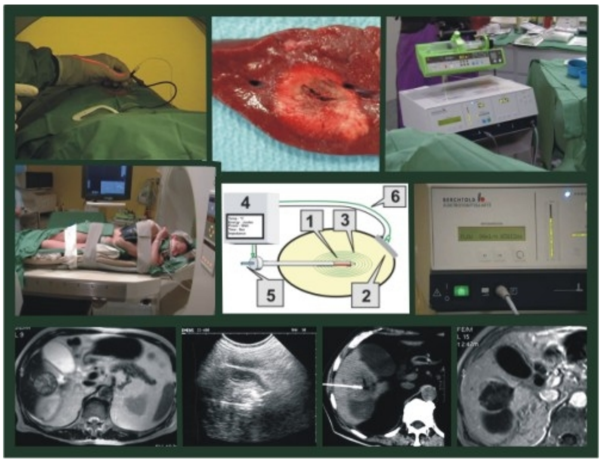
Radiofrequency liver tumor ablation with a novel wet electrode under CT and ultrasound guidance (RSNA 2001, ECR 2002)



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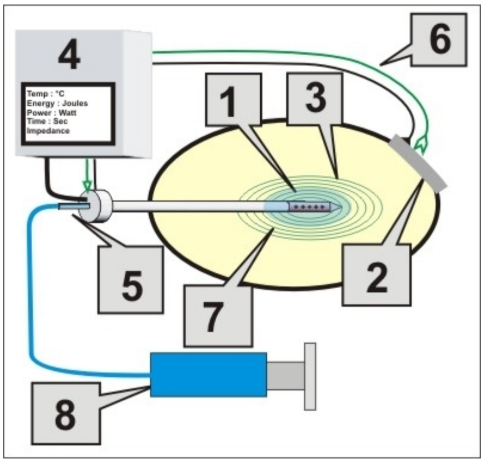
1) Introduction and Principle

- Radio-frequency ablation is the most promising minimally invasive technique used for tumor ablation. Current clinical experience suggests that it is effective, safe, and relatively simple. With this method, high-frequency alternating current is delivered to the tissue via a needle electrode.
- The electric current agitates the ions in the tissue around the tip of the electrode, creating heat, which leads to localized coagulation necrosis. The main destructive effect of this method occurs because the deposition of electromagnetic energy induces thermal injury to the tissue.



- 1. Needle probe
- 2. dispersive electrode (ground pad)
- 3. RF field
- 4. RF device
- 5. 7. 8. saline infusion
- 6. closed loop

Radio-frequency with a wet probe

- Basically, the term radio frequency refers not to the emitted wave but rather to the alternating electric current that oscillates in the range of high frequency (200-1,200 kHz). Schematically, a closed-loop circuit is created by placing a generator, a large dispersive electrode (ground pad), a patient, and a needle electrode in series. Both the dispersive electrode and needle electrode are active, while the patient acts as a resister. Thus, an alternating electric field is created within the tissue of the patient. Given the relatively high electrical resistance of tissue in comparison with the metal electrodes, there is marked agitation of the ions present in the tumor or liver tissue that immediately surrounds the electrode. This ionic agitation creates friction within the body and thus heat, which can be tightly controlled through modulation of the amount of radio-frequency energy deposited. The nature of the thermal damage caused by radio frequency heating is dependent on both the tissue temperature achieved and the duration of heating. Tissue and cells become more susceptible to chemotherapy or radiation when their temperature is increased to 42°C (i.e., hyperthermia), and heating tissues at 45°C for several hours produces irreversible cellular damage. Heating of tissue at 50°-55°C markedly shortens the duration necessary to irreversibly damage cells to 4-6 minutes. Near immediate coagulation of tissue is induced at temperatures between 60°C and 100°C and is manifest as irreversible damage to mitochondrial and cytosolic enzymes of the cells. At more than 100°-110°C, tissue vaporizes and carbonizes.

In vitro Radio frequency ablation under MR guidance. Visualization of the coagulation area

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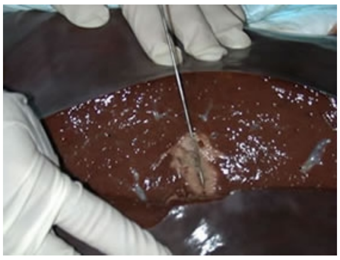
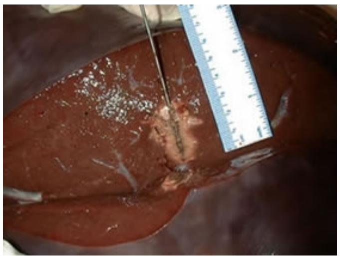


In vitro Radio frequency ablation under MR guidance. Visualization of the coagulation area



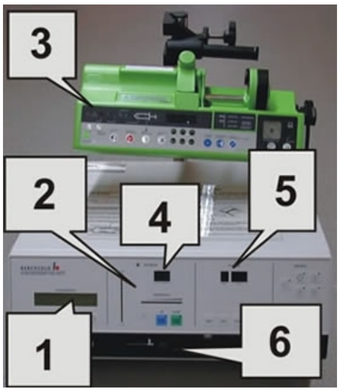
In vitro Radio frequency ablation under MR guidance. Visualization of the coagulation area

2) Material

- Sterile drapes, towels
- 22-gauge needle for anesthesia, scalpel
- Iodine, 1% lidocaine
- CT scan (Volume Zoom siemens®) and / or Sonography
- Radio Frequency device (Berchtold®) and needle

Radio-frequency device with injection of continuous saline

Radio-frequency device with injection of continuous saline



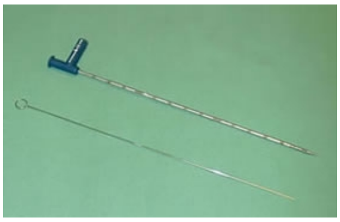
1-Monitor of Energy and temperature.
2-Impedance control
3-Injector for continuous injection of saline

4-Power
5-Timing
6-Needle electrode input

Ground Pad attachment

Procedure performed under general anesthesia and CT-guidance

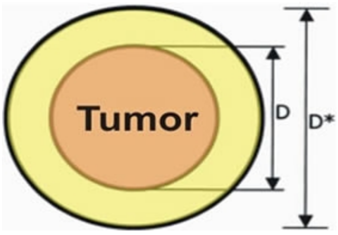
Needle electrode



Needle electrode with saline infusion at the tip

RADIO FREQUENCY DEVICES

For adequate destruction of tumor tissue, the entire volume of a lesion must be subjected to cytotoxic temperatures. Hence, effective heating throughout the target volume (i.e., the tumor and 5- to 10-mm thickness of normal tissue) is required. Thus, an essential objective of ablative therapy is achievement and maintenance of a 50°-100°C temperature throughout the entire target volume for at least 4-6 minutes. However, the relatively slow thermal conduction from the electrode surface through the tissues increases the duration of application to 10-30 minutes. Tissues cannot be heated to greater than 100°-110°C without vaporizing, and this process produces significant gas that both serves as an insulator and retards the ability to effectively establish a radio-frequency field. The vaporization or carbonization around the electrode tip can also retard heat conduction within the tissue, often in an asymmetric fashion. This process coupled with the rapid decrease in heating at a distance from the electrode essentially limits the extent of induced coagulation to no greater than 1.6 cm in diameter. Many investigators have explored and several corporations have manufactured new radio-frequency ablation devices based on technologic advances that increase heating efficacy. To accomplish this increase, the radio-frequency output of all commercially available generators has been increased to more than 150 watts, which may potentially increase the intensity of the radio-frequency current deposited at the tissue. Expandable electrodes permit the deposition of this energy over a larger volume. In addition, this design decreases the distance between the tissue and the electrode, thereby ensuring more uniform heating that relies less on heat conduction over a large distance. Alternate strategies to increase the energy deposited from a single radio-frequency electrode have also been developed. The internally cooled electrode design minimizes carbonization and gas formation around the needle tip by eliminating excess heat near the electrode. The removal of this heat by a "heat-sink" effect of flowing fluid in the electrode permits increased energy deposition and deeper tissue heating. Preferential cooling of the tissues near the electrode allows heating of tissues farther from the electrode when high radio-frequency current is being applied. A combined approach that involves use of a multiprobe cluster of internally cooled electrodes with pulsing has also been described with the claim of even greater coagulation than that achieved by any of the individual methods alone. Viewed in total, these technologic developments can be used to create an ablation lesion with a maximum diameter of 5.0 cm. We are using a new commercially available device using a single probe system with continuous infusion of saline without exceeding a 110°C maximum temperature threshold (60W, Berchtold®/ Germany). The continuous infusion of saline at the tip of the needle allows to increase heat and electrical conductivity. The Berchtold® radio frequency device relies on an electrical measurement of tissue impedance to determine that tissue boiling is taking place. The impedance rises can be detected by the generator, which can then reduce the current output and increase the saline flow. Injection of NaCl solution during RF ablation can increase energy deposition, tissue heating, and induced coagulation. Radio-frequency ablation is limited, however. With currently available devices, the largest focus of necrosis that can be induced with a single application is approximately 4-5 cm in greatest diameter. Thus, the diameter of suitable lesions must be less than 3-4 cm. Other limitations are the proximity of the tumors to large vessels, which may prevent adequate heating, as well as proximity to central bile ducts, which predisposes the patient to a risk of biliary complications. Finally, treatment of superficially located tumors carries a risk of injury to adjacent organs.



