

## Conventional and contrast-enhanced ultrasonography in the management of percutaneous renal tumour ablation

JM Correas<sup>1,2,3</sup>, C Hoeffel<sup>4</sup>, MO Timsit<sup>1,5</sup>, A Khairoune<sup>2</sup>, A Méjean<sup>1,5</sup>, O Hélénon<sup>1,2</sup>

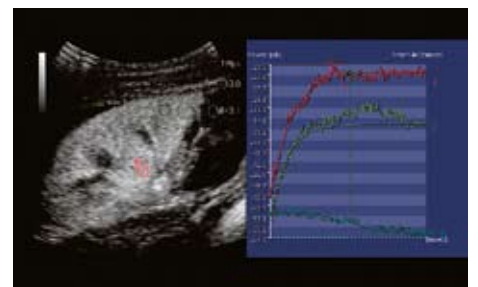
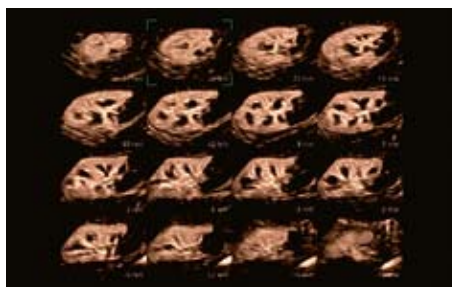
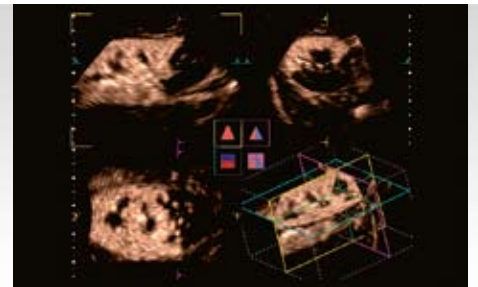
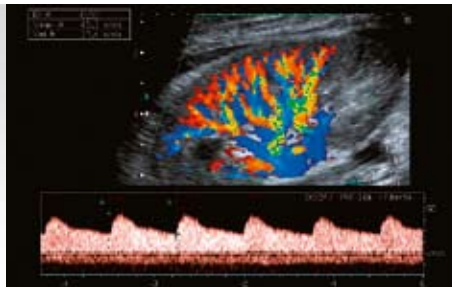
<sup>1</sup> Université Paris Descartes, Paris, France

<sup>2</sup> Necker University Hospital, Department of Adult Radiology, Paris, France

<sup>3</sup> UMR 930 – CNRS 2448, Université François, Rabelais, Tours, France

<sup>4</sup> Robert Debré University Hospital, Department of Radiology, Reims, France

<sup>5</sup> Necker University Hospital, Department of Adult Urology, Paris, France



### I – Introduction

The number of small renal tumours is increasing due to the large number of imaging examinations of the kidneys performed with various modalities and the true increasing incidence of renal cancer [1]. Conservative therapy of small renal tumours is now widely recognized as the reference technique for treatment of these small lesions, with typically lower pathology scores. The increasing rate of chronic renal failure in the elderly and the efficacy of conservative therapy to treat cancer as demonstrated by the urologists performing partial nephrectomy and tumourectomy emphasize the role of percutaneous minimally invasive ablative procedures, particularly in patients with surgical

contraindications. Radiofrequency ablation (RFA) is preferred when the procedure is performed percutaneously [2–5]. RFA of small renal cell carcinoma (RCC) is also a routine alternative to nephron sparing surgery from a cost-effectiveness perspective. The evaluation of the success of the procedure relies on imaging techniques showing the lack of enhancement within the lesion and the size and shape of the necrosis covering the entire tumour area.

Ultrasonography and contrast-enhanced ultrasonography (CEUS) play a key role at each step of renal tumour management using RFA. CEUS profits from recent improvements such as the introduction of third-generation ultrasound contrast agents with

high acoustic response at low acoustic power and the development of US imaging techniques detecting the specific microbubble signature. Available USCA and particularly SonoVue® (Bracco, Milano, Italy) are only approved for the visualization of the renal macrovascular bed and not for renal tumour detection, staging or therapy evaluation. However, this application has been included in the recent updated version of the Guidelines and Good Clinical practise recommendations for CEUS [6].

### II – RFA of renal tumours

The RFA principles applied to renal tumour ablation do not differ strongly from those of liver tumour treatment. Various types of systems can be used

**Fig. 1: Evaluation of the renal tumour before percutaneous ablation**

Figures 1, 2 and 3 refer to the same patient a forty-five year old male with vascular nephropathy, solitary right functioning kidney and mild chronic renal failure (creatinine clearance of 53 mL/min). During an ultrasound examination, a 2 cm renal tumor was incidentally discovered, corresponding to a papillary cancer at pathology. The patient was referred for radiofrequency ablation (RFA) due to the several comorbidity factors, including platelet aggregation inhibitors. However, the lesion was poorly located against the right colon.

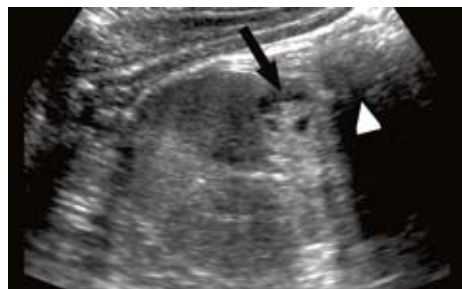


Fig. 1 c: Using the convex high frequency transducer (C10–3), the lesion was better depicted (black arrow). Despite abdominal maneuvers, the bowel still touched the tumor (arrow head).



