TUMOR ABLATION WORKSHOP 2003

More information on RFA, including patient information handouts @ www.cc.nih.gov/drd/rfa NIH RFA protocols: 1-800-411-1222

Thermal Ablation Overview: Radiofrequency Ablation and Hepatic Applications
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Ablation methods:
-Methods: Radiofrequency ablation (RFA), Percutaneous ethanol injection (PEI), Microwave, Laser, Cryotherapy, Focused ultrasound
-Do no harm: Know limitations, realistic goals, start in the liver
-RFA causes cell death by coagulation necrosis
-Heat effects upon tissue help predict ablation volume, avoid complications, and plan for clean treatment margins

Cryoablation has been used for many years during open surgery and is an effective method of tissue destruction. The ice ball may be easier than the RFA cloud to monitor with ultrasound, and cryo may be more effective in the ablation of tumor touching large blood vessels (speculative). However, RFA has less inflammatory response, less blood loss, fewer complications, and is easier to perform percutaneously due to the smaller probe size. However, several smaller cryo probes are recently available which may compare favorably with RFA (no studies to compare these). Microwave ablation may have theoretical advantages over RFA (if technical difficulties can be overcome) regarding uniformity and shape of thermal lesion. The thermal lesion heats up more uniformly, and is less dependent upon thermal conduction than RFA.

Percutaneous ethanol injection (**PEI**) has proven clinically effective in the treatment of hepatocellular carcinoma (HCC). Long term survival rates of PEI-treated patients with HCC are similar to those of patients treated surgically. The other ablative methods, including RFA, have only preliminary results, and long-term efficacy has yet to be proven by randomized, prospective trials. RFA may allow an increase in the rate of curative liver resection. RFA is superior to PEI for HCC, based upon higher necrosis rates in fewer treatment sessions than PEI, with similar complication rates, as reported by Livraghi, et al. However, PEI is certainly an acceptable method for smaller HCC's, when RFA is unavailable, or in specific settings making RFA higher risk.

PEI and RFA work better for HCC than for liver metastases. This is because most HCC occurs in the setting of cirrhotic liver disease. In this situation the tumor is "soft", whereas the surrounding liver parenchyma is "hard". This promotes the distribution of ethanol or heat within the tumor, particularly when the HCC is encapsulated. Patients with liver metastases typically have normal (soft) underlying hepatic parenchyma, whereas the metastasis is "hard", a situation which promotes the egress of ethanol from the lesion into the normal liver. Metastases also tend to be more infiltrative then HCC.

Possible dielectric differences allow large HCC to be more effectively and completely treated than large colorectal metastases to the liver, regardless of the ablation method. Most RFA clinical trials have concentrated on RFA of smaller hepatic lesions (< 3 cm), although RFA may be effective in the treatment of HCC **up to 5cm**, especially if encapsulated. Combining PEI and RFA, or **chemoembolization with RFA** for larger liver tumors may increase efficacy, but likely increase risk as well. The sequence and timing for combining chemoembo and RFA have not been characterized.

Laparoscopic RFA may also be useful for tumors in difficult locations, and a significant number of patients will have more liver lesions seen at open surgery by palpation and intraoperative ultrasound than on pre-procedural imaging. Laparoscopic RFA should be used if tumor margin will touch bowel. Tying off the portal triad during open RFA ("Pringle maneuver") markedly increases the ablation volume, and may allow RFA up to the edge of large vessels. The team approach with close collaboration with surgeons will give the best care; the percutaneous option is not always the best one.

RFA may be better than other ablative techniques because it is fast, easy, predictable, safe, and relatively cheap. Current and potential clinical applications include liver, kidney, adrenal, bone, lung, breast, neurolysis, debulking, and palliation. No consensus exists for liver RFA indications.

How does RFA work?

In RFA, a needle electrode (14-17.5 G) with an insulated shaft and a non-insulated or deployable distal tip is inserted into the lesion with imaging-guidance. The patient is made into an electrical circuit by placing grounding pads on the thighs or back muscles. The energy at the exposed tip causes ionic agitation and frictional heat, which leads to cell death and coagulation necrosis. If the tissue is too hot, vaporization and "charring" (like a burned hamburger with a raw center) may cause decreased energy absorption and less treated tissue volume. The impedence and / or temperature at the needle tip are monitored, and the generator output is adjusted to decrease "charring" and thus increase the volume of tissue treated.

