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Percutaneous coil placement prior to radiofrequency ablation of poorly visible hepatic tumors

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Abstract The aim of this study was to establish whether using a percutaneously inserted metallic coil as a target facilitates the radiofrequency (RF) ablation of tumors poorly seen on unenhanced computed tomography (CT) or ultrasound (US) studies. We inserted a metallic coil percutaneously via a 21-gauge needle under CT guidance into five tumors during the phase of contrast enhancement in five patients. The coil was subsequently used as a target to guide placement of the RF electrode under fluoroscopic guidance. The precision of position was then checked with CT or US. We also carried out a small experimental study to establish the effect of metallic coils on the pattern of coagulation induced by RF. Placement of a metallic coil into the tumor enabled rapid and accurate placement of the RF electrode. The tumors were ablated with no adverse effects. The experimental study showed that the area of coagulation extends predictably along the coil. The application of the above technique is useful when using RF to ablate tumors poorly visualized on US and unenhanced CT.

Keywords Radiofrequency ablation · Metallic coils · Computed tomography · Ultrasound · Fluoroscopy

Introduction

Thermal ablation with radiofrequency (RF) is increasingly used for the treatment of hepatocellular carcinoma and hepatic metastases with good technical results and a low rate of complications [1–5]. Computed tomography (CT) and ultrasound (US) are the imaging modalities most frequently used for guiding placement of the RF electrode [6–8]. However, some lesions are poorly visualized on US and unenhanced CT and only transiently demonstrated on CT during intravenous contrast enhancement. We present a new technique for localization of such lesions with the use of a percutaneously placed metallic coil prior to radiofrequency ablation (RFA). We have used this method of RFA in five patients. In addition, we have carried out a small experimental study to demonstrate the effect of the coil on the size and shape of the coagulation area achieved by RFA.

Materials and methods

The essential elements of the technique are the following. Previous contrast-enhanced CT studies are inspected to ascertain the location of the tumor to be treated. The patient lies on the CT table and the skin is cleaned. Magnified unenhanced CT images of the relevant part of the liver are obtained. Following injection of local anesthetic, a 21-gauge needle is inserted in the approximate location of the lesion estimated on the basis of anatomical landmarks demonstrated on both the previous contrast-enhanced CT images and the current unenhanced CT images. After administration of 100–150 ml of contrast medium intravenously, a spiral CT of the relevant part of the liver is carried out, demonstrating the tumor and its relation to the tip of the needle. The position of the needle is rapidly adjusted so that its tip lies in the center of the tumor. A metallic coil of appropriate caliber (0.018 in., 40 mm length and 3 mm diameter, Cook, Bloomington, Ind., USA) is then inserted via the needle, using the hard end of a 0.018-in. mandrill wire as a pusher. Conventional fluoroscopic guidance using a C-arm may be used during the insertion of the coil but this is not essential. Further CT images are obtained to confirm the position of the coil within the tumor.

