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## Electrodes and multiple electrode systems for radiofrequency ablation: a proposal for updated terminology

Received: 9 April 2004  
Accepted: 5 November 2004  
Published online: 12 February 2005  
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**Abstract** Research on technology for soft tissue radiofrequency (RF) ablation is ever advancing. A recent proposal to standardise terminology of RF electrodes only deals with the most frequently used commercial electrodes. The aim of this study was to develop a logical, versatile and unequivocal terminology to describe present and future RF electrodes and multiple electrode systems. We have carried out a PubMed search for the period from January 1 1990 to July 1 2004 in seven languages and contacted the six major companies that produce commercial RF electrodes for use in clinic. In a first step, names have been defined for the five existing basic designs of single-shaft electrode. These names had to be unequivocal, descriptive of the electrode's main working principle and as short as possible. In a second step, these basic names have been

used as building blocks to describe the single-shaft electrodes in combination designs. In a third step, using the same principles, a logical terminology has been developed for multiple electrode systems, defined as the combined use of more than one single-shaft RF electrode. Five basic electrode designs were identified and defined: plain, cooled, expandable, wet and bipolar electrodes. Combination designs included cooled-wet, expandable-wet, bipolar-wet, bipolar-cooled, bipolar-expandable and bipolar-cooled-wet electrodes. Multiple electrode systems could be characterised by describing several features: the number of electrodes that were used (dual, triple, ...), the electric mode (monopolar or bipolar), the activation mode (consecutive, simultaneous or switching), the site of the inserted electrodes (monofocal or multifocal), and the type of single shaft electrodes that were used. In this terminology, the naming of the basic electrode designs has been based on objective criteria. The short and unequivocal names of the basic designs can easily be combined to describe current and future combination electrodes. This terminology provides an exact and complete description of the versatile novel multiple electrode systems.

**Keywords** Radiofrequency ablation · Liver · Kidney · Soft tissues

## Introduction

The development of novel and ingenious electrodes for soft tissue (such as liver and kidney) radiofrequency ablation (RFA) is expanding rapidly. Multiple names to describe RF electrodes are being utilised. A proposal to address this semantic confusion was recently published by the IWGIGTA (International Working Group on Image-Guided Tumor Ablation) [1]. It described most of the commercial electrodes that were available at that moment. Since this publication, many new commercial and experimental electrodes, as well as several “multiple electrode systems” have been introduced.

The aim of this article is to update the existing classification and to present a logical and easily adoptable terminology for the generic classification of all RF electrodes and multiple electrode systems.

## Materials and methods

We carried out a PubMed search of the world literature for the period from January 1, 1990 to July 1, 2004 using the keywords (radiofrequency, radio-frequency or radio frequency) and (liver or hepatic or hepatocellular) on articles written in English, French, German, Italian, Spanish, Danish and Dutch. In addition, all abstract supplements from the same period published in *Radiology*, *American Journal of Radiology*, *Journal of Vascular and Interventional Radiology*, *European Radiology*, and *Surgical Endoscopy* were searched manually. Relevant papers were also identified from the reference lists of the papers previously obtained through the search and from abstracts of recent international meetings. Further, the six major companies that produce commercial RF electrodes were contacted: Valleylab, (formerly Radionics Boulder, CO, USA); RITA Medical Systems (Mountain View, CA, USA); Boston Scientific (formerly Radiotherapeutics; Natick, MA, USA); Berchtold (Tuttlingen, Germany); Invatec (Roncaldelle, Italy); and Celon AG Medical Instruments (Teltow, Germany) [2–7].

For each basic electrode design, a generic name has been defined which had to be unequivocal, descriptive of the electrode’s main working principle and as concise as possible. In a second step, these basic names have been combined to describe the combination electrode designs. In a third step, a logical description of the combined use of more than one RF electrode in multiple electrode systems has been worked out.

## Results

### Single-shaft electrodes

#### Basic designs

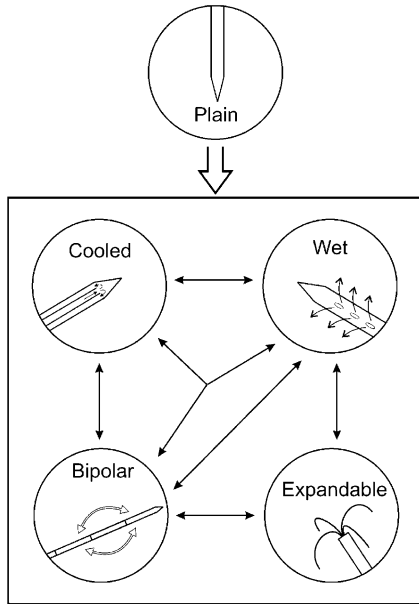
**Plain electrodes** The first experiments with RF ablation on liver tissue were performed with *plain* metal electrodes (Table 1, Figs. 1, 2, 3). The ablation diameter was very limited, due to a rapid rise in electric impedance with current shut-off. To overcome size limitations in RFA, modified single-shaft electrodes have been developed and tested since 1994. Four approaches have been followed: internal cooling (cooled electrodes), spreading RF current over a larger volume and enlargement of the electrode–tissue interface (expandable electrodes), saline perfusion through the electrode into the tissue (wet electrodes) and bipolar design (bipolar electrodes) [8, 9].