The active tip may be different lengths or configurations. Ultrasound is most commonly used for guidance, followed by CT and lastly MR. MR may ultimately provide thermography, which may improve outcomes, although this is in the research phase. The procedure may be safely performed on an outpatient basis with local lidocaine (or bupivacaine) anesthesia, and conscious sedation with Midazolam, Fentanyl, and Droperidol. In large lesions, and high-risk or complex cases, some prefer general anesthesia and overnight observation. Each treatment sphere takes 10-30 minutes of RFA, with multiple spheres added together to overlap large or irregularly shaped lesions. At the end of a single session, the access tract may be cauterized on the way out, which theoretically decreases the risk of needle tract seeding or bleeding. This is possible on 2 of the 3 systems by turning down the output while dragging the needle slowly out, monitoring temperature. To decrease back-bleeding, injecting gelfoam pledgets using a coaxial sheath has been described for the 3rd system.

4 RFA systems:

There are 4 RFA systems currently available in the US. 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. Although temperature and impedance are measured in several of the systems, each uses one parameter to maximize treatment diameter, and each system has a specific algorithm for treatment, which requires varying degrees of operator input. The position of the needle in relation to the heat applied is important knowledge.

Two of the 4 systems (**RITA** Medical Systems, Inc. Mountain View, CA, and **RadioTherapeutics** Corp. Mountain View, CA) use coaxially-deployed hooks or inner tines which expand into the tumor after the outer needle is placed into the tumor. The RITA needle has Christmas-tree like hook-tines, and the Radiotherapeutics has equidistant umbrella-like tines. The coaxial systems have the advantage of keeping the treatment needle stationary if the target is particularly mobile, as might occur with deep breathing or with deep sedation in a lateral dome lesion approached from a caudal subcostal access. They also may deliver a more uniformly spherical thermal lesion. The tips of the RITA hooks have thermocouples that report real-time temperature at the treatment volume margin, as the tissue heats up, which automatically maximizes treatment volume. The Radiotherapeutics and **Radionics** systems rely predominantly on monitoring impedance to avoid charring at the needle tip. The Radiotherapeutics system algorithm treats the sphere until impedance maximizes or until a time limit is reached. The RITA or Radiotherapeutics needles may be partly deployed to treat smaller lesions, whereas the Radionics needles may have different size active tips to ablate smaller lesions.

The third system (Radionics, Inc., Burlington, MA) requires a pump that perfuses chilled saline through the hollow ports inside the needles (in a closed system). This decreases charring and vaporization, and thus increases ablation volume. The impedance-controlled pulsing technique allows the tissue around the needle to cool between energy bursts. This will automatically turn the current down to near-zero when the impedance rises > 20 ohms above baseline, and let the tissue cool before turning it back up to the appropriate level. Radionics also has a triad or triple parallel needles on one probe, which creates a 4-5 cm diameter treatment sphere. The Radionics system requires the most user input, and is a more difficult set-up, but also provides versatility, with different size active tips and different output adjustments able to treat small nerve ganglia or quite large tumors. The new RITA system has a 7 cm array probe that uses injected hypertonic saline to maximize thermal lesions. The **Berchtold** system infuses normal saline to increase the burn. The current Radiotherapeutics system gets a 4 cm lesion.

The Radionics generator has 200 watts maximum, whereas the Radiotherapeutics has 200 W (old one 90 W), RITA has 150, or 200 W models, and Berchtold has 50 W. Needle gauges are 17.5G for Radionics, 14G or 15G for RITA and Radiotherapeutics, and 14-16 G for Berchtold . Radiotherapeutics has a truly coaxial system that allows CT scanning with needles in place (without bulky hubs), and also multiple needle placement for treatment planning. However, placing needles in close proximity to a thermal lesion during treatment can alter the shape and size of the thermal sphere. There is also a

smaller G needle available for Radionics which may be used for nerve ganglia ablation, smaller applications, or thermometry. Berchtold is the only vendor with FDA-cleared MR-compatible probes. RITA also has a bendable probe which helps fit in the CT gantry, and a coaxial system for hard bone RFA.

