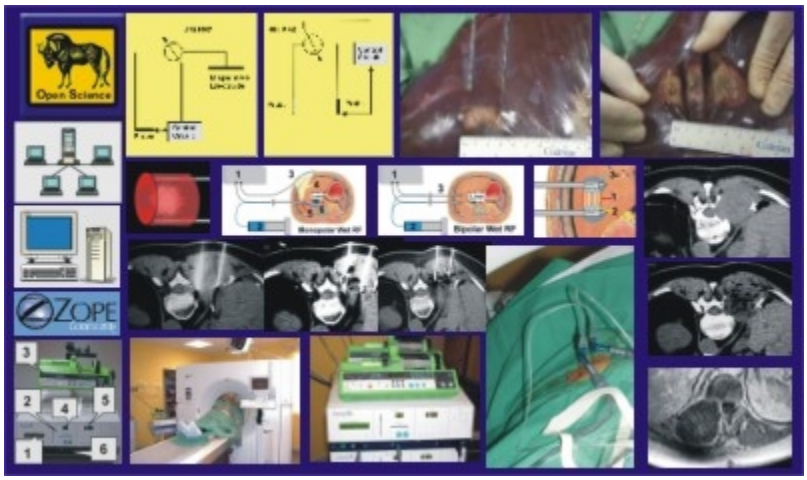

Bipolar Radiofrequency

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(ECR 2003 Cum Laude)

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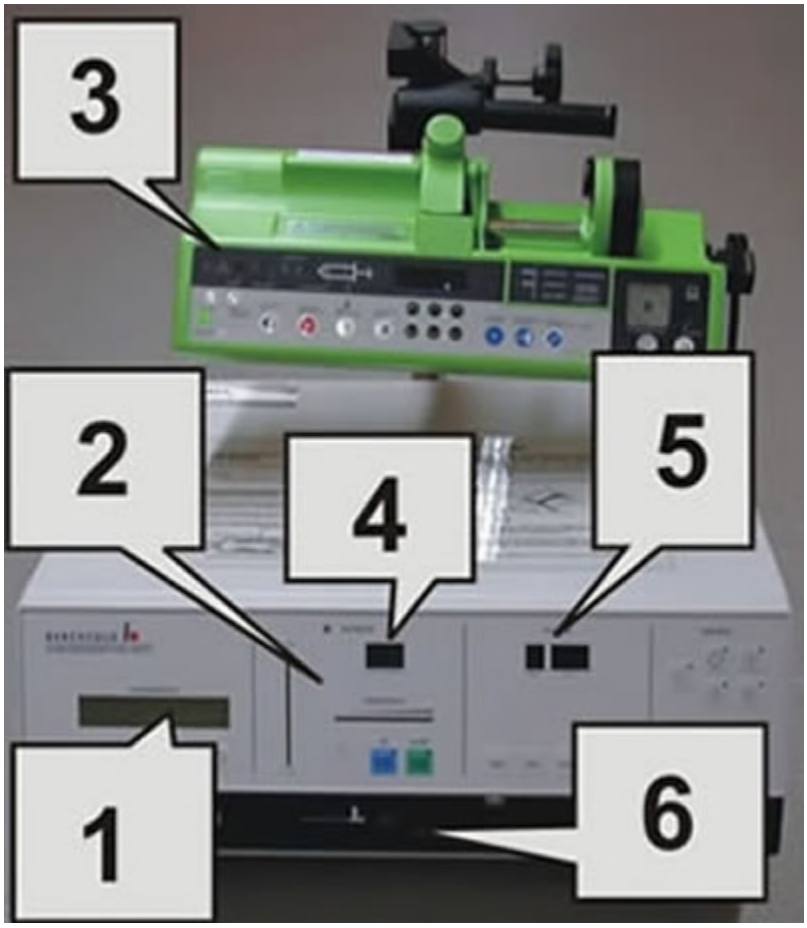
1) Abstract

Radio-frequency (RF) ablation has become an important means of treatment of nonresectable primary and metastatic tumors. Major limitations are small lesion size, which make multiple applications necessary, incomplete killing of tumor cells, resulting in high recurrence rates, and risk of damage to adjacent structures (bowel, nerve root). We examined a new bipolar RF ablation method incorporating two probes with perfused needle electrodes (Berchtold®). We performed bipolar ex vivo experiments on five beef livers. The electrodes were 3 cm apart. We used impedance-controlled mode. Lesion volumes were 16.5 cm3 ex vivo and 12.5 in vivo. The bipolar method creates faster, larger, more predictible lesions. It is less dependent on local inhomogeneity in liver tissue compared with monopolar RF ablation. A limitation of the bipolar method are: the power dissipation of the two probes that cannot be controlled independently in response to different conditions in the vicinity of each probe, insertion of two probes, and the maximum probes interval is limited to 3 cm.