Fig. 1 a: Using the abdominal broadband transducer (C6–1), the tumor was found to be slightly hyperechoic (black arrow). The bowel touched the tumor (arrow head).

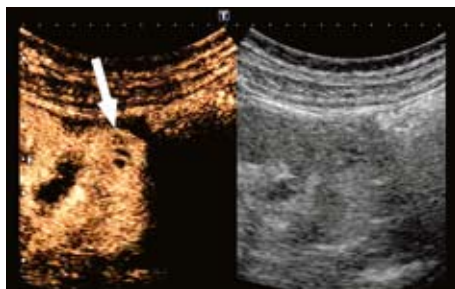


Fig. 1 d and e: At contrast-enhanced US performed after a bolus injection of SonoVue® (Bracco, Milan, Italy), the lesion appeared strongly perfused (Fig. 1 d). MicroFlow Imaging (MFI) improved lesion conspicuity compared to pulse subtraction acquisition (Fig. 1 e).

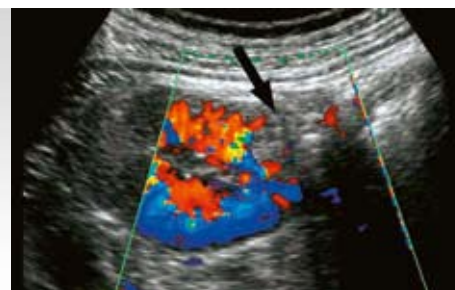


Fig. 1 b: At color Doppler US, the lesion appeared poorly vascular compared to the adjacent cortex.

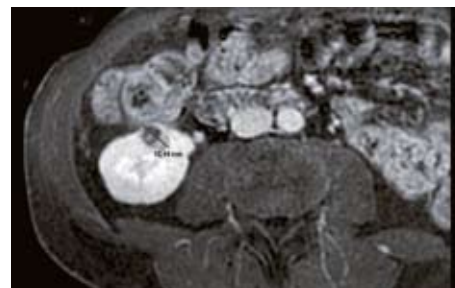
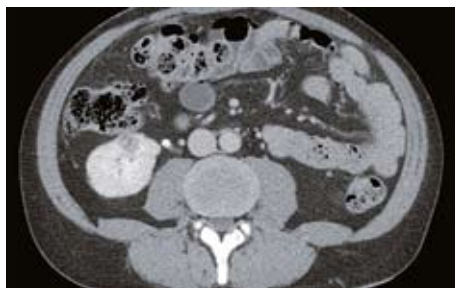
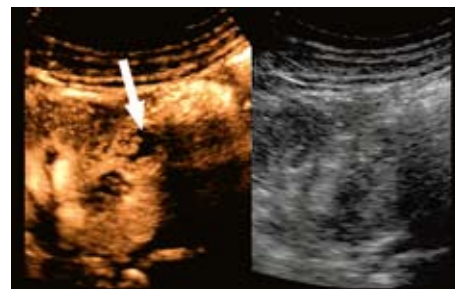


Fig. 1 f and g: Contrast-enhanced CT and MRI were performed with a limited amount of contrast media, following intravenous perfusion of saline. They confirmed the US and CEUS findings and allowed staging of the lesion (including adrenal glands, pancreas, liver and lungs).

including single and multiple cool-tip electrodes (Covidien, Boulder, CO, USA), expandable electrodes (Boston Scientific Corp, Natick, MA, USA; RITA Medical Systems INC, Mountain View, CA, USA), bi- and multipolar systems (Celon AG – Olympus, Teltow, Germany). Most protocols are derived from liver RFA protocols and are based either on temperature or impedance control. However, renal RFA exhibits some significant differences compared to liver RFA leading to a lower success rate. These differences should be taken into account in order to improve the success rate and bring it to the same level as surgical tumour-ectomy. The major difference between renal and liver ablation is due to the higher blood flow of

both normal renal parenchyma and tumours. Firstly, the cooling effect is much higher and requires optimal positioning of the electrodes to cover the entire volume of the lesion, particularly for the portion of the tumour adjacent to the normal cortex and to the sinus. Central tumours are more difficult to treat not really because of their depth but mainly because of the cooling effect resulting from the presence of sinusal veins and arteries. The collecting system participates to this cooling effect particularly if an infusion of cold saline is performed through a ureteral catheter in order to avoid damage of the caliceal and pelvis structures. It is therefore even more critical to ensure perfect positioning of the electrodes within the tumour volume and to

avoid passing through the tumour and entering the sinus with the risk of caliceal and vascular burning. Secondly, the volume of normal renal parenchyma stabilizing the needle electrodes is limited compared to the liver and the large displacement of the system with the respiratory movements. The limited amount of parenchyma surrounding the lesion is affecting the stability of the electrodes within the tumour if non-expandable needles are used. Large respiratory movements particularly in patients undergoing RFA under conscious sedation can induce secondary displacement of the active tip. Expandable electrodes, although more stable, can result in puncture of vessels or excretory structures within the renal

**Fig. 2: The role of US and CEUS during RFA**



Fig. 2a: The tumor biopsy was performed under real-time US guidance to avoid bowel damage. The tip of the true-cut needle was perfectly followed up to the renal tumor (arrow), despite the adjacent bowel (arrow head).



Fig. 2b: Hydrodissection was performed by locating the tip of a fine needle (22 Ga) between the renal tumor and the right colon and injection 10 mL of glucose solution at 30%. The tip of the needle (arrow) was easily seen in the fluid (star).