For a successful tumor ablation, a 1-cm-thick tumor-free margin around each tumor must be achieved.

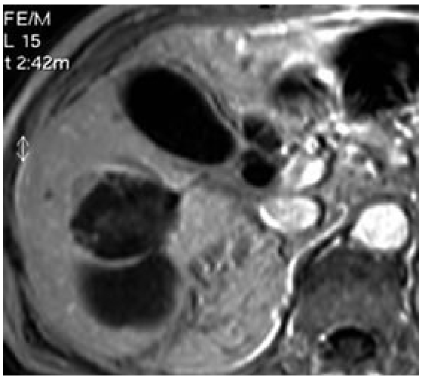
3) Methods

- 109 liver tumors were treated with radiofrequency ablation with a wet electrode under simultaneous control of impedance and temperature (Berchtold®, Tuttlingen, Germany). The study included 39 colorectal metastases (age of patients: 41-77 years old), 12 breast cancer metastases (age of patients: 44 -64 years old) and 58 hepatocellular carcinomas (HCC) (age of patients: 52-81 years old). The 18 to 16 gauge electrodes contain a coaxial lumen that enables a saline (0.9 %) interstitial infusion (1 ml/min, 40 W during 10 min).
- The volume of NaCl injected depends on power and impedance. If the impedance is high at the beginning of the procedure, the needle position should be modified. If the impedance is still high, 10% NaCl can be used. The NaCl concentration had significant but nonlinear effects on electrical conductivity, RF deposition, and heating.
- The Indications were:
  - Curative: HCC and colorectal liver metastases up to 4 cm in diameter
  - Palliative: HCC and colorectal liver metastases bigger than 3 cm in diameter
  - All solitary metastases resisting to conventional therapy
- Ten days after the procedure, the patient underwent the initial MRI control. After complete necrosis of the tumor, a control MRI was performed every 3 months the ablation areas were analyzed for overall conspicuity, presence of hemorrhage, enhancement patterns, and presence of residual tumor and its pattern.

hepatocellular carcinoma

Radio frequency, ultrasound monitoring

CT control



MR evaluation: nodular pattern incomplete ablation

4) Radiofrequency technique

Treatment Guideline for High frequency induced Thermo ablation

Option 1			
	Power-Setting(Watts)	Duration(minutes)	Observation
Start	40	1	Patient doesn't feel pain and Impedance is steadily lower than 400 Ohms (max. 4 LED on the display)
Second step	50	10	Patient doesn't feel pain and Impedance is steadily lower than 400 Ohms (max. 4 LED on the display)
Third step	Reposition of the needle		

Option 2			
	Power-Setting(Watts)	Duration(minutes)	Observation
Start	40	1	IF Patient feels pain and / or Impedance is steadily higher than 500 Ohms (5 - 10 LED on the display) THEN STOP
Second step	Reposition of the needle		

Option 3			
	Power-Setting(Watts)	Duration(minutes)	Observation
Start	40	1	Patient doesn't feel pain and Impedance isn't steadily higher than 400 Ohms (max. 4 LED on the display)
Second step	50	10	IF Patient feels pain and / or Impedance is steadily higher than 500 Ohms (5 - 10 LED on the display) THEN STOP
Third step	40	10	Patient doesn't feel pain and Impedance isn't steadily higher than 400 Ohms (max. 4 LED on the display)
Fourth step	Reposition of the needle		

Option 4			
	Power-Setting(Watts)	Duration(minutes)	Observation
Start	40	1	Patient doesn't feel pain and Impedance isn't steadily higher than 400 Ohms (max. 4 LED on the display)
Second step	50	10	IF Patient feels pain and / or Impedance is steadily higher than 500 Ohms (5 - 10 LED on the display) THEN STOP
Third step	40	10	IF Patient feels pain and / or Impedance is steadily higher than 500 Ohms (5 - 10 LED on the display) THEN STOP
Fourth step	Reposition of the needle		

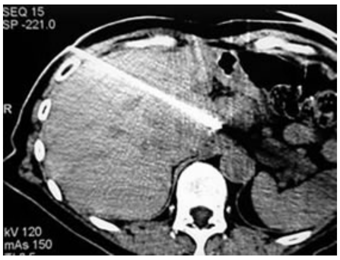
- Needle Retraction after Treatment: we use a 25 Watts setting and retract the needle-applicator within 20 - 30 sec. all along the track (5 mm/sec). We switch off the flow during the coagulation.
- We do not coagulate directly the capsular region
- Grounding Pads, Neutral Electrodes: for applications up to 45 Watts we use one pad (as close as possible to the needle). For applications from 50 to 60 Watts we use two pads (as close as possible to the needle).
- Multiple Punctures: In the case several punctures for one tumor are necessary, the distance between two or more punctures should be approximately 20 mm.

5) GUIDANCE

Radio-frequency ablation is performed percutaneously. Inaccurate targeting is probably the major reason that tumors are under treated, as opposed to inadequate energy deposition or thermal convection. The radio-frequency needle may be placed with US, CT, or MR imaging guidance. The guidance system is chosen largely on the basis of operator preference and local experience. Although acoustic shadowing due to nitrogen bubbles and obscuration of the US image by the radio-frequency current are major disadvantages. We are using routinely for liver and bone tumors ablations the CT guidance. The most important difference between surgical resection and radio-frequency ablation of hepatic tumors is the surgeon's insistence on a 1-cm-wide tumor-free zone along the resection margin, which for all but the smallest of lesions can be difficult to achieve with a single radio-frequency application. Failure to adhere to the surgical principle of obtaining at least a 1-cm-wide tumor-free margin will result in an unacceptably high rate of local tumor recurrence. Another important factor that affects the success of radio-frequency thermal ablation is the ability to ablate all viable tumor tissue and an adequate tumor-free margin. To achieve rates of local tumor recurrence with radio-frequency ablation that are comparable to those obtained with hepatic resection, physicians must produce a 360°, 1-cm-thick tumor-free margin around each tumor. This cuff is necessary to assure that all microscopic invasions around the periphery of a tumor have been eradicated.

Procedure performed under CT-guidance

CT control of the needle position



Precise CT-guidance

6) CT examination :

The advances in multidetector CT, have given the radiologist unique imaging capabilities that provide the opportunity to revolutionize the evaluation of liver tumors. The use of subsecond multidetector CT with ability to acquire multiple well-timed sets of image data has increased the ability to detect hepatic tumors and recurrences after treatment. A minimum of two phases of data acquisition are needed: an arterial phase (25-30-second delay) and a (portal) venous phase (60-second delay). CT examinations of the liver for suspected metastatic or primary tumor are performed with a multidetector CT (Somatom Volume Zoom/ Siemens) 2.5-mm collimation and reconstruction thickness (mm)/interval (mm) of 5/5 or 5/3. Computed tomography (CT) is used most frequently to determine whether the ablation is complete and to screen for early recurrences that may benefit from reablation. Complete ablation creates an area of necrosis that, at CT, is of low attenuation compared with the surrounding liver tissue, is often homogeneous, and has smooth margins. The disadvantages of CT are: potential radiation dose, the need of contrast-agent injection with it's usual inconvenient, timing of scanning is more critical as the increased speed of multidetector CT narrows the "temporal window" for desirable phase of enhancement.

