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Original Scientific Paper

SHORT-TERM OUTCOMES OF PERCUTANEOUS RADIOFREQUENCY AND MICROWAVE ABLATION IN THE TREATMENT OF SMALL RENAL MASSES

Lora Grbanović[1], Ana Marija Alduk[1], Nikola Knežević[2,3], Željko Kaštelan[2,3], Tvrtko Hudolin[2,3] and Maja Prutki[1,3]

[1]Department of Diagnostic and Interventional Radiology, Zagreb University Hospital Center, Zagreb, Croatia;
[2]Department of Urology, Zagreb University Hospital Center, Zagreb, Croatia;
[3]School of Medicine, University of Zagreb, Zagreb, Croatia

SUMMARY – Although the gold standard in the management of kidney tumors is surgical treatment, thermal ablation methods are a viable therapeutic option for patients with small (<4 cm) renal masses who are poor surgical candidates. The aim of this study was to compare the technical success, primary efficacy and complication rate of percutaneous radiofrequency and microwave ablation in the treatment of small renal masses. A retrospective analysis of consecutive patients with small renal masses treated with radiofrequency or microwave ablation between December 2017 and January 2022 was conducted. Response to the ablative therapy was assessed on contrast-enhanced computed tomography examination after 3 months. Ablations of 44 kidney lesions were performed in 43 patients. Sixteen lesions were treated with radiofrequency and 28 with microwave ablation. Both methods were associated with high technical success (100%). Primary efficacy rates of radiofrequency and microwave ablation were 81.3% and 89.3%, respectively. Ablation-related complications were noted only in the patients treated with microwave ablation (18.5%), all of them being low grade (Clavien-Dindo 1 and 2). Radiofrequency and microwave ablation exhibited comparable efficacy in the treatment of small renal masses. Microwave ablation was associated with a comparatively higher number of complications.

Key words: *Kidney neoplasms; Ablation techniques; Radiofrequency ablation; Microwave ablation*

Introduction

According to GLOBOCAN, renal cancer accounts for 2.2% of global cancer cases and 1.8% of deaths from cancer[1]. Up to 85% of primary malignant renal neoplasms are renal cell carcinomas (RCC), the most common type being clear-cell carcinoma[2]. In developed countries, the majority of RCC cases are detected incidentally[3]. The increase in RCC incidence over the past decades has partially been attributed to the increased utilization of abdominal imaging techniques including ultrasound (US), computed tomography (CT), and magnetic resonance imaging (MRI)[4,5].

Small, low-grade tumors represent the majority of incidentally detected renal lesions[6]. Small renal mass (SRM) is defined as an asymptomatic renal tumor measuring less than 4 centimeters in diameter[7]. Thirty percent of SRMs are benign[7]. SRMs which are RCC correspond to TNM category T1a[8]. For T1 stage RCC, the treatment of choice is partial nephrectomy, which is preferable to radical nephrectomy due to the preserved kidney function, lower risk of cardiovascular disorder development, and better quality of life[9]. Alternative therapy options for patients unsuitable for

Correspondence to: *Lora Grbanović, MD,* Department of Diagnostic and Interventional Radiology, Zagreb University Hospital Center, Kišpatićeva 12, HR-10000 Zagreb, Croatia
E-mail: grbanovic.lora@gmail.com

surgery include tumor ablation techniques, active surveillance, and watchful waiting[9]. The advantages of ablation techniques over surgical treatment are minimal invasiveness, lower inherent operative risks, shorter procedure and hospital stay length[10]. Apart from patients with high postoperative morbidity risk, ablation techniques can also be considered in the treatment of patients with solitary kidney[11,12], multifocal RCC (e.g., von Hippel-Lindau disease)[13-15], and recurrent RCC[16].

