Radio Frequency Ablation

The Key to Cancer Treatment

MAUREEN McDANIEL SACKENHEIM, RDMS, RDCS

Radio frequency (RF) ablation is the latest and most promising treatment for nonsurgical cancer patients. This article will explain the history of how RF ablation was developed, moving us through the quest for larger ablations. It will take the reader step by step through the actual procedure; explain the different RF systems available; describe the physics of how RF ablation works and why it is preferred over other predecessors, such as cryoablation, microwave ablation, laser ablation, chemoablation, and ethanol ablation; and describe the pitfalls of each. It will also mention the reasons why ultrasonography is the most popular guidance method, while computed tomography is used for follow-up.

Key words: cancer, ablation, radio frequency, tumors

Radio frequency (RF) ablation is the newest technique in the quest to treat cancer. Currently, ultrasound is considered the best method of guiding the electrodes into the tumors, although computed tomography (CT) is used for follow-up exams. Sonographers may be asked to assist in this treatment by providing ultrasound guidance and by operating the generator and placing the grounding pads. This article will give the history and physics of RF ablation, compare it to other ablation techniques, and describe the RF ablation procedure in the treatment of hepatic tumors, thus preparing the sonographer to better understand what may be expected of him or her.

History

In 1891, it was found that RF waves could pass through liver tissue, causing an elevation in tissue temperature without causing neuromuscular excitation. This finding led to the development of an electrocautery and medical diathermy in the early to mid-1900s. It used alternating current with RF in

From Kettering College of Medical Arts and Bethesda North Hospital.

Correspondence: Maureen McDaniel Sackenheim, 5339 Dellbrook Drive, Fairfield, OH 45014. E-mail: maureensack@hotmail.com.

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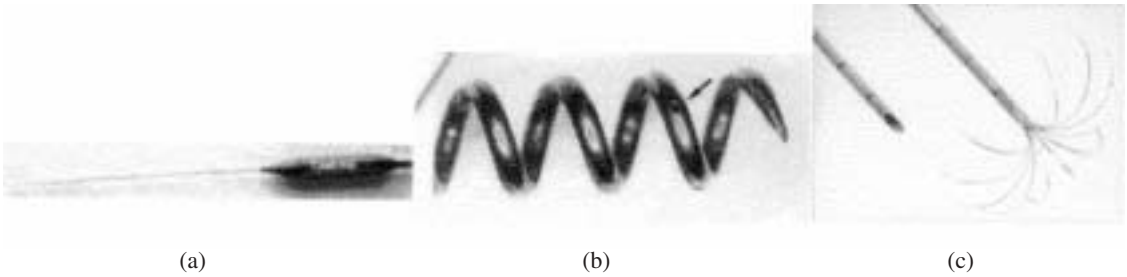

(a) (b) (c)

FIG. 1. (a) Cooled electrode. (b) Screw cannulated electrode. (c) Multiprobe electrode.[6]

its knifelike electrode to cauterize bleeding. This is when it was first documented that agitated ions cause frictional heat, but it was further realized that if high power was used, tissue would char.[1] Early studies on ex vivo porcine and bovine livers showed that we could use RF to necrose liver lesions.[2]

In the beginning, heating was too fast, causing charring and leaving underheated tissue in part of the lesion, thereby failing to necrose the entire tumor. Necrosing a lesion larger than 2 cm was also a problem. The quest was on to be able to cause necrosis of a bigger lesion, and different electrodes were subsequently developed.

Saline was added to the probe to keep it cool, prohibiting the tissue from "cooking" too fast.[3] This has been successful in leading to a larger area of necrosis and is still being used today by Radionics in their electrode (Fig. 1a).[1] Saline was also injected into the lesion before ablation, thus allowing a larger area of necrosis as well, because saline permits greater conduction of the electricity; however, this led to unpredictable sizes and shapes of necrosis. Then came a screw cannulated electrode (Fig. 1b), which allowed saline to be perfused into the lesion as it was being ablated,[4] and eventually the multiprobe electrode (Fig. 1c),[1] leading to a larger and more predictable area of necrosis. Finally, in October 1997, the FDA approved the RF ablation procedure using today's technology.[5] Patients now may have tumors up to 5 cm successfully ablated, but further electrode development promises ablation of even larger tumors. Currently, up to four lesions may be ablated during a single procedure, and RF ablation may be performed as needed thereafter for new metastasis.