The **RFA suite** is a typical interventional room with an RFA system. The ultrasound and the RFA generator must be plugged into different outlets with different circuits to avoid artifacts on the ultrasound monitor during treatments. Ultrasound-guidance may be the most common imaging guidance, and extensive percutaneous biopsy skills are required. However, needle placement location is more important than with biopsy, and must be precise to the mm. The factors influencing ablation volume have important treatment implications. Intra-procedural ultrasound contrast agents are under investigation (mainly in Europe).

RFA burn volume may be drastically altered by the **heat sink effect**, where blood perfusion (small or large vessel) cools nearby tissue, making untreated tumor more likely. Imaging follow-up is a difficult and subjective issue. The immediate post-treatment inflammatory granulation rind may be difficult, if not impossible, to differentiate from recurrence or untreated tumor. With dynamic MR and multislice CT, most residual tumor is evident by 6 months post-RFA. Tumor is more nodular or irregular than normal post-RFA rim. PET is probably better than MR which is better than CT for follow-up of liver RFA. The natural history of treated tumor / coagulation necrosis in the liver is slow shrinkage over the course of months to years, although scars may be permanent. Many centers image very early (procedure to 2 weeks), early (4 to 8 weeks), and quarterly for the first year, although this is widely variable.

Patient selection likely has a great impact on disease-free survival, and the variability in reported survival rates may partly reflect this. The technique is operator-dependent, and there is a steep learning curve, therefore one interventionalist's results or survival rates are not universal. The recent spread of RFA systems makes wise patient selection a necessity. Start with small, peripheral lesions centimeters away from vessels, porta hepatis, gallbladder, and colon. The liver is a forgiving organ in which to start.

Preprocedural evaluation includes biphasic CT, US, PT/PTT, CBC, Chem 12 w/ LFT's, markers (CEA, AFP), a hepatitis panel, EKG, CXR, and a type and cross. The most important step may be the US to plan the approach. The tissue down to the organ capsule is anesthetized, sedation or anesthesia is given, and a guiding needle may be placed, or the treatment probe itself. Treatment spheres are monitored with ultrasound such that overlapping spheres create a thermal lesion of coagulation necrosis encompassing the tumor and a 5-10 mm margin of normal tissue. This is the most difficult part of the procedure, and most beginners undertreat. Remember, it takes a lot morte spheres than you would think to envelope even a small lesion plus margins: It takes 14 x 3cm Spheres to get 3cm tumor + 1cm margin (See Dodd's article on treatment planning in AJR 2001 177:777-782).

Remove the grounding pads before sedation is gone, and bolus sedation just prior to applying current, but not so early to impair following breathing instructions. Capsular and diaphragmatic lesions as well as larger lesions or prior surgery in the area tend to cause more pain. Consider using general anesthesia for these.

One optimistic report suggests RFA yields complete necrosis of HCC's in over 85-90 % of cases in lesions smaller than 5 cm diameter in single sessions, with a low rate (< 10 %) of local recurrences. The same source reports 65-75 % complete efficacy in the control of local tumor growth in metastases not exceeding 4 cm. The reported rate of major side-effects or complications is anywhere from 2 % to 10 %, but most do not require surgery. Although local control may be attained in many patients with small tumors, most will develop metastatic disease at other sites. This tendency to gain local control with disease developing elsewhere may be due to the natural course of the disease. Certainly, results are directly related to patient selection, tumor type and location, and RFA technique. We are cautiously enthusiastic about the future of RFA, and will see whether these numbers withstand the test of time.

Interventional radiologists have the opportunity to be leaders in the development of emerging applications using this technology. The team approach is vital; the efforts of oncologist, surgeon, and hepatologist are often central to effective treatments. Although RFA is an evolving technique, initial results are promising. Careful patient selection is advisable until more standardized indications are developed. Long-term follow-up studies, further refinements in technique, as well as the combination of RFA with other treatments are all on the horizon. Start slowly and carefully.

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Frequently Asked Question's:

Where can I find more basic information?
http://www.cc.nih.gov/drd/rfa
Patient information, physician handouts, nursing care, cartoons, videos, publications, protocols.