Radiofrequency ablation (RFA) and microwave ablation (MWA) fall under the category of thermal ablation techniques, making use of locally applied heat for destruction of tumorous tissue. Both methods can be performed laparoscopically and percutaneously. RFA is an established method for the treatment of renal tumors, and MWA is a more recent method which was introduced a decade after RFA[17]. Although previous studies have demonstrated similar clinical outcomes of those techniques[18,19], due to the small evidence base MWA is still considered an experimental method[9].

Microwave ablation may have the advantages over RFA in terms of shorter ablation time and the ability to acquire higher temperatures while being less sensitive to the type of tissue[20]. It is also less susceptible to the 'heat sink' effect, the phenomenon of temperature drop caused by perfusion of the large vessel adjacent to the target lesion, which limits the effectiveness of the ablation[21]. The proposed ability of MWA to create larger ablation zones compared to RFA[20] was confirmed in an animal study[22]. According to prior research, MWA is associated with less periprocedural pain than RFA[23], thereby reducing the need of general anesthesia in some patients.

To date, there is a limited number of studies comparing the performance of RFA and MWA in the treatment of renal tumors. The objective of this study was to compare short-term outcomes of percutaneous RFA and MWA in the treatment of SRMs. The primary outcomes studied were technical success, primary efficacy, and complication rate.

Material and Methods

This retrospective study was granted approval by the institutional review board and the requirement for informed consent was waived. Radiology information system was reviewed to identify patients having undergone image-guided percutaneous ablation of known or suspected renal malignancy at our institution between December 2017 and January 2022. Patients in which biopsy of the tumor was not performed were excluded from the study, as well as the patients lost from follow-up.

The procedures were indicated by the multidisciplinary tumor board consisting of urologists, pathologists, radiologists and oncologists. Informed consent was obtained from the patients prior to the procedure.

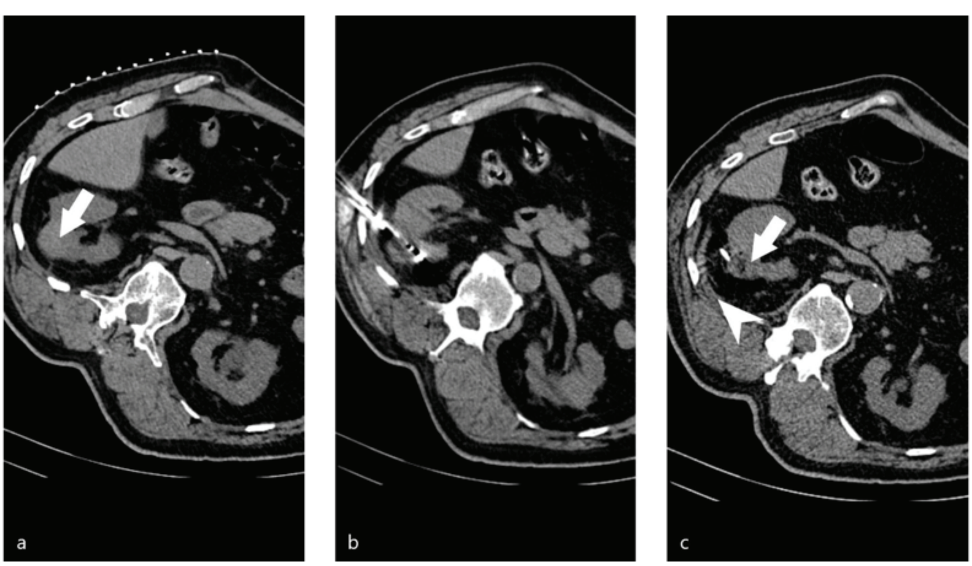

Fig. 1. Microwave ablation: (a) non-contrast computed tomography (CT) scan showing a mass in the right kidney (arrow); (b) intraprocedural CT depicting the antenna positioned inside the tumor; (c) post-procedural CT showing the ablation zone with gas bubbles (arrow) and small retroperitoneal hemorrhage (arrowhead).

