Radiofrequency thermal ablation in the treatment of malignant tumors

An Essay
submitted for partial fulfillment of master degree
in general surgery

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2008

Abstract

Radiofrequency ablation (RFA) provides an effective technique for minimally invasive tissue destruction. An alternating current delivered via a needle electrode causes localized ionic agitation and frictional heating of the tissue around the needle. Image-guided, percutaneous ablation techniques have been developed in most parts of the body, but the most widely accepted applications are for the treatment of hepatocellular carcinoma (HCC) in early cirrhosis, inoperable colorectal liver metastases, inoperable renal cell carcinoma and inoperable primary or secondary lung tumors. The procedures are well tolerated and the complication rates low. Most treatments in the lung, kidney and for HCC are performed under conscious sedation with an overnight hospital stay or as a day-case. Limitations of RFA include the volume of tissue that can be ablated and most centers will treat 3–5 tumors up to 4–5 cm in diameter. Early series reporting technical success and complications are available for lung and renal ablation. Liver ablation is better established and 5-year survival figures are available from several centers. In patients with limited but inoperable colorectal metastases, the 5-year survival ranges from 26 to 30% and for HCC it is just under 50%. In summary, RFA provides the opportunity for localized tissue destruction of limited volumes of tumor; it can be offered to nonsurgical candidates and used in conjunction with systemic therapy.

Introduction:

Heat has been used in medicine as long as history. Ancient Egyptian medicine used heated metal bars and the Greeks used heated stones to stop bleeding. Electrocautery has been used for decades in surgery to fulgurate, cauterize, cut tissue, and to stop bleeding. The first experiment in radiofrequency ablation (RFA) of living tissues is credited to d'Arsonval, who demonstrated that an alternating electric current greater than 10 kHz could pass through living tissue without causing neuromuscular excitation.[1]

The radiofrequency (RF) thermal ablation works by converting RF waves into heat. A high frequency alternating current (100 to 500 kHz), mostly 460 kHz, passes from an uninsulated electrode tip into the surrounding tissues and cause ionic vibration as the ions attempt to follow the change in direction of the rapidly alternating current. This ionic vibration causes frictional heating of the tissues surrounding the electrode, rather than the heat being generated by probe itself. The goal of radiofrequency ablation (RFA) is to achieve local temperatures such that tissue destruction occurs.[2] The RF probe itself does not release heat and local tissue heating depends on the thermal conductivity of the tissue and distance from the probe. Dependent on time and tissue perfusion, coagulative necrosis occurs when the tissue is heated to a temperature greater than 60ºC.[3]

The radiofrequency device:

There are four RFA systems currently available. They differ in the power of the generator, the technique used to maximize treatment volumes, the size of the needles, and in the electrical parameters monitored to maximize energy deposition.[4] Two of the four systems (RITA Medical Systems, Inc. Mountain View, CA, and Radio-Therapeutics Corp. Mountain View, CA) use coaxially-deployed hooks or inner tines which expand into the tumor after the outer needle are placed into the tumor.[5] The third is Radionics System and requires a pump that perfuse chilled saline through the hollow ports inside the needles, Needle gauges are 17.5G.[1] The 4th, is Berchtold system: infuses normal saline to increase the burn, Berchtold system is the only vendor with FDA with MR-compatible probes.[6]

Guidance Techniques and Applications:

RFA is generally done in a room devoted to CT or ultrasound imaging. Each RFA treatment takes about 12 to 30 minutes and the total procedure will be completed in one to three hours depending on how many tumor sites have to be treated.[7] The RF needle electrode is advanced into the tumor to be treated via a percutaneous, laparoscopic, or open route. Accurate imaging is essential for successful in situ tumor ablation (Tumors that are not seen cannot be targeted). And the choice

of RFA approach should be individualized according to size, location of the tumor and patient's condition.[8]

Radiofrequency in the liver tumors:

Hepatocellular Carcinoma (HCC) is one of the most common solid tumors in the world and its incidence has sharply increased within last 2 decades. This rise has been attributed to the concomitant increase in patients infected with hepatitis C virus and hepatitis B virus.[9] The liver has a rich systemic and portal blood supply, providing a potentially abundant source of circulating neoplastic cells.[10] Nodular hepatomas are optimally suited for RFA as they are often encapsulated, soft tumors surrounded by firm cirrhotic parenchyma which increase the efficiency of thermal ablation and reduce risk of recurrence.[1] Ideal tumors are smaller than 3cm in diameter completely surrounded by hepatic parenchyma, 1cm or deeper to the liver capsule and 2cm or more away from large hepatic or portal veins, The choice of RFA approach should be individualized according to size, location of the tumor and patient's condition.[11]

Radiofrequency in the renal tumors:

Nephron sparing techniques such as partial nephrectomy have been shown to be as effective as the traditional total nephrectomy, while providing a reduced morbidity and better preservation of renal function.[12] several groups have explored local ablation techniques in early small renal cell carcinoma and RFA has been very successful.[13] Contraindications may include a poor life expectancy of <1 year, multiple metastases, or difficulty for successful treatment due to size or location of tumor. Large tumors (>5 cm) or tumors in the hilum or central collecting system are not typically recommended for RF ablation.[14]

Role of radiofrequency in lung cancer:

Lung tumors are well suited to RF ablation because the surrounding air in adjacent normal parenchyma provides an insulating effect, thus facilitating energy concentration within the tumor tissue, the lung RF ablation can be safely and effectively performed via a percutaneous, transthoracic approach.[15] Radiofrequency ablation can be equally well applied to small lung tumors, either primary or secondary. After completion of the procedure, a single expiratory scan is obtained throughout the thorax and viewed at a narrow window width to detect subtle pneumothorax.[16]

Recent applications of radiofrequency in surgery:

Recent applications of radiofrequency in surgery are the following: breast-conserving surgery to ablate the malignant tumor and surrounding margin of tissue,[17] locally advanced cases of pancreatic tumors,[18] sacral chordoma[19] and ablation for palliation of painful skeletal metastases.[20]

Conclusion:

RFA will likely play a significant role in the future in the treatment of the patients with both primary and metastatic hepatic tumors, renal cell carcinoma and lung cancer who are not surgical candidates. Radiofrequency ablation represents a relatively safe, quick and highly effective treatment and the best results of RFA are expected with tumor size lesion 3-5 cm. Laparoscopic procedure proved to be feasible with low rate of serious complications.

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