

Radiofrequency ablation of kidney tumours and lesions: A review of the literature

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Venyo AKG. Radiofrequency ablation of kidney tumours and lesions: A review of the literature. *J Kidney Treat Diagn*. 2018;1(1):16-32.

Background: Even though radical nephrectomy and partial nephrectomy are accepted standard treatment for small localized renal tumours apart from active surveillance for selected patients, various papers have been published which have intimated that the use of radiofrequency ablation (RFA) is a safe and effective treatment alternative to surgical operations.

Aims: To review the literature related to RFA of kidney lesions to ascertain whether RFA of renal lesions, is safe and effective.

Methods: Various internet data bases were searched.

Results: Radiofrequency has been shown, in number of publications, to be a safe and very effective therapeutic option for small kidney masses that measure less than 3 cm to 4 cm and many studies had illustrated the efficacy of radiofrequency ablation in more than 95% of cases treated.

A study that comprised of 143 individuals, reported a recurrence-free survival of 96% with regard to patients who had undergone radiofrequency ablation for T1a kidney tumours, It had also been reported that with regards to patients who subsequently developed recurrent tumours locally, half of them did undergo retreatment by means of radiofrequency ablation and this resulted in 5 of the 6 cases that had undergone re-treatment by means of radiofrequency ablation having long-term control of their disease.

Similar recurrence-free survival between radiofrequency ablation treated cases and partial nephrectomy (91.7% following radiofrequency ablation versus 94.6% following partial nephrectomy) has been reported and cancer specific survival has also been illustrated to be similar between patients that were treated by means of radiofrequency ablation and partial nephrectomy (97.2% following radiofrequency ablation versus 100% following partial nephrectomy). It has been re-enforced that both radiofrequency ablation and partial nephrectomy are both effective with regards to the management of small kidney tumours.

In relation to kidney tumours that measure more than 3 cm up to 4 cm, mixed outcomes have been obtained and furthermore, local progression as well as incomplete treatment rates greater than 20% have been reported pursuant to radiofrequency ablation of bigger kidney tumours.

However, it has been shown that the incompletely treated lesions can be re-treated successfully by means of radiofrequency ablation. It had been iterated that radiofrequency ablation of kidney tumours that measure more than 3 cm could lead to long-term disease control in not more than 80% of individuals treated.

Some authors had suggested that additional to considerations related to the size of the tumours, tumours that are centrally located in the kidney should be treated by means of an alternative radiofrequency ablation technique in view of the heat sink as well as risk of damage to the urothelium.

Major complications ensuing radiofrequency ablation of kidney tumours have tended to be low (between 5% and 6%) and these major complications have tended to be less than pursuant to cryoablation, partial nephrectomy, and radical nephrectomy. Radiofrequency ablation has been shown to be effective for the treatment of Bosniak cysts in the kidney.

Radiofrequency ablation has been shown to be effective for the treatment of papillary cell type of renal cell carcinoma as well as for adenocarcinoma and an anecdotal report has shown that the outcome following ablation of papillary tumours is superior to that of adenocarcinoma.

Conclusion: RFA is a safe and effective option of treatment for small sized renal cell carcinomas and Bosniak cysts.

RFA is associated with minimal complications and good prognosis comparable to that of partial nephrectomy and radical nephrectomy as well as it can be performed as an outpatient procedure and local recurrence of tumour can also be re-treated by RFA.

RFA can be undertaken on patients unfit for partial nephrectomy or radical nephrectomy.

A global Consensus meeting would be recommended to decide whether RFA should be considered as a first line alternative treatment of choice option for patients who may be on active surveillance or those who may require treatment of curative intent for well localized renal cell carcinomas of up to 3 cm size.

Key words: Radiofrequency ablation, Renal cell carcinoma, Kidney cancer, Bosniak cysts, Small renal cancers, Estimated glomerular filtration rate, 5-year survival rate, Partial nephrectomy, Radical nephrectomy, Active surveillance. .

INTRODUCTION

Radiofrequency ablation (RFA) refers to a medical procedure that entails ablation, with utilization of local anaesthesia or conscious sedation anaesthesia or general anaesthesia part of the electrical conduction system of the heart, tumour, or other dysfunctional tissue and utilization of heat generated from medium frequency alternating current within the range of 350 to 500 KHz [1] Radiofrequency ablation tends to be undertaken in the outpatient setting where it tends to be administered under local anaesthesia or sedation [2] but with regards to radiofrequency ablation under general anaesthesia for example for the ablation of renal lesions the procedure could be undertaken through the day service or inpatient admission procedure. When radiofrequency ablation is administered by means of a catheter it tends to be referred to as radiofrequency catheter ablation [2].

Radiofrequency ablation procedures are now being undertaken in the 21st century in view of reports of the beneficial effects of the procedure. [2-5] Radiofrequency ablation tends to be undertaken under the guidance of radiological imaging (for example under ultrasound scan guidance, computed tomography (CT) scan guidance or magnetic resonance imaging (MRI) scan guidance). Depending upon the specific type of radiofrequency procedure and the organ / site of the radiofrequency ablation, the procedure could be carried out by any of the following: Interventional radiologist, interventional pain specialist (an anaesthetist), Otolaryngologist, a gastro-intestinal endoscopist, a surgical endoscopist, or a cardiac electrophysiologist [2].

Considering that radiofrequency ablation of kidney lesions, are only being undertaken sporadically in few specialist-centres most clinicians globally

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Received: February 21, 2018, Accepted: April 16, 2018, Published: April 20, 2018



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would not have had the chance to be familiar with radiofrequency ablations of kidney lesions as well as with the outcome of the procedure. The ensuing article on radiofrequency ablation of kidney lesions has been divided into (A) Overview which has included various lesions that are being treated globally by radiofrequency ablation and (B) Miscellaneous narrations and discussions from reported studies and cases.

METHODS

Various internet data bases were searched including: Google, Google Scholar, Educus, and PUBMED. The search words used included: radiofrequency ablation, radiofrequency ablation of renal cell carcinoma, radiofrequency ablation of renal tumours, radiofrequency ablation of renal lesions. Information obtained from 58 references relevant to radiofrequency ablation of renal lesions was utilized for the literature review.

RESULTS/LITERATURE REVIEW

Overview

1. Tumours

- **Malignant tumours:** Utilization of radiofrequency ablation has been reported in the treatment of various tumours including: lung tumours, [6-8] liver [9] and combined with chemotherapy to treat hepatocellular carcinoma [10], kidney and bone as well as other organs [2], pancreatic and bile duct carcinomas [11].
- **Benign tumours:** Radiofrequency ablation was introduced for the treatment of osteoid osteoma in the 1990s [12]. Radiofrequency ablation has been demonstrated in many studies to be less invasive as well as less expensive, to be ensued by less bone destruction, to exhibit similar safety and efficacy to surgical treatment procedures, to be ensued by 66% to 95% of patients declaring being asymptomatic [2,13-15]. Despite the initial high success rate reported after radiofrequency ablation of benign lesions, some studies had reported recurrence rates that had been similar, to the recurrence rates associated with surgical treatment [16]. Radiofrequency ablation is also being utilized in relation to palliative therapy of patients who have painful osseous metastases who have been adjudged not to be eligible or not to have responded to traditional treatment options including radiotherapy, chemotherapy, palliative surgical procedures, use of bisphosphonates, and analgesic medicaments [2,17].
- **Cardiology:** Radiofrequency ablation has been utilized in the management of recurrent atrial flutter, atrial fibrillation, supraventricular tachycardia, and atrial tachycardia, multi-focal atrial tachycardia and some types of ventricular arrhythmia [2].
- **Aesthetic dermatology:** It has been stated that various forms alternating current have been utilized as dermato-surgical procedure in the management of dermatological lesions [2]. Types of radiofrequency procedures utilized in the management of dermatological conditions include: electrosection, electrocoagulation, electrodesiccation, and fulguration [2]. Utilization of radiofrequency ablation in the management of skin lesions tends to be associated with minimal side effects and minimal complications [2].
- **Varicose veins:** Radiofrequency ablation has been utilized in the treatment of varicose veins and radiofrequency ablation of varicose veins has become an alternative treatment option to the surgical stripping of varicose veins [2]. Radiofrequency ablation is utilized to treat the great saphenous vein, the small saphenous vein, and the perforator veins [2].
- **Obstructive sleep apnoea:** The ensuing summations have been made relating to the use of radiofrequency ablation in obstructive sleep apnoea [2]: (a) Radiofrequency ablation was first studied with regards to obstructive sleep apnoea in a pig model [2,18]. (b) Radiofrequency ablation had been recognized as a somnoplasty option of treatment in selected situations by the American College of Otolaryngology [18] but had not been endorsed for general use in the guidelines of the American College of Physicians [19].
- **Pain management:** It has been stated that radiofrequency ablation or rhizotomy, is at times utilized in the treatment of severe chronic lumbar pain, where radiofrequency waves tend to be utilized to produce heat on specified nerves that had been identified encompassing the facet joints on **either side of the lumbar spine** [2]. It has been stated that in April 2017, the United States of America Food and Drug Administration did approve a commercial device that utilizes cooled radiofrequency ablation that produce effects that last for up to a year of pain relief from arthritis of the knee [5,20]. It had been stated that whether for knee or back pain, a drawback for radiofrequency ablation is that there tends to be recovery of nerve function with time, so the pain-relief tends to be temporary and tends to last between 3 months and 15 months with **regards to majority of patients** [2,5].
- **Barrett's oesophagus:** It has been stated that radiofrequency ablation has been demonstrated to a safe and effective treatment for Barrett's oesophagus [2]. Generally, two months pursuant to endoscopic radiofrequency ablation, a repeat upper gastro-intestinal endoscopy tends to be undertaken to establish if there is residual Barrett's oesophagus and if any Barrett's oesophagus is found, the lesion tends to be treated utilizing a focal radiofrequency ablation device [2]. It has been stated that between 80% to 90% or higher of patients in many clinical trials had experienced complete eradication of Barrett's oesophagus in about two to three treatments of radiofrequency ablation that was associated with favourable safety profile, as well as the treatment of Barrett's oesophagus by means of radiofrequency ablation had been durable for up to 5 years [2,21-25].
- **Miscellaneous utilizations:** TRAP sequence in multiple gestation pregnancies (Radiofrequency ablation has been successfully utilized to treat TRAP sequence in multiple gestation pregnancies [2]). Uterine fibroids (It has been stated that radiofrequency ablation is under investigation for the treatment of uterine fibroids with utilization of the heat energy of radiofrequency waves to ablate the fibroid tissue and that the radiofrequency ablation device did obtain United States of America Food and Drug Administration (FDA) approval in 2012 [2,26]. The radiofrequency ablation device tends to be inserted through a laparoscope probe and then guided inside the fibroid tissue with utilization of ultrasound probe). Morton's neuroma (It has been stated that Radiofrequency ablation is also utilized in the treatment of Morton's neuroma [2,27] and that the outcome of radiofrequency ablation of Morton's neuroma would appear to be more reliable in comparison with alcohol injections [2,28].

The approach to management of renal cell carcinoma tends to be guided by the probability of providing curative treatment or not and this tends to be related to the stage of the tumour as well as the degree of dissemination of the tumour [29-32]. Greater than half of patients who have early staged kidney cancer tend to be cured; nevertheless, stage (iv) kidney tumour tends to be associated with inferior prognosis [29].

