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Ablative therapies: Advantages and disadvantages of radiofrequency, cryotherapy, microwave and electroporation methods, or how to choose the right method for an individual patient?

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Abstract Several ablation techniques are currently available. Except for electroporation, all of these methods cause fatal damage at a cellular level and irreversible architectural deconstruction at a tissue level by thermal effects. Ablation of a tumor using one of these techniques, whether thermal or otherwise, requires applicators to be positioned from which the energy is delivered in situ. Some techniques, however, require several applicators to be inserted (multibipolar radiofrequency, cryotherapy and electroporation) whereas a single applicator is often sufficient with other technologies (monopolar radiofrequency and microwave). These methods are conceptually very similar but are distinguished from each other in practice through the technologies they use. It is essential to understand these differences as they influence the advantages and limitations of each of the techniques. There is no such thing as the perfect multifunctional ablation device and choice is dictated on an individual patient basis depending on the aim of treatment, which itself depends on each patient's clinical situation.

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Centrifugal radial ablation compared to convergent centripetal ablation: the difficult balance between simplicity and predictability

In situ destruction of a tumor has long been obtained using a centrifugal coverage method: energy dissipates towards the periphery from an applicator inserted into the center of the tumor target [1]. Ideally energy has to isotropically radiate with a minimum of loss in order to produce a fatal effect on the tumor, and beyond that over a targeted margin and a minimal thickness (Fig. 1). This centrifugal dispersive ablation strategy which is derived from the chemical ablation techniques is still the most widely used as it is the most simple to apply. It is the basis of techniques such as monopolar radiofrequency, microwave, laser and cryotherapy. Using these techniques, an overlapping ablation strategy is required for tumors over 3 cm in diameter (1.5 cm for laser and cryotherapy) in order to destroy the whole lesion with a sufficient margin. This may be achieved simultaneously if several applicators are used during the procedure (generally with laser and cryotherapy) [2]. Fundamentally, using several applicators with centrifugal dispersion methods does not change the operation of the procedure and final ablation is planned by simple summation of several overlapping centrifugal destructions caused by each of the applicators. If the applicators are sufficiently close together (which is essential to achieve continuous destruction between them) a more or less extensive synergistic effect occurs. It is important, however, to understand that each of the ablated regions created remains overall independent. As such, they represent areas of centrifugal radial destruction, the contribution of which to the success of the whole procedure is mostly influenced by the operator's ability to implant the applicator in the center of each of the desired individual destruction zones (Fig. 1). The conceptual simplicity of ablations carried out using dispersion techniques is their main advantage. This is particularly apparent for monopolar radiofrequency and microwave ablation which can destroy a relatively wide range of tumors up to approximately 3 cm in diameter using a single applicator and therefore with a single puncture. This assumes, however, that the shape of the targets treated is as spherical as possible and that the assumption of isotropic energy propagation is observed. These two conditions are generally met for small tumors (<2.5 cm) although over this size, large deviations from the ideal centrifugal ablation model are seen because of the heterogeneous nature of tissue properties (electrical and thermal conduction, light absorption and micro- and macrocirculatory thermal convection). Because of the overall spherical expansion of the ablation zone it is desirable for the target treated to be remote from important structures in order to reduce the risks of complications due to collateral thermal damage.

Another ablation strategy involves convergence of energy from the periphery towards the center of the tumor. A minimum of two applicators are inserted into the periphery of the tumor in order to deliver the energy concentrically within the target. In practice at present, only radiofrequency and electroporation which deliver a bipolar RF current can use this strategy satisfactorily. The continuity of the treatment zone is governed by the distance between the electrodes: 3 cm for radiofrequency and 2.5 cm for electroporation are the distances beyond which the risk of discontinuity of the treated areas becomes high. For volumetric dosimetry reasons, targets over 2 cm in diameter need to be treated along several axes of energy delivered, similarly to the crossed beams in external conformational stereotactic radiotherapy methods. When these systems are used, it is recommended that at least three electrodes be implanted for ''one shot'' treatment of lesions with a diameter of between 2 and 3 cm and four to six electrodes for lesions between 3 and 5 cm in size (Fig. 1). Energy is always delivered in bipolar mode, although sequentially between each pair of electrodes and bipolar radiofrequency and electroporation have therefore attracted the description ''multibipolar''. Regardless of the number of electrodes used, they need to be implanted in the periphery of the targets and no longer in the center. Better still, if the tumor is sufficiently small it is even recommended that they be implanted outside of the tumor itself following the ''no touch'' ablation principle [3]. The main use of the multibipolar centripetal convergent ablation techniques is that they provide reliable and safe destruction over a continuous safety margin for tumors up to 4 cm in diameter. They also offer the possibility of adjusting the shape of the ablation zone to that of the tumor, at the same time taking account of its location (Fig. 2). The cost of this is greater procedural complexity which invariably requires several applicators to be implanted, and all along relatively well controlled directions and distances apart.

The choice between a centrifugal radial approach and a centripetal convergent one depends on several clinical factors (Fig. 3). When several small targets need to be treated simultaneously (paucimultinodular disease) and/or at close time intervals (recurrent multicentric forms of disease), the simplicity and speed of conventional centrifugal ablative techniques emerge as essential benefits. Increasing the number of ablation sites (in one or more procedures) requires a functional parenchyma saving strategy combined with moderation in terms of the safety margins destroyed around each of the lesions treated (Fig. 4). Conversely, if following an ad hoc staging assessment the tumors appear to be single, centripetal convergent techniques are undoubtedly preferable. It is essential to offer patients the greatest possible chances of recovery by ensuring the best possible ablation margins (Fig. 5). Tumor sites at risk of collateral damage or of complex shape (contours difficult to identify on imaging) also argue in favor of centripetal convergent techniques which offer more options to adjust the ablation zone in order to take account of specific local limitations (Fig. 2). The lung however is not conducive to centripetal convergent ablation technologies as the air contained within the lung parenchyma around the tumor acts as an insulator (infinite impedance) which drastically reduces energy transfer in multibipolar mode. In practice these techniques can only be considered for sufficiently bulky lung lesions (at least 3 cm in diameter) into which several separate electrodes can be inserted at least 1.5 cm apart. In the standard indications for lung nodules under 3 cm in size, multimonopolar radiofrequency ablation techniques using deployable electrodes (umbrella or parasol) appear at present to be the most appropriate [4]. These allow excellent distribution of