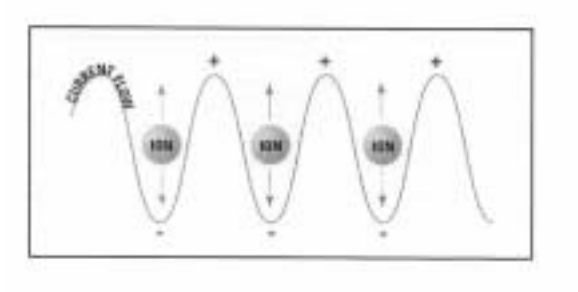

FIG. 2. A schematic of the ions trying to follow the path of the alternating current.

The Physics of RF Ablation

RF ablation is accomplished by sending high-frequency alternating current through an electrode with uninsulated tips. Because the tips are not insulated, the energy is allowed to travel into the targeted tissue surrounding the probe. The ions in this tissue then try to follow this same path of alternating current resulting in their agitation (Fig. 2), causing frictional heating within the tissue so that the probe itself does not become heated, only the tissue. Heating results in protein denaturation and a loss of intracellular fluids. Finally, the desiccated tissue loses its ability to conduct current. Some methods of RF ablation rely on the rising temperature of the surrounding tissue; one method relies on the rising impedance level of the tissue.[6] Impedance is defined by RadioTherapeutics[6] as "opposition to the flow of electrical current, measured in ohms." These methods will be discussed later.

Currently, all probes used are monopolar and require grounding pads to distribute the electricity to

keep the patient's tissue from charring. Progress is currently being made in the development of bipolar probes that would eliminate the use of grounding pads and the possibility of damage to the patient's skin and nontargeted tissue. Preliminary results show that the bipolar electrodes will cause necrosis of an elliptical shape rather than the current monopolar, spherical shape. Most neoplasms are spherical, and because it is preferable to necrose only the cancerous legion and a very small area of healthy parenchyma, bipolar electrodes may not be used any time soon.[3]

Other Ablation Procedures

Many other ablation techniques have been used with differing success over the years. Cryoablation is the oldest ablation technique used and the one associated with the most complications. It is also the most expensive to perform. This procedure relies on subfreezing temperatures delivered through cryoprobes circulating a cryogen. Tissue destruction happens at –20°C to –30°C. Patients must be able to undergo general anesthesia and have four or fewer lesions. Ultrasound is used to guide the probes, and most are performed intraoperatively. The most common complication has been bleeding, but others include fever, leukocytosis, and death.[7]

Another method, ethanol ablation, causes coagulation necrosis by causing the cells to become dehydrated. Dehydration then causes thrombosis and tissue ischemia. This is by far the least expensive but also the most unpredictable in size and shape of ablated tissue. While ethanol ablation has been successful in treating hepatocellular carcinoma, it has been ineffective in treating hepatic metastases, which are the most common liver tumors in the United States.[8] Contraindications to having this procedure include portal vein thrombosis, prothrombin time less than 40%, and extrahepatic disease. The numerous complications include peritoneal hemorrhage, hemobilia, liver abscess, and death.[7]

Chemoembolization has been elusive in finding the perfect combination of drugs to cause necrosis of the lesions, and the survival rates are dismal. Contraindications include portal vein thrombosis, biliary obstructions, cardiac or renal insufficiency, and others. The main complications are liver abscess and death.

Microwave ablation is similar to RF ablation, except that microwave ablation needs to be performed three times a week until complete ablation is reached. The survival rate is not as good as with RF ablation, and complications were more numerous including pleural effusion, hemorrhage, and abscess.