Why RFA?
Cheap, safe, fast, easy and predictable. Fewer sessions than alcohol. Safer than cryotherapy percutaneously.

Can you ablate non-liver tissue?
Yes, if you are careful. Collateral damage may be more likely. Realistically define goals with patient and referring oncologist or oncologic surgeon. Ablation rules in the liver do not apply elsewhere. Burns can be very unpredictable. RFA has been applied to extra-hepatic sites such as lung [16], bones [17] kidney [18-23], breast, and adrenal.

Conscious sedation or general anesthesia?
Physician preference. Liver lesions on the capsule or diaphragm as well as larger tumors tend to be more painful, and may require general anesthesia. Ask the anesthesiologist to suspend respirations for needle placements. Toradol is useful for post-procedural pain, although only use one or 2 doses to limit renal toxicity.

Ultrasound or CT?
Physician preference. Precise needle location is vital. Occasionally, using both CT and US alternating may provide the best placement and monitoring during treatment. Ultrasound images 2 to 5 minutes after RFA may be more accurate in defining ablation volume than intraprocedural images. Use 50 cc contrast boluses during RFA as needed. MR thermometry may prove useful in the future.

How often to follow-up imaging? Physician preference. Same-day enhanced imaging is done to document treatments and lack of complications. Follow-up imaging depends on tumor (location, growth rate, histology, organ, concern for incomplete treatment). Most failures are evident by 6-12 months.

What to tell the patient for post-procedure care?

For a PDF patient handout, see:
http://www.cc.nih.gov/ccc/patient_education/procdiag/pra.pdf

Which system?
Physician preference. There are strengths and weaknesses to each, making the availability of all systems desirable, but often impractical. We have all 4 and choose based upon patient and tumor specific issues (location, importance of minimizing collateral damage, proximity of large vessels, desired treatment volume and shape, importance of uniform lesion formation, bleeding risk, respiratory motion, probe pathway, safe deployment). Low power systems (50-100 watt) are not as good, especially for high flow tumors or kidney tumors.

Is RFA FDA-approved?
The 4 systems each have FDA 510K clearance for "soft tissue ablation". To what this exactly applies is unclear. At least 2 of the 4 have similar clearance for unresectable liver tumors.

Hippocrates quote: What is not cured by the knife may be cured by fire. (But RFA is not yet an alternative or substitute to surgery).

What to do with the post-procedural fever? Low grade fever may occur in the first few days to a week after RFA, especially with large ablations. A mild post-RFA syndrome may occur, which is generally much less symptomatic than the typical post-chemoembolization syndrome or post-tumor lysis syndrome. Treat and culture fevers above 101.

What about prophylactic antibiotics?
Controversial - We use Ampicillin and Gentamycin, or Cipro and Flagyl pre-RFA and we follow up with a week of antibiotics (?Cipro or Augmentin) in patients with ascites or in patients with central or portal lesions or with large lesions, or with kidney tumors touching the collecting system. The only possibly RFA-related deaths we have heard of occurred from peritonitis in patients without antibiotic coverage. Abscess risk is increased in patients with prior hepatic artery therapy, biliary to enteric anastomoses and even with sphincterotomy. We broaden spectrum of coverage in these patients.

How about hydration?
Hydration pre- and post-procedure should be as aggressive as the patient's medical condition allows. Aggressive hydration may limit renal toxicity or ATN from contrast or tumor-lysis related phenomena, and may decrease the symptoms of post-embolization.

Contraindications?
Relative contraindications include tumor volume >50% of the liver, uncorrectable coagulopathy, abutment of bowel, porta hepatis or central location, and Childs class C.

What about central liver lesions?

There are more risks and complications associated with treating cholangiocarcinoma as well as centrally-located liver lesions. Large vessel abutment may also limit successful tumor eradication. Targeting vessels or balloon occlusion of the nearby hepatic vein may help.

Temperature vs. Impedance control?
Both temperature and impedance are very inter-related and reflect tissue cooking or overcooking in a similar fashion. It probably does not matter which method is used. Temperature information at the periphery of the thermal lesion (from thermocouples on the RFA probes or external thermocouples) may help to assess skip areas next to vessels from heat sink.