**Cooled electrode** The *cooled* electrode [10–15] is a hollow electrode that contains an inner cannula, dividing the space inside the electrode into a concentric outer and inner lumen. The inner lumen is used to deliver a chilled fluid to the tip of the electrode and the outer returns the fluid to an external collection unit. The fluid does not leave the elec-

**Table 1** Single-shaft radiofrequency electrodes, basic designs: proposed terminology

Current proposal	IWGIGTA proposal	Other synonyms in literature
Plain	–	
Cooled	Internally cooled	Perfusion, closed perfusion, perfused, internally cooled-tip
Single cooled	Single internally cooled	
Cluster cooled	Cluster internally cooled	Array, clustered internally cooled, triple cooled
Expandable	Multitined expandable	Retractable, umbrella, Christmas tree, multiple hooked, array, anchor, multi-probe needle
Multitined expandable	Multitined expandable	Retractable, umbrella, Christmas tree, multiple hooked, array, anchor, multi-probe needle
Coiled expandable	–	
Bipolar	–	
Wet	Perfusion	Liquid, virtual, saline, saline-enhanced, saline-augmented, saline infusion, perfused, open perfused, saline solution perfusion

Basic electrode designs



**Fig. 1** Five basic designs of RF ablation electrodes (plain, cooled, wet, expandable and bipolar) have led to the development of six combination designs (cooled-wet, expandable-wet, bipolar-wet, bipolar-cooled, bipolar-expandable and bipolar-cooled-wet)

trode. This way, the tip is internally cooled to a temperature below 25°C to prevent charring of the tissue immediately adjacent to the tip. In a *cluster cooled* electrode [16], three parallel cooled electrodes have been mounted on the same shaft in a triangular fashion with an inter-electrode distance of 5 mm. The electrodes are activated simultaneously. The larger contact surface allows higher current intensity with less charring around the tip and therefore larger thermal lesions than with single cooled electrodes [16].

*Expandable electrodes* An expandable electrode is inserted as a straight insulated needle into the tissue. Once in the desired position, the active electrode is deployed from the hollow shaft of the probe. Two types exist: the *multitined* type and the *coiled* type.

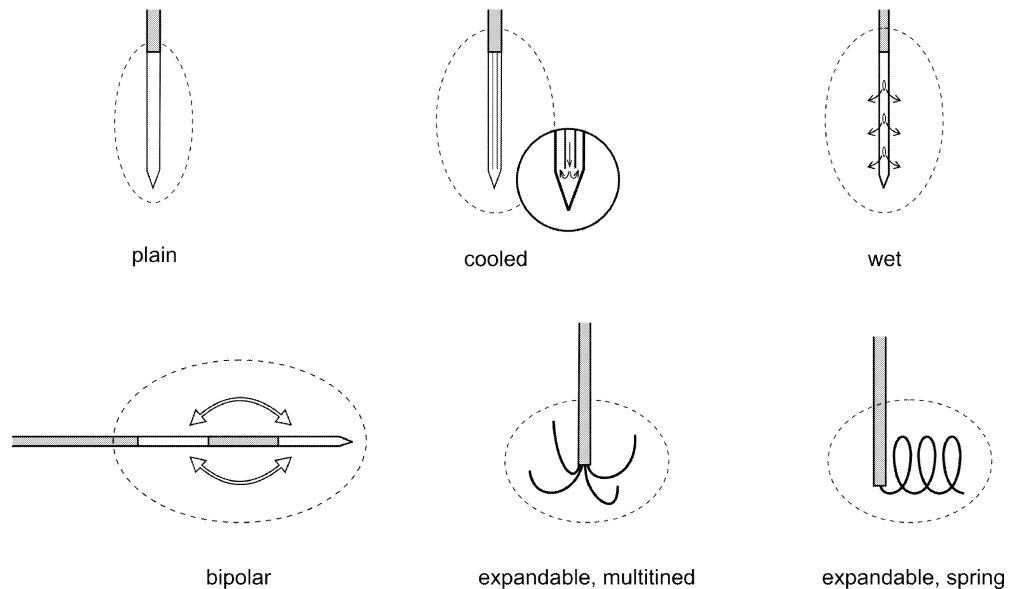
*Multitined* electrodes [17] are an array of 4–12 curved electrode tines (“prongs”) that are deployed from the hollow needle tip in an umbrella-like or Christmas tree-like fashion. The coagulation shape follows the configuration of the deployed prongs. The power is distributed over a wider surface area, therefore current density and the chance of charring decrease.