Laser ablation uses light at near-infrared wavelengths scattering within the tissue and converting light to heat to cause necrosis. The drawbacks include successful ablation of only 2 cm, tissue charring around the tip of the fiber, much more pain experienced by the patient, and survival rates less than RF ablation.[7]

RF Ablation Procedure

RF ablation is usually performed percutaneously on an outpatient basis under conscious sedation. It may also be performed laproscopically or intraoperatively under general anesthesia based on the size and locations of the lesions.[1,9]

Three US companies currently manufacture RF ablation systems. RITA Medical Systems, Inc. introduced an electrode consisting of a 14-gauge central needle housing seven to nine retractable probes, referred to as a "Christmas tree" electrode. Five of the retractable probes have thermosensors in their tips to monitor the temperature of the surrounding tissue. They use a 460-kHz generator, and successful ablation is determined when the targeted tissue reaches 80°C to 110°C.[10]

Radionics presents a single needle electrode with a thermosensor at the tip. Their generator uses 480 kHz, and successful ablation is determined when the temperature of the ablated tissue reaches 95°C to 105°C.[1]

RadioTherapeutics gives the ablation team an electrode similar to RITA Medical. The 14- to 15-gauge needle houses ten retractable prongs within and resembles an umbrella when deployed. Like RITA Medical, this system uses 460 kHz of power. These prongs do not have temperature sensors within them, as theirs is the only system based on impedance rather than temperature. As the tissue heats, the impedance of that tissue rises, making it more difficult to continue conducting the radio