How to overlap spheres?
This is the hardest part of this procedure. More overlap is better than less. Spheres can be added in cylinders through the same capsule puncture, or in three dimensions with more than one puncture. Treat deep first, since boiling bubbles obscure on ultrasound. Get spatial information memorized before first burn obscures.

COOKBOOK
Radionics Cookbook:
Hook up all lines. Place needle to far end of desired thermal lesion. Turn on generator 1st, then water pump, after verifying temperature rise. Start with low current (100-800 mA) for a minute or two before ramping to higher current. In pulsing mode, the current max will take care of itself, based upon tissue impedance. Peak currents should be maintained for > 10 seconds. Treat for 12 minutes. Turn off generator and pump simultaneously and wait 30 secs for maximum temperature. This is usually 60 – 90 degrees C. If less than 70, then there is likely a vessel near the probe tip, and a repeat treatment in a slightly different area is required.

Tumor Size:	# ablations:	needle type:
< 1 cm:	1	2 or 3 cm single
1-1.5 cm:	1	3 cm single
1.6-2.5 cm:	1	triple cluster
2.6-3.5 cm	5–6	triple cluster
3.6 – 5cm	> 6	triple cluster

200 watt generator.

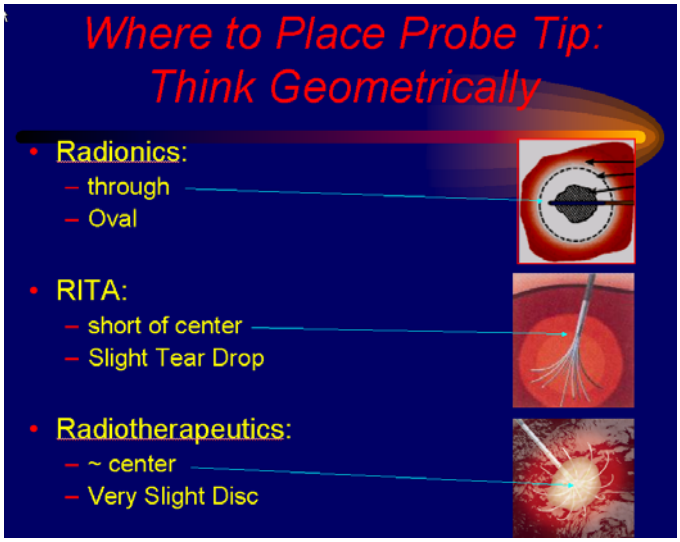
Radiotherapeutics Cookbook:
For RITA and RadioTherapeutics, use forward pressure to avoid outer needle "pull-back" during deployment. Deploy to test safety. Undeploy, then deploy hooks slightly proximal to the center of thermal sphere (can be done through coaxial outer needle if desired). RF current is applied according to protocol, until "roll-off" occurs at each sequential level of increasing power, or until the impedance rise in tissue indicates desiccation.
2cm, 3cm , 3.5 cm and 4cm probes available. 100 and 200 watt generators.

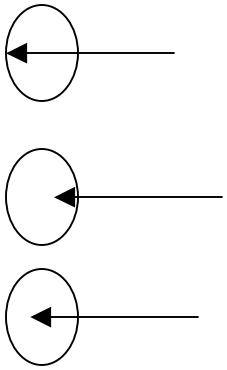
RITA Cookbook:

XL: Ensure safe full deployment. Undeploy, then deploy hooks in proximal part of thermal sphere in stages to 2,3,4,5…cm marks, with power set to 50, 70, 90, 110… watts, and target temp at 80, 105, 110, 110… and treat for time intervals or until target temperature is reached. If target temp not reached at any stage in 3 minutes, increase power by 20 watts. If target temp not reached, rotate probe to move out of vessel.
Xli is 7 cm sphere with 5% hypertonic saline pump into periphery of thermal lesion to increase thermal or electrical conductivity.
3, 5, 7 cm probes available. 50, 150, 200 watt generators.

Berchtold Cookbook:

Place needle, infuse normal saline 20-40 drops / min.





What are realistic goals?

