors; or patients with lesions adjacent to critical structures.

The thorax is a common site for the development of metastases from many primary cancers (Figure 1). In addition, there are some rare thoracic cancers, such as mesothelioma and thymoma, that can spread along the pleura. In many of these patients, surgery is not an option secondary to the burden of disease or their general condition. Alternate methods of controlling tumor growth and reducing pain include radiotherapy and image-guided thermal ablation therapy.

Cryoablation, a form of thermal ablation that induces cellular death through freezing, has particular advantages for tumors in the chest wall, ribs and pleura. This minimally invasive technique involves the percutaneous insertion of one or more cryoprobes into the tumor and induction of freezing by the rapid adiabatic expansion of argon gas within the cryoprobe (the Joule-Thompson effect). The temperature immediately surrounding the probe(s) is reduced to as low as -160° C (Figure 2). By carefully placing multiple cryoprobes, an ice ball can be sculpted to match the shape of any tumor (Figure 3). The developing ice ball is visible with CT, MR, or ultrasound imaging, which, unlike other ablation procedures, allows for real-time monitoring of the procedure. After the ice ball is seen to extend 5-10 mm beyond the edge of the tumor, the tissue is allowed to thaw. The freeze/thaw cycle is typically repeated two or three times. After the final freeze cycle, the probe is heated by the rapid expansion of helium, whose physical characteristics cause it to warm, not cool, as most other gases do. Warming allows the ice to melt and the probe to be withdrawn from the patient.

The cytotoxic effects of freezing are associated with intracellular damage due to ice crystal formation and the development of osmotic gradients that dehydrate cells. These effects occur when the tissue temperature drops below -20° C. This temperature is quickly reached adjacent to the probe in the center of the ice but not in the periphery of the ice ball, which is why it is essential to extend ice ball formation beyond the edge of the tumor.
Thawing causes further cellular damage due to reperfusion injury, thrombosis, and vascular stasis. In addition, recent evidence indicates that cryoablation increases natural killer cell activity, T-cell responses, and systemic interferon gamma production, all of which may enhance immune responses in the region surrounding the kill zone.

Cryoablation has several advantages over other ablative therapies. As illustrated above, the size of the ice ball and its relationship to critical structures can be visualized in real time, which is not possible with radiofrequency or microwave ablation. Cryoablation is less painful than heat-based techniques because freezing induces numbness. It may be performed under conscious sedation or general anesthesia. Patients describe an initial feeling of mild discomfort, which rapidly disappears as adjacent nerve fibers are stunned or destroyed. Unlike radiation therapy or surgery, cryoablation can be easily repeated, multiple times if necessary, if the tumor re-grows or new metastases develop.

**Indications**
Cryoablation is primarily a palliative therapy that can be used to treat metastatic disease in the chest arising from many types of extrathoracic cancers as well as those from primary tumors in the chest, such as thymoma or mesothelioma. Osseous metastases are extremely common and are estimated to be present in over 80% of cancer patients at the time of death; such metastases commonly develop in the ribs. Pain control is a challenge in these patients; fewer than 50% report adequate pain control. Mesothelioma and thymoma also result in painful metastases in the pleura and chest wall. Cryoablation can be performed when tumors recur after prior surgery and/or patients have reached the maximum safe radiation dose.

Cryoablation has also been used to treat chest wall soft tissue tumors such as recurrent schwannoma that were too close to the spine for complete surgical resection.

Input from a multidisciplinary tumor board is recommended to select patients for cryoablation.

**Efficacy**
Cryoablation results in necrosis of both tumor and nerve cells, which allows the source and the sensation of pain to be treated simultaneously. Recovery is rapid, which makes it a very effective palliative treatment. Cryoablation has been shown to be an effective technique for treating malignancies in bones and lungs, both by reducing tumor burden and by providing significant pain relief.
In patients with mesothelioma and thymoma, cryoablation is an effective treatment when metastatic disease is not widespread. In a study of 24 mesothelioma patients who were treated with cryoablation to control limited recurrent local disease, the local control rate was >90%, and median survival was 11.4 months following initial cryoablation. In thymoma patients, cryoablation is associated with low rates of local recurrence within a one-year period. However, the effectiveness of cryoablation on long-term survival in these patients has yet to be determined.

**Complications**

Cryoablation is generally a safe procedure with few complications. However, precautions must be taken to prevent damage to vital organs and skin. For this reason, hydrodissection is used to displace vital organs to protect them from freezing. Skin is generally warmed by placing a glove filled with warm water over areas at risk of freezing. Although bleeding can occur if cryoablation injures blood vessels, larger blood vessels are generally not affected because of the heat-sink effect of blood flow. Pneumothorax and pulmonary hemorrhage are possible. Rib fractures are uncommon.

**Scheduling**

Radiologists in the Division of Thoracic Imaging and Intervention at Massachusetts General Hospital perform thoracic cryoablation at the main campus in Boston, in collaboration with the Divisions of Interventional and Musculoskeletal Radiology as needed. Appointments can be made through ROE (inside Partners network) or ROE Portal (outside Partners network) or by calling 617-724-XRAY (9729).

**Further Information**

For further information on cryoablation of thoracic tumors, please contact Florian Fintelmann, MD, Thoracic Imaging and Intervention, Department of Radiology, Massachusetts General Hospital, at 617-724-4254.

We would like to thank Florian Fintelmann, MD, Thoracic Imaging and Intervention; Ambrose J. Huang, MD, Musculoskeletal Radiology; Ashok Muniappan, MD, Thoracic Surgery; and Raul Uppot, MD, Interventional Radiology, Massachusetts General Hospital, for their assistance and advice on this issue.
References


Al-Tariq QZ (2014). Percutaneous strategies for the management of pulmonary parenchymal, chest wall, and pleural metastases. AJR. American journal of roentgenology 203:709-16


©2015 MGH Department of Radiology

Janet Cochrane Miller, D. Phil., Author
Raul N. Uppot, M.D., Editor