It is generally understood that for the treatment of T1 kidney mass lesion a clinician needs to review all the treatment options that are available as well as the associated risks and benefits related to each individual patient and furthermore oncological issues, renal function issues and potential complications of the choice of management should be taken into consideration.

Some of the available options of treatment for the treatment of renal cell carcinoma include:

- Surgical operation in the form of radical nephrectomy and partial nephrectomy in some small renal carcinomas that suitably located for partial nephrectomy. The surgical operations can be undertaken by the open method or laparoscopic or robotic assisted laparoscopic method.
- Radiotherapy
- Immunotherapy
- Molecular-Targeted treatment
- Radiofrequency ablation is sporadically being used for the treatment of small localized tumours in selected centres where it is available but not globally

- Cryotherapy in selected centres where this is available has been used recently but this use has been limited so far globally
- Immunotherapy
- Molecular-targeted treatment
- Active surveillance has recently been added
- Electroporation potentially only in limited research centres in the world for selected cases

Surgical operation in the form of radical nephrectomy or partial nephrectomy are the generally known and accepted treatment of curative intent for localized renal cell carcinoma globally which is associated with good long-term prognosis for small localized renal cell carcinoma. This form of treatment also tends to be used as part of palliative treatment for some cases of metastatic renal cell carcinoma.

Radiofrequency ablation and cryotherapy which tends to be undertaken by an interventional radiologist under radiological imaging-guidance is being used in select centres in the developed countries where the facilities are available as alternative treatment modality in some selected patients who have been adjudged to be unsuitable candidates for surgical operation [29].

Targeted therapeutic option as well as immunomodulatory agents have become the accepted standard of management with regards to patients who have metastases from renal cell carcinoma [29].

Other treatment approaches are available in experimental stages in the developed world including: the use of vaccines, and non-myelo-ablative allogeneic peripheral blood stem cell transplantation [29].

Active surveillance has been used as an option to avoid or delay in patients who have been considered to have a high risk for undergoing surgical operation and some these tend to be patients who are older than 70 years, who have asymptomatic kidney tumours and small tumours that have been adjudged based upon serial to be slow growing [29].

Many manuscripts have been published over the past 20 years which indicate that radiofrequency ablation for localized small renal cancers and cysts is associated with minimal complications as well as good long-term prognosis, but these anecdotal publications have been published in diverse journals which are not available to many clinicians globally. Considering the fact that radiofrequency ablation of kidney tumours and Bosniak cysts are not undertaken in all centres in the world and majority of clinicians are not aware of the short term and long-term outcome of the procedure, the

ensuing miscellaneous narrations from various publications on radiofrequency ablation of renal lesions has been written to enable clinicians globally to ascertain on individual basis whether or not radiofrequency ablation for renal tumours and cysts should be accepted globally as an excellent alternative treatment of choice.

2. Miscellaneous narrations and discussions from reported cases and studies.

Gervais et al. [33] reported their early experience with radiofrequency ablation of renal cell carcinoma. They reported that they had performed 24 radiofrequency ablation treatments for nine tumours in 8 patients who had renal cell carcinoma (Table 1). Three smaller peripheral lesions that measured less than or equal to 3 cm were treated with single electrodes. All tumours except one tumour that measured more than 3 cm and or central lesions, were treated with cluster or multiple electrodes. The patients did return for a second treatment in situations when their follow-up radiological imaging demonstrated contrast enhancement by the tumours. They did undertake follow-up radiological imaging at 1 month follow up, 3-months follow-up, and then at 6-month intervals with a mean follow-up of 10.3 months. Seven patients were reported to be alive 6 months following their initial radiofrequency ablation. Gervais et al. [33] summarized their results as follows:

- All five exophytic tumours were free of contrast-enhancement on radiological imaging.
- One of three central located tumours, was free of contrast enhancement on imaging.
- One tumour which had both central localization was free of contrast enhancement on subsequent imaging post ablation.
- Three tumours that measured 3 cm or less than 3 cm were free of contrast enhancement post ablation.
- With regards to the six tumours that were larger than 3 cm, four were free of contrast enhancement post ablation.

Gervais et al. [33] made the ensuing conclusions:

- Percutaneous radiofrequency ablation constitutes a promising treatment option for select patients who have renal cell carcinoma.
- The ultimate role of radiofrequency ablation of renal cell carcinoma will continue to evolve, and this modality of treatment warrants further study.

Table 1. Radiofrequency ablation of renal lesions.

References	Details	Outcome
Gervais et al.	24 RFA treatments for nine tumours in 8 patients who had renal cell carcinoma. Three smaller peripheral lesions that measured less than or equal to 3 cm were treated with single electrodes. All tumours except one tumour that measured more than 3 cm and or central lesions, were treated with cluster or multiple electrodes. The patients did return for a second treatment in situations	All five exophytic tumours were free of contrast-enhancement on radiological imaging. One of three central located tumours, was free of contrast enhancement on imaging. One tumour which had both central localization was free of contrast enhancement on subsequent imaging post ablation. Three tumours that measured 3 cm or less than 3 cm were free of contrast enhancement post ablation. Of six tumours that were larger than 3 cm, four were free of contrast enhancement post ablation.
Gervais et al.	RFA of renal cell carcinoma was undertaken over a 6-year period, in which 100 kidney tumours in 85 patients were treated.	All 52 small tumours that measured less than 3 cm and all 68 exophytic tumours did undergo complete necrosis irrespective of size even though many large tumours that measured more than 3 cm required a second ablation session. By using multivariate analysis, they found that both small size (p < 0.0001) and non-central location (p=0.0049) did prove to be independent predictors of complete necrosis following a single ablation treatment session. Location represented a significant predictor (p=0.015) of complete necrosis following any number of treatment sessions. The complications were either self-limited or they were readily treated, and these did include haemorrhage (major haemorrhage 2, minor haemorrhage 3),

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Watkins and Parkinson.	Thirteen radiofrequency ablation treatment procedures had been undertaken for 11 tumours in 11 patients.	<p>inflammatory tract mas (1), transient lumbar plexus pain (2), ureteric injury (2), and skin burns (1).</p> <p>The ages of the patients did range from 61 years to 88 years and the mean age was 74.4 years.</p> <p>Radiological imaging was undertaken following the RFA with a follow-up that ranged between 2 months and 26 months and the mean follow-up time was 8 months.</p> <p>There was no evidence of residual tumour pursuant to the first radiofrequency ablation therapy in 82% of cases in that nine out of the 11 tumours were no longer seen.</p> <p>Two patients did undergo a second RFS treatment and of these, one patient had the second RFA treatment for residual tumour and the second patient had the second RFA treatment for recurrent tumour.</p>
Carrafiello et al.	Between January 2003 and August 2008 26 patients, aged 70 to 87 years, mean age of 79 years had undergone RFA for renal tumours. Of the 26 patients 15 were male and 11 were female who were affected by 27 renal tumour lesions; 25 of the lesions were renal cell carcinoma and 2 were oncocytoma of the kidney and one patient was affected by two renal cell carcinomas; the cohort of patients did undergo 29 RFA treatments in which 3 patients did undergo two treatments as a result of residual tumour found following performance of CT scan of abdomen one month after first RFA treatment.	<p>Technical success was achieved in all patients.</p> <p>18 patients who did not have any complications and who did not have any co-morbidity were discharged on the day of the procedure. Seven patients who did have co-morbidity were kept overnight and discharged the next day. One patient out of the 27 patients did require hospitalization.</p> <p>Based upon the results of CT scan or MRU scan performed one month after the ablation procedures, it was confirmed that primary success had been achieved in 25 out of the 27 cases with no residual tumour and in two out of the 27 lesions an incomplete ablation was confirmed and in view of this the two patients did undergo a second ablation. At six months of follow-up there was no radiological imaging evidence of any more tumour or lesion. And during the subsequent follow-up none of the patients had any sign of disease. No major complications were noted but one patient needed assistance due to the appearance of a peri-renal urinoma and a very small pneumothorax which did resolve after a few days following the ablation procedure.</p>
Mylona et al.	Between October 2000 and June 2005, 18 patients with solitary kidney and renal cell carcinoma had undergone per-cutaneous CT-guided RFA. The diameters of the tumours had ranged between 1 cm to 7 cm and there was no radiological imaging evidence of spread of tumour the kidney. The patients did have a follow-up that ranged between 12 months and 72 months with a mean follow-up of 31.2.	<p>In all cases the RFA electrode had been successfully placed within the lesion.</p> <p>The 18 tumours had been totally treated with 24 RFA sessions.</p> <p>With regards to small 1 cm to 3 cm exophytic tumours technical success was achieved in 85.7% of the tumours and residual tumour was totally seen in 6 out of 18 tumours that required a second radiofrequency ablation treatment. The recurrence rate was 11.1%; however, no recurrence was found with regards to tumours that were less than 3 cm in diameter. No major complications were encountered.</p> <p>The serum creatinine levels of the patients were normal in 17 out of the 18 patients up to the 3rd month follow-up.</p> <p>The survival of the patients had ranged between 12 months and 72 months.</p>
Zagoria et al.	48 renal cell carcinomas in 41 patients had been treated by means of RFA. The sizes of the tumours ranged between 0.7 cm and 8.2 cm and the median was 2.6 cm. Out of the 48 renal cell carcinomas, 5 constituting 12% of cases did develop recurrence following a single ablation session. The median size of the index lesion in the cases that developed recurrence was 5.2 cm and this had ranged between 4 cm and 5.3 cm in comparison with 2.2 cm median size of tumours that did not have local recurrence of which the sizes had ranged between 1.7 cm and 3.1 cm (P=0.0014).	<p>No recurrences were developed in renal carcinomas that measured less than 4 cm that had been treated. Seventeen patients (41%), had treatment for 18 renal cell carcinomas, died during their follow-up period at a median time of 34 months in which the follow-up ranged between 10 months and 47 months. One patient (2%) died due to metastatic renal cell carcinoma, and on the contrary, 16 patients had died of causes not related to their renal cell carcinoma. Twenty-four patients who had 30 renal cell carcinomas that had been treated by means of radiofrequency ablation had survived. With regards to the remaining renal cell carcinomas whose follow-ups had ranged between 54 months and 68 months and a median follow-up of 61 months, no patient within this group of survivors had developed metastatic renal cell carcinoma, 1 patient did develop recurrence which was diagnosed at 68 months following the ablation treatment. The long-term recurrence-free survival following radiofrequency ablation was computed to be 88%.</p>
Olweny et al.	comparative 5-year oncologic outcomes for radiofrequency ablation versus partial nephrectomy in patients who had clinical T1a renal cell carcinoma was undertaken.	<p>A total of 37 patients in each group met the selection criteria. The RFA cohort of patients was significantly older than the partial nephrectomy group and they did have more advanced co-morbidities; however, other patient characteristics had been similar. With regards to RFA versus partial nephrectomy, the follow-up had ranged between 5.8 years and 7.1 years and the</p>