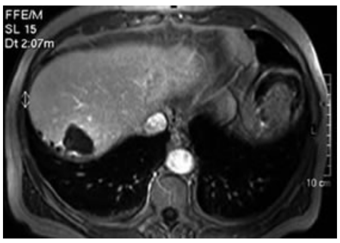
Successful treatment of a small metastasis from colon cancer. Contrast-enhanced CT scan obtained 10 days after RF ablation with insertion of a single infused electrode shows a hypoattenuation without contrast enhancement, suggestive of a complete response.

Treatment of a large HCC lesion. Transverse contrast-enhanced arterial phase CT scan obtained 10 days after radio-frequency ablation shows an ablation defect with a diffuse, ill-defined enhancement around the defect. These findings are indeterminate.

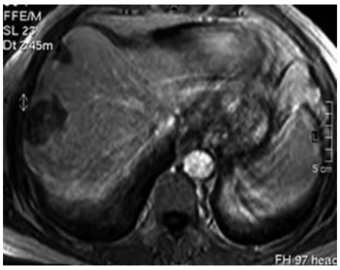
7) MRI examination:

Major technical advances in MR imaging have led to its wider use in the evaluation of cancer patients. MR imaging is a powerful tool in the evaluation of primary liver neoplasms. Determination of tumor extent and tissue characterization is provided with standard spin-echo T1- and T2- weighted imaging and is enhanced by the application of advanced sequences such as gradient-echo, fast spin-echo, and fat suppression techniques. Intravenously administered contrast agents, such as gadopentenate dimeglumine provides additional opportunities for lesion characterization. Fat-suppressed T1- weighted imaging with dynamic gadolinium enhancement has also yielded results comparable with those of contrast-enhanced CT. Dynamic hepatic arterial-phase contrast material-enhanced imaging is essential with both CT and MR imaging. Biphasic contrast material-enhanced dynamic MR imaging is an important technique for evaluating liver and bone disease. However, in the liver several potential diagnostic pitfalls may be encountered, including lobar, segmental, subsegmental, and subcapsular hyperperfusion abnormalities; early-enhancing pseudolesions, particularly in the medial segment of the left hepatic lobe; heterogeneous hyperperfusion abnormalities throughout the liver; and hypointense pseudolesions due to vascular artifacts, unenhanced hepatic vessels, partial volume artifacts, magnetic susceptibility artifacts, and regenerative nodules in cirrhosis.

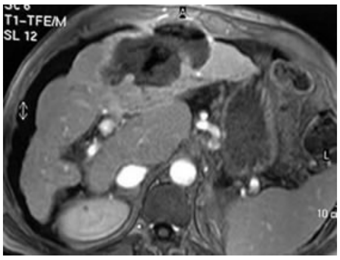
These abnormalities sometimes have appearances similar to those of true lesions or tumor spread to the surrounding liver parenchyma on arterial-dominant phase dynamic MR images. In most cases, however, no corresponding abnormalities are seen with other pulse sequences or on delayed-phase MR images. Recurrence of hypervascular tumor tissue may sometimes be seen only during the arterial phase of a multiphasic protocol. This fact emphasizes the importance of scanning technique. Arterial-phase images are most useful for evaluating hypervascular hepatomas, and hypervascular bone metastases (thyroid cancer, renal cell carcinoma) whereas differentiation of coagulated areas from hypoattenuating tumor tissue is usually easiest with images obtained during the (portal) venous and equilibrium phases in patients who undergo treatment for hepatic and bone metastases. MR imaging was used to determine whether the ablation is complete and to screen for early recurrences that may benefit from reablation. Complete ablation creates an area of necrosis that, at MR imaging, is of low signal intensity compared with the surrounding tissue, is often homogeneous, and has smooth margins. Precontrast T1-weighted spoiled GRE images were acquired in the transverse and coronal planes, and T2-weighted fat-saturated turbo spin-echo or spin-echo images were acquired in the transverse plane. Gadolinium-based contrast material, administered intravenously, was used in conjunction with a breath-hold spoiled GRE sequence in all patients. Gadolinium chelates were injected at a dose of 0.1 mmol per kilogram of body weight, and images were acquired immediately, at 45 seconds, at 90 seconds, and at 5 minutes after administration. Image acquisition immediately after the administration of contrast material was performed in the hepatic arterial-dominant phase, which was defined as the enhancement phase in which contrast material is present in portal veins and hepatic arteries and not present in hepatic veins. Recent studies have also shown that current magnetic resonance (MR) imaging-with hepatic arterial-dominant phase, spoiled gradient-echo (GRE) techniques and enhancement with a gadolinium-based contrast agent or with T2-weighted fat-saturated spin-echo techniques-may be equivalent or superior to CTAP (CT during arterial portography) for the detection of liver metastases. RC Smelka et al. reported a mean sensitivity and specificity for lesion detection (liver metastases) were, respectively, 0.884 and 0.444 for CTAP (CT during arterial portography) and 0.968 and 0.857 for MR imaging. CTAP and MR were not different with respect to sensitivity (P = .50) but were marginally different with respect to specificity (P = .063), which did not, however, achieve statistical significance. No false-positive or false-negative lesions due to perfusion abnormalities were detected at MR imaging. This study suggested that MR imaging was as sensitive as, and more accurate than, CTAP. Although a trend for greater specificity was observed, a significant difference was not reported, which presumably reflected, in part, the small number of patients. MR imaging also demonstrated lesions that were missed or misclassified at CTAP. The multiphase technique is also very useful in bone metastases evaluation after radio frequency ablation. This technique allows to detect residual tumor in all types of bone metastases (different vascularization).



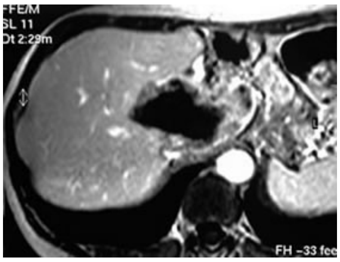
Successful treatment of 3 metastases from colon cancer. MR imaging obtained 3 months after radio-frequency ablation shows ablation defects without contrast enhancement, suggestive of a complete response.



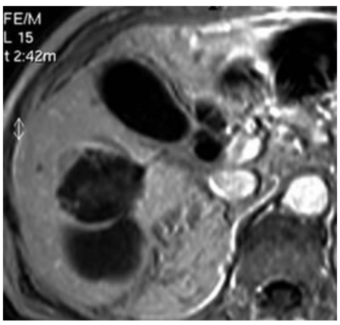
Successful treatment of 3 metastases from colon cancer. MR imaging obtained 3 months after radio-frequency ablation shows ablation defects without contrast enhancement, suggestive of a complete response.



Successful treatment of a large HCC lesion. Transverse contrast-enhanced MR imaging obtained 3 months after treatment shows ablation defect without contrast enhancement, suggestive of a complete response.



Large metastases from colon cancer. Incomplete ablation. MR imaging obtained 10 days after the procedure shows irregular shape contrast enhancement with nodular pattern.



Incomplete ablation of a large HCC lesion. MR imaging obtained 3 months after the radio-frequency ablation shows a nodular contrast enhancement in the border of the tumor.

8) Results

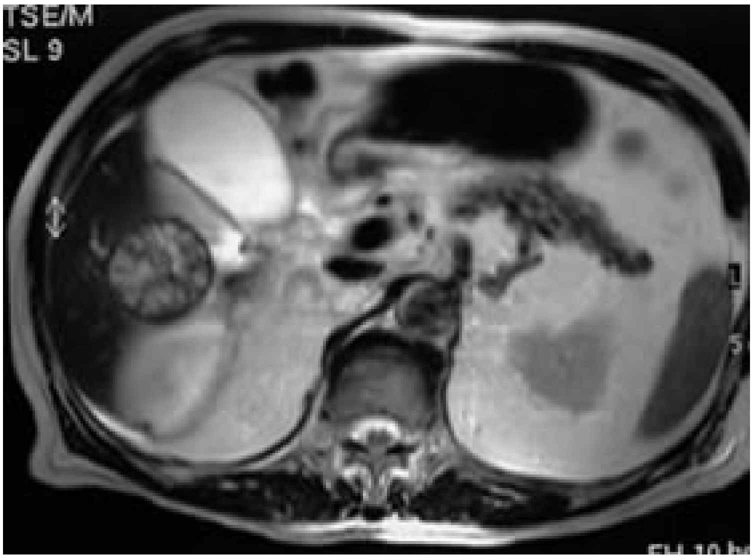
In HCC	
Tumor size	complete necrosis
25 mm < Tumor< 35 mm	77 % of cases
Tumor> 35 mm	61 % of cases
In metastases	
Tumor < 25 mm	100 % of cases
25 mm < Tumor< 35 mm	76 % of cases
Tumor> 35 mm	42 % of cases

