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Percutaneous hepatic ablation: What needs to be known in 2014

O. Seror

Department of Radiology, Jean-Verdier Hospital, avenue du 14-Juillet, 93140 Bondy, France

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Abstract  Percutaneous treatments for liver tumors were initially reserved for patients deemed to be inoperable and whose tumors were small in both size and number. As a result of the widening range of both techniques and technologies these treatments have gradually become incorporated into increasingly complex treatment strategies for increasingly broad patient groups. The place reserved for these techniques, which are still dominated by monopolar radiofrequency ablation, which is now facing strong competition from second-generation microwaves, is governed by each center’s knowledge and skills in the techniques. This review describes the possible indications for percutaneous ablation depending on clinical findings and the technical and technological choices made.

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In the last two decades, percutaneous treatments for malignant liver tumors have advanced considerably. They are better tolerated than partial hepatectomy [1–3] and can radically treat tumors, which are small in both size and number with very few contraindications [4, 5]. The most widely used method of those available has been monopolar radiofrequency ablation, although in the last 2 years this has attracted strong competition from microwaves [6], which have seen major technological advances. Other techniques such as multipolar radiofrequency ablation [7] and irreversible electroporation [8] use implantation of several electrodes operating in pairs in bipolar mode. These methods, which are conceptually very different from monopolar radiofrequency ablation and microwaves, are bringing new prospects for treatment.

Generally, compared to older chemical methods such as alcoholization, physical ablation techniques produce more predictable results, which are almost independent of the
type of tumor. Several randomized trials [9–11] have confirmed that radiofrequency ablation is superior for the treatment of hepatocellular carcinoma (HCC). There has been an underlying trend in the last few years to use first line percutaneous physical ablation techniques to treat small malignant liver tumors in favor of excision surgery [3,5,12–14].

Guiding and monitoring percutaneous hepatic ablation

Ultrasound computed tomography (CT) and to a lesser extent, magnetic resonance imaging (MR) can be used for percutaneous hepatic ablation. The choice of method depends less on the operator’s usual practice than on the intrinsic properties of each of the methods. There are no comparative studies available as yet on this subject and it is quite remarkable that almost all of the major series published have been carried out under ultrasound guiding and monitoring [4,5,12]. This preference in the expert centers is undoubtedly partially explained by its low cost and ready availability of ultrasound. Furthermore, however, the intrinsic properties of ultrasound: multiplanar examination, real time and excellent unenhanced tissue contrast resolution makes ultrasound perform extremely well in guiding and monitoring percutaneous ablation of liver tumors [15]. The predominant role of ultrasound in this situation should be further increased by the use of microbubble contrast media and the major advances in 3D imaging, fusion and instrumentalized geolocalization [16].

The new flat sensor angiography tables allow 3D CT-like images to be obtained and should shortly also become necessary guiding and early assessment tools for percutaneous ablation techniques. In addition, and unlike CT, they offer maximum patient accessibility making ultrasound extremely easy to use simultaneously in guiding and monitoring procedures.

Radiofrequency ablation technologies and their results

The generic term “radiofrequency” in reality poorly reflects the large technological differences between instruments. Monopolar mode, which is still at present by far the most widely used (a generator connected to two electrodes: one active electrode is implanted in the center of the treatment area and the second “passive” electrode is a dispersion plate stuck onto the patient’s skin) in fact groups together several devices which are very different in design (Fig. 1). In order to increase the volume of tissue destroyed by impact with these systems, energy diffusion from the active electrode implanted in the tumor must be improved. Three major concepts have been developed to achieve this; these differ mostly in the design of the electrodes, which may either be linear or deployable.

A few animal model studies have shown that the shape and volume of the ablation areas obtained in the liver can vary depending on the monopolar device used [17,18]. Differences can also be seen on an intention-to-treat basis as the feasibility of treatment varies for a given site depending on the design of the electrode. Deployable electrodes are more difficult to use for superficial tumors. Linear electrodes, which are not bulky and can be seen in a single plane section, are undoubtedly more straightforward to position, particularly for sites considered to be difficult.