		<p>median follow-up was 6.5 years versus a follow-up range of 5.4 years to 7.3 years and a median follow-up of 6.1 years (P=0.68) respectively. The 5-year overall survival was 97.2% versus 100% (P=0.31), Cancer specific survival was 97.2% versus 100% (P=0.31). The disease-free survival was 89.2% versus 89.2% (P=0.78), the local recurrence free rate was 91.7% versus 94.6% (P=0.96), and metastatic free survival was 97.2% versus 91.8% (P=0.35) respectively. The limitations include analysis of retrospective data, loss to follow-up, limited statistical power, and limited generalizability of their data.</p>
Allen et al.	<p>Thirty-eight subjects which included 19 men and 19 women with ages ranging between 46 years and 95 years and mean age 71 years had undergone RFA for 40 cystic renal neoplasms that had been classified as Bosniak III in 25 cases and Bosniak IV in 40. Percutaneous biopsy had been undertaken in 36 out of the 40 (90%). With regards to patients who had radiological imaging follow-up at least 1 year that totalled 21, the duration of their surveillance had ranged between 1.6 years and 5 years and their mean surveillance period was 2.8 years. The estimated glomerular filtration rate was measured prior to the RFA and at the last follow-up consultation more than 6 months pursuant to the RFA procedure.</p>	<p>According to the results of histology examination of the percutaneous biopsies from the renal lesions, 22 out of 36 of the lesions (61.1%) were malignant and 14 of the 36 biopsies (38.9%) were adjudged to be inconclusive.</p> <p>No local tumour progression was subsequently found, and no individual subsequently developed metastatic disease.</p> <p>One individual did develop a new solid kidney mass during follow-up.</p> <p>Two patients out of the 38 (5.3%) developed minor complications pursuant to the ablation procedure, one of them developed dysuria and the other developed mild hydronephrosis that was related to the development of a blood clot in the ureter.</p> <p>There was one major complication out of the 38 individuals (2.6%) which was the development of pulmonary oedema.</p> <p>On average, the estimated glomerular filtration rate had decreased by 2.5 mL / min per 1.73 m².</p>
Nakasone et al.	<p>Ten patients who had 12 renal cell carcinomas who were adjudged not to be candidates for surgical operation were studied. All the tumours had ranged in size between 18 mm and 66 mm and the mean tumour size was computed to be 31 ± 3.9 mm and all the tumours had been treated by means of percutaneous ablation several hours following the embolization of the vessels supplying the tumours with iodized oil and gelatine sponges. The following were evaluated: technical success, effectiveness, effect on renal function, and complications ensuing the treatment. Adjudication of the effectiveness of the treatment was made based upon computed tomography and / or magnetic resonance imaging scans that were obtained every three months after the radiofrequency ablation. The effect of the treatment upon renal function was assessed based upon the serum creatinine level and the glomerular filtration rate prior to, one week after the treatment procedure, and three months following the treatment procedure.</p>	<p>Selective renal arterial embolization followed by percutaneous radiofrequency ablation was technically successful in all the patients.</p> <p>Based upon the results of contrast CT scan or contrast MRI scan that was obtained one week and 3 months after the RFA they had observed necrosis in the embolized segment of all the renal cell carcinomas.</p> <p>There no major complications recorded during and after the procedure.</p> <p>All patients did report tolerable pain and burning sensation during the process of RFA.</p> <p>Following the RFA procedure, five patients (50%) reported having back pain, and one patient each developed fluid collection, sub-capsular haematomas, haematuria, or nausea.</p> <p>During a mean-follow-up period of 47 ± 3.8 months there was no case of recurrence.</p> <p>They did not observe or record any significant difference in serum creatinine and glomerular filtration rate before and after treatment.</p>
Gahan et al.	<p>. A total of 229 patients had been included in the study analysis of patients who had RFA for renal cell carcinoma.</p> <p>The mean age of the patient cohort was 64.5 ± 13.8 years who had a median follow-up of 48 months, but the follow-up had ranged between 12 months and 65 months.</p> <p>The mean size of the tumour cohort was 2.5 cm ± 0.8 cm.</p> <p>There was no difference between the papillary carcinoma and clear cell carcinoma sub-types of the renal cell carcinomas based upon their age distribution, the size of the tumour, or the months of their follow-up.</p> <p>A total of 181 (75.7%) of the tumours histologically diagnosed as clear cell carcinoma and 48 (20.1%) of the tumours were histologically diagnosed as papillary sub-type.</p>	<p>The mean size of the tumour cohort was 2.5 cm ± 0.8 cm.</p> <p>There were 15 failures of treatment with ablation in the clear cell sub-type of renal cell carcinomas and 0 failure of treatment following ablation in the papillary sub-type which gave an estimated 5-year disease free survival of 89.7% and 100% for the clear cell renal cell carcinoma sub-type and papillary sub-type of renal cell carcinoma respectively (P=0.41)</p>
Schneider et al.	<p>2 patients one aged 62 years and the other 71 years who developed chyluria that were diagnosed incidentally in follow-up contrast enhanced computed tomography scans following RFA of their renal tumours.</p>	<p>2 patients one aged 62 years and the other 71 years who developed chyluria that were diagnosed incidentally in follow-up contrast enhanced computed tomography scans. Even though no untoward sequels occurred the two cases that were reported in men were documented to illustrate that chyluria could develop pursuant to radiofrequency ablation of renal tumours.</p>
Wah et al.	<p>Overall, 200 tumours had been treated by means of RFA and the sizes of the tumours did range between 1 cm and 5.6 cm and the mean size of the tumours was 2.9 cm. The ages of the patients did range between 21 years</p>	<p>Overall, 200 tumours had been treated by means of radiofrequency</p>

	<p>and 88.6 years and the mean age of the patients was 67.7 years. The mean follow-up of the patients was 46.1 months.</p>	<p>Their primary technical success and overall technical success rate amounted to 95.5% and 98.5% respectively. Logistic regression analysis of their data did identify two independent predictors of successful radiofrequency ablation in a single sitting and these were (a) tumour size that was less than 3 cm, and (b) exophytic location of the tumour.</p> <p>The major complications that they encountered included injury to the ureter in six patients, development of calyceal – cutaneous fistula in one patient, and the development of abscess in two patients. Two independent predictors of injury to the ureter included (a) central location of the tumour, and (b) lower pole position of the tumour.</p> <p>Within their cohort 165 patients RFA of 200 tumours only four patients did develop significant deterioration in renal function that amounted to greater than 25% decrease in glomerular filtration rate. Overall, 161 patients (98% of the 165 patients) had preservation of their renal function. Any change in renal function pursuant to RFA was not influenced by tumour factors or by solitary status of kidney.</p> <p>Within their series of 200 RFA of renal tumours in 165 patient's statistical analysis of their data had determined that the 5-year overall survival, cancer specific survival, local recurrence free survival, and metastasis-free survival, rates were correspondingly 75.8%, 97.9%, 93.5%, and 87.7%.</p>
<p>Lee et al.</p>	<p>The treatment of forty kidney lesions in 37 patients that included 27 males and 10 females whose mean age was 70 ± 13 years who had been treated by means of computed tomography scan-guided radiofrequency ablation from 2006 and 2013.</p>	<p>The statistical analysis included the following parameters: the entire ablated cohort with particular- attention paid to sub-groupings based upon (a) whether the patients' renal masses did measure less than 3 cm or equal to / greater than 3 cm, (b) whether the tumour was histologically examined biopsy proven renal cell carcinoma. To evaluate changes in the lesion pursuant to the ra, a mixed-effects ANOVA model was fitted to the lesion size values over time. With regards to the results, Lee et al. [45] reported that Kaplan-Meier survival curves did show trends toward worse primary recurrence and overall survival in lesions ≥3cm, but there were not statistically significant (P=13 and P=27 respectively). The results did show that secondary recurrences had been the same in both groups and the rate of change with time in the size of the lesion pursuant to radiofrequency ablation did not significantly differ either by the initial size of the lesion (P=65), or between histologically biopsy examination proven diagnosis of renal cell carcinoma and non-biopsy proven renal cell carcinoma (P=46).</p>
<p>Cadeddu et al.</p>	<p>Two retrospective studies; one study did look at 47 benign small kidney tumours that measured less than 3.5 cm that were incidentally discovered incidentally in 41 patients in which the tumours were adjudged to be benign based upon histology examination of biopsy of each tumour. The second study was focussed upon 159 kidney tumours majority of which were renal cell carcinoma in 142 patients who did undergo radiofrequency ablation of the tumours as primary treatment.</p>	<p>With regards of the study of small benign renal tumours only one treatment session was required. Pursuant to a mean follow-up of 45 months none of the patients developed a recurrence, which they had defined as tumour growth and contrast enhancement on follow-up axial imaging. The investigators did report their results on line ahead of print in Urology and they also reported that the median pre- and post-radiofrequency ablation glomerular filtration rate of the patients was 77 and 68 mL / min 1.73 m2 respectively.</p>
<p>Psutka et al.</p>	<p>Retrospectively reviewed the long-term oncologic outcomes for 185 patients who had sporadic T1 renal cell carcinoma and the median follow-up of the patients was 6.43 years and the interquartile range of follow-up ranged between 5.3 years and 7.7 years.</p>	<p>Psutka et al. [47] summarized their results and limitations of the study as follows:</p> <p>The median size of the tumours was 3 cm; but the size did range between 2.1 cm and 3.9 cm.</p> <p>The stages of the tumours were recorded as T1a: 143 (77.3%) of cases or T1b: 42 which constituted 22.7% of cases.</p> <p>Twenty-four patients that constituted 13% of cases required re-treatment fur residual disease.</p> <p>Twelve local recurrences which amounted to 6.5% of cases were documented; 6 recurrences in the T1a disease that amounted to 4.2% and 6 recurrences in T1b disease amounting to 14.3% of cases (P=0.0196).</p> <p>The median time to observation of recurrence was 2.5 years.</p> <p>Local salvage radiofrequency ablation was undertaken in six patients and of these five patients remained disease free at 3.8-year median follow-up.</p> <p>Multi-variate analysis demonstrated that tumour stage was the sole significant predictor of disease free survival. During the last follow-up 164 patients that amounted to 88.6% of patients were disease free (T1a: 132 patients which amounted to 92.3% of T1a cases; T1b 32 patients amounting to 76.2% of</p>