Pre-ablation CT scan was performed to assess the relations between the tumor and surrounding structures, determine appropriate patient position during ablation, and safe path of the electrode or antenna. The patients underwent standard preoperative anesthesiology evaluation.

All patients undergoing RFA and a small number of patients undergoing MWA were treated under general anesthesia. A larger proportion of patients undergoing MWA were treated under combined local anesthesia and conscious sedation.

The ablations were performed by a single interventional radiologist experienced in CT-guided interventions. The procedures were performed under CT guidance (Somatom Definition AS+ 128, Siemens, Erlangen, Germany). In cases where kidney movement during respiration was pronounced, ablations were performed under CT fluoroscopy guidance (CTF) using the same CT device. Tumor biopsies were done either in a separate act before ablation or concomitantly with ablation.

Microwave ablations were carried out using the Emprint™ Microwave Ablation System (Medtronic Inc., Boulder, Colorado, USA) with a single antenna and maximum power of 100 W. The time of ablation depended on tumor size and was adjusted according to the manufacturer's recommendations. In some cases, overlapping ablations were performed to achieve the appropriate zone of ablation. CT images of MWA procedure are displayed in Figure 1.

Radiofrequency ablations were performed using the Starburst® SemiFlex electrode (Angiodynamics, New York, USA) and Sunburst XL 1500® generator (Angiodynamics, New York, USA). Pre-programmed procedure duration was 9 minutes. Ablation was repeated after electrode repositioning if a larger ablation zone was required.

Hydrodissection was done in patients with the tumor localized adjacently to bowel loops or neural structures by instilling 5% glucose solution in order to displace the aforementioned structures. Non-contrast CT was performed immediately after the ablation to evaluate the ablation zone and detect complications, which were categorized in accordance with the Clavien-Dindo classification. Study outcomes were defined according to the tumor ablation terminology standardization guidelines[24]. Technical success was defined as completion of the planned ablation according to the protocol. Primary efficacy rate describes whether the tumor was effectively ablated, and was defined as the percentage of tumors that were successfully treated with the initial ablation. In this study, the primary efficacy rate was assessed on multiphase contrast-enhanced CT at the follow-up three months after the procedure. If there was absence of contrast enhancement in the ablation zone, the ablation was considered successful. The follow-up also included physical examination and laboratory tests.

Statistical analysis was performed in Python (version 3.8.10) using the SciPy package[25]. Two-tailed Fisher exact test and unpaired t-test were used, with the level of significance set at $p<0.05$.

Results

Image-guided percutaneous thermal ablation of 44 renal tumors was performed in 43 patients. The mean age of the patients was 69 (range: 52-81) years. Thirteen (30.2%) patients were female, and 30 (69.8%) were male. In one patient, two tumors were treated during the same MWA procedure. Tumor characteristics are summarized in Table 1.

Sixteen (36.4%) tumors were treated with RFA, and 28 (63.6%) with MWA. In 35 (81.4%) patients, the indication for ablation was advanced age and/or comorbidities, and in 8 (18.6%) patients the indication was a tumor located in a solitary kidney.

All 27 (100%) MWA procedures and 14 (87.5%) RFA procedures were CT-guided. Two (12.5%) RFA procedures were CTF-guided. The mean procedure duration was 5.5 (range: 3-12) minutes for MWA and 10.6 (range: 9-18) minutes for RFA. Hydrodissection was performed in 4 (9.3%) out of 43 procedures.

Out of 27 MWA procedures, 22 (81.5%) were performed using a combination of conscious sedation and local anesthesia, and 5 (18.5%) were carried out under general anesthesia. All sixteen (100%) RFA procedures were performed under general anesthesia.

Biopsy of renal tumors was performed concomitantly with ablation in 34 (79.1%) patients, and 9 (20.9%) patients underwent biopsy in a separate act.