Fig. 2c: The CT control confirmed the presence of the glucose fluid spontaneously hyperdense (star) between the tumor (arrow head) and the colon. This small amount of fluid moved the bowel, improving the safety of the RFA procedure.



Fig. 2d: The RFA electrode is safely located within the tumor under US guidance, with good visualization of the needle tip (arrow).

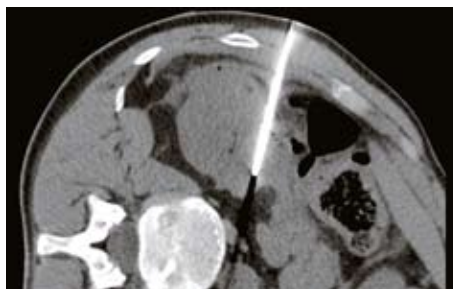


Fig. 2e: The CT scan confirmed the appropriate placement of the electrode and the presence of a safe distance to the bowel.

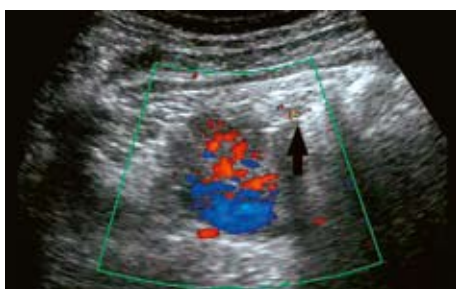


Fig. 2f and 2g: After RFA treatment, color Doppler US (Fig. 2f) did not generate additional information except the presence of some bubbles surrounding the treated area (black arrow). CEUS confirmed the lack of enhancement at the level of the tumor (arrow head). The tumor remained heterogeneous and some hypersignals corresponding with some bubbles resulting from the heat of the RFA procedure were noted despite the delay of 20 min between the end of the treatment and the US examination.



sinus if they are inserted too deep in central lesions. The most appropriate position for the system opening is not easily defined, as the kidney is not fixed within the retroperitoneum and can be pushed and moved during the expansion of the multitined electrodes.

Thirdly, renal function is very sensitive to the reduction of effective renal tissue particularly in case of previous reduction of renal parenchyma (previous contralateral nephrectomy, tumourectomy or polar nephrectomy on the same kidney) or pre-existing disease affecting the renal function (mellitus diabetes, nephroangiosclerosis, etc.). Renal RFA should limit as much as possible the destruction

of normal parenchyma surrounding the tumour itself. In patients referred for renal RFA, the renal function should be estimated using Glomerular Filtration Rate (GFR), as it is regarded as the best overall measure of the kidney function [7]. About one fourth of patients with normal preoperative serum creatinine levels referred for renal surgery can exhibit mild chronic renal failure with an estimated GFR lower than 60 mL/min per 1.73m<sup>2</sup> [8]. The risk of renal function decrease is significantly different in patients undergoing partial nephrectomy compared to radical nephrectomy ( $p < 0.0001$  [8]). Only 3% of patients undergoing partial nephrectomy presented a new onset of GFR lower than 45 mL/min per 1.73 m<sup>2</sup>, compared

to 36% of patients undergoing radical nephrectomy. These numbers strongly prompt the preservation of renal parenchyma particularly in patients with small renal tumours who typically present longer lifetime.

### III – The RFA procedure

In our centre, the RFA procedure is performed during a short hospitalisation of 36 hours after approval of the indication by the local multi-disciplinary renal committee (including urologists, nephrologists, radiologists and cancerologists). The US machine (Toshiba Aplio XV, Nasu, Japan) is moved to the CT suite. The patient is positioned in the CT bed and turned around in order to better

**Fig. 3: The role of US and CEUS after the RFA procedure**



Fig. 3a: The tumor is better detected eight weeks after RFA (arrow).

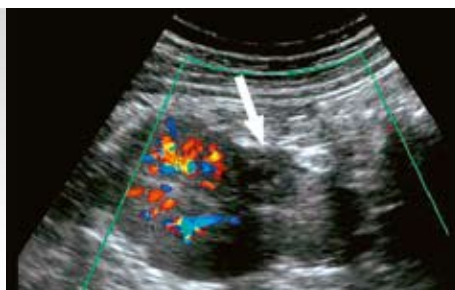


Fig. 3b: Color Doppler US did not reveal any residual vascularity or vascular complication such as renal arterio-venous fistula and false aneurysm.

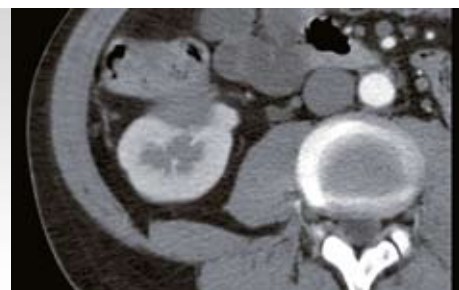


Fig. 3c: Despite the mild chronic renal failure, contrast-enhanced CT was performed after hyperhydration using reduced dose of iodinated contrast media (1 mL/kg body weight). The lesion was perfectly homogeneous and did not enhance at all. There was no fat interface between the tumor and the right colon.



Fig. 3d, e and f: Contrast-enhanced US confirmed the lack of enhancement of the lesion. At the early arterial phase (Fig. 3d), the normal renal tissue at the deep pole of the lesion was slightly delayed and weaker. It remained completely homogeneous during venous and delayed phases (Fig. 3e). Four-dimensional contrast US study might generate additional information as it allows assessment of the entire treated volume.