	<p>T1b patients; p=0.0038). The overall survival was similar irrespective of tumour stage (P=0.06). Five patients did develop metachronous kidney tumours which amounted to 2.7% of cases. Four patients did develop extra-renal metastases which amounted to 2.2% of cases, and three of these patients died of metastatic renal cell carcinoma which amounted to 1.6% of cases.</p>	<p>d between 64 years and 83 years</p>
<p>Takaki et al.</p>	<p>Patients whose ages had ranged between 44 years and 86 years and whose mean age was 70.7 years that had histological diagnosis proven renal cell carcinoma were enrolled in their phase II study. The cohort of the patients included 24 men whose ages had ranged between 44 years and 86 years with a mean age of 69.5 years; and nine women whose ages had ranged between 64 years and 83 years with a mean age of 74.1 years. Takaki et al. [48] reported that the mean maximum diameter of the tumours had ranged between 1.5 cm and 5.0 cm and the mean maximum diameter of the tumours was 2.9 cm ±1.0 standard deviation. They did evaluate the primary endpoint with the common Terminology Criteria for Adverse Events. Secondary endpoints of the study included changes in kidney function, the effectiveness of the technique, local tumour progression, and survival of the patients. Mann-Whitney U test was utilized to evaluate the kidney function.</p>	<p>There were no severe adverse effects; however, three out of 33 patients that amounted to 9% of patients did develop grade 2 adverse events.</p> <p>Even though the mean glomerular filtration rate at 1- year follow-up after radiofrequency ablation was similar, to the baseline pre-radiofrequency ablation value in 26 patients who had bilateral kidneys (P=0.14), the mean glomerular filtration rate was noted to be significantly reduced in six patients who had a solitary kidney (P=0.03).</p> <p>Tumour contrast-enhancement did disappear following a single radiofrequency treatment session in 31 patients and following two radiofrequency ablation treatment sessions in the other two patients which did yield rates of primary and secondary technical effectiveness of 94% in 31 out of 33 cases and 100% in 33 out of 33 cases respectively.</p> <p>No local tumour progression was identified during the mean follow-up of 20.0 months and a follow-up that ranged had ranged between 11.6 months and 27.6 months.</p> <p>The computed respective 1-year, overall-, and renal cell carcinoma related survival rates were documented as 97% at 95% confidence level; 91% at 100% confidence level; and 100%.</p>
<p>Takaki et al.</p>	<p>Between June 2002 and March 2012, 60 patients whose ages had ranged between 39 years and 86 years and a mean age of 65.2 years and who had a single renal cell carcinoma that measured 4.1 cm to 7.0 cm that were staged as having T1b tumours. They reported that 21 of these patients had undergone radiofrequency ablation and 39 patients had undergone radical nephrectomy. Eight of the patients did undergo selective renal artery embolization prior to undergoing radiofrequency ablation of their tumours. Takaki et al. [49] compared the overall renal cell carcinoma-related, and disease-free survival rates, the percentage decrease in the glomerular filtration rate, and safety by utilizing the log-rank for survival analysis, paired Student t test for glomerular filtration rate analysis, and Fisher exact test for safety analysis.</p>	<p>The overall survival rate was significantly inferior in the radiofrequency ablation group in comparison with that of the radical nephrectomy group (48% versus 97% at 10 years respectively; 95% confidence interval: 12.4%, 76.7% versus 78.2%, 99.5%; P < 0.009. The renal cell carcinoma-related survival rate (94% [95% CI: 62.6%, 99.1%] with radiofrequency ablation versus 100% with radical nephrectomy at 10 years), P=0.99) were comparable between the two groups. No treatment-related deaths did occur.</p> <p>Even though the major complication rates were noted to be similar between the two patient groups (8.0% [two of 25 patients] versus 5.1% [two of 39 patients], P=0.61), the percentage decrease in the glomerular rate was significantly lower in the radiofrequency ablation group than the radical nephrectomy group at the last follow-up (12.5% ± 23.4 versus 32.3% ± 20.8 respectively; P < 0.003)</p>
<p>Atwell et al.</p>	<p>A retrospective study of 385 patients who had 445 tumours that measured 3.0 cm or smaller who had undergone thermal ablation from 2000 through 2010. Two hundred and fifty-six tumours in 222 patients had been treated by means of radiofrequency ablation. The mean size of the tumours was 1.9 ±0.5 cm [± standard deviation]. One hundred and eighty-nine tumours in 163 patients had been treated by means of cryoablation of which the mean tumour size was 2.3 cm ±0.5 cm.</p>	<p>Five technical failures were encountered (1.1%) which included one (0.4%) of the tumours that had been treated by radiofrequency ablation and four (2.1%) of the tumours that had been treated by cryoablation (p=0.17).</p> <p>With regards to the 218 tumours that had been treated by means of radiofrequency ablation who had a follow-up longer than 3 months, seven (3.2%) did develop local tumour recurrence, at a follow-up time that ranged between 1.2 years and 4.1 years with mean follow-up time of 2.8 years pursuant to undergoing treatment.</p> <p>With regards to the 145 tumours that had been treated by cryoablation and followed up longer than 3 months, four (2.8%) did develop local tumour recurrence during a follow-up that ranged between 0.3 years and 1.6 years with a mean follow-up of 0.9 years.</p> <p>With regards to biopsy proven renal cell carcinoma, the estimated local recurrence-free survival rates at 1 year, 3 years, and 5 years following radiofrequency ablation were 100%, 98.1%, and 98.1% respectively in comparison with 97.3%, 90.6%, and 90.6% respectively following cryoablation (p=0.09).</p> <p>Ten major complications occurred out of the 232 (4.3%) of the radiofrequency ablation procedures and in 8 out of the 176 (4.5%) of cryoablation procedures (p=0.91)</p>

Anderson et al.	<p>A comparison of the short-term radiological and clinical outcomes of RFA performed under combined ultrasound scan- and computed tomography scan-guidance with that of a previously undertaken ultrasound-guidance for renal tumours within their institution. From November 2009 to November 2013, 60 patients whose ages did range from 34 years to 86 years with a mean age of 70.1 years who had renal masses that were adjudged to have measurements within the ranges of 13 mm to 50 mm in maximum diameter and a mean maximum diameter of 25.4 ± 6.8 mm did undergo percutaneous radiofrequency ablation under the combined guidance of ultrasound scan and computed tomography scan. Anderson et al. [51] compared the technical success rate, the recurrence-free survival rate, the rate of complications, and the percentage change in the estimated glomerular filtration rate with that of a previously published series of 41 patients with small renal cell carcinomas that had been treated under ultrasound scan-guidance between November 2002 and December 2008.</p>	<p>The tumour and patient characteristics had been similar between the two tumour treatment groups.</p> <p>The primary and secondary technical success rate was found to be significantly higher in relation to the group that was treated with combined ultrasound scan / computed tomography guidance when compared with the group of patients that had been treated under the guidance of ultrasound scan alone (100% and 100% versus 82% and 91% respectively).</p> <p>The local recurrence-free survival rate was significantly better in the combined ultrasound scan / computed tomography – guided group in comparison with the ultrasound scan-guided group ($P=0.016$).</p> <p>No significant difference was found in the rate of overall complications (13% versus 17%) or in the mean percentage reduction in the estimated glomerular filtration rate following the respective treatment options ($1.1 \pm 18.3\%$ versus $5.0 \pm 11.7\%$).</p>
Xu et al.	<p>A retrospective review of five patients who had renal cell carcinoma in autosomal dominant polycystic kidney disease (ADPKD) from January 2009 to December 2014 with a median follow-up of 33 months. The tumours had been ablated with the use of Cool-tip RFA system under the guidance of CEUS. During the follow-up of each patient contrast computed tomography scan /magnetic resonance imaging scans as well as renal function tests were undertaken.</p>	<p>The diameter of the treated kidney tumours did range between 1.7 cm and 5.2 cm and the mean diameter of the tumours was 3.1 cm.</p> <p>The success rate of the initial ablation was 4 out of five (80%).</p> <p>Contrast enhanced computed tomography / magnetic resonance imaging scan undertaken after six months pursuant to the ablation procedure revealed that none of the patients developed any local recurrence.</p> <p>None of the patients required dialysis during the peri-procedural period.</p> <p>Two patients did develop minor complications.</p> <p>No significant difference was found with regards to the estimated glomerular functions of the patients between the pre-radiofrequency ablation period and the post-radiofrequency ablation period.</p>
Breen et al.	<p>Radiofrequency ablation was performed on 105 kidney tumours in 97 patients with a mean tumour size was 32 mm and the tumour size had ranged between 11 mm and 68 mm. The ages of the patients did range between 36 years and 89 years and the mean age was 71.7 years. The radiofrequency was undertaken under ultrasound guidance in on 43 occasions and under CT scan guidance on 62 occasions. Follow-up radiological imaging was undertaken by means of contrast-enhanced CT scan within 10 days pursuant to the ablation and at 6 monthly intervals thereafter. Multivariate analysis was undertaken to determine variables related to the procedural outcomes.</p>	<p>Eighty-three tumours (79%) had been completely treated at one sitting. Twelve of the remaining tumours had been successfully re-treated by means of further ablation as well as a clinical decision had been taken not to re-treat 7 patients. One patient who had a small residual crescent of tumour had been undergoing follow-up assessment and could be considered for further treatment. With regards to another patient, re-treatment had been abandoned because of the development of a complicating pneumothorax and difficulty in obtaining access. One patient had been waiting for further re-treatment ablation. The overall technical success rate had been 90.5%.</p> <p>Multivariate analysis demonstrated that the size of the tumour was the only significant variable that had affected the outcome of the procedure ($P=0.007$, Pearson χ^2)</p> <p>Five patients did develop complications.</p> <p>No local tumour recurrence developed on follow-up.</p>
Thompson et al.	<p>This was a study of 1,424 patients who had cT1a kidney tumours. 1057 patients had undergone partial nephrectomy, 180 patients did undergo radiofrequency ablation, and 187 patients did undergo cryoablation.</p>	<p>Within the cohort, local recurrence-free survival was found to be similar within the 3 treatment groups ($P=0.49$); nevertheless, metastases-free survival was significantly better following partial nephrectomy ($P=0.005$) and cryoablation ($P=0.021$) in comparison with radiofrequency ablation. Thompson et al. [56] additionally reported 379 patients who had cT1b kidney tumours and of these patients, 326 patients had undergone partial nephrectomy, 53 patients had undergone cryoablation. There were also 8 patients who had cT1b tumours who had undergone radiofrequency ablation of tumours but they had been excluded from the second study. Within this second cohort of patients, local recurrence-free survival ($P=0.81$) and metastases-free survival ($p=0.45$) had been adjudged to be similar between the partial nephrectomy and the cryoablation groups of patients. Within both the cT1a and the cT1b groups of patients, partial nephrectomy patients had been significantly younger, had lower Charlson scores and had superior overall survival ($P<0.001$ for all). The limitations of the study were stated to be the retrospective nature of the study and the selection bias.</p>

<p>Best et al.</p>	<p>159 kidney tumours had been treated by radiofrequency ablation. The patients had been evaluated with contrast-enhanced radiological imaging pre-operatively, and at 6 weeks, 6 months, and at least yearly thereafter.</p>	<p>The size of the tumour had ranged between 0.9 cm and 5.4 cm and the median size was 2.4 cm.</p> <p>The follow-up had ranged between 1.5 months and 120 months and the median follow-up was 54 months.</p> <p>Renal cell carcinoma had been confirmed in 72% out of the 150 tumours that had pre-ablation renal biopsy which amounted to 94% of all the patients.</p> <p>The 3- and 5- year disease-free survival had been comparable at 92% and 91% overall, and had been dependent upon the size of tumour, being 96% and 95% for tumours that were smaller than 3.0 cm, and 79% and 79% respectively, for tumours that had measured 3 cm or larger than 3.0 cm (P 0.001). Majority of failures (14 out of 18) had been local, either incomplete ablation or local recurrences.</p> <p>The study had been based upon an intent to treat analysis, hence, the study had included patients who were ultimately found to have benign tumours, even though the outcome had been comparable in patients who had carcinoma.</p>
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Gervais et al. [34] reported their experience with radiofrequency ablation of renal cell carcinoma undertaken in their institution over a 6-year period, in which 100 kidney tumours in 85 patients had been undertaken. They interpreted absence of enhancement on computed tomography or magnetic resonance imaging scan after radiofrequency ablation as complete coagulation necrosis. They analysed the results by tumour size and location using multi-variate analysis and they regarded a p value of 0.05 or less as significant. With regards to the results, they reported that all 52 small tumours that measured less than 3 cm and all 68 exophytic tumours did undergo complete necrosis irrespective of size even though many large tumours that measured more than 3 cm required a second ablation session. By using multi-variate analysis, they found that both small size (p<0.0001) and non-central location (p=0.0049) did prove to be independent predictors of complete necrosis following a single ablation treatment session. Location represented a significant predictor (p=0.015) of complete necrosis following any number of treatment sessions. The encountered complications were either self-limited or they were readily treated, and these did include haemorrhage (major haemorrhage 2, minor haemorrhage 3), inflammatory tract mas (1), transient lumbar plexus pain (2), ureteric injury (2), and skin burns (1). Gervais et al. [34] made the following conclusions:

- Radiofrequency ablation is a promising minimally invasive therapy for renal cell carcinoma in patients who have been adjudged not good candidates for surgery.
- Small tumour size and non-central location of the tumour were favourable tumour characteristics, even though large tumours could sometimes successfully be treated with multiple ablative sessions.