A *coiled* electrode has a spring that leaves the tip and that is deployed perpendicularly to the shaft [18].

*Wet electrode* The *wet* electrode [19, 20] (Figs. 1, 2, 3, and 4) consists of a hollow electrode with one or more holes at

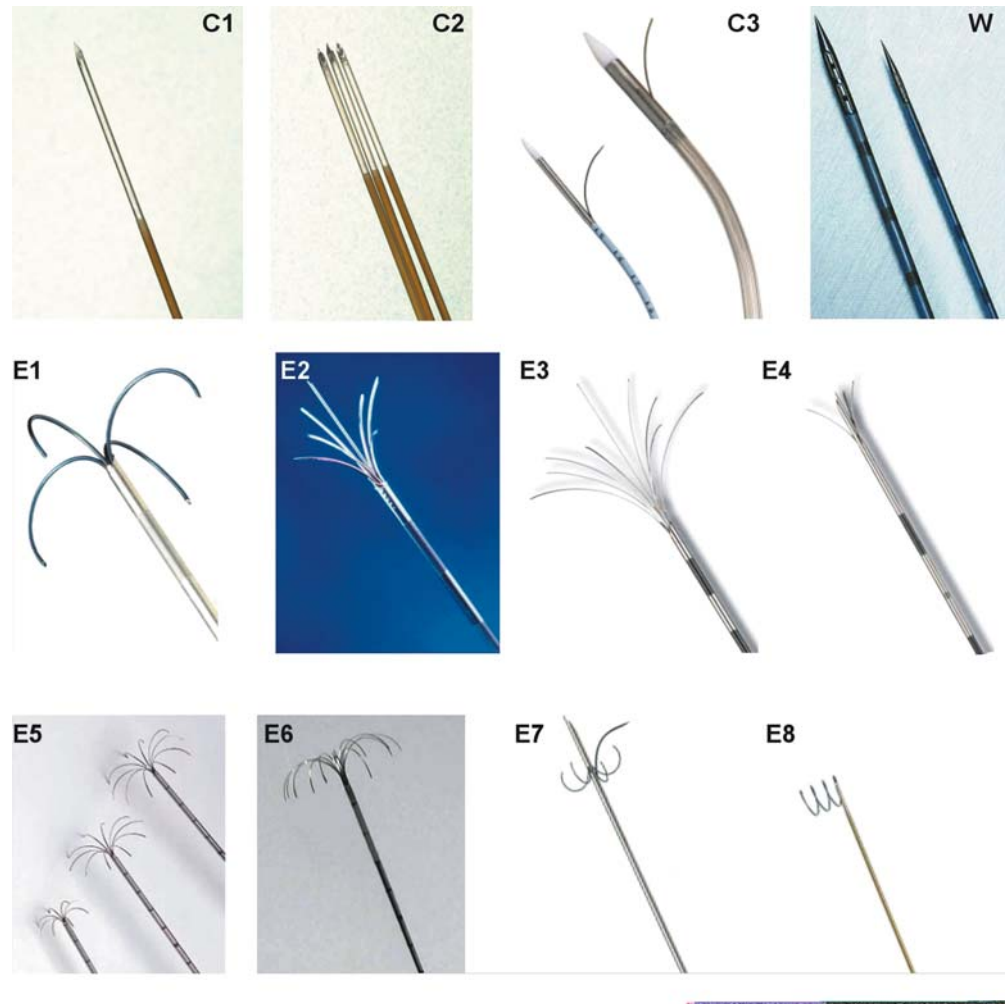
**Fig. 2** Single shaft electrodes: basic designs