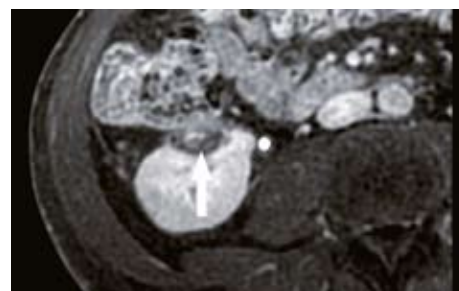
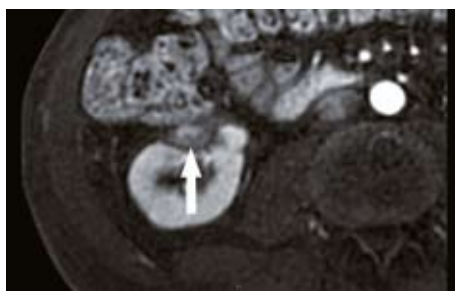
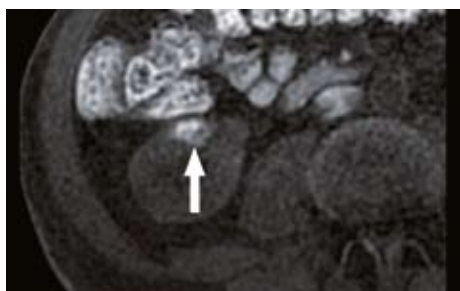


Fig. 3g, h and i: Contrast-enhanced MRI confirmed the successful treatment after one year. Note that the non-enhanced fat suppressed T1-weighted gradient acquisition is mandatory to detect the hypersignals due to coagulation necrosis, and avoid misdiagnosis of tumor recurrence.

visualize the lesion using US and optimise access. As the treatment is conducted under conscious sedation, even the prone position can be adopted. Non-enhanced CT is performed to evaluate the precise anatomical relationship of the needle track, particularly with the colon and the pleura (for interior lesions or lesions located at the upper pole of the kidney). After cutaneous disinfection and local anaesthesia, the RFA electrode is inserted under real-time US guidance. If the lesion is not visible with conventional US, contrast-enhanced US can be used to facilitate needle positioning. In our institution, most procedures are performed using a 200 W generator and saline-cooled electrodes (Cool-tip system, Covidien, Boulder, CO, USA).

The number of electrodes and the size of the active tip are adapted to the tumour diameter and vascularity. When the lesion's maximum diameter is below 2 cm, a single electrode is typically used. When it is between 2 and 3 cm, the number of electrodes depends upon the degree of tumour vascularity: hypovascular tumours can be treated with a single electrode of 30 mm active tip, while hypervascular lesions require multiple electrodes. When the tumour diameter is above 3 cm, multiple electrodes are used systematically (either cluster electrode or 2 to 3 individual electrodes connected to the switching controller).

**IV – The role of CT and MRI before and after RFA**

Contrast-enhanced CT or MRI is requested before renal RFA to evaluate the lesion in terms of size, number, location, vascularity, relationship to adjacent structures and renal sinus and detection of metastases. They are also used during follow-up to confirm the lack of residual tumour and other tumour localization.

Multidetector-CT is our preferred technique in the absence of contra-indication to iodinated contrast agent administration (mainly chronic renal failure and severe allergic reactions to previous administration). Multiplanar reformats (MPR) provide key information for anatomical relationships to the

**Fig. 4: Evaluation of the lesion before renal tumor percutaneous ablation**

Figures 4, 5 and 6 also refer to the same patient, a seventy-nine year old female with a few comorbidity factors (including platelet aggregation inhibitors for cardiac arrhythmia, systemic hypertension, and age). A 4 cm left renal tumor was incidentally discovered at CT. The renal biopsy was performed immediately before the RFA procedure in order to simplify patient management, and pathology revealed the presence of a sarcomatoid tumor. The indication of radiofrequency ablation (RFA) was approved by our local multidisciplinary committee.

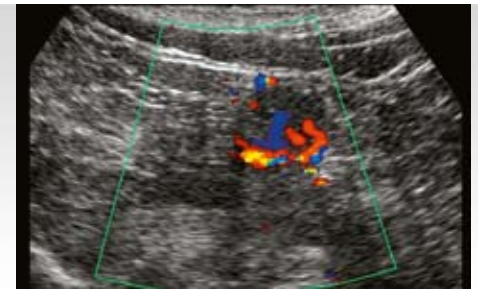


Fig. 4 a and b: The tumor was isoechoic to the surrounding cortex and mainly identified due to the mass effect (Fig. 4 a). Large vessels were detected within and around the tumor at color Doppler US (Fig. 4 b).



Fig. 4 c and d: CEUS confirmed the presence of an almost homogeneous hypervascular tumor. MFI (Fig. 4 d) better showed the hypervascular pattern of the lesion with some areas enhancing much more than the normal cortex.