Watkins and Parkinson. [35] in 2007 reported their retrospective review of radiofrequency ablation of kidney tumours that had been undertaken in their establishment between January 2004 and June 2006. Watkins et al. [35] reported that thirteen radiofrequency ablation treatment procedures had been undertaken in their institution for 11 tumours in 11 patients. With regards to the results the authors made the following summations:

- The ages of the patients did range from 61 years to 88 years and the mean age was 74.4 years.
- Radiological imaging was undertaken following the radiofrequency ablation with a follow-up that ranged between 2 months and 26 months and the mean follow-up time was 8 months.
- There was no evidence of residual tumour pursuant to the first radiofrequency ablation therapy in 82% of cases in that nine out of the 11 tumours were no longer seen.
- Two patients did undergo a second radiofrequency ablation treatment and of these, one patient had the second radiofrequency ablation treatment for residual tumour and the second patient had the second radiofrequency ablation treatment for recurrent tumour.

Watkins and Parkinson [35] made the ensuing conclusions:

- Radiofrequency ablation represents an emerging useful treatment option for small kidney tumours.
- Some short-term studies have reflected the usefulness of radiofrequency ablation for small kidney tumours; nevertheless, long-term findings following radiofrequency ablation of kidney tumours are still not available.

Carrafiello et al. [36] evaluated the feasibility of undertaking radiofrequency ablation of kidney tumours in a day hospital setting. They reported that between January 2003 and August 2008 26 patients whose ages had ranged between 70 years and 87 years with a mean age of 79 years had undergone radiofrequency ablation for renal tumours. Of the 26 patients 15 were male and 11 were female who were affected by 27 renal tumour lesions; 25 of the lesions were renal cell carcinoma and 2 were oncocytoma of the kidney and one patient was affected by two renal cell carcinomas; the cohort of patients did undergo 29 radiofrequency ablation treatments in which 3 patients did undergo two treatments as a result of residual tumour found following performance of computed tomography scan of abdomen one month after first radiofrequency ablation treatment. The authors summarized pertinent features of the patients and tumour characteristics as follows:

- Three of the 26 patients did have a single kidney related to progressed nephrectomy due to renal cell carcinoma.
- Three out of 26 patients had been documented as carriers of oncological co-morbidity and four patients out of the 26 patients had been noted to have medical co-morbidity. 16 out of the 26 patients did not agree to undergo the option of surgical operation of nephrectomy.
- The dimensions of the diameter of the lesions averaged 2.4 cm but these did range between 1 cm and 4 cm.
- Seventeen out of the 27 tumours were adjudged to be exophytic; 5 of the 27 tumours were parenchymal lesions; 3 of the 27 lesions were centrally located; 2 out of the 27 lesions were adjudged to be mixed.
- All the lesions had been characterized by means of computed tomography or magnetic resonance imaging scanning.
- Twenty-one lesions out of the 27 lesions had been ablated under the guidance of ultrasound scan and six out of the 27 lesions were ablated under the guidance of computed tomography scan.
- Upon completion of the ablation treatment of each patient ultrasound scanning was undertaken to confirm there were no early complications of the procedure prior to discharging the patients from the day hospital.

Carrafiello et al. [36] summarized their results as follows:

- They had obtained technical success in all the patients.
- 18 patients who did not have any complications and who did not have any co-morbidity were discharged on the day of the procedure. Seven patients who did have co-morbidity were kept overnight and

discharged the next day. One patient out of the 27 patients did require hospitalization.

- Based upon the results of computed tomography scan or magnetic resonance imaging scan performed one month after the ablation procedures, it was confirmed that primary success had been achieved in 25 out of the 27 cases with no residual tumour and in two out of the 27 lesions an incomplete ablation was confirmed and in view of this the two patients did undergo a second ablation. At six months of follow-up there was no radiological imaging evidence of any more tumour or lesion. And during the subsequent follow-up none of the patients any sign of disease. No major complications were noted but one patient needed assistance due to the appearance of a peri-renal urinoma and a very small pneumothorax which did resolve after a few days following the ablation procedure.

Carrafiello et al. [36] made the ensuing conclusions:

- In their study they had demonstrated the feasibility of radiofrequency ablation treatment in a day-hospital for selected patients.
- The preliminary results of radiofrequency ablation of renal cell carcinoma would appear to be promising and this form of treatment could prove to be a useful therapeutic option for patients who are considered unsuitable for surgery.

Mylona et al. [37] reported that between October 2000 and June 2005, 18 patients who had solitary kidney and renal cell carcinoma had undergone per-cutaneous CT-guided radiofrequency ablation within their establishment. They stated that the diameters of the tumours had ranged between 1 cm to 7 cm and there was no radiological imaging evidence of spread of tumour the kidney. They utilized a radiofrequency ablation-system that had expandable needle electrode with 7 or 9 arrays. The patients did have a follow-up that ranged between 12 months and 72 months and their mean follow-up was 31.2 months and during their follow-up they did undergo clinical and laboratory evaluation. With regards to the results Mylona et al. [37] reported the following:

- In all cases the radiofrequency ablation electrode had been successfully placed within the lesion.
- The 18 tumours had been totally treated with 24 radiofrequency ablation sessions.
- With regards to small 1 cm to 3 cm exophytic tumours technical success was achieved in 85.7% of the tumours and residual tumour was totally seen in 6 out of 18 tumours that required a second radiofrequency ablation treatment. The recurrence rate was 11.1%; however, no recurrence was found with regards to tumours that were less than 3 cm in diameter. No major complications were encountered.
- The serum creatinine levels of the patients were normal in 17 out of the 18 patients up to the 3rd month follow-up.
- The survival of the patients had ranged between 12 months and 72 months.

Mylona et al. [37] made the following conclusions:

- Radiofrequency ablation does constitute an alternative treatment option for patients who have small renal cell carcinomas in a solitary kidney and who are not ideal candidates for surgical resection of their tumours because their renal function need to be preserved.
- These patients would have an immediate solution to their clinical problem, through the utilization of a minimally invasive therapy that is not associated with any serious complications.

Zagoria et al. [38] reported a total of 48 renal cell carcinomas in 41 patients which had been treated by means of radiofrequency ablation. They reported that the sizes of the tumours had ranged between 0.7 cm and 8.2 cm and the median size of the tumours was 2.6 cm. Out of the 48 renal cell carcinomas that had been treated, 5 constituting 12% of cases did develop recurrent following a single ablation session. The median size of the index lesion in the cases that developed recurrence was 5.2 cm and this had ranged between 4 cm and 5.3 cm in comparison with 2.2 cm median size of tumours that did not have local recurrence of which the sizes had ranged between 1.7 cm and 3.1 cm (P=0.0014). The authors also reported that no recurrences were developed in renal carcinomas that

measured less than 4 cm that had been treated. Seventeen patients that amounted to 41% of patients who had had treatment for 18 renal cell carcinomas died during their follow-up period at a median time of 34 months in which the follow-up had ranged between 10 months and 47 months. One patient who amounted to 2% of cases died due to metastatic renal cell carcinoma, and on the contrary, 16 patients had died of causes not related to their renal cell carcinoma. Twenty-four patients who had 30 renal cell carcinomas that had been treated by means of radiofrequency ablation had survived. With regards to the remaining renal cell carcinomas whose follow-ups had ranged between 54 months and 68 months and a median follow-up of 61 months, no patient within this group of survivors had developed metastatic renal cell carcinoma, 1 patient did develop recurrence which was diagnosed at 68 months following the ablation treatment. The long-term recurrence-free survival following radiofrequency ablation was computed to be 88%. Zagoria et al. [38] made the following conclusions:

- Radiofrequency ablation could result in durable oncological control for renal cell carcinomas that measure less than 4 cm.
- Radiofrequency ablation constitutes an effective treatment option for patients with renal cell carcinomas that measure less than 4 cm who are poor candidates to undergo surgical nephrectomy operation.
- With regards to patients who have renal cell carcinomas larger than 4 cm alternative forms of treatment rather than radiofrequency ablation should be considered.

Olweny et al. [39] reported on comparative 5-year oncologic outcomes for radiofrequency ablation versus partial nephrectomy in patients who had clinical T1a renal cell carcinoma. Olweny et al. [39] reported that that a total of 37 patients in each group met the selection criteria. The radiofrequency ablation cohort of patients was significantly older than the partial nephrectomy group and they did have more advanced comorbidities; however, other patient characteristics had been similar. With regards to radiofrequency ablation versus partial nephrectomy, the follow-up had ranged between 5.8 years and 7.1 years and the median follow-up was 6.5 years versus a follow-up range of 5.4 years to 7.3 years and a median follow-up of 6.1 years (P=0.68) respectively. The 5-year overall survival was 97.2% versus 100% (P=0.31), Cancer specific survival was 97.2% versus 100% (P=0.31). The disease-free survival was 89.2% versus 89.2% (P=0.78), the local recurrence free rate was 91.7% versus 94.6% (P=0.96), and metastatic free survival was 97.2% versus 91.8% (P=0.35) respectively. With regards to limitations of the study, the authors stated that the limitations include analysis of retrospective data, loss to follow-up, limited statistical power, and limited generalizability of their data. Olweny et al. [39] concluded that in appropriately selected patients, radiofrequency ablation would constitute an effective minimally invasive treatment option for the treatment of cT1a renal cell carcinoma, that is associated with comparable long-term oncologic outcomes to nephron-sparing surgery.

Allen et al. [40] undertook a study to ascertain whether per-cutaneous radiofrequency ablation is effective and safe for the treatment of cystic renal neoplasms. They did undertake a retrospective review of imaging-guided radiofrequency ablation of Bosniak III and IV cysts from their institution. They reported that thirty-eight subjects which included 19 men and 19 women whose ages had ranged between 46 years and 95 years and whose mean age was 71 years that had undergone radiofrequency ablation 40 cystic renal neoplasms that had been classified as Bosniak III in 25 cases and Bosniak IV in 40. They also reported that percutaneous biopsy had been undertaken in 36 out of the 40 lesions which would amount to 90% of the lesions. With regards to patients who had radiological imaging follow-up at least 1 year that totalled 21, the duration of their surveillance had ranged between 1.6 years and 5 years and their mean surveillance period was 2.8 years. Allen et al. [40] reviewed the electronic records for complications related to the radiofrequency ablation. They measured the estimated glomerular filtration rate prior to the radiofrequency ablation and at the last follow-up consultation more than 6 months pursuant to the radiofrequency ablation procedure. With regards to the results, Allen et al. [40] made the ensuing summations:

- According to the results of histology examination of the percutaneous biopsies from the renal lesions, 22 out of 36 of the lesions which amounted to 61.1% of the cases were malignant and 14 of the 36 biopsies that amounted to 38.9% were adjudged to be inconclusive.
- No local tumour progression was subsequently found, and no individual subsequently developed metastatic disease.
- One individual did develop a new solid kidney mass during follow-up.
- Two patients out of the 38 patients that amounted to 5.3% of patients developed minor complications pursuant to the ablation procedure, one of them developed dysuria and the other developed mild hydronephrosis that was related to the development of a blood clot in the ureter.
- There was one major complication out of the 38 individuals which amounted to 2.6% of cases which was the development of pulmonary oedema.
- On average, the estimated glomerular filtration rate had decreased by 2.5 mL/min per 1.73 m².