- Ten days after the procedure the patients underwent a MRI scan. The most important features are the size of the necrotic defect, which, immediately after treatment, should be larger than that of the pretreatment tumor, and the sharpness of the margins, which indicates an abrupt change in attenuation between the necrotic tissue and surrounding liver tissue. Enhancement, when present, is due to perfusion abnormality or granulation tissue and forms a regular rim or a homogeneous zone at the margin of the defect. It is seen immediately after ablation but may be prolonged. Enhancement is affected by the scanning technique. Over time, the size of the defect remains stable or decreases. Any variation from this general pattern is suggestive of incomplete ablation or recurrence.
- In 28% of these cases, a thin regular rim enhancement without nodular pattern was observed. In patients with complete necrosis, the lesion size remained stable on follow up MRI or progressively decreased in size. Residual tumors show a nodular and/or heterogeneous enhancement on dynamic sequences and delayed T1 after gadolinium injection.
- Minor complications occurred with fever, local pain, and pleural and peritoneal effusion. In one case a major complication occurred, with a hepatic abscess, 4 weeks after the procedure in a cirrhotic patient.
- On control MRI, complete necrosis was obtained in metastases:
  - Tumor < 25 mm: 100 % of cases
  - 25 mm < Tumor< 35 mm: 76 % of cases
  - Tumor> 35 mm: 42 % of cases (average: 2.5 sessions and 3.7 cm diameter).
- On control MRI, complete necrosis was obtained in HCC:
  - Tumor < 25 mm: 100 % of cases
  - 25 mm < Tumor< 35 mm: 77 % of cases
  - Tumor> 35 mm: 61 % of cases (Average: 1.9 sessions and 4.3 cm diameter)

9) CASES

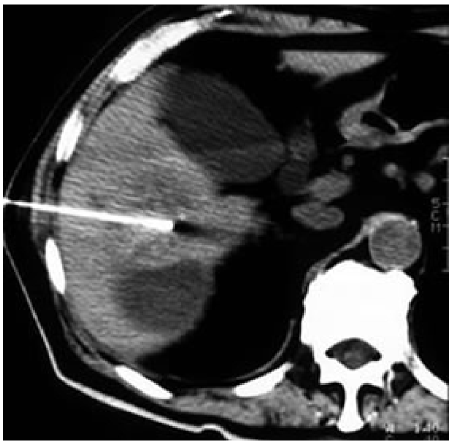
Case 1

Description :HCC lesion with subcapsular hematoma. After the first radio-frequency ablation, MR imaging obtained 10 days after radio-frequency ablation shows an ablation defect with a diffuse, ill-defined enhancement around the defect. These findings were indeterminate. MR imaging obtained 3 months after the radio-frequency ablation shows a nodular contrast enhancement in the border of the tumor with irregular shape contrast enhancement with nodular pattern. Incomplete ablation of a large HCC lesion.



HCC lesion MRI before RF

HCC lesion CT before RF

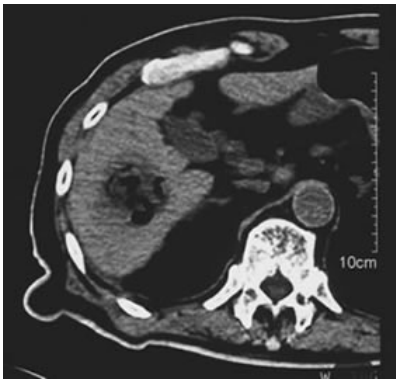


HCC lesion CT RF needle placement

HCC lesion CT RF (gas)

HCC lesion Radio frequency, ultrasound

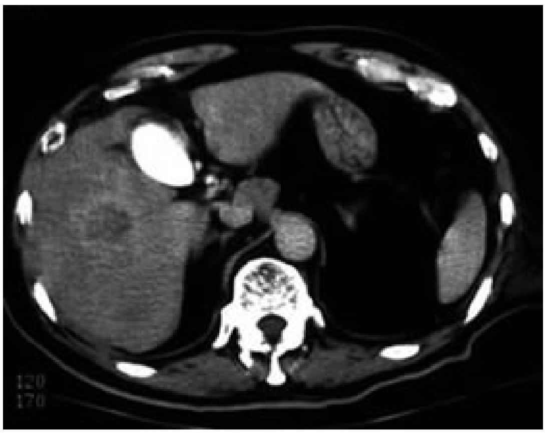
HCC lesion Radio frequency, ultrasound monitoring