2) Material and methods

- We used a Berchtold® Elektrotom 106 Hitt generator and Berchtold® 16-gauge probes with 2.5 cm electrode length for creating bipolar lesions. For clinical use, the probes are inserted 3 cm apart and infused (hypertonic saline 5.85%, 50 Watt, 62 ml/ hour). Initially we created different bipolar ablation where we varied probe distance in 0.5-cm increments. We found the ideal distance (i.e., largest lesion size) at 3 cm probe distance. For interval less than 1 cm a risk of short cut and electric arc is possible. In this case, less power should be applied. For creating bipolar lesions, we attached a second probe to the generator replacing the dispersive electrode using a modified cable for connection. The control circuit varies the applied power depending on the impedance.
- We used five ex vivo beef livers for experiments. We performed preliminary ex vivo experiments with bipolar configuration at probe distances of 4, 3.5, 3, 2.5, and 1 cm. When the distance was 4 and 3.5 cm, in some cases we found a gap of viable tissue between two lesions created by the two probes after performing ablation. Subsequently, probes were placed 3 cm apart. Both monopolar and bipolar ablations were performed for 10 min using impedance-controlled mode. After the experiments were completed, the liver was placed in 10% formalin for fixation. The lesion border was determined by optical inspection in ex vivo livers. In patients, an MR was performed 10 to 14 days after the procedure to evaluate the lesion size with dynamic sequences and injection of contrast medium. Lesion volume was computed by multiplying the lesion area of each slice-by-slice thickness, and summating results for all slices.
- After ex-vivo experimentation we used the bipolar technique in vivo for patients in 25 cases of tumors including liver and bone. For clinical use, all procedures were performed with the patients under general anesthesia. The placement of the electrodes was guided by CT. The probes were inserted to trap the tumor in a pincer technique.

Berchtold Radio-frequency device with injection of continuous saline. The same generator is used for bipolar technique.



Berchtold Radio-frequency device: 1. Monitor of Energy and temperature. 2. Impedance control. 3. Injector for continuous injection of saline. 4. Power. 5. Timing. 6. Needle electrode input.

Interventional CT room.

3) Results

- Ex Vivo Lesion volumes were 16.5 cm3. The lesion was always almost limited between the probes with only 5 mm necrosis outside the probes with a cylindrical shape.
- In Vivo Lesion volumes were 12.5 cm with limitation of the necrosis between the probes.

Ex vivo bipolar RF.

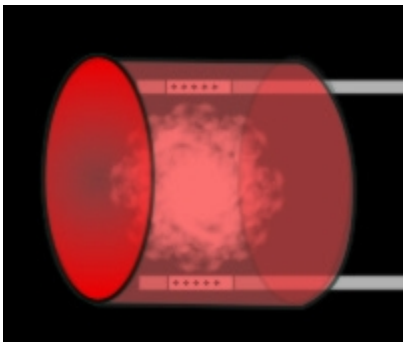
Ex vivo bipolar RF. Short application time (less than 5 minutes). Coagulation almost limited between the needles.

4) Discussion

Advantages of the bipolar technique

The bipolar radiofrequency method uses two electrodes that pass a current through a section of tissue. The current heats and destroys a cylindrical shaped volume of tissue clamped between the electrodes. First, we have tested the technique on five ex-vivo beef livers. We propose a bipolar method for creating larger, faster and more controllable lesions.

- The lesions are less dependent on local heterogeneity of the tissue such as blood perfusion and are strictly limited between the probes. The major contribution toward larger lesion size of bipolar ablation is based on a thermodynamic effect. Heat is trapped between the two probes and higher temperatures are reached. This results in a lesion of larger size than that of two lesions produced sequentially by monopolar ablation with probes placed at the same position.