Allen et al. [40] concluded that imaging-guided radiofrequency ablation is an effective and safe treatment option for Bosniak III and Bosniak IV cystic renal neoplasms which is associated with outcomes that are comparable to those of surgical therapies.

Nakasone et al. [41] undertook a retrospective study to evaluate the technical success, effectiveness, and complications that developed in patients with unresectable renal cell carcinoma pursuant to undergoing single-session sequential combination treatment that consisted of renal arterial embolization followed by radiofrequency ablation. Nakasone et al. [41] reported that ten patients who had 12 renal cell carcinomas who were adjudged not to be candidates for surgical operation were included in their pilot study. They reported that all the tumours had ranged in size between 18 mm and 66 mm and the mean tumour size was computed to be 31 ± 3.9 mm and all the tumours had been treated by means of percutaneous ablation several hours following the embolization of the vessels supplying the tumours with iodized oil and gelatine sponges. The authors evaluated the technical success, effectiveness, effect on renal function, and complications ensuring the treatment. Adjudication of the effectiveness of the treatment was made based upon computed tomography and/or magnetic resonance imaging scans that were obtained every three months after the radiofrequency ablation. The effect of the treatment upon renal function was assessed based upon the serum creatinine level and the glomerular filtration rate prior to, one week after the treatment procedure, and three months following the treatment procedure. Nakasone et al. [41] summarized their results as follows:

- Selective renal arterial embolization followed by percutaneous radiofrequency ablation was technically successful in all the patients.
- Based upon the results of contrast computed tomography scan or contrast magnetic resonance imaging scan that was obtained one week and 3 months after the radiofrequency ablation they had observed necrosis in the embolized segment of all the renal cell carcinomas.
- There no major complications recorded during and after the procedure.
- All patients did report tolerable pain and burning sensation during the process of radiofrequency ablation.
- Following the radiofrequency ablation procedure, five patients (50%) reported having back pain, and one patient each developed fluid collection, sub-capsular haematomas, haematuria, or nausea.
- During a mean-follow-up period of 47 ± 3.8 months there was no case of recurrence.
- They did not observe or record any significant difference in serum creatinine and glomerular filtration rate before and after treatment.

Nakasone et al. [41] made the following conclusions:

- Their pilot study had indicated that sequential combination treatment by renal arterial embolization followed by percutaneous radiofrequency ablation is feasible in patients with inoperable renal cell carcinoma.

- The treatment complications would be regarded as acceptable and excellent effects were obtained.

Gahan et al. [42] reported upon the radiofrequency ablation outcomes based upon renal cell carcinoma histological sub-types based upon analysis of data of procedures undertaken in two centres. The authors reported that a total of 229 patients had been included in the study analysis. Gahan et al. [42] summarized the results of their analysis as follows:

- A total of 229 patients had been included in the analysis.
- The mean age of the patient cohort was 64.5 ± 13.8 years who had a median follow-up of 48 months, but the follow-up had ranged between 12 months and 65 months.
- The mean size of the tumour cohort was 2.5 cm ± 0.8 cm.
- There was no difference between the papillary carcinoma and clear cell carcinoma sub-types of the renal cell carcinomas based upon their age distribution, the size of the tumour, or the months of their follow-up.
- A total of 181 (75.7%) of the tumours histologically diagnosed as clear cell carcinoma and 48 (20.1%) of the tumours were histologically diagnosed as papillary sub-type.
- There were 15 failures of treatment with ablation in the clear cell sub-type of renal cell carcinomas and 0 failure of treatment following ablation in the papillary sub-type which gave an estimated 5-year disease free survival of 89.7% and 100% for the clear cell renal cell carcinoma sub-type and papillary sub-type of renal cell carcinoma respectively (P=0.41).

Gahan et al. [42] made the following conclusions:

- Their report was the first report that had suggested there was a significant difference in success of radiofrequency ablation based upon the sub-type of renal cell carcinoma ablated and showing that papillary renal cell carcinoma is associated with a more favourable outcome in comparison with clear cell renal cell carcinoma.
- Their results would indicate that more studies would be required to look at how best the follow-up after radiofrequency ablation should be with regards to the sub-types of renal cell carcinomas.

Schneider et al. [43] reported 2 patients one age 62 years and the other 71 years who developed chyluria that were diagnosed incidentally in follow-up contrast enhanced computed tomography scans. Even though no untoward sequels occurred the two cases that were reported in men were documented to illustrate that chyluria could develop pursuant to radiofrequency ablation of renal tumours.

Wah et al. [44] prospectively evaluated their clinical experience with percutaneous image-guided (ultrasound scan or computed tomography scan) radiofrequency ablation 200 kidney tumours in 165 patients from June 2004 to 2012. They defined the response to treatment and technical success by absence of contrast-enhanced computed tomography or magnetic resonance imaging. They prospectively documented all the major and minor complications, the glomerular filtration rate prior to and pursuant to the radiofrequency ablation, the management and outcomes of the complications and oncological outcome of each patient. They utilized multi-variate analysis to ascertain variables that were associated with major complications as well as the glomerular filtration rate change pursuant to the radiofrequency ablation. They presented the results of the overall survival (OS), 5-year cancer specific survival (CSS), local recurrence-free survival (LRFS), and metastasis-free survival (MFS) with the utilization of the Kaplan-Meier curves. Wah et al. [44] summarized their results as follows:

- Overall, 200 tumours had been treated by means of radiofrequency ablation and the sizes of the tumours did range between 1 cm and 5.6 cm and the mean size of the tumours was 2.9 cm. The ages of the patients did range between 21 years and 88.6 years and the mean age of the patients was 67.7 years. The mean follow-up of the patients was 46.1 months.
- Their primary technical success and overall technical success rate amounted to 95.5% and 98.5% respectively. Logistic regression

analysis of their data did identify two independent predictors of successful radiofrequency ablation in a single sitting and these were (a) tumour size that was less than 3 cm, and (b) exophytic location of the tumour.

- The major complications that they encountered included injury to the ureter in six patients, development of calyceal-cutaneous fistula in one patient, and the development of abscess in two patients. Two independent predictors of injury to the ureter included (a) central location of the tumour, and (b) lower pole position of the tumour.
- Within their cohort 165 patients undergoing radiofrequency ablation of 200 tumours only four patients did develop significant deterioration in renal function that amounted to greater than 25% decrease in glomerular filtration rate. Overall, 161 patients who amounted to 98% of the 165 patients had preservation of their renal function. Any change in renal function pursuant to radiofrequency ablation was not influenced by tumour factors or by solitary status of kidney.
- Within their series of 200 radiofrequency ablation of renal tumours in 165 patient's statistical analysis of their data had determined that the 5-year overall survival, cancer specific survival, local recurrence free survival, and metastasis-free survival, rates were correspondingly 75.8%, 97.9%, 93.5%, and 87.7%.

Wah et al. [44] concluded that Radiological image-guided radiofrequency ablation is a safe, nephron sparing and effective treatment option for small renal cell carcinoma (RCC) lesions which is associated with a low rate of tumour recurrence and it has a good 5-year cancer specific and metastasis-free survival rates.

Lee et al. [45] reported their experience with the treatment of forty kidney lesions in 37 patients that included 27 males and 10 females whose mean age was 70 ± 13 years who had been treated by means of computed tomography scan-guided radiofrequency ablation from 2006 and 2013. Their statistical analysis included the following parameters: the entire ablated cohort with particular-attention paid to sub-groupings based upon (a) whether the patients' renal masses did measure less than 3 cm or equal to/greater than 3 cm, (b) whether the tumour was histologically examined biopsy proven renal cell carcinoma. To evaluate changes in the lesion pursuant to the radiofrequency ablation, a mixed-effects ANOVA model was fitted to the lesion size values over time. With regards to the results, Lee et al. [45] reported that Kaplan-Meier survival curves did show trends toward worse primary recurrence and overall survival in lesions ≥ 3 cm, but there were not statistically significant ($P=13$ and $P=27$ respectively). The results did show that secondary recurrences had been the same in both groups and the rate of change with time in the size of the lesion pursuant to radiofrequency ablation did not significantly differ either by the initial size of the lesion ($P=65$), or between histologically biopsy examination proven diagnosis of renal cell carcinoma and non-biopsy proven renal cell carcinoma ($P=46$). Lee et al. [45] made the ensuing conclusions:

- Radiofrequency ablation is safe and effective option for the treatment of renal tumours.
- The overall success of ablation of tumour was not related to the initial size of the tumour.
- Serial changes in the size of the tumour pursuant to radiofrequency ablation are similar irrespective of the original size of the tumour and whether the lesion had been proven to be renal cell carcinoma by histological examination of biopsy specimen the lesion.

Cadeddu et al. [46] conducted two retrospective studies; one study did look at 47 benign small kidney tumours that measured less than 3.5 cm that were incidentally discovered incidentally in 41 patients in which the tumours were adjudged to be benign based upon histology examination of biopsy of each tumour. The second study was focussed upon 159 kidney tumours majority of which were renal cell carcinoma in 142 patients who did undergo radiofrequency ablation of the tumours as primary treatment. With regards of the study of small benign renal tumours only one treatment session was required. Pursuant to a mean follow-up of 45 months none of the patients developed a recurrence, which they had defined as tumour growth and contrast enhancement on follow-up axial imaging. The investigators did report their results on line ahead of print in Urology and they also reported that the median pre- and post- radiofrequency

ablation glomerular filtration rate of the patients was 77 and 68 mL/min 1.73 m^2 respectively. Cadeddu et al. [46] made the ensuing iterations and conclusion:

- Their study was limited by the fact it was a retrospective designed study and the was a small sample study.
- Long-term follow-up radiological imaging might not be necessary provided successful ablation of the kidney tumour is determined during the initial post-ablation cross-sectional imaging study. Thus, patient radiation exposure and cost of follow-up could be reduced.
- Even though intermediate and long-term publish data has supported the efficacy of radiofrequency ablation with regards to the treatment of renal cell carcinoma, little or no data has existed that have clearly illustrated the efficacy of radiofrequency ablation in ablating incidentally found benign renal tumours. Furthermore, unlike the frequent follow-up radiological imaging that is required in relation to treated malignant tumours, the most-appropriate-follow-up radiological imaging of these biopsy confirmed benign tumours was not known.