Another system operating in multipolar mode has been available in clinical practice for several years. This involves implanting several (up to six) cooled bipolar linear electrodes, which are activated sequentially in pairs (Fig. 2). It is no longer necessary with this device therefore to use a dispersion electrode as all the energy produced by the generator is delivered into the treatment area. Unlike the

![Diagram](image1.png)

Figure 1. a: diagrammatic representation of an ablation area with ideal centrifugal extension from a central tumor energy source: monopolar, mono-electrode radiofrequency (RF) ablation, mono-aerial microwave ablation, monofiber laser ablation, mono-applicator cryoablation; b: diagrammatic representation of ablation by ideal summation (sequential or simultaneous) of three ablation areas with isometric centrifugal extension from three paracentral energy sources within the tumor. Multi-electrode, monopolar RF ablation, multi-aerial microwave ablation, multifiber laser ablation, multi-applicator cryoablation.

![Diagram](image2.png)

Figure 2. Diagrammatic representation of multipolar ablation by sequential bipolar activation of all electrode pairs (three electrodes allowing three possible combination of electrodes pairs). The ablation area extends centripetally between the three energy sources implanted in the periphery of the tumor or even, if the tumor is sufficiently small, outside of the tumor = “no touch” technique. This type of procedure is only possible with multi-electrode multipolar radiofrequency and irreversible electroporation.
monopolar systems, the tissue is not destroyed by centrifugal diffusion of heat from the electrode but centripetally in the spaces between each electrode pair. As a result, in multipolar mode it is no longer the center of the tumor but its periphery, which needs to be punctured. Compared to conventional monopolar devices, this system has several fundamental advantages: improved energy efficiency for the same sample power and in particular more predictable margins of the ablation areas produced (determined by implanting the electrodes). These advantages have been demonstrated in several pilot studies, which, in particular, have shown that it has become possible to completely destroy tumors with a diameter well in excess of three centimeters [19,20]. In addition, in multipolar mode, it is no longer necessary to puncture the tumors themselves, which can be treated using the concept of “no touch ablation”, borrowed from oncolgy surgery [19]. As a result, far more than being a technological advance, multipolar mode has introduced a genuine paradigm shift into percutaneous tumor ablation.

**Microwave technologies and their results**

Like radiofrequency, microwave is a hyperthermia ablation technique and Penn’s biothermodynamic equation [21] also applies when modeling the final result of tissue destruction by microwave ablation. In addition, like monopolar radiofrequency ablation, energy is propagated centrifugally from the electrode (aerial). Here again, several electrodes can be used simultaneously, as in monopolar radiofrequency ablation, to increase the ablation volume primarily by sum-mating the areas of destruction around each electrode. If the intention is to create a continuous area of ablation, as in monopolar radiofrequency ablation the aerials need to be positioned in such a way that the individual ablation areas overlap (Fig. 1). If the intention is to obtain the same result with a single aerial, as in single electrode monopolar radiofrequency ablation, several successive ablation cycles need to be performed, moving the aerial after each impact in order to overlap the areas destroyed.

By design, therefore, microwave is subject to the same limitations as conventional monopolar radiofrequency ablation, although the second-generation microwave devices, which have recently become available, have reigned interest in the technology, as the transfer of microwave energy to tissue is more efficient than with radiofrequency. A microwave electromagnetic wave excites water molecules over a radius of approximately 2 cm (from the center of the aerial) whereas a radiofrequency wave mobilizes ionic charges located within a radius of just a few millimeters around the electrode. With microwave, therefore, the passive tissue heat conduction effect contributes less to the final volume of the area destroyed than with radiofrequency ablation. The microwave temperature peaks are higher and achieved faster than with radiofrequency. In addition, and unlike radiofrequency ablation, carbonization of tissue in contact with the microwave aerial (which generally occurs as the temperatures reached are > 100 °C) does not stop the process of energy transfer to the tissue.