Realistic Goals

Diameter (cm)	Complete Local Control
< 2.5	90 %
2.5-3.5	70-90%
3.5-5	50-70%
>5	<50%

Bone and Pain RF Ablation

RF has been applied to both benign and malignant bone tumors. The first use was for small painful benign osteoid osteomas [2]. Osteoid osteomas predominantly occur in

the pediatric age group and arise within the cortex of long bones. Most of these tumors require removal either by surgical or percutaneous methods. Occasionally, these tumors spontaneously regress. Surgical removal is the most expensive treatment and requires a cortical osteotomy with the accompanying risks of anesthesia, surgical wound complication and incomplete removal [2] A core of bone is removed with a bone-cutting biopsy needle. Once the overlying dense cortical bone has been traversed to the center of the osteoid osteoma a conventional (non-internally cooled) RF electrode is placed within the center. The internally-cooled RF electrodes are not needed in this application because the area of treatment is almost always under 10mm in diameter. A 6 minute RF energy application with the temperature maintained at 90 ^{0}C. is almost always sufficient to destroy the small central nidus of prostaglandin producing cells. The output in watts is typically less than 10 and the impedance is usually less than 150 ohms. The electrode is removed and a small bandage is applied to the skin. Cure with one session can be as high as 90% [2]. The ablated region of bone typically undergoes dimineralization after about 6 weeks. Healing of the thermocoagulation defect is slow and radiographic changes may take as long as one year.

Preliminary studies in malignant bone tumor RF is showing promise. Previously irradiated foci of tumor can be treated locally. Pain reduction, control of hemorrhage and local tumor eradication can be attained [13]. In areas where tumor abuts vital structures such as the spinal cord, RF may not be effective since local thermal injury may not be desirable. Spinal RF can be performed in the vertebral body when the cortex between the electrode and the spinal canal is intact [14]. RFA can be performed in conjunction with vertebroplasty. Cortical and cancellous bone are relative insulators of RF energy compared with soft tissue. The bone and pulsating cerebrospinal fluid between the spinal canal and vertebral body may act as heat sinks dispersing the RF energy.

In larger tumors a combination of RF and external beam radiotherapy may improve local recurrence rates. In theory, thermocoagulation of the central, less vascular tumor (often not effectively treated with radiation) with RF may make the peripheral well-oxygenated tumor more effectively treated with radiation. Large multi-center trials are being devised at the national level to evaluate the efficacy at pain control in sites of metastatic disease. ACRIN and Mayo are heading multicenter trials of RFA for bone tumors.

Renal Mass RF Ablation:

Recurrent malignancy in areas of prior radiation treatment, localized metastatic disease and primary neoplasms in patients who are poor surgical candidates can be approached with RFA. Possible advantages of ablative therapies compared to surgical resection is their anticipated reduced morbidity and mortality, low cost, and the ability to perform procedures repeatedly on an outpatient basis. Renal cell carcinomas are often incidental findings in older patients in which the standard of care has been total or partial nephrectomy [15]. The growth pattern in many renal cell carcinomas can be slow and the risk of metastasis variable [15].

Patient selection should include those with known contraindications to partial or complete nephrectomy due to cormorbid conditions or advanced age, and small tumor

burden. Centrally located masses may be harder to treat and the complication rate may be higher [21]. This is likely related to the higher blood flow in the renal hilum that prevents complete thermocoagulation due to a heat sink effect. Also, thermal injury to the central collecting system can cause urinoma.

CT and ultrasound are often used in combination to optimize probe positioning, especially for isoechoic small lesions. RF lesion size varies according to the size of the electrode, the current, duration of the treatment and the local blood flow. Renal cell carcinomas may require more treatment than their counterparts in the liver due to higher organ and tumor blood flows. The first placement of the RF electrode should be adjacent to the margin of tumor and normal cortex. This theoretically reduces the effective blood flow to the remainder of the mass, thus reducing any heat sink effect on subsequent ablations.

Complications in the kidney include hemorrhage, urinoma, abscess, paresthesias, transient hematuria, and pain. In our experience hemorrhage has not been an issue and if large central vessels are avoided any smaller vessels are thermocoagulated during the procedure. Ureteral stricture may occur with a tumor touching ureter.