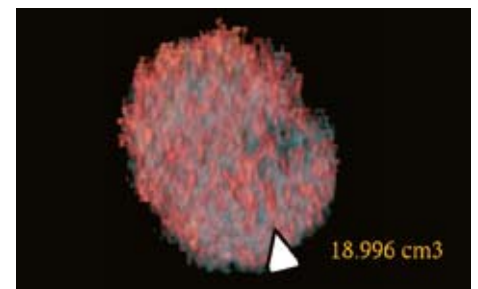


Fig. 4 e, f and g: At contrast-enhanced CT, the lesion was as much enhanced as the normal cortex. However, the cranio-caudal length was underestimated and was over 4 cm. The true tumor volume was almost reaching 19 cm<sup>3</sup>.

adjacent organs such as the spleen and the liver, the pleura and the digestive structures. Low osmolality iodinated contrast medium is administered at sufficient dose (2 mL/kg body weight) to localize the lesion and assess the relationship to the vascular structures as well as to the excretory system. Renal MRI is an alternative technique in case of contra-indications to iodinated contrast agents. It is performed using a torso phased-array coil on a 1.5 Tesla unit and includes axial fat-suppressed T2-weighted sequence, in and out of phase acquisition, 3D breath-hold fat-suppressed T1-weighted fat-saturated spoiled gradient-echo sequence before and after Gadolinium chelates administration (Dotarem®, Guerbet SA, Aulnay-s-s-Bois, France). MRI is increasingly used in the follow-

up of young patients to reduce exposure to radiation (hereditary renal cancer, young population) and the risk of renal dysfunction after iodinated contrast media administration (particularly in case of pre-existing renal failure and in the elderly). Typical follow-up is performed for assessment of residual unablated tumour or detection of tumour recurrence. Unlike surgical procedures, the success rate of RFA varies according to the tumour size and location from 85 to 95% [2–4, 9]. Most incomplete treatments can be detected during the first three months of follow-up. Contrast-enhanced computed tomography (CE-CT) is typically used for most monitoring purposes, but it can induce renal failure or accelerate renal function deterioration due to nephrotoxicity. However, this technique cannot

be used in non-cooperative patients and may not be easily available. Recently, a major concern has been raised on nephrogenic systemic fibrosis (NSF) which may be associated with the use of gadolinium contrast agents in patients with chronic renal failure [10].

Today, there is no clear consensus nor are there any evidence-based criteria for method or timing of post-treatment surveillance imaging [2, 3]. The optimal imaging technique should be inexpensive, easy to perform, non-invasive, well accepted and tolerated by the patients, providing high sensitivity and specificity for the detection of residual disease.

**Fig. 5: The role of US and CEUS during and after the first RFA procedure**

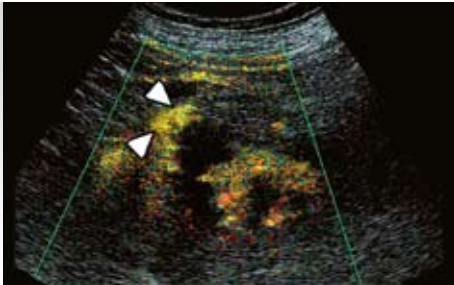


Fig. 5 a: Immediately after RFA (performed with a cluster electrode, Covidien – Valleylab, Boulder, CO, USA), CEUS was performed using the VRI mode, after a bolus injection of SonoVue® (2.4 mL). Strong persisting enhancement was detected at the upper pole of the lesion (arrow heads) and immediately retreated by inserting a single cool-tip RF electrode.



Fig. 5 b: At day 1, gray-scale imaging showed no complications such as collection or dilatation of the excretory system.



Fig. 5 c: CEUS revealed two bulky areas enhancing at the upper and lower part of the tumor (arrow heads) at day 1. This information was critical to schedule the next RFA session.

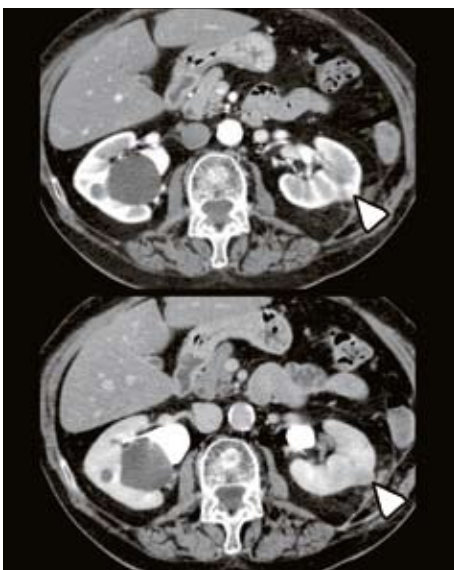
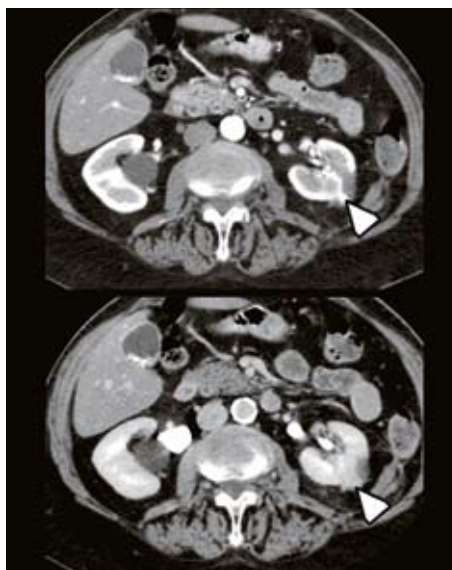


Fig. 5 d and e: Contrast-enhanced CT performed at six weeks (immediately before the second RFA session) confirmed the diagnosis of 2 renal tumor residues at the upper anterior part of the ablated area (Fig. 5 d) and lower posterior part of the ablated area (Fig. 5 e).



**V – US and CEUS modality**

The detection of renal tumours by US depends on size, echogenicity, localization and appearance of the normal kidney (size and echostructure). Renal solid masses are better seen when they are located in the right kidney and involve the mid-portion with extra renal development. The detection of renal cell carcinoma is incidental in almost 83% of the cases but conventional US sensitivity remains lower for lesions smaller than 3 cm in diameter compared to CT [11, 12]. CEUS is not recommended for systematic detection of renal tumours [6] but can be useful in selected indications.