How does this work in clinical practice? It is clear that for the equivalent volume of tissue destruction microwave is considerably faster than radiofrequency ablation [22], although at present there are no convincing clinical results to confirm that it is possible with microwave to extend the limits of maximum tumor size, which can be destroyed through impact without increasing the risk of complications. In practice, and as with monopolar radiofrequency ablation beyond 1.5 cm either side of the electrode with, the final results are variable a single energy delivery cycle (without repositioning), as they are very dependent on the tissue macro- and microperfusion conditions. In addition, and unlike radiofrequency ablation in which tissue impedance routinely rises during the procedure, with microwave there is currently no tissue feedback, which can be used to judge the progress of the ablation. The charts provided by the manufacturers are of limited use as they are produced from *ex vivo* experiments. The increase in ablation volumes by microwave reported in some clinical studies is more due to frequent repositioning of the aerials during the procedures (facilitated by the short energy delivery cycles of 1/3 to 1/2 of those with RF) than to the greater intrinsic efficiency of microwave [23]. At present, there is therefore no serious argument to routinely recommend the use of microwave ablation to treat tumors over 3 cm in size. As with monopolar radiofrequency ablation, the need to reposition electrodes for tumors over 3 cm in size makes microwave ablation less predictable and higher risk.

**Irreversible electroporation technology and its results**

Irreversible electroporation causes delayed or immediate cell death by permanently damaging the membrane function of cells which are exposed to a very high potential (1000 V–3000 V) high intensity (20 A–50 A) pulsed electrical field lasting a few microseconds (50 μs–90 μs) [8]. These electromagnetic field pulses trigger massive local mobilization of tissue ionic charges, which exceed the physiological capacity of cell membrane transport, irreversibly interrupting the cells homeostasis. Unlike the other physical destruction techniques, electroporation is not therefore a thermotherapy although there is a minor Joule effect.

The results of electroporation are not therefore in principle affected by the thermal blood flow convection effect. In addition, as the Joule effect of electroporation is negligible, the method does not denature macromolecules such as collagen fibers. Although their cell component is “affected” the “electrophoresed” tissues retain an intact connective tissue architecture. Small bile ductules and vessels within the electrophoresed areas therefore often remain patent. Electroporation is therefore particularly promising to treat central hilar liver tumors in which thermotherapies are contraindicated because of the risks of biliary stenosis. In practical terms, alongside multipolar radiofrequency, ablation electroporation also relies on the principle of implanting several electrodes (2 to 6), which are sequentially activated in pairs in bipolar mode (Fig. 2). Electrolocalization is a technique, which is still not widely used: few clinical results have been published and patient numbers have been small, with limited follow up. Nevertheless, its specific aspects, which make the method a relatively
safe treatment option in inoperable juxtahilar liver tumors have been confirmed [24].

Other technologies

Other physical destruction methods are used including laser photocoagulation, cryotherapy and focused ultrasound. Although clear technological improvements have been made with these techniques over recent years, their use in treating liver tumors is still marginal. They have not yet shown to offer sufficient advantages over other thermal methods to justify their more widespread use.

Indications and contraindications for percutaneous ablation of liver tumors

Indications

Curative treatment

Alongside excision surgery, percutaneous ablation techniques form part of the radical curative local treatments. They are therefore conventionally considered in patients who do not have widespread disease and who do not have extrahepatic spread. The most widely accepted rule for percutaneous treatment to be used is the rule of "two 3s": 3 cm maximum diameter and up to 3 concomitant sites.

The debate over the place of percutaneous treatments compared to their direct competitor, excision surgery, is still wide open. Radiofrequency ablation is still very often described as a salvage treatment in patients not accepted for excision, although there are no robust data justifying this strategy either for metastases (of colorectal cancers) [25] or for HCC [26]. For similar patient groups, survival after surgery is not significantly better than after radiofrequency ablation [14,27], although compared to excision, radiofrequency treatment is far better tolerated and less expensive. It can also be easily repeated in the event of recurrence (which occurs in over fifty per cent of patients 5 years after excision or percutaneous treatment, both for metastases and for HCC). As a result, there is now a strong basis for offering patients radiofrequency ablation first line for small tumors (≤ 3 cm in monopolar mode and ≤ 5 cm in multipolar mode), including those with operable disease.