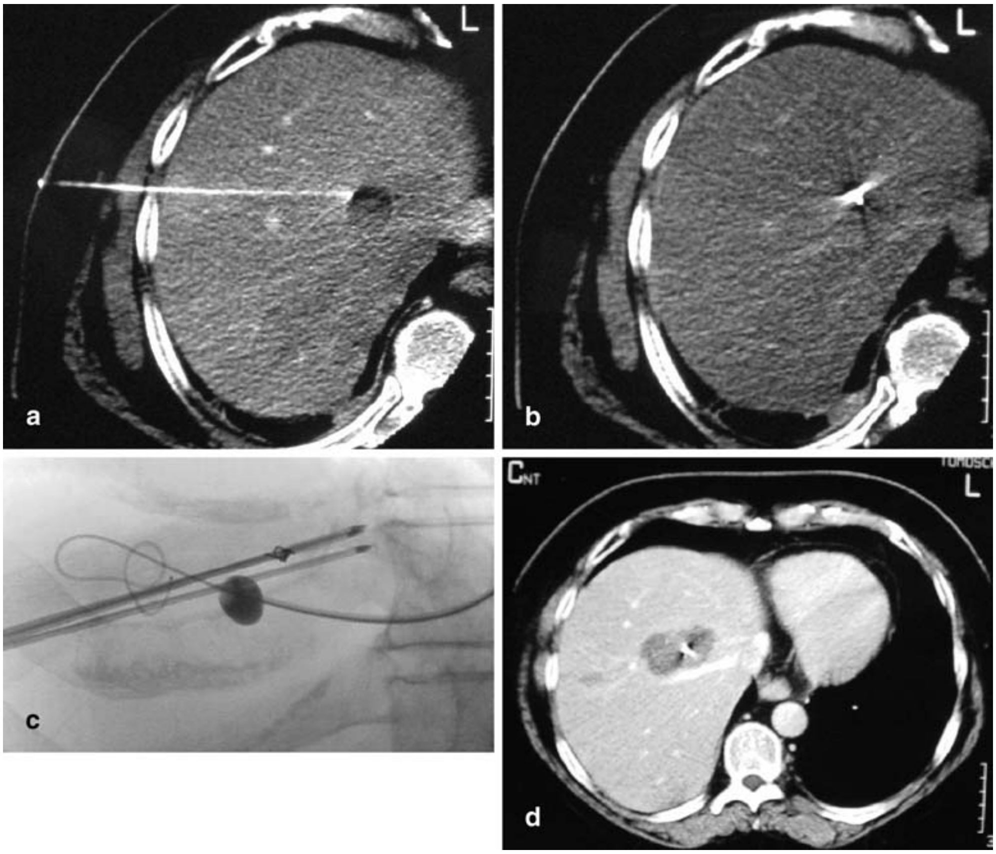

Fig. 1 **a** A single metastasis from a colonic carcinoma lies immediately adjacent to a large tributary of the right hepatic vein. A 21-G needle was inserted in the vicinity of the lesion prior to intravenous injection of contrast medium. The position of the needle was adjusted during contrast enhancement so that its tip lies in the center of the lesion. **b** A 0.018-in. metallic coil of 40 mm length and 3 mm diameter was pushed through the needle into the tumor. **c** An occlusion balloon was placed in the right hepatic vein during the whole RFA procedure, in order to reduce the amount of heat being carried away from the lesion by fast-flowing blood. A cluster, cooled RF electrode (Radionics, Burlington, Mass.) was inserted under fluoroscopic guidance aiming at the metallic coil. **d** A 3.5–5.5-cm area of coagulation is demonstrated on CT 3 days after the procedure. The more peripheral, linear lesion was caused by "hot withdrawal" of the electrode to reduce the risk of hemorrhage

The RFA procedure may be carried out immediately after placement of the coil or on another day. The coil is clearly visible on CT and fluoroscopy and can usually be seen well on US images. Any of these imaging modalities can be used to guide the RFA procedure. It is most conveniently performed in a fluoroscopic unit equipped with a C-arm or U-arm. Fluoroscopic images at 90° to each other allow the RF electrode to be guided easily into the tumor using the metallic coil as a target. Once the RF electrode is in position the patient is given sedation intravenously and the tumor treated in the same way as in patients in whom the procedure is guided using cross-sectional imaging. In patients in whom the coil is also clearly seen using US, a combination of US and fluoroscopic guidance can be used for the RFA. The temperatures reached during treatment are far too low to damage the coil, which can be used to guide a second or third treatment if necessary.

We have used this technique in four patients with hepatic metastases from primary colonic carcinoma and one patient with hepatocellular carcinoma. Written, informed consent was obtained from all patients. In all cases the tumors were not visible clearly on US or on unenhanced CT. US-specific contrast agents could not be used with the US equipment available in the interventional unit.

In case 1, a single metastatic lesion was located next to a large tributary of the right hepatic vein (Fig. 1a). The exact coil location was demonstrated (Fig. 1b). In this patient the right hepatic vein was occluded during treatment with a latex balloon (Boston Scientific, Watertown, Mass., USA) inserted using a right transjugular approach to reduce the amount of heat taken away by flowing blood and thus increase the area of necrosis [9]. The RF electrode was inserted under fluoroscopic guidance aiming at the metallic coil (Fig. 1c). A good ablation result with a 3.5–5.5-cm coagulated area was demonstrated on follow-up CT 3 days after the procedure (Fig. 1d).

In case 2, the patient had had a hepatic resection to deal with a single metastasis but had developed a second lesion approximately 6 months after surgery. The new metastasis was in an immediately subdiaphragmatic position in the dome of the liver and was visible on US examination. It was treated successfully under US guidance. However, a third lesion developed 3 months later. This was not visible during US scanning but was clearly demonstrated by contrast-enhanced CT. A coil was placed within it, as previously described, and RFA was performed using a combination of US and fluoroscopic guidance. The follow-up CT 1 week after the procedure revealed complete coagulation of the metastasis.

In case 3, a 73-year-old man presented with a 4-cm hepatocellular carcinoma in the right lobe of the liver. This was faintly visible on the arterial phase of contrast-enhanced CT as a subcapsular hyperdense mass but was not seen clearly during the portal venous phase. It was invisible on the unenhanced CT images and on US examination. This patient needed three sessions of RFA over a 6-month period because of local tumor edge recurrence appearing as rim enhancement on CT. On each occasion the procedure was facilitated by the presence of two metallic coils. Re-treatment with the coils in place was much faster than when the procedure is carried out under CT or US guidance alone, as the electrode could be inserted accurately and rapidly under fluoroscopic guidance. Eight months after the last treatment there was no evidence of recurrence.