Single shaft electrodes, basic designs



**Fig. 3** Examples of commercial electrodes with a basic design.

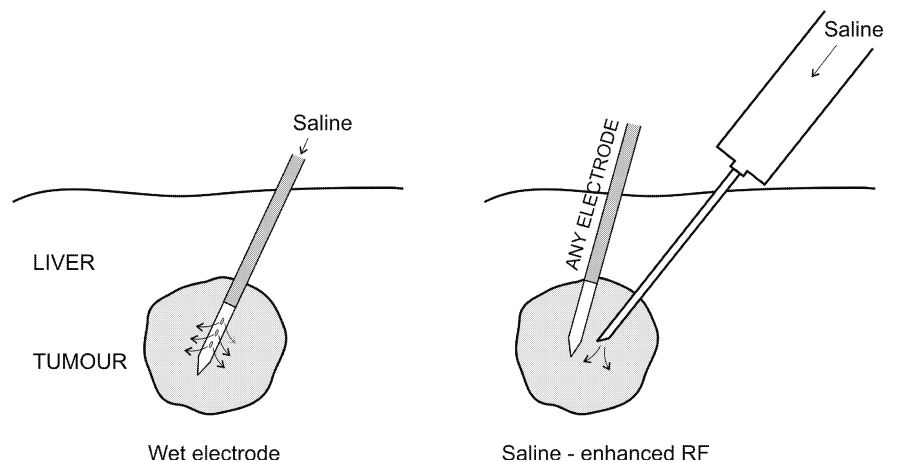
*C(ooled)* 1 Radionics Cool-tip RF single 3-cm tip; *C(ooled)* 2 Radionics Cool-tip RF cluster; *C(ooled)* 3 Convatec MIRAS IOC and Convatec MIRAS LC (top to bottom); *W(et)* Berchtold HiTT 1-cm tip/1.2 mm diameter and 1.5-cm tip/2 mm diameter; *E(xpandable)* 1 RITA model 30; *E(xpandable)* 2 RITA model 70; *E(xpandable)* 3 RITA model 90/StarBurst XL; *E(xpandable)* 4 RITA StarBurst SD; *E(xpandable)* 5 Boston Scientific LeVeen 2, 3, and 3.5 cm; *E(xpandable)* 6 Boston Scientific LeVeen 4 cm; *E(xpandable)* 7 Invatec MIRAS LN; *E(xpandable)* 8 Invatec MIRAS RC



the uninsulated distal end through which an isotonic or hypertonic saline solution is infused into the tissue. The infused saline improves thermal and electrical tissue conductivity, which allows for a greater than 10-fold increase in power deposition compared to a plain electrode [21].

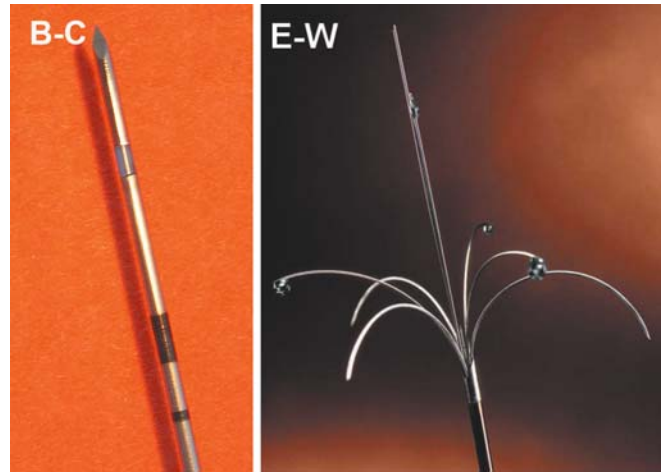
*Bipolar electrodes* In *bipolar* electrodes, both electrodes are incorporated proximally and distally on the same neutral probe with a variable distance between them [22, 23]. The electric current flows between the two electrodes, and no grounding pad is used.

**Fig. 4** Wet electrode-RF ablation versus saline-enhanced RF ablation



**Table 2** Single-shaft radiofrequency electrodes, combination designs: proposed terminology

Current proposal	Synonyms in literature
<b>Double combination designs</b>	
Cooled–wet	Perfusion, perfused–cooled, wet–cooled, open–perfused
Expandable–wet	Perfusion
Bipolar–wet	
Bipolar–cooled	
Bipolar–expandable	Bipolar
Bipolar–cooled–wet	
<b>Triple combination designs</b>	
Bipolar–cooled–wet	Bipolar perfused–cooled



**Fig. 6** Examples of commercial electrodes with a combination design. *B*(ipolar)–*C*(ooled) CelonProSurge 150T30 electrode, *E*(xpandable)–*W*(et) RITA model 100/StarBurst XLi 70

*Double combination electrode designs*

**Cooled–wet electrode** The *cooled–wet* electrode allows continuous infusion of interstitial saline along the cooled electrode (Table 2, Figs. 1, 5, 6). The cooled–wet electrode yields larger ablation zones than both the wet and the cooled electrode separately [24, 25].