Bipolar RF. The bipolar RF technique creates a cylindrical shaped lesion (red) around the tumor.

- The bipolar RF technique creates a cylindrical shaped lesion. Dependence of lesion size on local differences in cooling mediated by perfusion is reduced. This is supported by the fact that the standard deviation of bipolar ablation lesion size relative to its mean is smaller than for the monopolar case. Furthermore when a tumor is localized near sensible structures (Bowel, nerve root), the necrosis is well limited between the probes and accidental coagulation of the nearby organs can easily be avoided.
- The proposed bipolar method reduces treatment time. The use of bipolar technique with a distance of 3 cm produces a well-limited coagulation between the electrodes with a maximum diameter of 4.3 cm plus/minus 0.5 cm after 5 to 10 minutes ex vivo.

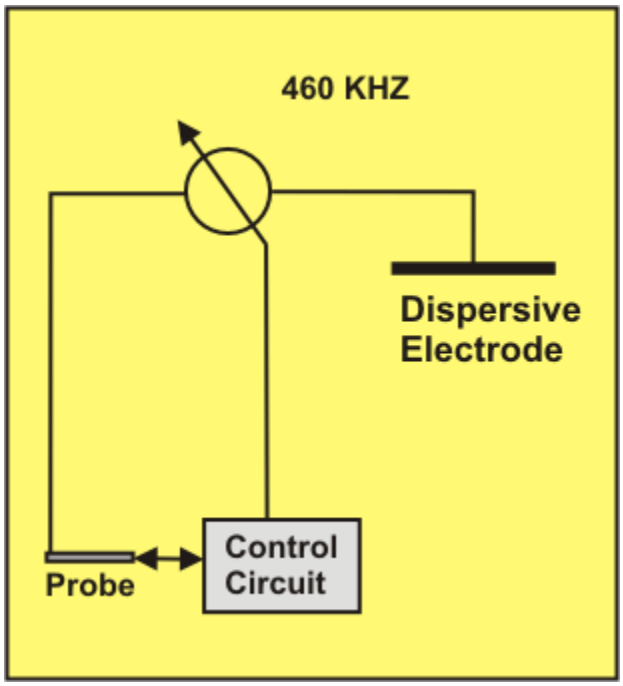
Drawbacks of the bipolar technique

The bipolar technique also introduces new drawbacks and difficulties:

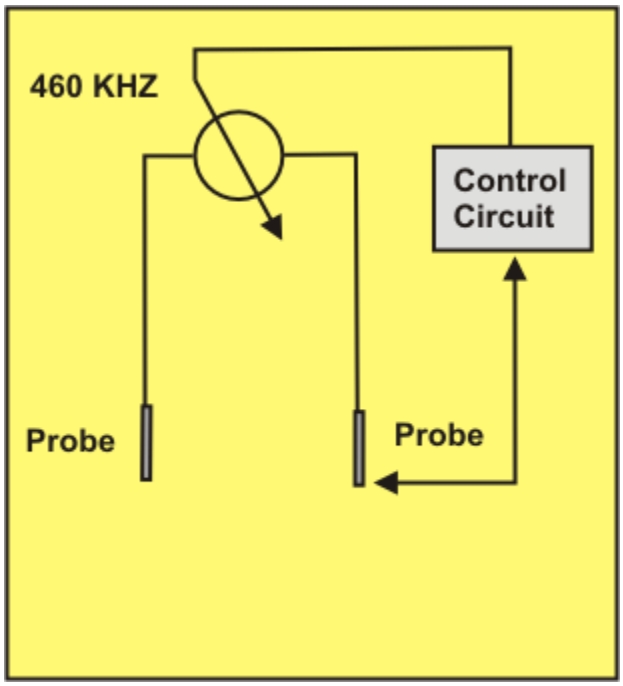
- The probes must ideally be parallel, the best distance between probe is 3 cm, probe temperature can be different and there is risk of hot saline diffusion.
- The best results are obtained when the probes are parallel together and the tumor is limited in between. However Insertion of two parallel probes can be difficult in some cases. The ideal gap between the two probes depends upon the local properties of the ablation site and is different for each ablation. We performed preliminary ex vivo experiments with probe distances of 4, 3.5, 3, and 2.5 cm. When the distance was 4 and 3.5 cm, in some cases we found a gap of viable tissue between two lesions created by the two probes after performing ablation. We chose a distance of 3 cm for subsequent experiments. A different distance might be appropriate if probes with other geometries are used.
- In RF ablation, most of the active heating occurs within a range of a few millimeters from the electrodes. Similar resistivity and current density are present in the vicinity of both probes. Therefore, a comparable amount of energy is converted into heat next to each of the two probes. If one probe is cooled more by blood perfusion than the other, more heat energy is carried away. One probe