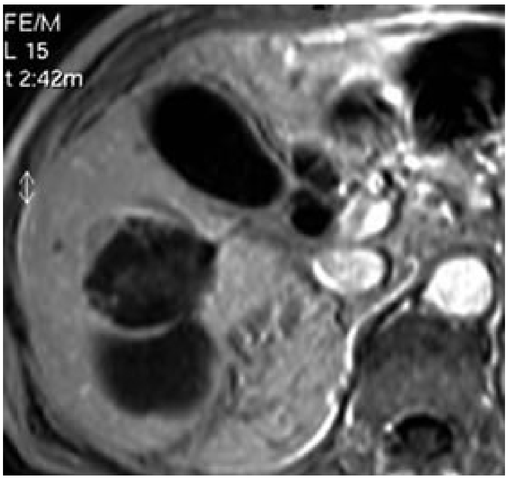
CT imaging after the procedure

CT imaging after the procedure

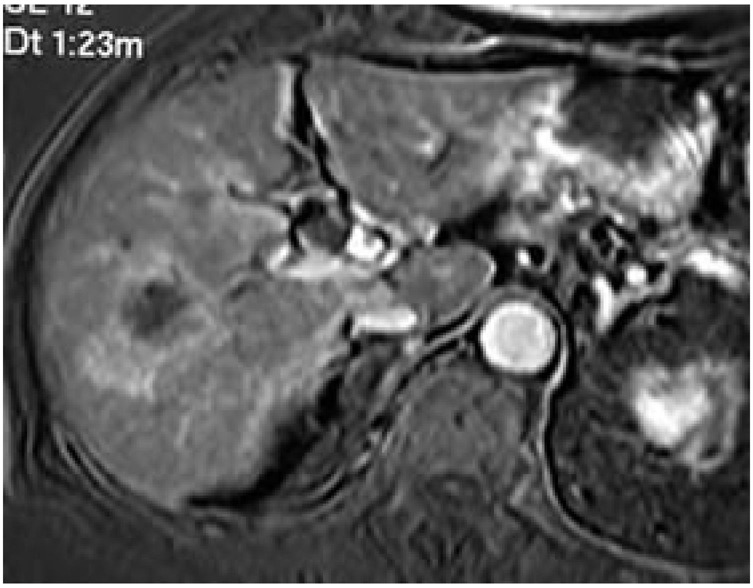
CT imaging after the procedure



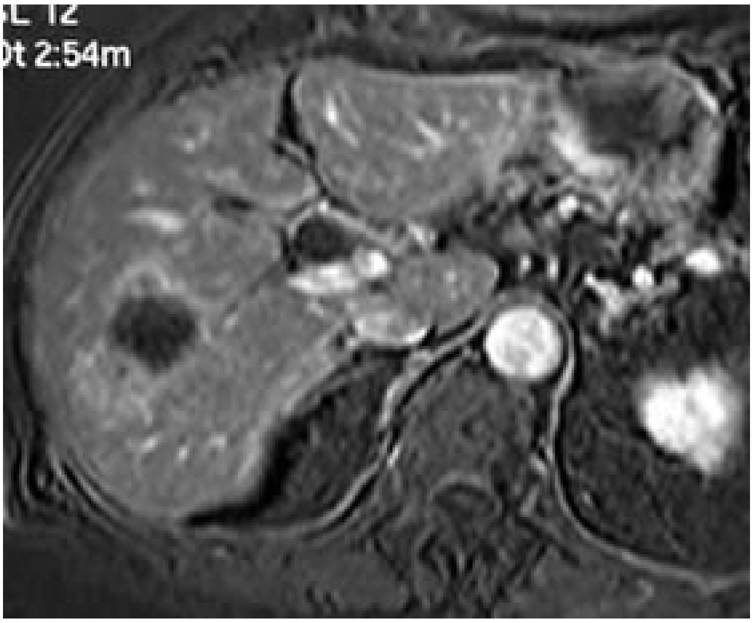
CT imaging after the procedure



MRI imaging after the procedure



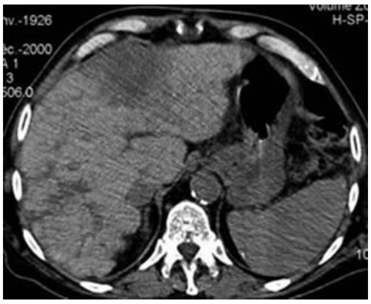
MRI recurrence: nodular pattern



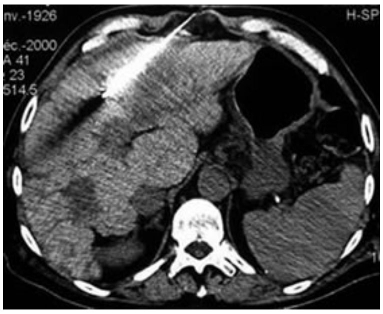
MRI recurrence: nodular pattern

Case 2

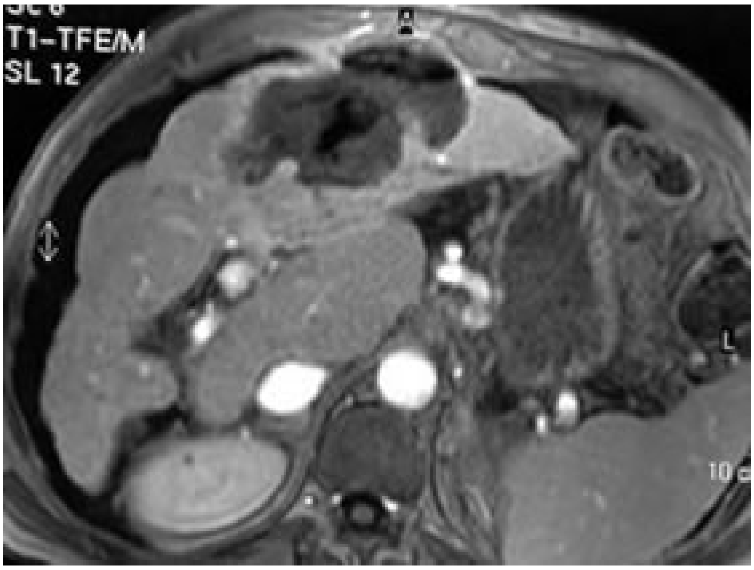
Description : Description : Successful treatment of a large HCC lesion. Transverse contrast-enhanced MR imaging obtained 3 months after 3 radio-frequency ablations shows ablation defect without contrast enhancement, suggestive of a complete response. However, The patient developed a large abscess 4 months after the procedure.



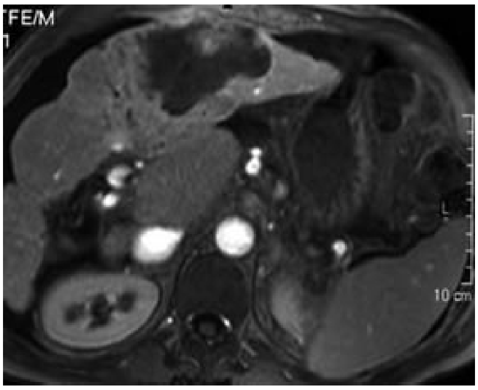
CT large HCC lesion



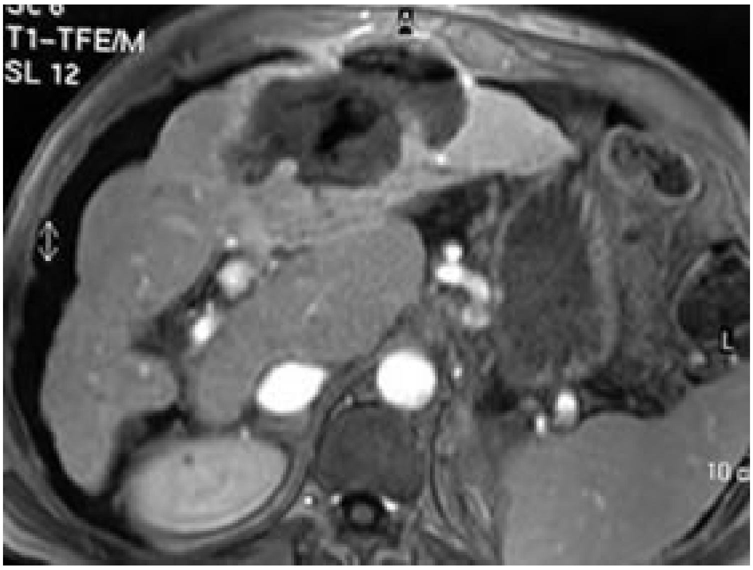
CT imaging HCC lesion CT RF



CT imaging obtained 3 months after 3 radio-frequency ablations shows ablation defect without contrast enhancement, suggestive of a complete response



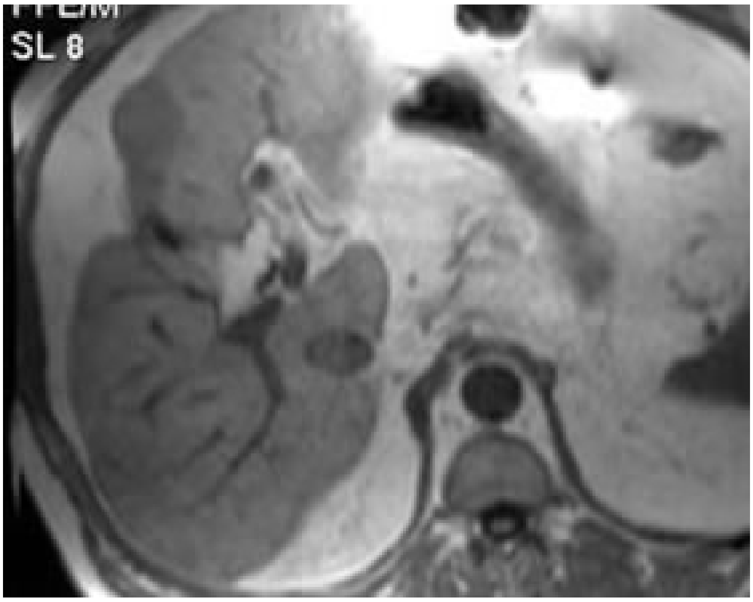
MR imaging obtained 3 months after 3 radio-frequency ablations shows ablation defect without contrast enhancement, suggestive of a complete response



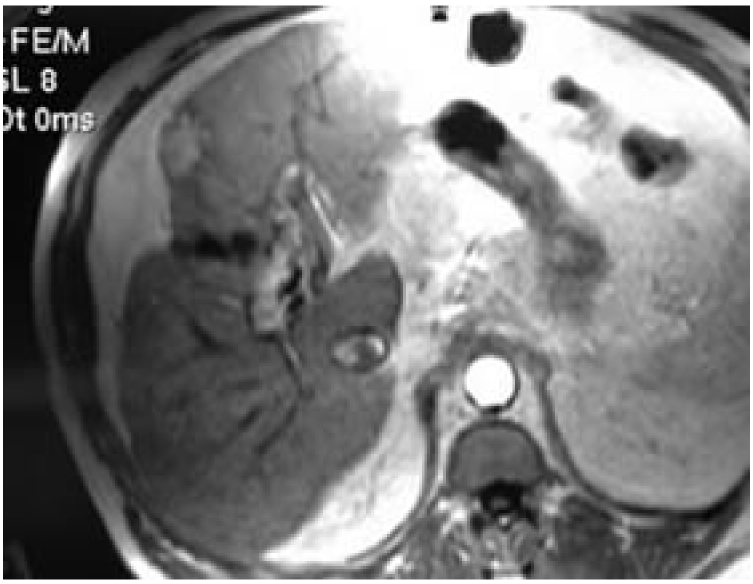
MRI: abscess

Case 3

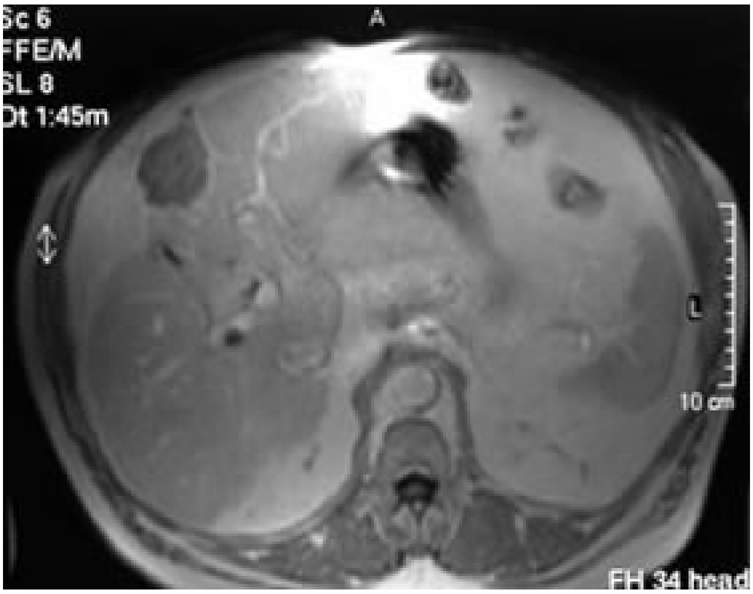
Description : Successful treatment of a single HCC. Transverse contrast-enhanced MR imaging obtained 3 months after treatment shows ablation defect without contrast enhancement, suggestive of a complete response.