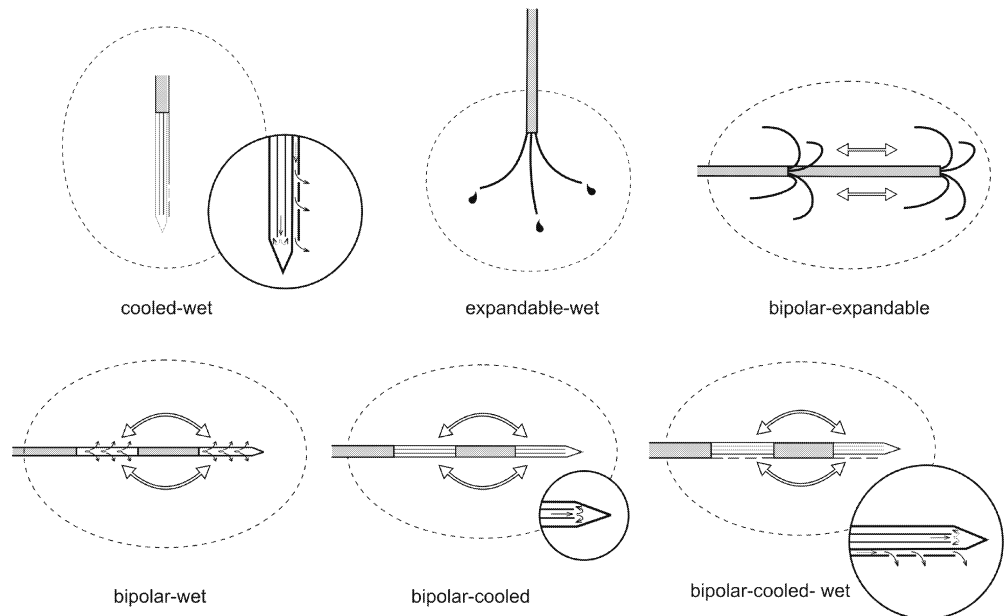
**Expandable–wet** The *expandable–wet* electrode, which unites features of both techniques, is more effective than the wet or expandable electrode separately in an experimental setting [26, 27].

**Bipolar–wet electrode** A *bipolar–wet* electrode consists of an insulated shaft with two electrodes, connected in a bipolar fashion and separated by an insulated portion. Saline flows into the tissue at both active parts [28].

**Bipolar–cooled electrode** A *bipolar–cooled* electrode consists of an internally cooled and insulated shaft with two exposed electrode parts, connected in a bipolar fashion and separated by an insulated portion [22].

**Fig. 5** Single shaft electrodes: combination designs

**Single shaft electrodes, combined designs**



**Bipolar-expandable electrode** A bipolar-expandable electrode consists of two expandable electrodes that are incorporated in parallel into one shaft [29]. Current flows between the two expanded parts.

#### Triple combination electrode designs

**Bipolar-cooled-wet electrode** A bipolar-cooled-wet electrode consists of a cooled-wet electrode with a second, more proximal exposed electrode part, connected in a bipolar fashion and separated by an insulated portion [30] (Table 2; Figs. 1, 5).

#### Multiple electrode systems

Multiple electrode systems are defined as the combined use of more than one single-shaft electrode (Table 3; Figs. 7, 8). Their use can be described according to the number of electrodes used, electric mode, activation mode, and location of the inserted electrodes. Multiple electrode systems have been built with many types of electrodes. The number of possible combinations using these different variables is infinite.

**Table 3** Multiple electrode systems: proposed terminology

Current proposal	Synonyms in literature
According to number	
Dual, triple, quadruple, ...	
According to electric mode	
Monopolar	
Bipolar	
According to activation mode	
Consecutive	Sequential
Simultaneous	
Switching	Multipolar, sequential, alternative, alternating
According to site of insertion	
Unifocal	
Multifocal	
According to electrodes	
Plain electrode system	Multiprobe array, bipolar, multibipolar, multielectrode
Wet electrode system	Bipolar saline-enhanced
Cooled electrode system	
Expandable electrode system	
Cooled-wet electrode system	
Bipolar-cooled electrode system	Multipolar

#### Number of electrodes used

A multiple electrode system can consist of two (*dual*), three (*triple*), four (*quadruple*), or more electrodes.

#### Electric mode

A multiple electrode system can be used in the *monopolar* mode [29, 31–35]. The electric current flows from all the electrodes that have the same polarity towards the grounding pad. Alternatively, in the *bipolar* mode [36–42], the current flows between two parallel inserted electrodes or groups of electrodes. The inaccurate term “bipolar RFA” should be avoided, because it can cause confusion. Instead, authors should clearly describe whether they use a bipolar *single-shaft electrode* or whether they use the bipolar *mode* between two (or more) *parallel* inserted electrodes in *multiple electrode systems*.

#### Activation mode

Multiple electrodes can be activated *consecutively* [31, 34, 35]; the second electrode is activated after completion of the session of the first electrode etc. They can also be activated *simultaneously* [29, 32–34], or in a rapid *switching* mode using a switch box [29, 34].