CEUS improves the depiction of normal renal blood flow [13] and tumour vascularity using real-time low mechanical index (MI) pulse subtraction with

high temporal and spatial resolution [6, 14].

Moreover, US contrast agents such as SonoVue® (BR1, Bracco, Milano, Italy) are well tolerated and do not exhibit any renal toxicity in clinical practice. CEUS can be considered as an alternative to CT and MRI in the follow-up of renal tumours treated with RFA [15]. Following the baseline examination using Tissue Harmonic Imaging and colour Doppler US, the US machine is switched to pulse subtraction with a double screen technique with gray-scale anatomical reference. After IV bolus administration of 2.4 mL of SonoVue® followed by 10 mL saline flush, the transit of the microbubbles is monitored continuously at low MI (< 0.1) within the normal renal parenchyma and the tumour. The kidney and the tumour can be imaged in different planes until

the disappearance of the microbubbles. Cine-loops are stored digitally for the review.

**V – 1 The role of US before RFA**

Before RFA, US and colour Doppler US are systematically used to evaluate the renal mass in terms of identification, anatomical relationship, vascularity and accessibility. The examination is performed in supine and oblique positions in order to optimize visualisation and access of the lesion prior to the procedure. For tumours located at the upper pole of the kidney, it is critical to localize the pleura and its displacement with respiration. The liver and gallbladder must be identified for right-side and the spleen and pancreas tail for left-side lesions. The precise relationship to bowel structures can

**Fig. 6: The role of US and CEUS during and after the second RFA procedure**

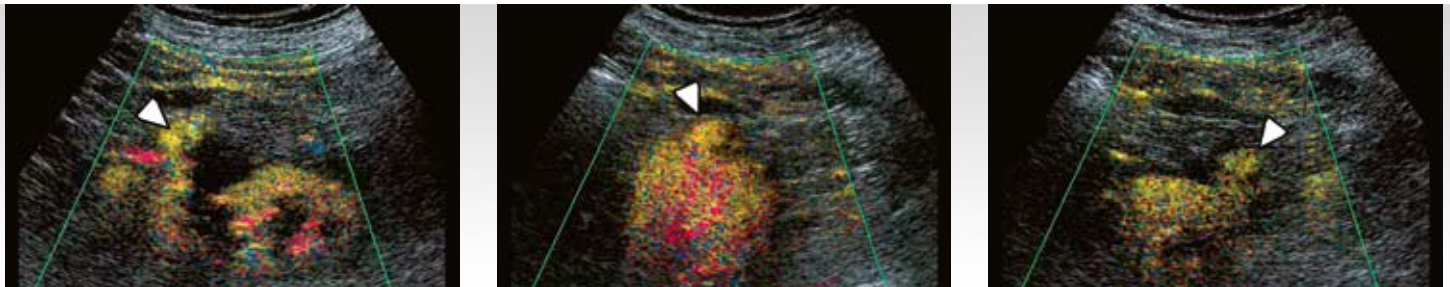


Fig. 6 a, b and c: CEUS was performed immediately before the RFA procedure in the longitudinal (Fig. 6 a) and transverse planes (Fig. 6 b and c). The residual tumor areas were easily detected (arrow heads).



Fig. 6 d: The cool-tip electrode was inserted and the tip of the needle was located close to the suspected area. The colour artifact (arrow) was extremely useful to identify the tip of the electrode.



Fig. 6 e: CEUS was then performed in the same plane to precisely detect the residual tumor area (arrow head) and the tip of the electrode (arrow) was immediately advanced onto the tumor.



Fig. 6 f: By switching back to conventional THI mode, the position of the electrode was controlled. The same procedure was applied for the treatment of the lower pole residue.

Contrast-enhanced US using VRI mode was used to guide the second RFA procedure exactly to the site of the persisting tumor areas. The entire RFA procedure for retreating the two tumor residues took less than one hour.

be difficult to analyze and requires non-enhanced CT. Colour Doppler US is useful to detect tumour vascularity as well as vessels that might be crossing the needle path.

In our experience, CEUS has demonstrated to be extremely useful to evaluate tumour perfusion. At the beginning, this parameter was simply evaluated in comparison to the normal adjacent renal parenchyma, as an hyper-, iso- or hypo-enhancing lesion. Recently, tumour perfusion quantification has become feasible in routine practise using SonoTumour<sup>®</sup>, a software developed by Bracco Research. One or two cine-loops are acquired during a breath-hold at the arrival of the microbubbles for approximately one minute and saved in DICOM format. This software is able to linearize the data and to aggregate two cine-loops. It can also compensate for breathing movements when the displacement of the organ is limited to the imaging plane (at a certain degree). The quantitative parameters are extracted from the time intensity curves modelled with complex exponential function. Absolute as well as relative values are obtained from a reference area. Thus, regions of interest (ROI) are placed upon the entire tumour and the reference area. In our experience, the normal renal parenchyma adjacent to the tumour was found to be the more suitable reference area. After that first minute dedicated to perfusion estimation, the entire kidney is scanned on the two orthogonal planes. The tumour area with the highest perfusion is carefully localized for the further RFA procedure. The electrode should target this area in order to avoid early recurrence due to the persistence of tumour parenchyma and improve the performance of the technique.