Combined treatments

Percutaneous treatments are usually only considered in more extensive disease in combination with other treatments such as hepatectomy, chemotherapy for metastases [6] or chemoembolization for HCC. The purpose of these combined treatments is also to completely eradicate any active lesion (0 residual tumor [R0]). Multipolar mode, which can completely and reproducibly destroy tumors up to 8 cm in diameter [19] can reduce the need for treatment combinations, which can occasionally be poorly tolerated (Fig. 3).

Figure 3. Eighty-one-year-old female patient with a peripheral cholangiocarcinoma 8 cm in diameter in the dome of the liver treated by multipolar radiofrequency ablation. The mass on computed tomography (CT) before treatment in the portal phase on axial (a) coronal (b) and sagittal (c) sections. One month after multipolar radiofrequency ablation (6 electrodes) and protection of the diaphragm by creating artificial ascites: axial (d) coronal (e) and sagittal (f) CT showing complete destruction of the tumor area up to contact with the portal and suprahepatic vessels.
The arrival of second-generation microwave devices enable "one shot" ablations of small tumors (≤ 3 cm) in under three minutes (application) and offers future prospects for multifocal disease (> 3 sites) or multiple recurrences (multicenter carcinogenesis). In this case, ablation appears to be used less to eradicate the cancer than to attempt to achieve long-term control, preserving patient’s best possible quality of life.

'Holding' treatment pending liver transplantation for HCC

Patients in France with a small HCC (Milan criteria: 1 nodule ≤ 5 cm or up to 3 nodules ≤ 3 cm), which has developed in well-compensated cirrhosis (Child-Pugh A) have waiting time of approximately 1 year for a transplant. The question therefore often arises as to the benefit of treating the HCC pending transplantation in order to keep the patient within the Milan transplantation criteria. Percutaneous treatments, chemoembolization and even a combination of both techniques are often used in this situation. Some European centers have reported that over 30% of patients who have not been treated come off the waiting list because of tumor progression [28]. In reality, the problem which arises is not to know whether percutaneous treatments can keep patients within the eligibility criteria for transplantation (the answer to this is obviously yes) but to ensure that the post-transplant prognosis of patients who have had ‘holding’ treatment pending transplantation is similar to that in patients who have been transplanted as early as possible. There is, however, no tangible evidence in the literature to answer this question, although it is a crucial one. The risk of tissue dissemination along the needle puncture path is often cited as a reason to opt for chemoembolization pending transplantation. This solution does not appear to be well founded as chemoembolization only achieves total necrosis of small HCC in under a third of cases [29]. Because of the shortage of transplants, access to transplantation is being increasingly limited for patients with HCC who do not have liver impairment. In reality, the majority of these "technically transplantable" patients will never be transplanted. "Holding" treatment is therefore more likely to be the only first line tumor therapy, which they will receive for several months. This treatment should therefore be as radical as possible in order to offer the patient the best chances of long-term survival. Using the Milan criteria and apart from excision, only percutaneous destruction techniques are potentially curative and they should therefore be used in priority, including situations when transplantation is planned, because, as described above, transplantation is far from a certainty in patients with good liver function. In addition, a "salvage" transplant is still possible in these patients if their HCC recurs after percutaneous treatment [19]. The risk of dissemination should not therefore be overstated and should always be assessed depending on the specific clinical situation. Risks of dissemination are increased in:

- subcapsular tumors which cannot be approached without passing through non-malignant liver tissue (less than 1 cm);
- when initial (unprotected) biopsies have been taken;
- greatly elevated serum α-fetoprotein concentrations;
- poorly differentiated tumors (> Edmonson grade II).

In these situations, “no touch” multipolar mode is a very attractive alternative [19] (Figs. 2 and 4).