#### Insertion site of the electrodes

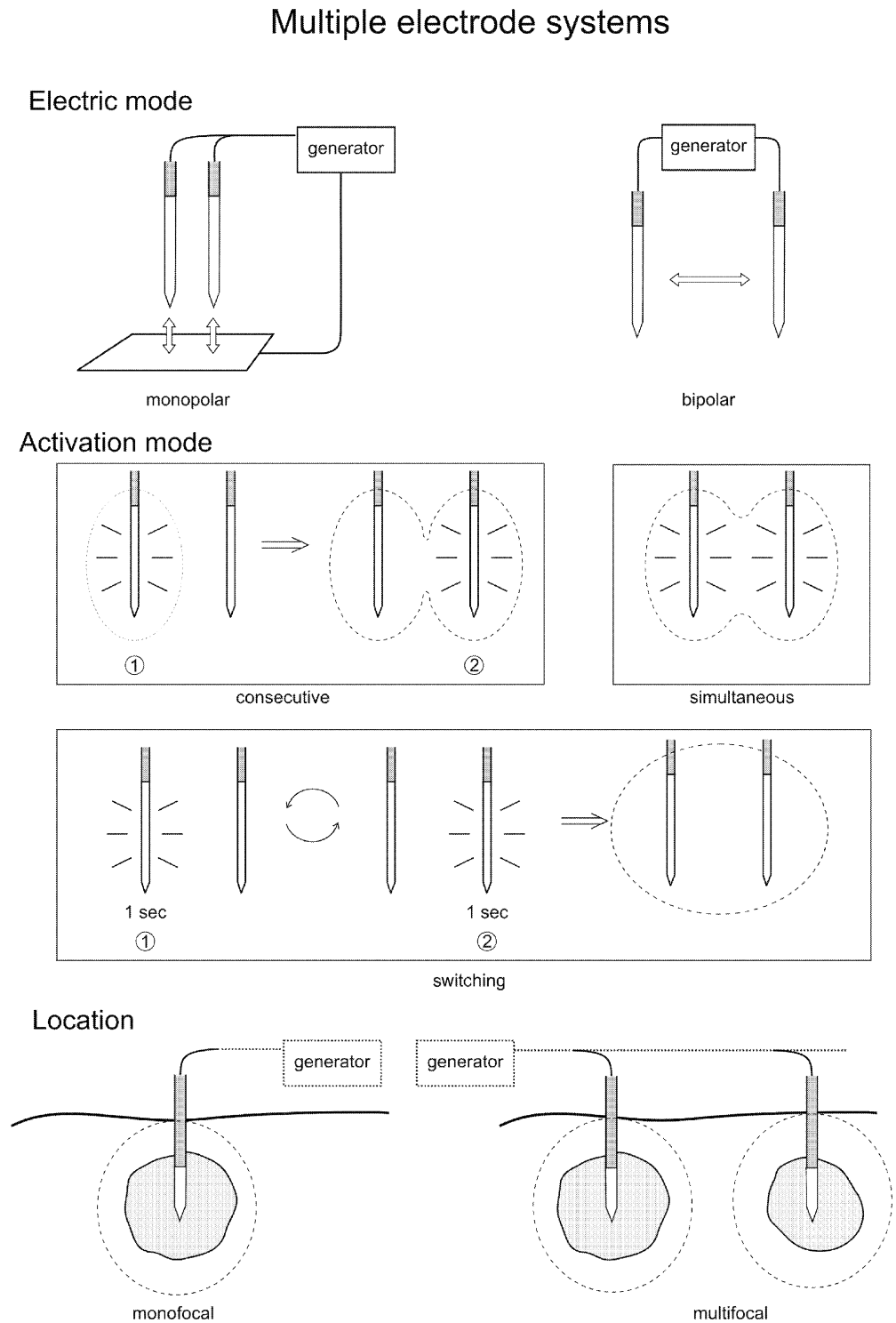
Usually, the multiple electrodes are inserted in the same part of the organ to treat the same tumour (*monofocal* RFA). Alternatively, two (or more) (groups of) electrodes can be inserted in a different part of the organ, to obtain a simultaneous treatment at different locations (*multifocal* RFA, e.g. *bifocal* or *trifocal* RFA) [43]. For multifocal RFA, the interposition of a switch box between electrodes and generator is necessary. This switch box is usually programmed to distribute the current in an alternating mode to the different locations, but it can be programmed in any activation mode as well as in any electric mode (Mulier, unpublished data).

#### Types of electrodes used in multiple electrode systems

Multiple electrode systems can be made with any of the available single-shaft electrodes. The following systems have been described in the literature.

A *plain electrode system* consists of two or more plain electrodes that are inserted in a parallel way into the tissue. Two electrodes can be arranged in a bipolar mode [29, 36], or current can be applied simultaneously to multiple electrodes in a monopolar mode [29, 31, 32]. A third option is

**Fig. 7** Multiple electrode systems: they can be characterised by the number of electrodes used (not shown), the electric mode (example with two plain electrodes), activation mode (example with two plain electrodes), site of insertion (example with one plain electrode at each location) and (not shown) type of single shaft electrodes used