Ablation-related complications were only observed in patients that underwent MWA, but the difference in complication rate between the groups of patients treated with RFA and MWA was not statistically significant ($p=0.14$). Five out of 27 (18.5%) patients treated with MWA developed perirenal hematomas, four (80%) of which corresponded to Clavien-Dindo grade 1, and one (20%) corresponded to Clavien-Din-

Table 1. Characteristics of tumors treated with microwave ablation and radiofrequency ablation

		Microwave ablation	Radiofrequency ablation
Number of tumors (n)		28	16
Mean diameter (cm)		2.4 (range: 1.4-4)	2.6 (range: 1.2-3.7)
Side (n, %)	Left kidney	15 (53.6)	12 (75.0)
	Right kidney	13 (46.4)	4 (25.0)
Localization (n, %)	Upper third	9 (32.1)	3 (18.8)
	Middle third	13 (46.4)	9 (56.3)
	Lower third	6 (21.4)	4 (25.0)
Histopathologic diagnosis (n, %)	Clear-cell RCC	13 (46.4)	13 (81.3)
	Oncocytic tumor	7 (25.0)	2 (12.5)
	Angiomyolipoma	2 (7.1)	1 (6.3)
	Papillary RCC	1 (3.6)	
	Nondiagnostic	5 (17.9)	

RCC = renal cell carcinom

Table 2. Microwave ablation and radiofrequency ablation outcomes

		Microwave ablation	Radiofrequency ablation
Tumors treated (n)		28	16
Technical success (n, %)		28 (100)	16 (100)
Primary efficacy (n, %)		25 (89.3)	13 (81.3)
Patients treated (n)		27	16
Type of anesthesia (n, %)	General	5 (18.5)	16 (100)
	Local + analgosedation	22 (81.5)	0 (0)
Ablation related complications (n, %)		5 (18.5)	0 (0)
Mean procedure duration (min)		5.5 (range: 3-12)	10.6 (range: 9-18)
Mean hospital stay (days)		2.6 (range: 1-7)	3.1 (range: 1-10)

do grade 2 complications. The patients were treated conservatively with a satisfactory outcome. Complications not related to the ablation were noted in four (9.3%) patients. Two (50%) patients developed urticaria in response to intravenous contrast administration, and two (50%) patients suffered biopsy-related complications of hemorrhage and pneumoretroperitoneum, both Clavien-Dindo grade 1, which were treated conservatively with a good outcome. In those patients, ablation was carried out after it was determined that the complications were not life-threatening.

Technical success was achieved in 100% of the ablations. At the follow-up after 3 months, the primary efficacy rate was 89.3% (25/28) in the tumors treated with MWA, and 81.3% (13/16) in the tumors treated with RFA. Difference in the primary efficacy rate was not statistically significant (p=0.65). Summary of the outcomes is presented in Table 2.

Four (66.7%) out of six residual tumors were located in the middle third of the kidney and two (33.3%) were located in the upper third of the kidney. Histopathologically, five (83.3%) out of six residual tumors were clear-cell renal carcinoma, and one (16.7%) was oncocytic tumor.

Among three patients with residual tumors initially treated with RFA, one (33.3%) was successfully treated with a single repeat RFA, and two (66.7%) patients underwent subsequent MWA. In one patient, complete ablation was achieved after one MWA, and in the other patient after two ablations.

One (33.3%) out of three patients with residual tumor initially treated with MWA was subsequently treated with two additional MWA procedures, with satisfactory outcome after the second procedure, and one (33.3%) patient was treated surgically. In one (33.3%) patient with residual tumor after MWA, no decision on further treatment was made at the time of writing this manuscript.

There was no significant difference in the length of hospital stay between patients treated with RFA (M 3.1, SD 2.5) and MWA (M 2.6, SD 1.5) (t(41)=0.84, p=0.41).