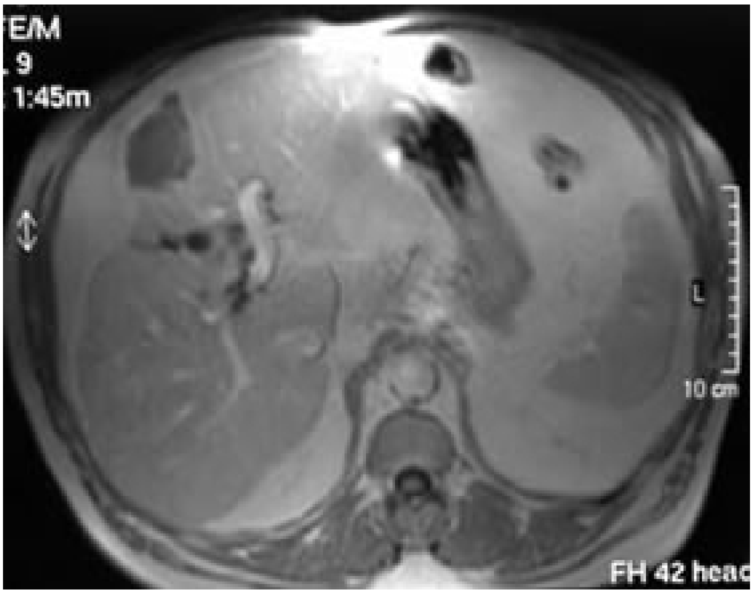
single HCC MRI T1



single HCC MRI T2



MR imaging obtained 1 months after treatment shows ablation defect without contrast enhancement



MR imaging obtained 3 months after treatment shows ablation defect without contrast enhancement, suggestive of a complete response

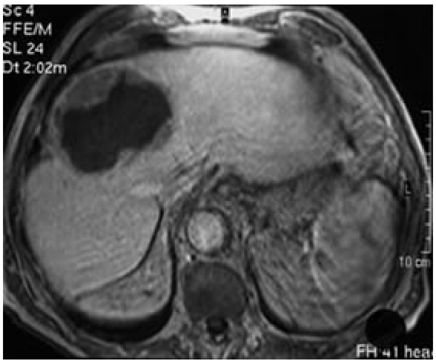
Case 4

Description : Incomplete ablation of a large HCC. Control MR imaging shows irregular and nodular contrast enhancement typical of incomplete treatment.

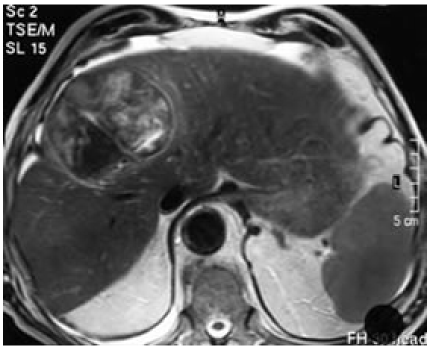
Single Large HCC CT

Single Large HCC CT RF

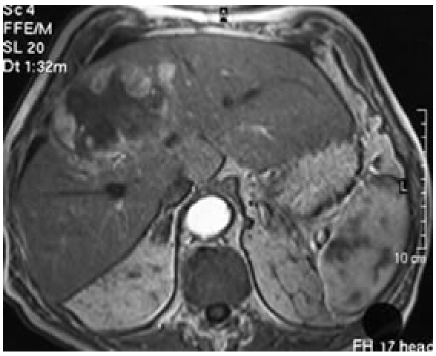
Single Large HCC CT after RF



large HCC. Control MR imaging shows irregular and nodular contrast enhancement typical of incomplete treatment



large HCC. Control T1 MR imaging incomplete treatment



large HCC. Control MR T1+C imaging shows irregular and nodular contrast enhancement typical of incomplete treatment

Case 5

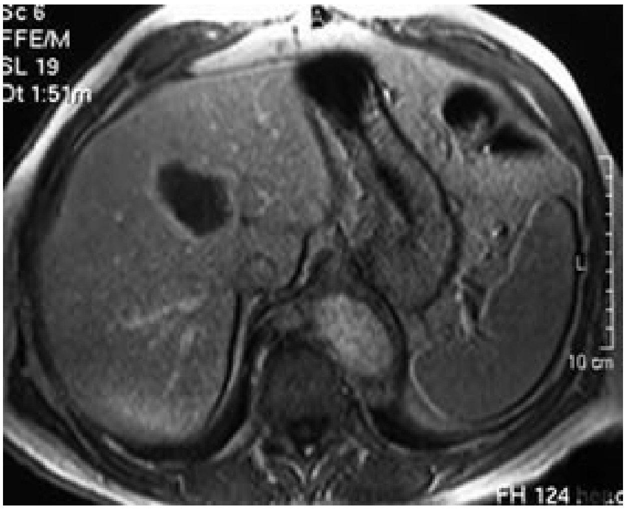
Description : Radio-frequency ablation of two metastases from colon cancer under CT-guidance

Radio-frequency ablation of two metastases from colon cancer under CT-guidance

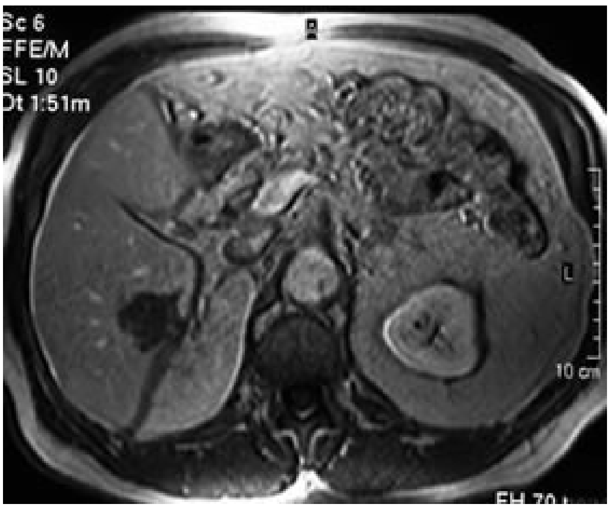
Radio-frequency ablation of two metastases from colon cancer under CT-guidance

Radio-frequency ablation of two metastases from colon cancer under CT-guidance

Radio-frequency ablation of two metastases from colon cancer under CT-guidance



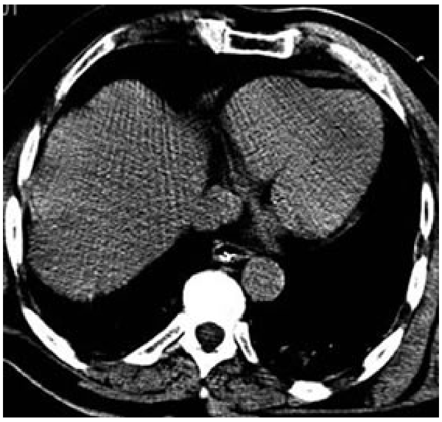
MR imaging 3 months after the procedure no nodular and irregular enhancement, successful ablation.