Pain / Palliation:

Early reports show promise for RFA of painful soft tissue tumors that are recalcitrant to conventional radiation and pharmacologic therapies. Radiation therapy and opiates may be ineffective or suboptimal options for this difficult clinical problem, which may leave patients overly sedated or in pain during their last months of life . Our pilot study of soft tissue tumors for pain showed a high response rate between one week and one month following treatment. We treated painful tumors from the neck to the leg, including 26 tumors in 14 patients, with promising early results, however limited follow-up data. All 14 patients reported subjective pain relief verbally by one week following RFA with 6 of 14 reporting pain improvement one day following the procedure. This group was comprised of a myriad of histologies and locations, and tumor abutment to vital structures did not preclude RFA. In these cases however, extreme care was taken to avoid collateral damage to adjacent structures. Pain relief and debulking can be achieved without obtaining clean margins. An intramural NIH study has begun of RFA for recalcitrant soft tissue pain with quality of life and pain inventory questionnaires (see www.cc.nih.gov/drd/rfa).

RFA of nerve ganglia has been effective in the treatment of multiple pain syndromes including trigeminal neuralgia, celiac ganglion pain, cluster headaches, chronic segmental thoracic pain, cervicobrachialgia, and plantar fascitis. RFA has also been used for inflammatory, idiopathic, and tumor-related pain. Multiple minimally-invasive neurodestructive techniques have been safely applied for pain control, including radiofrequency lesioning, cryoanalgesia, and chemical neurolysis with agents such as phenol, alcohol, and hypertonic saline. Neurodestruction, decreased interstitial or intra-tumoral pressure, or decreased pressure upon adjacent structures may be the mechanism of pain relief in patients with focal tumor pain.

Lung:

First reported in 2000, RFA for primary and metastatic lung tumors is in its infancy. At RSNA 2001 and 2002, there were over 100 lung cancer patients reported treated with RFA, however results are widely mixed with local recurrence rates from 33 to 74 % in short term follow-up. Pneumothorax rates appear to be in the range of 10 to 20 %, with other complications less common, such as bleeding, fistula, hemoptysis, subcutaneous emphysema, effusions, fever, infection, and pain. One peri-procedural death has been reported from bleeding and one patient had a stroke, possibly related to cerebral embolism. The safety issues central to lung RFA have not been completely addressed or documented. Specifically, the theoretical risk of cerebral embolism must be addressed in an animal model or large number human study prior to claiming absolute safety. The lack of the usual lung filtering mechanism on the pulmonary vein side and the direct path to the arterial tree represents a major unanswered question for this application. Bubbles can be seen in the carotid artery during lung RFA, of unknown significance. Central tumors close to the hilum may present added risk for bleeding. Chest tube trays should be immediately available at the bedside. The addition of general anesthesia may make pneumothorax more likely. Unilateral intubation may help control bleeding in cases of excessive bleeding.

The surrounding air in adjacent normal lung parenchyma may provide insulation for the thermal lesion, making cooking easier or faster than in the well-vascularized liver. This technique may be used as an experimental adjunctive therapy to conventional chemotherapy and radiation in inoperable patients. Before this becomes as commonplace as liver, bone or renal RFA, safety and efficacy need to be addressed in a more rigorous fashion however.

Breast:

RFA for breast cancer is also in its infancy. Large prospective trials have shown there is no significant change in survival when comparing mastectomy and breast lumpectomy followed by radiation for most breast cancer patients. There has been a trend towards less radical interventions for biopsy and excision in the past decade. Whether this trend will extrapolate to treatment with RFA is another question. MR thermometry and improved detection of breast cancer with MR may make this a more accurate guidance method for RFA in the future.

RFA will have to render a near-perfect success rate to compete with surgical options. However, RFA may play a debulking role that may not be in direct competition with excision (RFA in combination with radiation). An Italian pilot study reported in Cancer, 26 patients withshaft of the needle. The exact role of RFA in the breast cannot be established before sufficient surgical excision data with pathologic correlation of margins is available.