In case 4, a patient who had had a previous left hepatic resection for metastases from a previously resected carcinoma of the colon developed two new lesions in the liver remnant. One of these was faintly visible on unenhanced CT but the other was not. Neither was seen on US scanning. Both appeared transiently during contrast-enhanced CT. A metallic coil was placed in the lesion, which could not be seen on unenhanced CT, as described above.

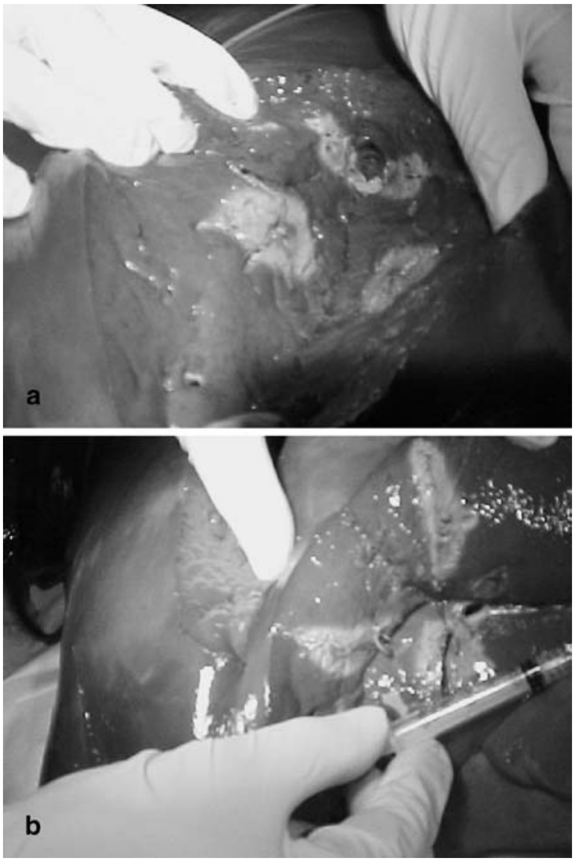

Fig. 2 **a** With the coil "coiled-up" the coagulated area is rounded. **b** With the coil extended the coagulated area is elongated

This was treated during the same session under fluoroscopic guidance with an excellent immediate result.

In case 5, a patient who had had a resected colonic carcinoma presented with a solitary metastasis in the right lobe. The lesion was not visible on US and poorly seen on unenhanced CT images but clearly detectable on contrast-enhanced CT scanning. A metallic coil was placed in the center of the lesion and the patient was treated under fluoroscopic guidance with an excellent result on the post-treatment CT.

In all cases the measurements of impedance and current indicated by the RF equipment were similar to those observed when RF is used to treat liver tumors without coils in place; thus, the presence of the metallic coils did not seem to have any major influence on current or impedance. The appearance of the coils on fluoroscopy and CT images did not change following the RF procedures.

In order to evaluate whether the embolization coils when placed near the RF electrodes altered the electromagnetic field distribution (energy and heating fields), we carried out limited experiments in ex vivo porcine liver tissues.

A large ex vivo porcine liver specimen was placed on a grounding pad and the locations marked on its surface. Metallic coils, 4 cm×3 mm (MREYE, Cook, William Cook Europe a/s, Bjaeverskov, Denmark), were deployed in two of the three locations approximately 4 cm deep to the liver surface. Using US and fluoroscopic guidance, electrodes were guided to the coils and RFA was carried out, as follows:

– Location 1: A single 10-cm RF probe (Radionics); no coils
– Location 2: A single 10-cm RF probe (Radionics) with the metallic coil inserted in the center of the targeted area with coil coiled-up
– Location 3: A single 10-cm RF probe (Radionics) with the metallic coil layered out, i.e., not coiled-up

Three further locations were selected and the above procedures were repeated changing only the RF system (Berchtold Elektroton 106 Hitt, Germany). In each of the six locations, RF energy was applied in a standardized manner for each system and stopped when the area ablated adequately (persistently high impedance; 3 cm coagulated area). The coagulated areas were imaged using US and fluoroscopy during and after ablation. Each location was dissected out, the pattern of coagulation was inspected visually.