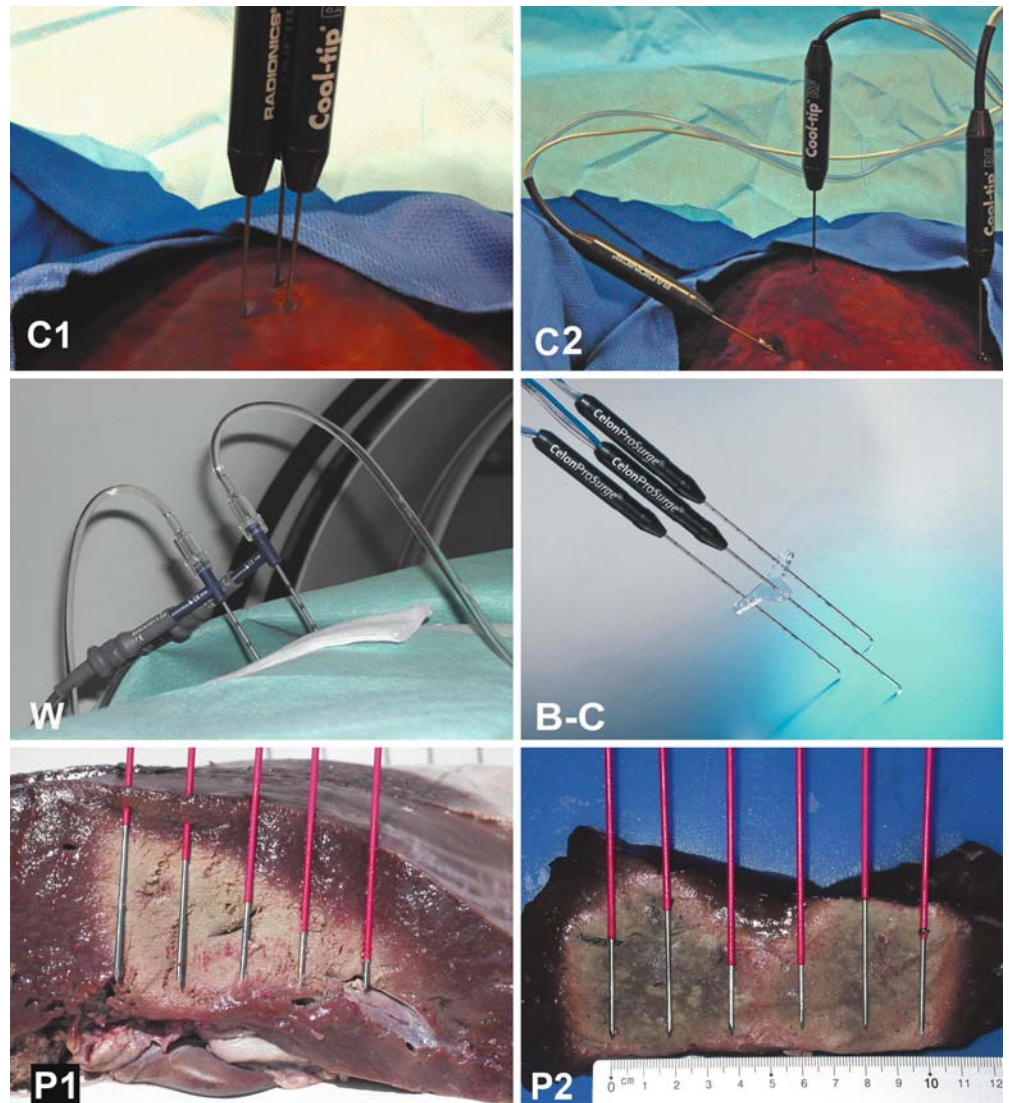


to insert multiple plain electrodes in a parallel way, half of which are connected to the positive pole and half of which are connected to the negative pole [37, 38, 42].

Similarly, by inserting two or more parallel electrodes of the same kind, a *wet electrode system* [39, 40, 44], a *cooled*

*electrode system* [33, 34], an *expandable electrode system* [29, 35, 41, 45], a *cooled-wet electrode system* [30, 44] and a *bipolar-cooled electrode system* [7] have been described.

**Fig. 8** Examples of multiple electrode systems. *C(ooled)* 1 Three Radionics Cool-tip RF single 3-cm tip with monofocal insertion in the switching and monopolar mode to treat 3 one large tumour; *C(ooled)* 2 three Radionics Cool-tip RF single 3-cm tip with multifocal insertion in the switching and monopolar mode to treat three different sites at the same time; *W(et)* two Berchtold HiTT electrodes with monofocal insertion in the bipolar mode to treat one large tumour; *B(ipolar)*–*C(ooled)* three CelonProSurge 150T40 electrodes that will be used with monofocal insertion in the switching and bipolar mode to treat one large tumour; *P(lain)* 1 two rows (only one shown) of five plain metal electrodes of uneven lengths, spaced apart 2 cm and activated in a bipolar and simultaneous mode in ex vivo beef liver; note the triangular shape of the coagulation that closely matches the distribution of the unexposed parts of the electrodes; *P(lain)* 2 two rows (only one shown) of six plain metal electrodes of uneven lengths, spaced apart 2 cm and activated in a bipolar mode in ex vivo beef liver; the three pairs of electrodes left and the three pairs right have been activated consecutively. Note the bilobar shape of the coagulation that closely matches the distribution of the unexposed parts of the electrodes