### V – 2 The role of US during RFA

During RFA, US plays a key role in optimizing electrode placement and reducing the duration of the procedure. Patient position is determined in order to reduce the distance between the skin and the target and to avoid anatomical structures sensitive to heat. If this is done by US, a non-enhanced CT is performed to verify that the position is optimal. After skin disinfection and local anaesthesia combined with IV sedation, the electrode(s) is/are inserted using US because of its real-time performance and high spatial resolution. The appropriate selection of the transducer is critical. The wide-band abdominal transducer (C6–1) is the reference probe because it offers high resolution and contrast. If the lesion is really superficial, higher frequency transducers, such as the curvilinear C10–3 or even the linear transducer L12–5 with abdominal preset can be useful. However, with high frequency transducers image quality can be rapidly affected by the presence of peri-renal bleeding or gas deposition. We found that the micro-convex transducer (6C1) is extremely helpful when the lesion is poorly visible due to limited intercostal accessibility. In our department, guidance is always performed free-hand to allow better visualization of the electrode track and detection of the tip. When the position of the electrode seems adequate, a non-enhanced CT scan is performed in order to check the electrode position through the entire tumour and the relationship to the surrounding structures.

If the lesion was not correctly assessed during conventional US, administration of an ultrasound contrast agent is useful in order to improve lesion detection and conspicuity. All contrast imaging techniques can be used. Split-screen technology with pulse/power modulation is particularly suitable for guiding electrode insertion for tumours with

poor accessibility (either central or anterior, or located at the upper pole). The electrode is visible on the anatomical display while the targeted tumour is enhanced on the contrast display. Vascular Recognition Imaging (VRI) was also found to be useful as the electrode is visible on the anatomical greyscale background. The tip of the electrode is seen as an hyperechoic dot with both techniques. However, at peak enhancement, its detection becomes difficult due to the strong enhancement of the normal cortex and the tumour.

CEUS is also very useful after insertion of the electrodes, particularly when the lesion is small and poorly seen with conventional US. In fact, the kidney is highly mobile in the retroperitoneum and the needle introduction can affect the position of the lesion by rotating or translating the kidney. In patients with chronic renal failure, the reference imaging technique is MRI and the procedure is guided by combined US and non-enhanced CT. When baseline US is not helpful, the position of the lesion obtained from the reference MRI cannot be matched with non-enhanced CT due to some kidney displacement. The injection of SonoVue<sup>®</sup> improves visualisation of the lesion and confirms the appropriate position of the electrode within the tumour volume.

CEUS plays a critical role in the treatment of persisting tumour tissue (residual tumour following RFA or tumour recurrence) after a previous ablation session. In this case, the electrode should be placed within the residual tumour detected as a persisting enhancing area. MRI might be the technique of choice but due to the limited access to this modality and the technical requirements (open system, MRI compatible equipment, etc.) this might not be feasible. CT value is limited by the required administration of iodinated contrast agent and the transient enhancement of the residual

**Fig. 7: The role of US and CEUS after the RFA procedure**



Fig. 7 a: At day 1, the lesion did not exhibit any color Doppler signals (arrow heads).



Fig. 7 b: CEUS confirmed the lack of any abnormal enhancing area within the tumour area, and particularly at the upper and lower poles.

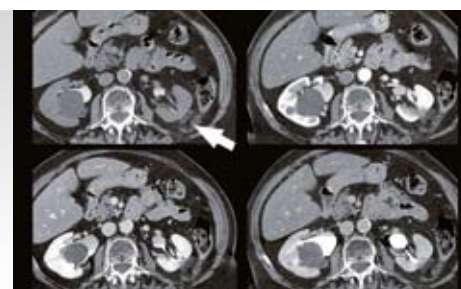


Fig. 7 c: Contrast-enhanced CT at two years confirmed the success of the procedure.

tumour (mainly during arterial phase which cannot be repeated during the procedure). The lack of real-time guidance is an additional limitation as most residual tumours are small and should be treated at an early stage to take opportunity of the size reduction. CEUS is in our experience the preferred guiding imaging modality, as the duration of the enhancement is typically short (less than five minutes) and bolus administration of USCA can be repeated in order to localize the enhancing area with no limitation in case of renal failure. High spatial and temporal resolutions are extremely useful to reduce the duration of the new procedure and increase the success rate. Due to this approach, the failure rate for the second procedure does not exceed the failure rate of the first one.

### **V – 3 The role of US during follow-up of renal RFA**

The frequency of incomplete RFA treatment (persisting tumour) and tumour recurrence is ranging between 7% and 20% of the procedures, depending on tumour size, location and perfusion (3, 4, 9, 16). The ability to timely and accurately diagnose the tumour while minimizing the inconvenience of the imaging modality and its potential renal toxicity is critical. MD-CT is the reference imaging modality for surveillance as it allows not only the detection of residual and recurrent tumours but also the evaluation of metastatic sites including the lungs. However, the administration of iodinated contrast media is mandatory for the abdominal study and their nephrotoxicity remains a limitation [17, 18]. In patients undergoing RF ablation of a renal tumour, the rate of decreased renal function can reach 16%, particularly in the case of solitary functioning kidney. RFA can also contribute to the acceleration of the impaired renal function, limiting the use of contrast-enhanced CT [18].

Patients with chronic renal insufficiency can take advantage of the lack of nephrotoxicity of Gadolinium chelates. Pre- and post-contrast MRI is an alternative imaging modality that can be used for RFA follow-up, particularly in case of renal failure and in young patients in order to reduce the amount of ionizing radiations [19, 20]. However, with MRI spatial resolution is lower than with MDCT. There is no comparison study evaluating the performance of CE-MRI in comparison to CE-CT. Some concerns have been raised about the rare association between nephrogenic systemic fibrosis and the use of intravenous gadolinium contrast material in patients with chronic renal failure [21].