Psutka et al. [47] assessed the oncologic effectiveness of radiofrequency ablation for the treatment of biopsy proven renal cell carcinoma. Psutka et al. [47] retrospectively reviewed the long-term oncologic outcomes for 185 patients who had sporadic T1 renal cell carcinoma and the median follow-up of the patients was 6.43 years and the interquartile range of follow-up ranged between 5.3 years and 7.7 years. The exclusion criteria in the study included exclusion of patients who had had previous renal cell carcinoma, metastatic renal cell carcinoma, or T2 renal cell carcinoma. They utilized the chi-square and Wilcoxon rank-sum tests to compare proportions and medians, respectively. They did calculate the disease-specific survival and overall survival by utilization of Kaplan-Meier analysis, then stratified by tumour stage, and they made comparisons by using log-rank analysis. The 5-year disease-free survival and the overall survival rates were recorded. They considered a p value <0.05 statistically significant. Psutka et al. [47] summarized their results and limitations of the study as follows:

- The median size of the tumours was 3 cm but the size did range between 2.1 cm and 3.9 cm.
- The stages of the tumours were recorded as T1a: 143 (77.3%) of cases or T1b: 42 which constituted 22.7% of cases.
- Twenty-four patients that constituted 13% of cases required re-treatment as a result of residual disease.
- Twelve local recurrences which amounted to 6.5% of cases were documented; 6 recurrences in the T1a disease that amounted to 4.2% and 6 recurrences in T1b disease amounting to 14.3% of cases ($P=0.0196$).
- The median time to observation of recurrence was 2.5 years.
- Local salvage radiofrequency ablation was undertaken in six patients and of these five patients remained disease free at 3.8-year median follow-up.
- Multi-variate analysis demonstrated that tumour stage was the sole significant predictor of disease free survival. During the last follow-up 164 patients that amounted to 88.6% of patients were disease free (T1a: 132 patients which amounted to 92.3% of T1a cases; T1b 32 patients amounting to 76.2% of T1b patients; $p=0.0038$). The overall survival was similar irrespective of tumour stage ($P=0.06$). Five patients did develop metachronous kidney tumours which amounted to 2.7% of cases. Four patients did develop extra-renal metastases which amounted to 2.2% of cases, and three of these patients died of metastatic renal cell carcinoma which amounted to 1.6% of cases.

Conclusions and learning points iterated by Psutka et al. [47] include:

- In poor surgical candidates, radiofrequency ablation of renal cancer does result in durable local control and low-risk of recurrence in T1a renal cell carcinoma.
- Higher stage renal cell carcinoma would correlate with an inferior disease-free survival

- Long-term surveillance is necessitated pursuant to radiofrequency ablation
- Patient selection based upon the characteristics of the tumour, comorbid disease, and life expectancy of the patient would be of paramount importance with regards to the treatment of modality of choice.
- Radiofrequency ablation of biopsy proven T1a renal cell carcinoma could provide durable oncologic control of the tumour. Local recurrences in these patients tend to be rare, and with regards to those who recur locally, majority of these local recurrences may be successfully managed by utilization of salvage radiofrequency ablation.

Takaki et al. [48] prospectively evaluated the safety and effectiveness of radiofrequency ablation with the use of a multiple-electrode switching system for the treatment of renal cell carcinoma. Takaki et al. [48] reported that between November 2009 and December 2010, 33 patients whose ages had ranged between 44 years and 86 years and whose mean age was 70.7 years that had histological diagnosis proven renal cell carcinoma were enrolled in their phase II study. The cohort of the patients included 24 men whose ages had ranged between 44 years and 86 years with a mean age of 69.5 years; and nine women whose ages had ranged between 64 years and 83 years with a mean age of 74.1 years. Takaki et al. [48] reported that the mean maximum diameter of the tumours had ranged between 1.5 cm and 5.0 cm and the mean maximum diameter of the tumours was 2.9 cm \pm 1.0 standard deviation. They did evaluate the primary endpoint with the common Terminology Criteria for Adverse Events. Secondary endpoints of the study included changes in kidney function, the effectiveness of the technique, local tumour progression, and survival of the patients. Mann-Whitney U test was utilized to evaluate the kidney function. With regards to the results, Takaki et al. [48] reported the following:

- There were no severe adverse effects; however, three out of 33 patients that amounted to 9% of patients did develop grade 2 adverse events.
- Even though the mean glomerular filtration rate at 1- year follow-up after radiofrequency ablation was similar, to the baseline pre-radiofrequency ablation value in 26 patients who had bilateral kidneys (P=0.14), the mean glomerular filtration rate was noted to be significantly reduced in six patients who had a solitary kidney (P=0.03).
- Tumour contrast-enhancement did disappear following a single radiofrequency treatment session in 31 patients and following two radiofrequency ablation treatment sessions in the other two patients which did yield rates of primary and secondary technical effectiveness of 94% in 31 out of 33 cases and 100% in 33 out of 33 cases respectively.
- No local tumour progression was identified during the mean follow-up of 20.0 months and a follow-up that ranged had ranged between 11.6 months and 27.6 months.
- The computed respective 1-year, overall-, and renal cell carcinoma related survival rates were documented as 97% at 95% confidence level; 91% at 100% confidence level; and 100%.

Takaki et al. [48] made the following conclusions:

- Radiofrequency ablation with a multiple-electrode switching system is a safe and effective treatment option for renal cell carcinomas. Nevertheless, further study is warranted to ascertain whether this technology is superior to other previously described methods.

Takaki et al. [49] compared the clinical outcomes of radiofrequency ablation with those following radical nephrectomy in patients who had T1b renal cell carcinoma in a retrospective study. They reported that between June 2002 and March 2012, 60 patients whose ages had ranged between 39 years and 86 years and a mean age of 65.2 years and who had a single renal cell carcinoma that measured 4.1 cm to 7.0 cm that were staged as having T I b tumours. They reported that 21 of these patients had undergone radiofrequency ablation and 39 patients had undergone radical nephrectomy. Eight of the patients did undergo selective renal artery

embolization prior to undergoing radiofrequency ablation of their tumours. Takaki et al. [49] compared the overall renal cell carcinoma-related, and disease-free survival rates, the percentage decrease in the glomerular filtration rate, and safety by utilizing the log-rank for survival analysis, paired Student t test for glomerular filtration rate analysis, and Fisher exact test for safety analysis. Takaki et al. [49] summarized their results as follows:

- The overall survival rate was significantly inferior in the radiofrequency ablation group in comparison with that of the radical nephrectomy group (48% vs 97% at 10 years respectively; 95% confidence interval: 12.4%, 76.7% versus 78.2%, 99.5%; P<0.009. The renal cell carcinoma-related survival rate (94% [95% CI: 62.6%, 99.1%] with radiofrequency ablation versus 100% with radical nephrectomy at 10 years), P=0.99) were comparable between the two groups. No treatment-related deaths did occur.
- Even though the major complication rates were noted to be similar between the two patient groups (8.0% [two of 25 patients] versus 5.1% [two of 39 patients], P=0.61), the percentage decrease in the glomerular rate was significantly lower in the radiofrequency ablation group than the radical nephrectomy group at the last follow-up (12.5% \pm 23.4 versus 32.3% \pm 20.8 respectively; P<0.003).

Takaki et al. [49] concluded that radiofrequency ablation constitutes a safe procedure for patients who \pm ablation does provide comparable renal cell carcinoma-related and disease-free survival and preserves renal function.

Atwell et al. [50] undertook a retrospective study of 385 patients who had 445 tumours that measured 3.0 cm or smaller who had undergone thermal ablation from 2000 through 2010. Two hundred and fifty-six tumours in 222 patients had been treated by means of radiofrequency ablation. The mean size of the tumours was 1.9 \pm 0.5 cm [\pm standard deviation]. One hundred and eighty-nine tumours in 163 patients had been treated by means of cryoablation of which the mean tumour size was 2.3 cm \pm 0.5 cm. With regards to the results, Atwell et al. [50] reported the following:

- Five technical failures were encountered (1.1%) which included one (0.4%) of the tumours that had been treated by radiofrequency ablation and four (2.1%) of the tumours that had been treated by cryoablation (p=0.17).
- With regards to the 218 tumours that had been treated by means of radiofrequency ablation who had a follow-up longer than 3 months, seven (3.2%) did develop local tumour recurrence, at a follow-up time that ranged between 1.2 years and 4.1 years with mean follow-up time of 2.8 years pursuant to undergoing treatment.
- With regards to the 145 tumours that had been treated by cryoablation and followed up longer than 3 months, four (2.8%) did develop local tumour recurrence during a follow-up that ranged between 0.3 years and 1.6 years with a mean follow-up of 0.9 years.
- With regards to biopsy proven renal cell carcinoma, the estimated local recurrence-free survival rates at 1 year, 3 years, and 5 years following radiofrequency ablation were 100%, 98.1%, and 98.1% respectively in comparison with 97.3%, 90.6%, and 90.6% respectively following cryoablation (p=0.09).
- Ten major complications occurred out of the 232 (4.3%) of the radiofrequency ablation procedures and in 8 out of the 176 (4.5%) of cryoablation procedures (p=0.91).

Atwell et al. [50] made the following conclusions:

- Radiofrequency ablation and cryoablation are both effective form of treatment in the management of renal masses that measure 3 cm or less than 3 cm.
- Major complications emanating from either of the procedures are not frequent.

Anderson et al. [51] retrospectively compared the short-term radiological and clinical outcomes of radiofrequency ablation performed under combined ultrasound scan- and computed tomography scan-guidance with that of a previously undertaken ultrasound-guidance for renal tumours within their institution. Anderson et al. [51] reported that from November 2009 to November 2013, 60 patients whose ages did range from 34 years

to 86 years with a mean age of 70.1 years who had renal masses that were adjudged to have measurements within the ranges of 13 mm to 50 mm in maximum diameter and a mean maximum diameter of 25.4 ± 6.8 mm did undergo percutaneous radiofrequency ablation under the combined guidance of ultrasound scan and computed tomography scan. Anderson et al. [51] compared the technical success rate, the recurrence-free survival rate, the rate of complications, and the percentage change in the estimated glomerular filtration rate with that of a previously published series of 41 patients with small renal cell carcinomas that had been treated under ultrasound scan-guidance between November 2002 and December 2008. With regards to the results, Anderson et al. [51] made the following summations:

- The tumour and patient characteristics had been similar between the two tumour treatment groups.
- The primary and secondary technical success rate was found to be significantly higher in relation to the group that was treated with combined ultrasound scan/computed tomography guidance when compared with the group of patients that had been treated under the guidance of ultrasound scan alone (100% and 100% versus 82% and 91% respectively).
- The local recurrence-free survival rate was significantly better in the combined ultrasound scan/computed tomography-guided group in comparison with the ultrasound scan-guided group ($P=0.016$).
- No significant difference was found in the rate of overall complications (13% vs 17%) or in the mean percentage reduction in the estimated glomerular filtration rate following the respective treatment options ($1.1 \pm 18.3\%$ versus $5.0 \pm 11.7\%$).

Anderson et al. [51] concluded that the utilization of combined ultrasound scan/computed tomography guidance when performing radiofrequency ablation of kidney tumours did result in superior primary and short-term outcome in comparison with the use of ultrasound scan guidance alone in patients that were treated in the same institution.