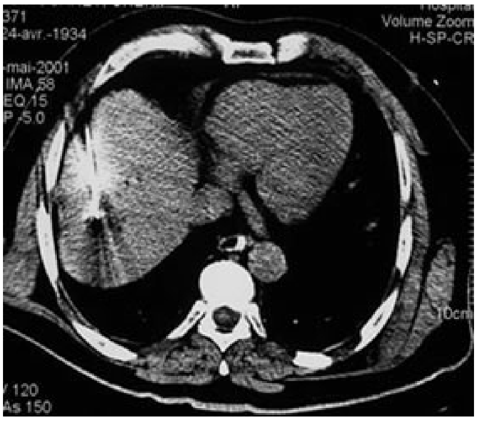
MR imaging 3 months after the procedure no nodular and irregular enhancement, successful ablation.

Case 6

Description : metastasis incomplete ablation

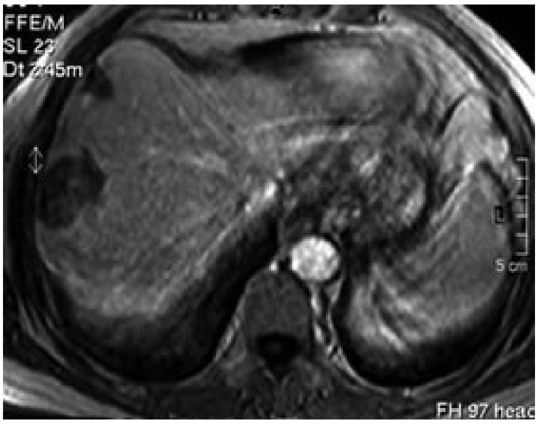


CT metastasis

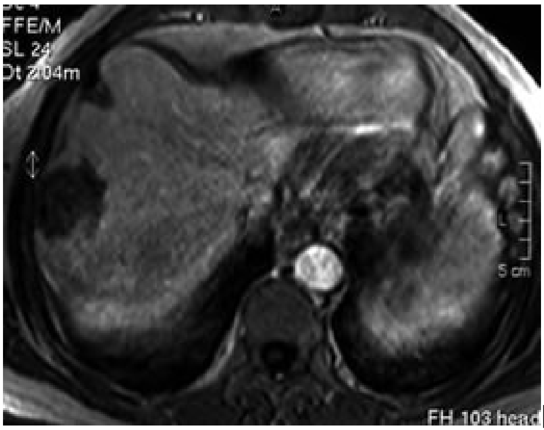


needle positioning

radio frequency ablation



MR imaging after 10 days indeterminate result



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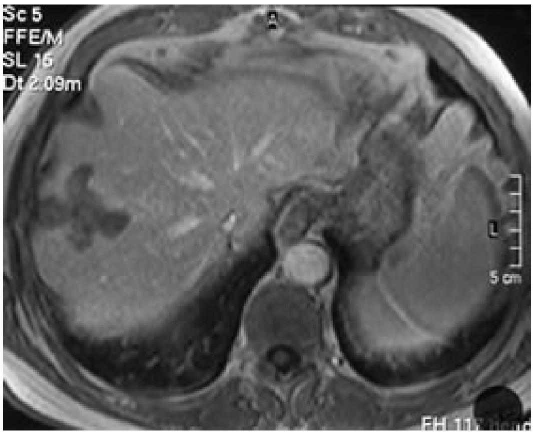
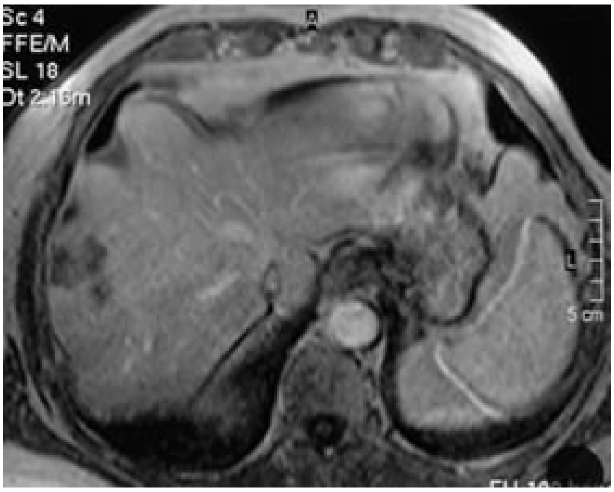
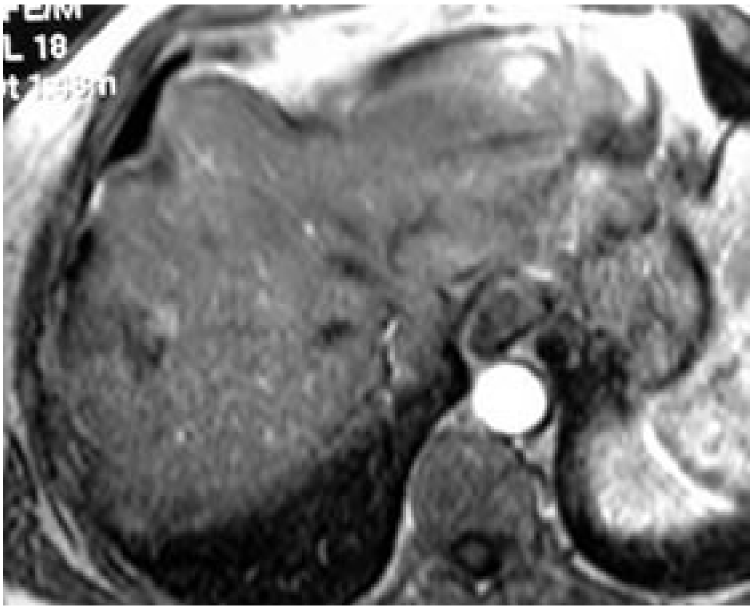
MR imaging after 10 days indeterminate result



MR imaging after 3 month . Tumor recurrence



MR imaging after 3 month . Tumor recurrence

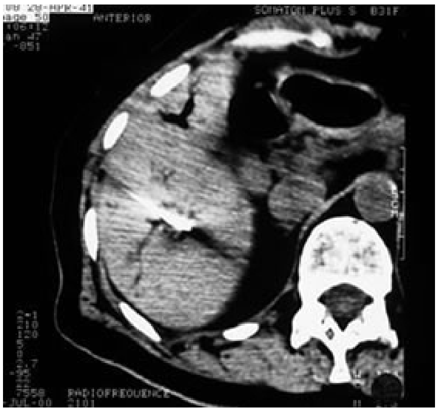


MR imaging after 3 month . Tumor recurrence

MR imaging after 3 month . Tumor recurrence

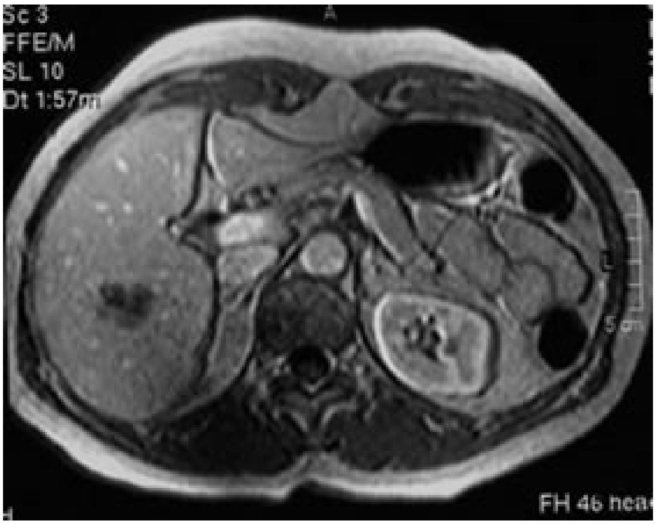
Case 7

Description : metastasis from colon cancer. Incomplete ablation



radio frequency ablation (gas)