Adrenal:

Treatment options for primary and metastatic adrenal tumors are limited. For adrenocortical carcinoma, chemotherapy and radiation therapy play a limited role. However, repeat surgical resection may prolong survival. Extrapolation from this data suggests that local adrenal tumor destruction with RFA may improve survival in select patients. We have treated 15 tumors in 8 patients with primary adrenocortical carcinoma with a high short-term technical success rate for tumors < 5 cm. Pheochromocytoma,

aldosteronoma, and metastases to the adrenal may also be treated with RFA, with the appropriate endocrine evaluation (and blockade for pheo).

Other organs:

RFA has also been attempted to a very limited degree in tumors of the prostate, pancreas, brain, thyroid, parathyroid, lymph nodes, bronchus, bowel, retroperitoneum, renal collecting system, pelvis, spleen, head and neck, and bladder. Each location has unique limitations and risks and should not be undertaken without a thoughtful review of existing options and potential complications. Nerves, vessels, or ducts near the field represent a common scenario. RFA of the capsule-free pancreas may predispose to pancreatitis for example and prostate RFA may cause outlet obstruction.

As with many of the extra-hepatic applications, upfront consultation with other medical, surgical, oncology, radiation therapy, pain and palliative care specialists is paramount to successful achievement of realistic goals. One of the most important considerations is knowing when to say, "No"

More information on RFA may be found at: www.cc.nih.gov/drd/rfa

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Alcohol Ablation / Injectables (PEI):

Techniques and Results

A multi-side hole, conical tip needle (Bernardino, Cook, Inc) is useful due to it's improved tip echogenicity and linear tracking. Rex medical also is evaluating a deployable array for injectable therapies, such as alcohol, chemotherapy gels (like cisplatin – Matrix pharmaceutricals), or acetic acid. Acetic acid spreads across fissures better than alcohol.

The total volume of ethanol for a given tumor is estimated as $4/3\Pi(d/2+0.5)^3$ where d is the tumor diameter, however this assumes liquid completely displacing solid, which of course does not occur. For lesions less than 3-5cm in diameter and less than 3 in number it has generally been applied as a multi-session outpatient procedure with 2-3 sessions per week until the entire volume is treated. The needle is placed within the tumor and ethanol injected as 0.2-0.4ml mini-boluses to the predetermined amount while observing the hyperechoic diffusion of ethanol sonographically within the lesion. The needle position is changed during subsequent sessions until the whole tumor is treated. Typically 5-10 ml is injected per session, but somewhat larger volumes have been well tolerated.

Some authors have proposed a synergistic effect between central tumor ablation by alcohol or thermal energy and peripheral tumor therapy via chemoembolization. The devascularization accomplished by PEI has also been advocated as facilitating thermal ablation techniques by decreasing thermal energy dissipation by flowing blood. These theoretic synergies remain unproven with regard to effectiveness and patient survival.

Table: 3 & 5 year survival for PEI

Category	1 year	3 year	5 year
Child A class, d<5cm	98 %	79 %	47 %
A, #<3, d<3cm	94 %	68 %	36 %
A, d=5-8 cm, encapsulated	72 %	57 %	na
d>5cm infiltrating, multiple	73 %	42 %	na

A-Child class A, d- diameter, #- tumor number, na – not available

A typical outpatient protocol

Suitable lesions: <3-5 cm HCC
Approximate Ethanol volume: $4/3\Pi(d/2+0.5)^3$

Materials:
Dehydrated ethanol 98% (Faulding pharmaceuticals, NJ)
5cc Syringe with connecting tubing
21ga needle (PEIT needle or Chiba)

Diameter	Volume
1 cm	4.2 ml
2 cm	14.1 ml
3 cm	33.5 ml
4 cm	65.4 ml
5 cm	113 ml
6 cm	180 ml

1. Localize lesion and clean overlying skin
2. Under US guidance place 21 ga needle into lesion
3. Inject ethanol slowly as 0.2-0.4ml boluses every 10-20 sec.
4. Observe hyperechoic ethanol diffusion. Reposition needle as needed.
5. Slowly withdraw needle 30-60 seconds after injection complete
6. Observe for 1-2 hours post injection. Oral analgesiscs as needed.
7. Each treatment cycle typically is 3-6 injection sessions with 5-10ml injected per session.