can therefore reach a higher temperature than the other. This can lead to boiling and vaporization. Impedance will rise, and the RF generator shuts down. In 5 patients, during bipolar ablation the impedance showed a sudden rise resulting in the shutdown of the generator. In these cases, we used the temperature-controlled method. If the temperature of the hotter probe is controlled to be kept at 95 °C, the other probe will not reach this temperature and heating near this probe will be kept lower.

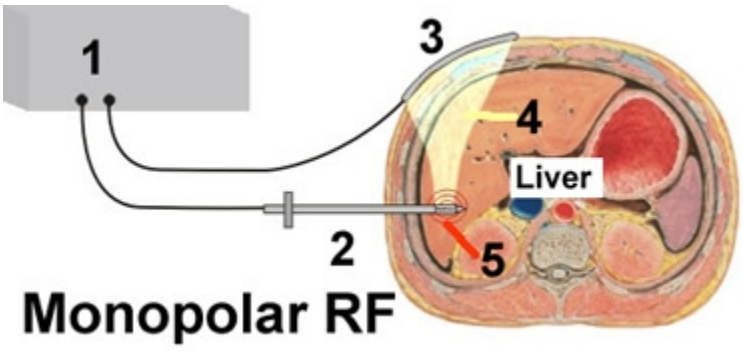
- Another drawback of the wet electrode is the risk of diffusion of hot saline. This risk can be decreased with the reduction of the volume of fluid injected by using hypertonic saline (5.85%). Using this method reduces the amount of saline injected.