### Saline-enhanced RF ablation

In *saline-enhanced RF ablation* [46], saline is directly injected into the tissue near the electrode tip [47–50]. The injection needle is not incorporated into the electrode, in contrast to the wet electrode (Fig. 4, Table 4). Saline-enhanced RF ablation can be performed in combination with any of the existing electrodes and multiple electrode systems. Saline-enhancement has been reported for *cooled* electrodes [47, 49–51], *multiple plain* electrodes [46] and *expandable* electrodes [48]. Saline is usually injected as a bolus prior to RF ablation [47, 49, 50], in contrast to the wet electrode, with which usually a continuous infusion after a pre-RF ablation bolus is used.

Reports on saline-enhanced RF ablation should specify details on the injection method.

**Table 4** Wet electrode-RF ablation versus saline-enhanced RF ablation

	Wet electrode RF ablation	Saline-enhanced RF ablation
Method of saline instillation	Saline infused through electrode	Saline injected through separate needle
Site of saline exit	Side-holes of electrode	Tip of separate needle
Device	Dedicated electrode	Saline injection can be combined with any electrode
Timing of saline instillation	Usually bolus pre-RF ablation plus continuous infusion during RF ablation	Usually bolus pre-RF ablation



## Discussion

Research and clinical application of soft tissue RF ablation is booming. Proposals have recently been launched to standardise reporting on RF ablation. A recent paper from the IWGIGTA (International Working Group on Image-Guided Tumor Ablation) proposes standardised terms for various aspects in the broad field of image-guided tumour destruction [1]. Other papers focused on standardised reporting of one specific aspect of RF ablation, such as RF ablation treatment protocols [52], size and geometry of RF ablation lesions [18] and severity of complications [53, 54]. All these efforts at standardisation are crucial to improve scientific communication on RFA.

The IWGIGTA proposal described most of the commercial electrodes that were available at that moment (Table 1). It did not yet cover the many new commercial and experimental electrodes, as well as several “multiple electrode systems” that have been introduced since. The aim of this article is to update and adapt the existing classification and to present a logical and easily adoptable terminology for the generic classification of all RF electrodes and multiple electrode systems.

At present, the naming of many new experimental and commercial electrode types is much influenced by *subjective factors*: personal preferences of the inventors or major users, or fancy names for marketing purposes. In order to obtain a logical terminology for RF electrodes that was scientific and acceptable to all, we first developed *objective criteria* that had to be fulfilled to name the basic electrode designs. These names had to be unequivocal, descriptive of the electrode’s main working principle and as short as possible. A short name was crucial to be able to combine these names to describe the combination designs in a second step.

As a logical consequence of these objective criteria, two of the terms for the basic designs of the IWGIGTA proposal had to be adapted.

In the present terminology proposal, the term *wet electrode* replaces “perfusion electrode”. The term “perfusion electrode” is still equivocal: this name is currently being used in the literature for both the *wet electrode*, which is perfused with saline which leaves the tip through small

holes (“open perfusion electrode” [44], or “externally perfused electrode” [55]); and for the *cooled electrode*, which is perfused with water which does not leave the electrode (“closed perfusion electrode” [56], or “internally perfused electrode” [55]). Further, the IWGIGTA classification uses the same term “perfusion electrode” for both the *wet* and the *cooled-wet* electrode, which clearly have a different design and efficacy [24, 25, 57].

The term we propose, *wet electrode*, is short, unequivocal, descriptive of the electrode’s main working principle and used by several pioneering authors in this field [21, 24, 25, 58–60]. It is currently being used as part of the name to describe several experimental electrodes and multiple electrode systems [24, 25, 27, 44, 57, 60].

The term “internally cooled” electrode from the IWGIGTA classification has been shortened to *cooled electrode*, which is equally clear (as an externally cooled electrode does not exist) but shorter and easier to combine in names such as *cooled-wet*; *bipolar-cooled* etc.

The system of short unequivocal names for the basic electrode designs allows the easy introduction of combined names for electrodes with a *combination design*, even for future electrodes that have yet to be designed. Conversely, the clarity of the combined names facilitates the understanding of the design.

The introduction of the concept of *multiple electrode systems*, that consist of the combination of more than one single-shaft electrode and that can be used in many modes, was essential to cover this most recent and promising evolution in RF ablation technology. The names of these modes have been standardised too. The unequivocal term *switching* mode replaces the term “sequential”, which has been used as a synonym for both the *alternating* and the *consecutive* mode.

Due to superficial similarities, saline-enhanced RF ablation and wet electrode-mediated RF ablation are often confounded. It is hoped that the present definition, the table and the illustration can help to clearly distinguish these different technologies.

**Acknowledgements** The authors wish to thank Marie-Bernadette Jacqmain for the illustrations and Christian Deneffe for layout.

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