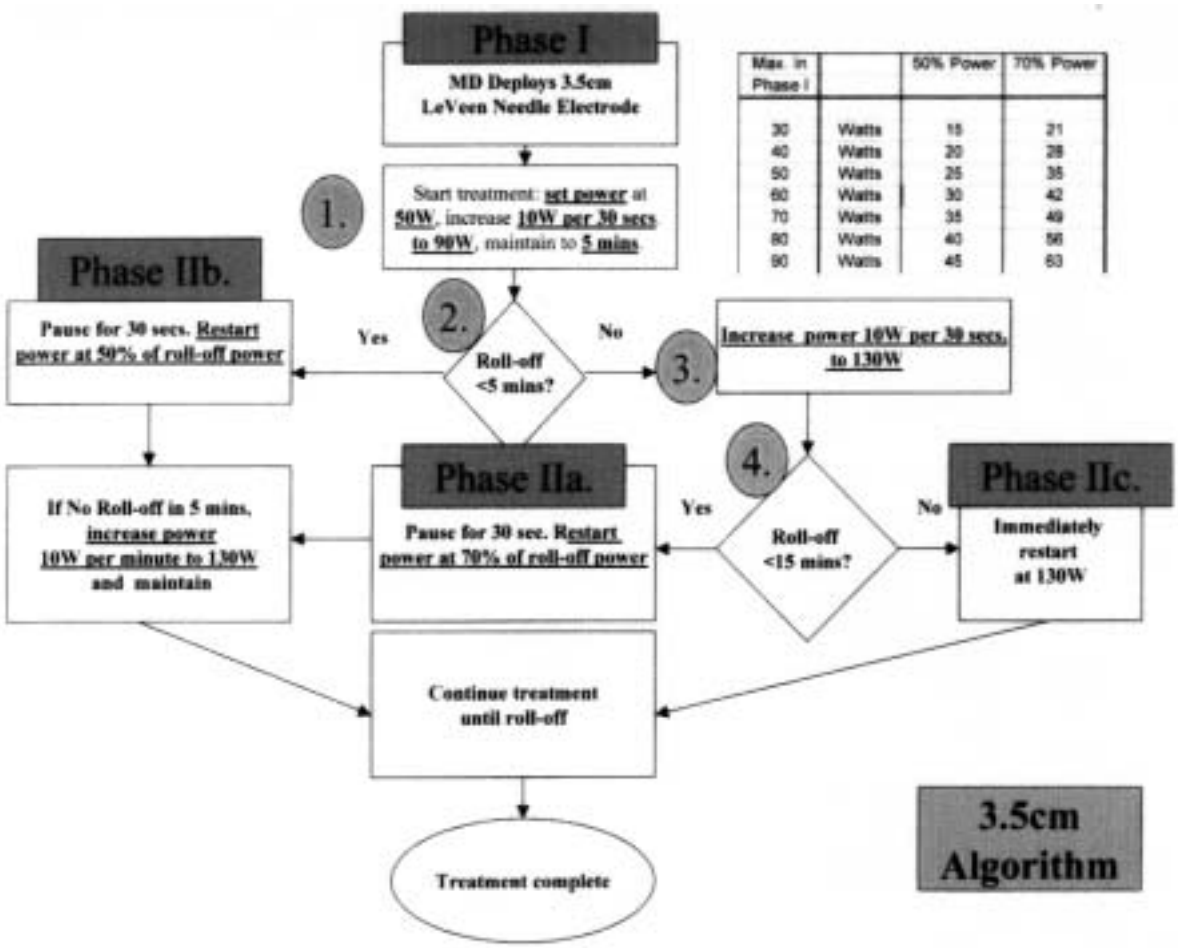

FIG. 3. This is the algorithm RadioTherapeutics uses for their 3.5-cm electrode. Different sizes of electrodes are used for both the RadioTherapeutics and the RITA Medical Systems, dependent on the size of the tumor needing ablation. The algorithms vary slightly from size to size.

waves. Ablation is complete when the impedance rises greater than 300 ohms, termed *roll-off*, at which time the power simultaneously falls.[6]

Each system has its own algorithms, and although they may seem overwhelming at first glance, taken step by step, they are quite simple to follow. An example of Radiotherapeutics's algorithm is shown in Figure 3.

The patient is told to have only clear fluids after midnight and nothing for 2 hours before the procedure.[8] First, grounding pads are placed on the patient's legs according to the manufacturer's instructions and connected to the generator. Then conscious sedation, such as verset and fentanol, are given. Next, the electrode is placed within the lesion, preferably with ultrasound guidance.[9,11] CT may be used, but the real-time capability of ultrasound is an incomparable advantage. Color Doppler may be used with ultrasound as well, ensuring that the electrode is avoiding any major blood vessels. When using CT, the interventional radiologist must wear cumbersome lead and expose the patient to radiation, and placement is more time-consuming and expensive than using ultrasound. Once within the tumor, the electrode is deployed (if using RITA Medical's or RadioTherapeutics's systems). The generator is then turned on, and following the algorithm, ablation is completed.

There is very little pain for the patient, unless the tumor is close to the Glisson capsule, which con-

tains a high concentration of nerves. If the diaphragm is injured during the procedure, the patient may experience some pain for about 2 weeks. The biggest risk is having the ablation infiltrate the bile ducts and gallbladder. The patient may be left on intravenous fluids for 4 to 6 hours, and bedrest is recommended for the rest of the day.[9] RF ablation is usually performed as an outpatient procedure. Patients may be sent home with a prescription to relieve pain, but most do not need the pain medication. The electrodes may be used for more than one tumor on the same patient, but they are not to be used from patient to patient. The cost of these disposable electrodes ranges from $500 to $1000 depending on the size of the electrode. Patients have follow-up CTs at 3 months, 6 months, 9 months, 12 months, and every year thereafter. CT is used rather than ultrasound because it can more accurately show the exact location for comparative purposes. CTs will show the ablated tissue decreasing in size over time as the body reabsorbs this necrosed tissue.[12]

Conclusion

RF ablation is being tried in many other new areas. It has been successfully used in treating osteoid osteomas,[3,9] renal cell carcinoma, breast carcinoma, lung cancer, pancreatic tumors, and thyroid and parathyroid glandular lesions.[3] The future offers the possibility of using it for prostate and adrenal cancers as well. Although surgical resection is still the gold standard, many are predicting RF ablation will eventually surpass resection as the recommended treatment because it offers the patient less pain, less expense, and a quicker recovery.

In the United States, there are 155,000 new cases of hepatic cancer every year. Twenty-five percent of patients with colorectal cancer have liver metastasis at diagnosis, and 50% develop metastasis within 5 years. Of all these patients, only one in eight is a surgical candidate.[8] In the past, we have treated nonsurgical patients with chemotherapy and radiation, although these methods have been ineffective. RF ablation offers us a very safe alternative to preexisting treatments in the never-ending quest to treat cancer.

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