### **V – 3a Immediate assessment of RFA efficacy**

CEUS can be used during the RFA procedure itself to evaluate the immediate result of the ablation. The increase in temperature results in hyperechoic appearance due to large bubble production involving both the targeted tumour and the surrounding tissues (adjacent renal tissue and perirenal fat). After fifteen to twenty minutes, the artefacts within the adjacent renal tissue and the tumour are reduced and CEUS can be performed varying the imaging plane to limit the shadowing effect of residual bubbles. When the perirenal fat is involved in the treatment, the persistence of these artefacts is increased and it is critical to use a field of view that avoids the path of the electrodes. The detection of residual tumour relies on the presence of a nodular or crescent-like enhancement displaying characteristics identical to those observed before treatment. Meticulous comparison with pre-contrast examinations is critical and the CEUS performed immediately before RFA should be performed in the same position and view as the control. CEUS is also useful to verify the position of the

electrode within the tumour when its identification is poor using baseline US. The comparison before MRI and/or CT performed previously can be of limited value due to the possible rotation or translation of the kidney during the insertion of the electrode. CT can be useful if the administration of iodinated contrast media is not contra-indicated. In this case, CEUS is the only imaging technique that allows confirmation of the right location of the electrode. In the case of chronic renal failure, it is even more critical to avoid the destruction of normal parenchyma.

### **V – 3b Follow-up assessment of RFA efficacy**

CEUS offers some definite advantage in the follow-up of renal tumours treated by RFA. The concept of CEUS follow-up of tumours after ablation was introduced first for hepatocellular carcinoma (23–24). Four years ago, we decided to develop this imaging technique for RFA follow-up when it appeared clear that it was a useful tool. Recently, Meloni published a retrospective study evaluating the performance of CEUS during RFA follow-up [15]. Despite the fact that there is only one published paper, the interest in this indication is growing fast. In our institution, an initial evaluation of RFA efficacy is performed within 24 hours immediately before discharging the patient using CEUS and CE-CT depending on the renal function. A second evaluation is scheduled six to eight weeks later. In our experience, this second evaluation offers best sensitivity for the detection of residual tumour. Any contrast enhancement within the ablation zone should be considered residual tumour tissue [15, 25–27]. To avoid misinterpreting vascular structures for residual disease, particularly the common reactive hyperemia seen at CEUS, we consider as residual disease any nodular or crescent-

like enhancement displaying characteristics reflecting those observed before treatment. Meticulous comparison with pre-contrast examinations is thus of paramount importance. The evaluation of RFA efficacy by any imaging modality is not so obvious than it could appear from the literature. Discrepancies between the imaging techniques are not unusual. The identification of the residual tumour is made possible by a slight difference of contrast enhancement that can last only a few seconds. False positive results can be found at 24 hour CEUS and CT due to enhancing areas within the treated area that will disappear during follow-up. They can be attributed to detached normal renal cortex or patent peripheral vessels that underwent necrosis or occlusion over time. CEUS limitations are encountered in obese patients and for central lesions, particularly in patients with multiple tumours, cysts and previous RFA procedures. This situation is usual in hereditary renal cancers such as von Hippel Lindau disease. In this case, MDCT performance is superior to CEUS. CEUS is superior to CT/MRI for the depiction of normal and abnormal vessels, such as small RFA-induced arteriovenous fistula that is misinterpreted as residual disease in most cases.

#### VI – Perspectives

Perspectives involving US improvements are extremely promising for the management of renal tumour by RFA. The basic requirement is excellent contrast resolution and spatial resolution for the perfect assessment of tumour shape and limits. The detection of the needle track and visualization of the needle tip remain a challenge. The use of real-time 3D (4D) (including multiple planes) should be useful for appropriate electrode positioning within the tumour volume. 3D acquisition will bring better spatial visualization of the distribution of electrodes in the lesion, improving the detection of areas not included in the ablated volume. Treatment planning will be facilitated, particularly if the modality is also available in conjunction with USCA administration. The injection will facilitate the identification of residual tumour and guide retreatment. These new modalities are also expected to reduce the duration of the procedure including the immediate evaluation of the procedure efficacy. Elastography can also be applied in order to improve

the immediate and follow-up evaluation of the procedure with regard to detection of residual tumour. However, the presence of large bubbles can affect the compliance of the tissue. Fusion imaging of US and CT/MRI is also a very promising tool for renal RFA procedures. However, the technique must be able to use previous CT/MRI volumes acquired in different positions. In practise, RFA is performed in most cases in prone or oblique positions, while previous references CT/MRI were acquired in supine position. Another clear issue results from the fusion precision. Because the efficacy of the heat production is limited by the huge perfusion from both normal and tumor tissues, the electrodes should be perfectly distributed within the tumour volume. A precision of less than 3 to 4 mm seems reasonable here.

#### VII – Conclusion

RFA of renal tumours is an efficient alternative to conservative surgery. However, the rate of success remains lower due to the higher tissue perfusion of both normal renal parenchyma and renal cell carcinomas. Technical issues include the limited amount of renal tissue stabilizing the electrodes and the increasing incidence of renal failure. US and CEUS play a critical role at each step of the management of renal RFA, including renal biopsy, treatment planning, guidance of the electrodes and immediate and delayed follow-up. Further developments including 3D-US and 3D-CEUS, elastography and fusion imaging should increase the role of US. Contrast-enhanced CT and MRI are still major players in the evaluation of renal tumours before and after ablation. However, their cost, limited access and potential risks with contrast agents can represent a limitation compared to US, despite higher sensitivity for the detection of residual tumours.

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