Xu et al. [52] undertook a study to assess the functional and oncologic outcomes of percutaneous radiofrequency ablation with contrast-enhanced ultrasonography (CEUS) for renal cell carcinoma in patients who autosomal dominant polycystic kidney. Xu et al. [52] undertook a retrospective review of five patients who had renal cell carcinoma in autosomal dominant polycystic kidney disease (ADPKD) from January 2009 to December 2014 with a median follow-up of 33 months. Xu et al. [52] reported that the tumours had been ablated with the use of Cool-tip radiofrequency ablation system under the guidance of CEUS. During the follow-up of each patient contrast computed tomography scan /magnetic resonance imaging scans as well as renal function tests were undertaken. Xu et al. [52] summarized their results as follows:

- The diameter of the treated kidney tumours did range between 1.7 cm and 5.2 cm and the mean diameter of the tumours was 3.1 cm.
- The success rate of the initial ablation was 4 out of five (80%).
- Contrast enhanced computed tomography/magnetic resonance imaging scan undertaken after six months pursuant to the ablation procedure revealed that none of the patients developed any local recurrence.
- None of the patients required dialysis during the peri-procedural period.
- Two patients did develop minor complications.
- No significant difference was found with regards to the estimated glomerular functions of the patients between the pre-radiofrequency ablation period and the post-radiofrequency ablation period.

Xu et al. [52] made the following conclusions:

- Their initial experience of this technique for renal cell carcinoma in ADPKD was favourable ADPKD.
- Radiofrequency ablation could be a good choice for renal cell carcinoma in ADPKD.

Salient points related to radiofrequency ablation of renal lesions ascertained have been summarized as follows [53]:

- Radiofrequency has been shown publications to be a safe and very effective therapeutic option for small kidney masses that measure less than 3 cm to 4 cm and many studies had illustrated the efficacy of radiofrequency ablation in more than 95% of cases treated [34,42,50,54,55].
- Psudka and associates [47] in their study that comprised of 143 individuals that had a follow-up of more than 6 years, reported a recurrence-free survival of 96% with regards to patients who had undergone radiofrequency ablation for T1a kidney tumours. They also reported that with regards to patients who subsequently developed recurrent tumours locally, half of them did undergo retreatment by means of radiofrequency ablation and this resulted in 5 of the 6 cases that had undergone re-treatment by means of radiofrequency ablation having long-term control of their disease.
- Similar recurrence-free survival between radiofrequency ablation treated cases and partial nephrectomy (91.7% following radiofrequency ablation versus 94.6% following partial nephrectomy) has been reported [39], and cancer specific survival has also been illustrated to be similar between patients that were treated by means of radiofrequency ablation and partial nephrectomy (97.2% following radiofrequency ablation versus 100% following partial nephrectomy) [39]. It has been re-enforced that both radiofrequency ablation and partial nephrectomy are both effective with regards to the management of small kidney tumours [50].
- With regards to kidney tumours that measure more than 3 cm up to 4 cm, mixed outcomes have been obtained and furthermore, local progression as well as incomplete treatment rates greater than 20% have been reported pursuant to radiofrequency ablation of bigger kidney tumours [39], [47,57]. However, it has been shown that some of the incompletely treated lesions can be re-treated successfully by means of radiofrequency ablation. However, it is important to note of the fact that Best and associates [57] had iterated that radiofrequency ablation of kidney tumours that measure more than 3 cm could lead to long-term disease control in not more than 80% of individuals treated [57].
- Some authors [34,44], had suggested that additional to considerations related to the size of the tumours, tumours that are centrally located in the kidney should be treated by means of an alternative radiofrequency ablation technique in view of the heat sink as well as risk of damage to the urothelium.
- Major complications ensuing radiofrequency ablation radiofrequency ablations of kidney tumours have tended to be low (between 5% and 6%) and these major complications have tended to be less than pursuant to cryoablation, partial nephrectomy, and radical nephrectomy [50,58].

Breen et al. [55] reported radiofrequency ablation which was performed on 105 kidney tumours in 97 patients with a mean tumour size was 32 mm and the tumour size had ranged between 11 mm and 68 mm. The ages of the patients did range between 36 years and 89 years and the mean age was 71.7 years. The radiofrequency was undertaken under ultrasound guidance in on 43 occasions and under CT scan guidance on 62 occasions. Follow-up radiological imaging was undertaken by means of contrast-enhanced CT scan within 10 days pursuant to the ablation and at 6 monthly intervals thereafter. Multivariate analysis was undertaken to determine variables related to the procedural outcomes. Breen et al. [55] summated the results as follows:

- Eighty-three tumours (79%) had been completely treated at one sitting. Twelve of the remaining tumours had been successfully re-treated by means of further ablation as well as a clinical decision had been taken not to re-treat 7 patients. One patient who had a small residual crescent of tumour had been undergoing follow-up assessment and could be considered for further treatment. With regards to another patient, re-treatment had been abandoned because of the development of a complicating pneumothorax and difficulty in obtaining access. One patient had been waiting for further re-treatment ablation. The overall technical success rate had been 90.5%.

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- Multivariate analysis demonstrated that the size of the tumour was the only significant variable that had affected the outcome of the procedure (P=0.007, Pearson X²).
- Five patients did develop complications.
- No local tumour recurrence developed on follow-up.

Breen et al. [55] concluded that:

- Their experience had suggested that radiofrequency ablation is a safe and effective, minimally invasive treatment for small kidney tumours.

Thompson et al. [56] reported on 1424 patients who had cT1a kidney tumours. 1057 patients had undergone partial nephrectomy, 180 patients did undergo radiofrequency ablation, and 187 patients did undergo cryoablation. Within the cohort, local recurrence-free survival was found to be similar within the 3 treatment groups (P=0.49); nevertheless, metastases-free survival was significantly better following partial nephrectomy (P=0.005) and cryoablation (P=0.021) in comparison with radiofrequency ablation. Thompson et al. [56] additionally reported 379 patients who had cT1b kidney tumours and of these patients, 326 patients had undergone partial nephrectomy, 53 patients had undergone cryoablation. There were also 8 patients who had cT1b tumours who had undergone radiofrequency ablation of tumours but had been excluded from the second study. Within this second cohort of patients, local recurrence-free survival (P=0.81) and metastases-free survival (p=0.45) had been adjudged to be similar between the partial nephrectomy and the cryoablation groups of patients. Within both the cT1a and the cT1b groups of patients, partial nephrectomy patients had been significantly younger, had lower Charlson scores and had superior overall survival (P<0.001 for all). The limitations of the study were stated to be the retrospective nature of the study and the selection bias. Thompson et al. [56] made the ensuing conclusions:

- Within a large cohort of sporadic cT1a kidney masses, they had observed that recurrence-free survival had been similar for partial nephrectomy and percutaneous ablation patients.
- Metastases-free survival had been superior partial nephrectomy and cryoablation patients in comparison with radiofrequency ablation for cT1a patients.
- Overall survival was superior following partial nephrectomy, likely because of selection bias.
- If the results are validated an update to clinical guidelines would be warranted.

Best et al. [57] identified 159 kidney tumours that had been treated by radiofrequency ablation. The patients had been evaluated with contrast-enhanced radiological imaging pre-operatively, and at 6 weeks, 6 months, and at least yearly thereafter. Best et al. [57] summarized the results as follows:

- The size of the tumour had ranged between 0.9 cm and 5.4 cm and the median size was 2.4 cm.
- The follow-up had ranged between 1.5 months and 120 months and the median follow-up was 54 months.
- Renal cell carcinoma had been confirmed in 72% out of the 150 tumours that had pre-ablation renal biopsy which amounted to 94% of all the patients.
- The 3- and 5- year disease-free survival had been comparable at 92% and 91% overall, and had been dependent upon the size of tumour, being 96% and 95% for tumours that were smaller than 3.0 cm, and 79% and 79% respectively, for tumours that had measured 3 cm or larger than 3.0 cm (P 0.001). Majority of failures (14 out of 18) had been local, either incomplete ablation or local recurrences.
- The study had been based upon an intent to treat analysis, hence, the study had included patients who were ultimately found to have benign tumours, even though the outcome had been comparable in patients who had carcinoma.

Best et al. [57] made the ensuing conclusions:

- Radiofrequency ablation treatment success of the small kidney mass would tend to be strongly correlated with the size of the tumour.

- Radiofrequency ablation does provide excellent and durable outcomes, particularly, with regards to tumours smaller than 3 cm.
- With regards to kidney tumours that measure 3 cm or larger than 3 cm, about 20% would recur pursuant to radiofrequency ablation such that alternative treatment techniques should be considered. Nevertheless, majority of treatment failures, tend to be local and are often successfully treated with another radiofrequency ablation treatment session.

In addition to the afore-mentioned summations radiofrequency ablation has been shown to be effective for the treatment of Bosniak cysts in the kidney and Radiofrequency ablation has been shown to be effective for the treatment of papillary cell type of renal cell carcinoma as well as for adenocarcinoma and an anecdotal report has shown that the outcome following ablation of papillary tumours is superior to that of adenocarcinoma.

SUMMARY

Various reported studies and cases have illustrated the safety and efficacy of treating patients with small localized solid and cystic small renal tumours confined to the kidney by means of radiological imaging guided radiofrequency ablation.

Radiofrequency ablation treatments of renal tumours tend to be successful with regards to majority of small lesions, especially when they measure ≤ 3cm, based upon evidence of non-contrast enhancement of treated lesions based upon post procedure imaging. However, larger lesions may require further radiofrequency ablation treatment sessions to ensure complete and successful treatment of the renal lesion.

Radiofrequency ablation of renal tumours can be undertaken on patients who are adjudged to be unfit for major surgery in the form of laparoscopic nephrectomy or open nephrectomy because of comorbidities.

The duration of hospital stay following radiofrequency ablation of renal tumours tends to be short.

Patients generally tend to tolerate radiofrequency ablation of renal tumours well.

There tends to be minimal complications associated with radiofrequency ablation of renal tumours; however, complications that have been reported include haematuria, chyluria, injury to the ureter, calyceal-cutaneous fistula and peri-renal abscess formation.

The short-term, intermediate-term and long term oncological outcomes tend to be good with occasional recurrences that can be diagnosed during follow up and if these are diagnosed and they remain localized to the kidney they can further be treated by radiofrequency ablation as an option, but this would not preclude partial nephrectomy or radical nephrectomy as an alternative option.

Radiofrequency ablation for small renal tumours would tend to be associated with oncological outcomes that are similar in comparison with partial nephrectomy or radical nephrectomy; but the complications and morbidity associated with radiofrequency ablation of small renal tumours would appear to be less in comparison with major nephrectomy procedures.

Patients who are fit to undergo partial nephrectomy or radical nephrectomy for small renal tumours could also be considered for radiofrequency ablation if there is a well-trained interventional radiologist to undertake the procedure as an alternative option to nephrectomy.

Radiofrequency ablation of renal tumours tends to be associated with preservation of renal function with very minimal decrease in renal function to the procedure and the procedure should be considered in situations of small renal tumours in solitary kidneys.

CONCLUSIONS

Radiofrequency ablation is a safe and effective option of treatment for small sized renal cell carcinomas and Bosniak cysts.

The procedure is associated with minimal complications and good prognosis comparable to that of partial nephrectomy and radical nephrectomy as well as it can be performed as an outpatient procedure and local recurrence of tumour can also be re-treated by radiofrequency ablation.

The procedure can be undertaken on patients who are deemed to be unfit for partial nephrectomy or radical nephrectomy.

A global consensus Multi-disciplinary team meeting of Urologists, oncologists and interventional radiologists would be recommended to review the evidence that the procedure is safe and effective with good results to offered as a first line alternative treatment of choice option for patients who may be on active surveillance or those who may require treatment of curative intent for well localized renal cell carcinomas of up to 3 cm size.

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