Palliative treatment

Partial resection of malignant liver tumors does not significantly prolong patient survival and surgical tumor reduction is therefore not indicated. In addition, hepatectomy can only be considered in patients with liver metastases if the procedure would remove all visible tumors (R0). This surgical concept has been extrapolated to the percutaneous treatments which are not conventionally therefore indicated for palliative use. One randomized trial, however, has shown that the combination of radiofrequency ablation with chemotherapy significantly prolongs survival in patients with metastatic liver disease (colorectal in origin) in whom R0 excision cannot be achieved [30]. No comparable data are currently available for HCC. It is possible, however, that as in the example of the palliative treatment par excellence, chemoembolization, a reduction in tumor volume with percutaneous treatment could lead to improved survival in some patients.

Figure 4. Sixty-year-old male patient with superficial hepatocellular carcinoma in segment III treated by no touch multipolar radiofrequency ablation. Computed tomography (CT) in the arterial phase (a) shows a subcapsular, hepatocellular carcinoma in segment III, 3 cm in diameter. One month after no touch multipolar radiofrequency ablation the CT (b) shows appearances of complete destruction with excellent safety margins.
Contraindications

Hemostasis

There are few absolute contraindications and these are mostly concern patients at high risk of bleeding. Conventionally, patients with serious coagulation abnormalities are therefore excluded. The contraindications to percutaneous treatments for most groups are:

• prothrombin ratio < 50%;
• platelet count < 50,000;
• activated partial thromboplastin time > 10 points over the control.

Although not formally proven, thermoregulation of the needle puncture path at the end of the procedure by slowly withdrawing activated electrodes “hot withdrawal” (which is impossible with electroporation and difficult or even dangerous with microwave) is recommended in order to reduce the risk of bleeding. This maneuver also reduces the risk of tumor dissemination.

Cirrhosis

Paradoxically, cirrhosis does not appear to either increase or worsen bleeds after percutaneous ablation. The risks of liver decompensation, however, are greater in patients who have the most severe coagulation abnormalities.

Clinical ascites is also one of the contraindications for radiofrequency ablation, as the risk of bleeding appears to be greater. Major ascites on a background of cirrhosis is an indication of serious liver dysfunction, a situation, which generally contraindicates any treatment for HCC.

Site

Some anterior subcapsular tumors cannot be punctured directly without passing through non-malignant liver tissue. The risk of bleeding complications and tumor dissemination is greater in this situation. Limited resection is often the best alternative treatment for these tumors and is a particularly reasonable option as the procedure is technically straightforward and limited. As we have described, if surgery is contraindicated, “no touch” multipolar radiofrequency ablation is an attractive alternative to percutaneous methods (Fig. 4).

Other tumor site contraindications are often quoted depending on the center, equipment, technique and experience of the operators. Some tumor sites carry large risks of collateral damage. This applies particularly to central (hilar) tumors, which carry a risk of biliary stenosis. Treatment of tumors located close to the gastrointestinal tract, particularly the colon, are at greater risk of peritonitis from perforation and the minimum safe distance of 1 centimeter between the border of the tumors and these structures is commonly recommended. Some preventative measures such as cooling the biliary tract by endoluminal injection of iced water when the energy is delivered or retracting the treatment area from gastrointestinal structures by hydro- or gas dissection, all these sites to be treated in some situations when no surgical alternative is available [3].

Percutaneous treatment of other sites such as tumors located close to the gallbladder or diaphragm also requires some precautions, particularly when the contact areas extend over a centimeter. In order to protect the diaphragm artificial ascites is created with dextrose before the procedure (filling the peritoneal cavity by injecting 1 to 3 L of 5% glucose with the patient in the Trendelenburg position). The gallbladder can be drained preventatively or even cooled by circulating water (in this case the cooling circuit requires dual catheterization of the gallbladder). In addition, electroporation, which is not a thermotherapy, could be a first line technique in these situations, if its preliminary results are confirmed (Fig. 5).