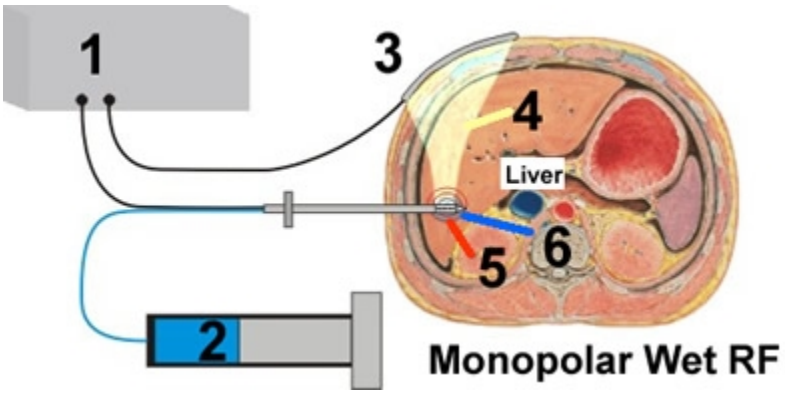
Monopolar RF



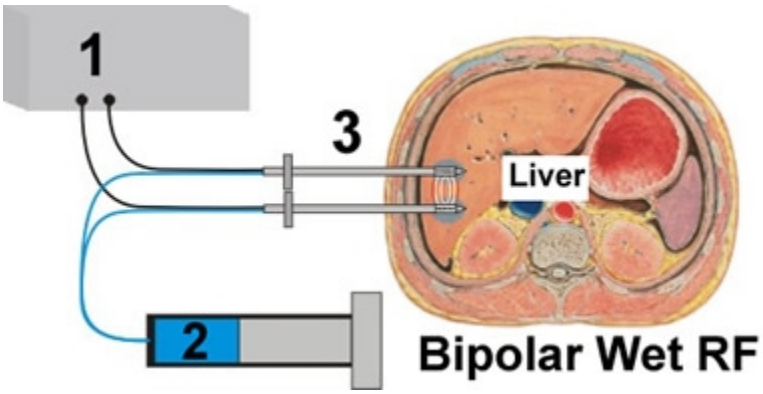
Bipolar RF



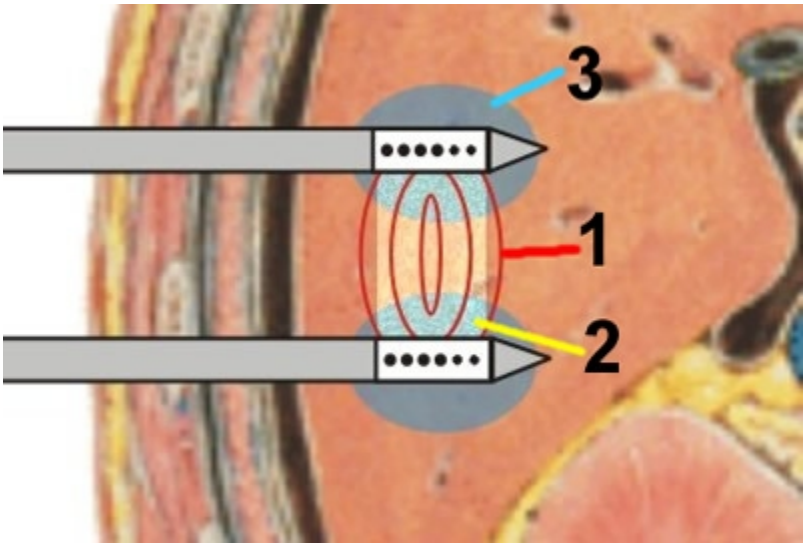
1. **RF generator. 2. Continuous saline infusion. 3. Dispersive electrode (ground pad). 4. Closed loop. 5. Heating**



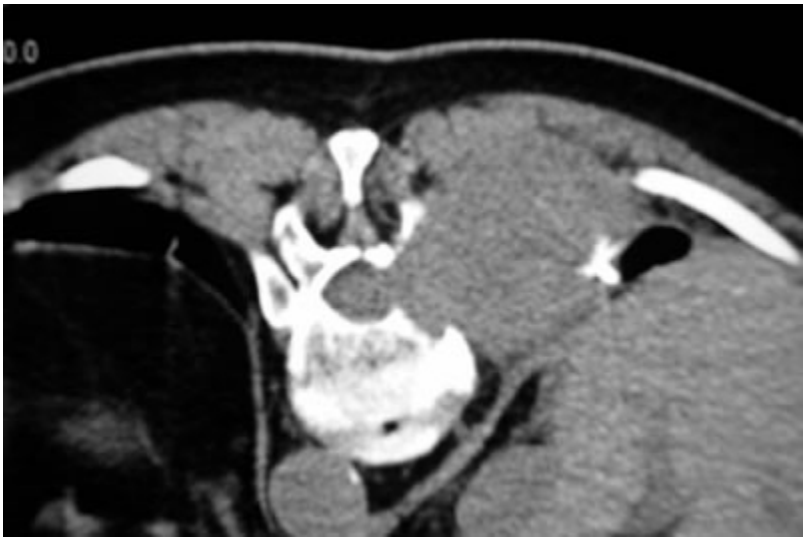
1. **RF generator. 2. Continuous saline infusion. 3. Dispersive electrode (ground pad). 4. Closed loop. 5. Heating. 6. Saline infusion.**



1. **RF generator. 2. Continuous saline infusion. 3. Bipolar needle electrodes inserted parallel together.**

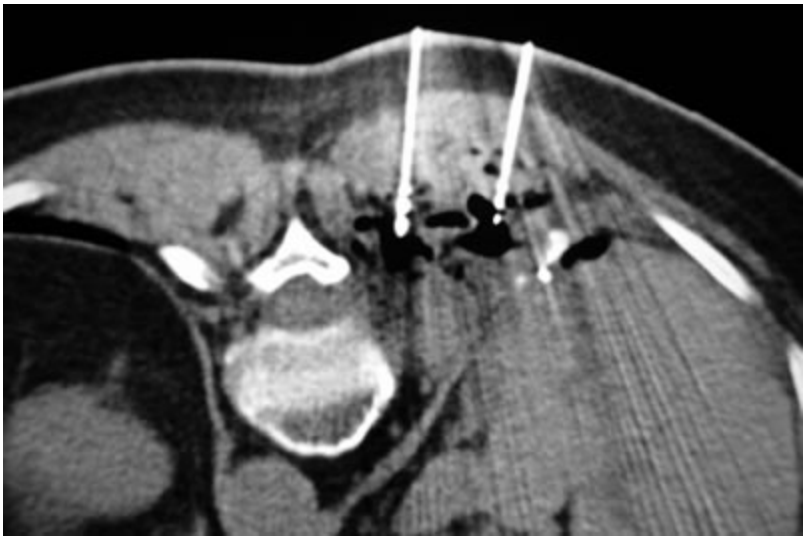


1. **Heating. 2. Closed loop between the electrodes. 3. Continuous infusion of saline.**