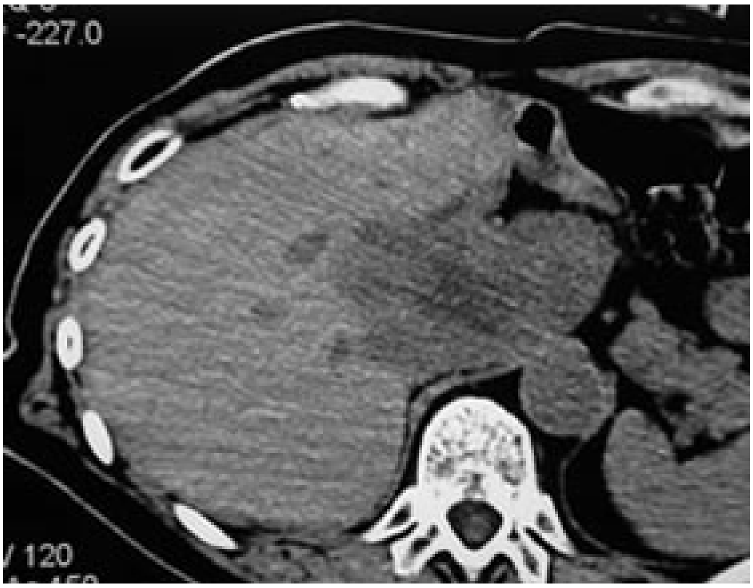
MR imaging after 10 days



MR imaging 3 months after procedure: tumor recurrence

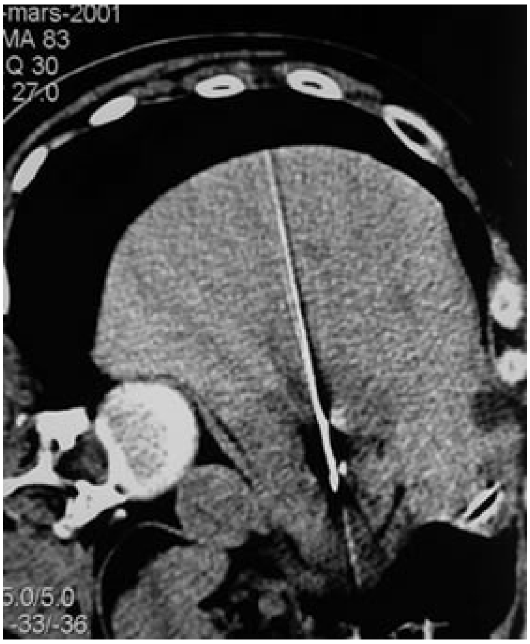
Case 8

Description : breast cancer liver metastasis. Two radio frequency ablations, incomplete necrosis

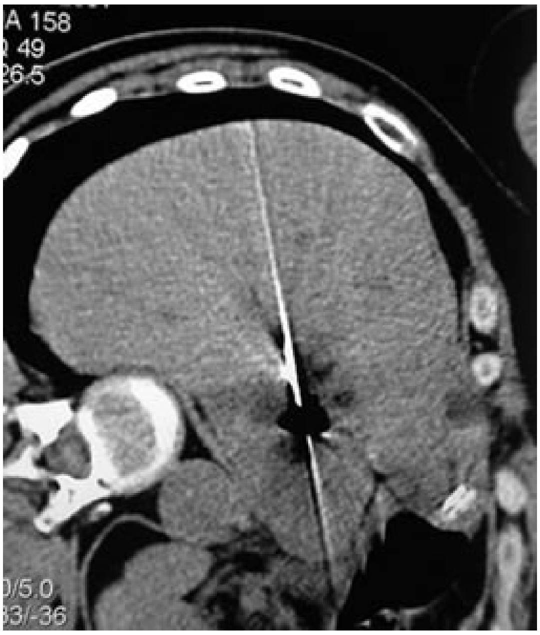


CT breast cancer liver metastasis

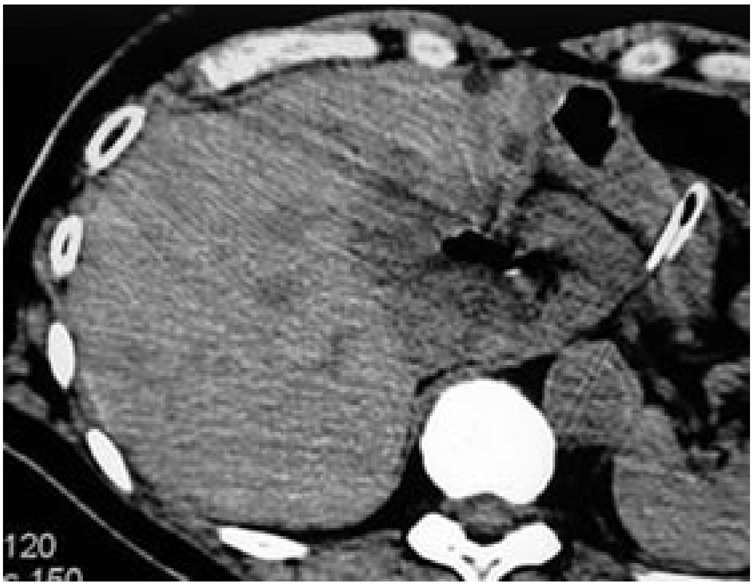
needle positioning



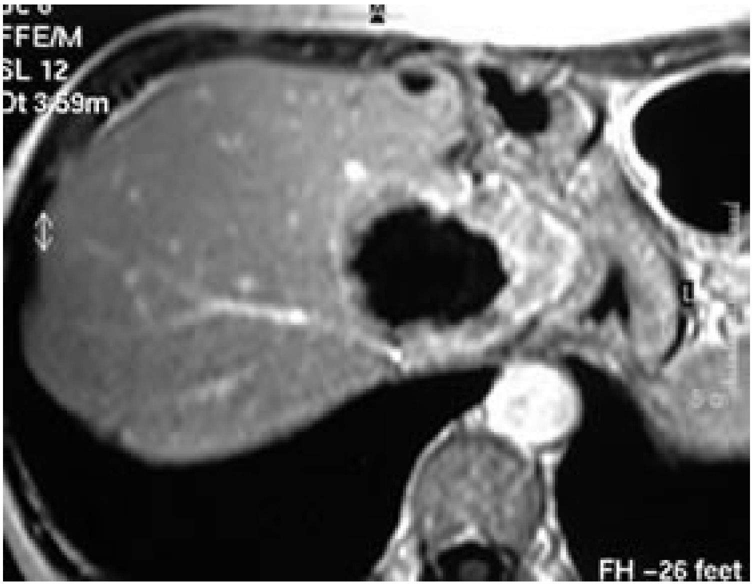
CT radio frequency ablation



CT radio frequency ablation (gas)

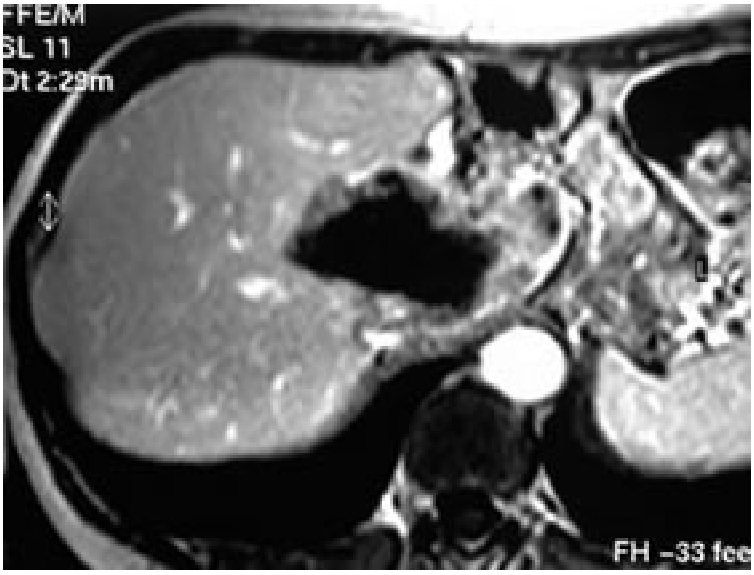


radio frequency ablation (gas)



MRI incomplete necrosis

MRI incomplete necrosis



MRI incomplete necrosis

10) Conclusion

- The wet electrode technique increases the total electrode surface area with improved thermal and electrical conductivity.
- Two mechanisms have been proposed to account for the improved tissue heating and increased RF-induced coagulation with simultaneous saline infusion:
  - 1/ that NaCl alters tissue properties such as electrical conductivity to permit greater RF energy deposition, or
  - 2/ that the infusion of fluid during RF application improves the thermal conduction within the tissues by more rapidly and effectively convecting heat over a larger tissue volume.
- NaCl concentration had significant but nonlinear effects on electrical conductivity, RF deposition, and heating.
- Injection of NaCl solution during RF ablation can increase energy deposition, tissue heating, and induced coagulation.

This method allows avoidance of desiccation and impedance rises and allows treatment of larger lesion sizes. Also with a low electrode cost, this coagulation method proved to be very cost efficient as well and easy to use.