Non-functional sphincter of Oddi

Patients with a previous history of biliary-gastrointestinal anastomosis or sphincterectomy have a 50% risk of developing an abscess in the thermal ablation area. No antibiotic prophylaxis or antibiotic therapy has been shown to be effective in preventing this complication. It is difficult, however, to consider patients without a functional sphincter of Oddi but who are also inoperable and have an absolute contraindication for any percutaneous treatment, as this would remove the last possibility of curative treatment. The risk of percutaneous treatment may be taken in this situation

Figure 5. Sixty-five-year-old female patient with left intraportal hepatocellular carcinoma treated by electroporation. Computed tomography in the arterial phase (a) shows a left intraportal hypervascular mass. One month after irreversible electroporation (with 4 electrodes) dynamic MRI in the arterial phase (b) shows appearances of complete destruction with no related biliary damage.
provided that the patients are monitored very carefully in the weeks after the procedure. Any abscess, which develops should be treated promptly with drainage and appropriate antibiotic therapy.

Electromagnetic interferences
Delivering electromagnetic pulses close to a pacemaker can theoretically damage it. In practice, this applies with monopolar RF and microwaves but not with bipolar RF (as in order for interference to develop, the pacemaker would need to be located between the two active electrodes!). From this perspective, multipolar RF is the safest technique. In reality, monopolar and microwave ablation may be carried out in patients with pacemakers [31] although a cardiology opinion is recommended before the procedure. If the decision is made to continue, these patients should be treated under ad hoc resuscitation safety conditions. Electroporation which also uses bipolar mode but with very high RF intensities and potentials is, however, completely contraindicated in heart disease (of any type) because of the risk of a serious arrhythmia (even if the RF pulses are only delivered during the ECG refractory period [S-T]).

Conclusion
The emergence of effective reproducible mini-invasive percutaneous treatments such as radiofrequency has profoundly changed the management of small malignant liver tumors for which the only radical treatment until recently has been excision surgery. Outside of the transplantation situation, the first line treatment of early stages (TNM I) of HCC should now be with percutaneous ablation techniques. There is a well-acknowledged lack of information in the literature to establish the exact role of percutaneous methods for treatment of localized hepatic metastases, particularly those from colorectal cancer compared to excision surgery. It does, however appear here again that percutaneous methods can offer long-term survival, which is entirely similar to the survival obtained after hepatectomy. These still too scarce findings should be followed by randomized trials to compare percutaneous techniques with excision for the treatment of metastases.

Combination treatments using percutaneous destruction techniques and endarterial therapies have long been considered to be the most promising strategies to improve and extend the indications for the percutaneous treatments. Considerable technological advances in recent years have brought new future prospects for treatment. The second-generation microwave devices, which are far faster than monopolar radiofrequency ablation technically, enable complete treatment of 5 to 8 small (<3 cm) liver tumors in a single session. Multipolar radiofrequency ablation can achieve controlled thermo-ablation of both small and larger tumors (5 cm, <8 cm), whether or not these are superficial. Irreversible electroporation now offers radical treatment for central, inoperable liver tumors. These new treatment methods clearly need to be confirmed on a larger scale although the speed of technological change in the field of ablation is such that now even more than before our clinical research must be permanently incorporated into our routine clinical practice.

Clinical case
A 57-year-old man followed up for Child-Pugh A 5 mixed post-HVC and alcoholic cirrhosis (the patient was still drinking) (PR 60%, Bilirubin 30 μg/mL) was found to have four nodules under 3 cm in diameter with (CT) appearances of hepatocellular carcinoma. His alpha-fetoprotein was 10 ng/mL (Fig. 6).

Questions
1. What treatment would you consider?
   A. Transplantation.
   B. Excision.
   C. Chemoembolization.
   D. Ablation(s).
2. Which of the ablation techniques do you think is most appropriate?
   A. Multipolar radiofrequency ablation.
   B. Electroporation.
   C. Microwave.
   D. Conventional monopolar radiofrequency ablation.
3. The lesions are not entirely visible on ultrasound:
   A. This is a contraindication to ablation techniques: arterial chemoembolization therapy would be better.
   B. The ablation procedure should be performed under CT guidance.
   C. The ablation procedure should be performed by flat sensor angiography with cone beam CT guidance.
   D. Ultrasound guidance with pre-treatment CT or MR guidance could be considered.
4. The repeat CT performed a month after treatment shows a good response in the four lesions treated. Three months later, however, when the patient had stopped drinking completely and his liver function had improved, three new nodules were found. What do you propose? (Fig. 7):
   A. Chemoembolization.
   B. Radioembolization.
   C. Transplantation.
   D. A percutaneous ablation procedure.