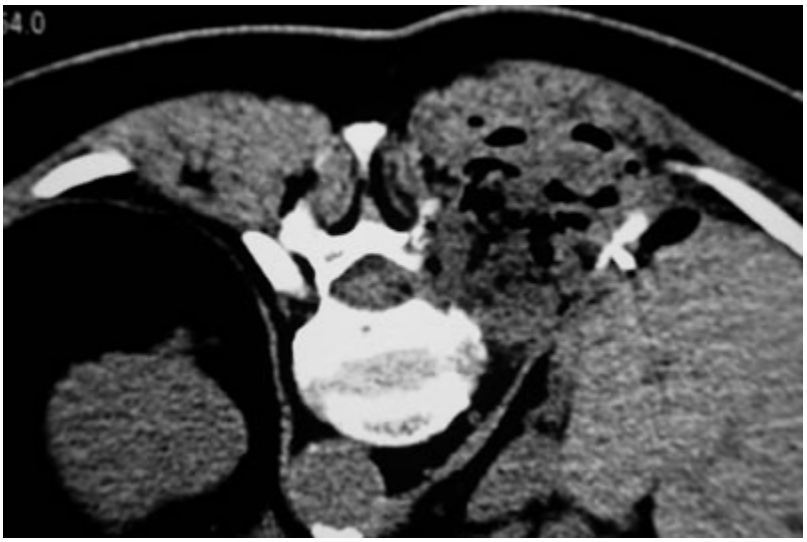


Bipolar technique to avoid neurological complications.

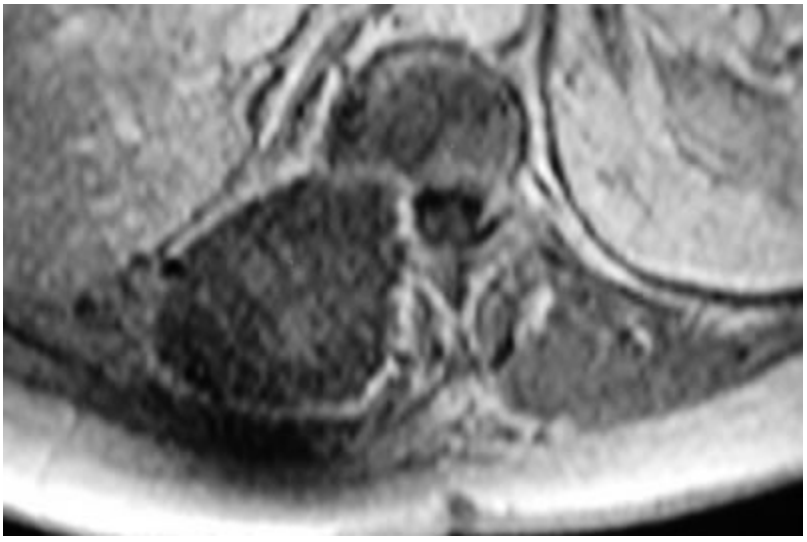
CT scan during RF ablation.



Ablation between the electrodes. Coagulation outsides the electrodes limited to 5 mm maximum. RF ablation duration 5 minutes perposition.



CT scan after the procedure.



MR imaging 2 days after the procedure (T1-weighted + gadolinium). Large necrosis of the tumor. No complications. Excellent pain relief.

5) Conclusion

Wet-bipolar RF techniques seem to be promising especially for kidney, spine, and difficult liver lesions. We propose a bipolar method for creating larger, faster and more controllable lesions. The bipolar method reduces treatment time. Furthermore when a tumor is localized near sensible structures (Bowel, nerve root), the necrosis is well limited between the probes and accidental coagulation of the nearby organs can be easily avoided. Insertion of two parallel probes can be difficult in some cases. The best results are obtained when the probes are parallel together and the tumor is limited in between.

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