In locations 1 and 2, i.e., in the absence of a coil or with the coil coiled-up (Fig. 2a), the area of coagulation was near-circular. There was no significant difference in the time required for ablation or other parameters (impedance, current, wattage, or temperature) when each electrode type was used with and without the coils. However, the pattern of coagulation was affected by the presence and shape of the coil. When the coil was layered out (location 3), the area of coagulation extended in an almost linear fashion along the length of coil. This was observed with both the Radionics and the Berchtold electrode systems (Fig. 2b). When the coil was coiled-up there was no discernible change in the pattern of coagulation.

Discussion

In most patients thermal ablation of hepatic metastases is guided by US or CT. However, some tumors are very poorly visible on either US or unenhanced CT. Furthermore, they may appear only transiently on CT images following enhancement with intravenous contrast medium, only to disappear on images obtained a few minutes later. Such lesions are difficult to treat with thermal ablation as accurate positioning of RF electrodes cannot always be accomplished during the short period during which they are visible on CT following intravenous contrast medium enhancement. The use of anatomical landmarks for electrode placement can help but is often insufficiently accurate. It is much easier to perform the procedure under CT guidance when the tumor is visible on unenhanced images, as this allows sufficient time for accurate placement of the RF electrode. However, even when the tumor is easily visible, thermal ablation under CT guidance can be very difficult in the case of lesions that have to be accessed using a steeply oblique approach, for example, those located immediately below the dome of the diaphragm. For such tumors, US guidance is frequently employed but this can be done only when the tumor is seen reasonably well on US images.

Ultrasonic contrast agents are useful in demonstrating vascular lesions, such as hepatocellular carcinoma, but they are not as effective in visualizing relatively avascular tumors, such as colorectal metastases. Other, more recently developed US contrast agents may reveal avascular metastatic areas by enhancing the surrounding normal liver parenchyma, but the experience with these materials is relatively limited [10]. Furthermore, US examination, even with the use of contrast media, cannot distinguish reliably between coagulated and viable tumor.

The technique we have outlined above allows accurate placement of RF electrodes irrespective of the degree of visibility of tumors on US or unenhanced CT images. Provided the mass is visible, if only transiently, on enhanced CT it can be accessed under fluoroscopic guidance following placement of the metallic coil.

MR-compatible electrodes are now available commercially. However, MRI is cumbersome and time consuming as a method of guidance in thermal ablation procedures. If a tumor is visible on MRI but cannot be visualized on US or CT images it may be possible to use MRI to place a MR-compatible metallic coil, which can be used subsequently for fluoroscopic guidance of the procedure as described above.

The technique described in this paper may also be useful in patients in whom the original lesion has been treated without the aid of a coil, when residual or recurrent tumor invisible on US or unenhanced CT images is detected. In such cases the coil can be placed within the viable tumor to be targeted during the ablation procedure. Furthermore, if a patient has been previously treated following coil placement and residual tumor is demonstrated on follow-up CT, the relative position of the coil and the residual tumor can be noted and used to guide a second treatment without placement of a second coil. In our experience, the minimal artifacts produced on follow-up CT do not interfere with the visualization of any residual or recurrent tumor.

In some patients a fine needle can be inserted within the tumor under contrast-enhanced CT guidance but without subsequent insertion of a metallic coil. The electrode can be inserted in tandem with the fine needle, which can be subsequently withdrawn. However, this method has certain disadvantages. Firstly, the fine needle may make subsequent accurate placement of the electrode more difficult. Secondly, if there is residual tumor or edge recurrence, the placement of a needle as a radiopaque marker needs to be repeated when re-treatment is carried out. The use of a coil avoids these drawbacks. The coil placement technique is also useful when treating very small lesions in areas which may be difficult to access, such as under the dome of the diaphragm, even when such lesions are visible on US and CT images. In such cases, placement of a coil using CT or US guidance combined with fluoroscopy can make subsequent procedures on the same lesion much easier.

The results of the brief ex vivo experiments we carried out showed that when the coil is extended it leads to extension of the coagulated area along its length. However, when a coil is used to mark the position of the tumor, it is placed in a coiled-up position as this facilitates localization. A coiled-up coil has no perceptible effect on the size or shape of the coagulated area. Our clinical experience is in keeping with the experimental findings: the coiled-up coils did not have any major influence on the size or shape of the coagulated area, as they are placed in the center of the tumor. The area of coagulation induced by the electrode extends well beyond the coil which, therefore, has no impact on the overall result. In any case, it seems that small metallic objects, such as surgical clips, do not increase the risk of RFA in the liver [11].

The vast majority of patients requiring RFA can be treated under US or CT guidance alone. However, a small number will have lesions that are too poorly visible on unenhanced CT or US. MRI guidance can be difficult and time consuming. Ultrasonic contrast media do not always help to visualize colorectal metastases very well. We believe that the technique we have described provides a good solution to a difficult problem.

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