Answers
1. Answer D. A. Temporary contraindication to HT (the patient has not stopped drinking). If the patient stopped his excessive alcohol consumption the average transplant waiting time is 1 year for Child-Pugh A disease. He is slightly outside of the Milan criteria (tumors < 3 cm although number > 3). As a minimum, therefore, “holding” treatment should be offered. B: more than three segments contain tumor and active cirrhosis is present. These represent a contraindication to excision surgery. C. This is the treatment very often recommended in this situation of multifocal HCC. It is therefore by necessity non-selective. The risk of deterioration of liver function after treatment is high in this case in an alcoholic patient who is still drinking. In addition,
the effect of endarterial therapy is difficult to predict and rarely complete (it is a palliative treatment).

2. Answer C and D (Fig. 8). A. The challenge in this situation is to control the disease as radically as possible without deteriorating liver function. Multipolar RF achieves near constant average safety margins of 1 cm when the nodules are small, as they are in this case (< 3 cm). With 4 tumors, however, a significant amount of functional liver parenchyma would be sacrificed. The benefit/risk balance of multipolar RF does not therefore appear to be positive in this case. B. This is a new technique, which has not been shown to be effective compared to the more conventional methods such as RF or microwave. Electroporation is a reasonable method if thermotherapies (RF MW) are absolutely contraindicated, particularly for central, inoperable tumors juxtapositioned between the vascular convergence and common bile duct.

3. Answer D. A. Fusion and virtual navigation technologies have greatly improved guiding imaging in recent years. Lesions, which cannot be seen on ultrasound can now be located and treated in most cases using these technologies. B. This is far more intensive, time consuming (human and machine), exposes the patient to irradiation (multiple nodules) and also inexact (poor contrast in the liver nodules without enhancement). C. Compared to CT these new generation angiography tables are helpful as they allow better patient accessibility. They also have rotational 3D (cone beam CT) guiding and fusion instruments, which allow the difficultly located target to be punctured. These low contrast images do in addition, however, deliver a relatively large amount of irradiation (high angular sampling of the RX beams for images with the best tissue contrast).

4. Answer C and D. A. This is an option, but why choose a treatment which is only partially effective and unpredictable when there are "only three" small lesions? B. This is a treatment currently being assessed, which has not been shown to be superior to chemoembolization. C. Yes, in this young patient who has stopped excessive alcohol consumption. Transplant would seem at present the best long-term treatment option. Local or locoregional treatments, even if effective, will not prevent the later development of new lesions as this patient has evidence of multicenter carcinogenesis. He is still however Child-Pugh stage A and his liver function has even improved, so a transplant waiting time of at least a year should be planned. D. Percutaneous ablation is a perfectly appropriate "holding" treatment pending transplantation. It also has the advantage over chemoembolization of being repeatable almost without limit (as long as there are not too many lesions) and being more radical. This is significant, as transplantation remains a possibility for all patients on the list. There is of course a risk of dissemination along the puncture path after percutaneous treatment. This risk is sufficiently low, however, not to represent an absolute contraindication in patients.

Figure 6. Three computed tomography section levels in the arterial phase of contrast enhancement showing four hypervascular nodules (with wash-out in the portal phase not shown on the figure) under 3 cm in diameter. Note also the hepatic dysmorphism and small amount of ascites indicating decompensated cirrhosis (alcoholic, still drinking).
Figure 7. Three computed tomography section levels in the arterial phase of contrast enhancement showing areas of destruction by application of microwave energy.

Figure 8. Strategy plan for multiple percutaneous ablations to reduce the number of punctures and length of the procedure.
awaiting transplant. The risk is particularly low in our patient as none of the lesions to be treated are located beneath the capsule.

**Disclosure of interest**

The author declares that he has no conflicts of interest concerning this article.

**References**


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