Discussion

The development of thermal ablation technologies has enabled new treatment strategies for renal tumors, which are increasingly being used in the treatment of patients unable to undergo surgery, patients with multiple renal tumors, or with the tumor located in a solitary kidney. In this study, we compared short-term outcomes of two thermal ablation methods in the treatment of small renal masses, i.e., RFA, which is a well-established method, and MWA, an emerging method that is still considered experimental. Previous studies investigating RFA and MWA outcomes in the treatment of renal tumors are predominantly single-arm studies. Only a few comparative studies have been conducted[18,19].

According to the previous research, 70% of residual tumors treated with ablation are radiographically detected in the first three months after the procedure[26], which was the length of the follow-up in our study. Patient groups treated with RFA and MWA exhibited comparable short-term outcomes. Technical success was high (100%) in all RFA and MWA procedures, which is in concordance with the prior research[18,27]. The primary efficacy rate of 89.3% in the patients treated with MWA and 81.3% in the patients treated with RFA is similar to the previously reported short-term follow-up results as well[18,19].

The complication rates in the previous studies range from 0 to 17% for RFA[18,19,28,29], and from 1.7 to 27% for MWA[18,19,27,30,31]. In this study, ablation-related complications were only observed in the patients treated with MWA (18.5%). All of those patients developed perirenal hematomas. It is important to emphasize that all complications were low-grade (Clavien-Dindo grade 1 and 2), did not require surgical or radiological intervention, and the patients recovered successfully. While the complication rates in this study fall within the range of the previously published results, it is worth noting the difference between the complication rates of RFA and MWA. Even though the difference was not statistically significant, the higher complication rate recorded in the patients treated with MWA could reflect the ability of MWA to create larger ablation zones and achieve higher temperatures[20], resulting in more pronounced tissue destruction and hemorrhage. The second explanation might be a comparatively greater operators' experience with RFA since MWA is a newer method and in our department, it was introduced a few years after RFA.

Residual tumors were located in the upper and middle third of the kidney, which could be attributed to the limited accessibility during ablation due to the more complex anatomic relations. The majority of residual tumors were clear-cell RCC, and one was oncocytic tumor. Although previous research did not demonstrate a statistically significant association between malignant pathology and local tumor progression after ablation[32], in this study we observed a higher proportion of RCC in residual tumors (83.3%) compared to the proportion of RCC in all ablated tumors (61.4%). Considering the previously reported higher recurrence rate in tumors larger than 3 centimeters[33], the failure of primary ablation in our study could be attributed to tumor size in three patients. In two patients initially treated with RFA, residual tumors were most likely a result of the 'heat sink' effect due to the proximity of vascular structures. The cause of the one remaining residual tumor initially treated with MWA is unknown. The guidelines point to salvage ablation as the preferred treatment of recurrent disease following the failed thermal ablation[9]. Other treatment options include surveillance and surgical extirpation[34]. In this study, four patients with residual tumors were subsequently successfully treated with repeat ablation, and in one patient radical nephrectomy was performed. One patient with residual tumor after MWA is currently awaiting decision on further treatment.

While it is largely agreed that percutaneous biopsy of the tumor undergoing ablative treatment should be performed, timing of biopsy is a polarizing topic, with some authors claiming little benefit from the biopsy performed separately from the ablation[35], and others recommending it[9]. The latest European Association of Urology guidelines recommend performing the biopsy before, and not concomitantly with thermal ablation[9]. Performing ablation and biopsy in the same act has the advantages of avoiding multiple procedures and time saving, but the downside is that some benign lesions are unnecessarily treated as well. The majority of biopsies in our study were performed concomitantly with ablation (79.1%). The results of the histopathologic analysis in our study correspond to the previously published analysis of pathologic characteristics of SRMs, in which RCC accounts for the majority of biopsied lesions[36]. Angiomyolipomas accounted for 6.8% of all ablated lesions and were considered definitely benign. Although the ablation of benign renal tumors may be beneficial in selected patients for symptom control and preventing complications such as mass effect and hemorrhage[20], patients in this study did not fall into this category. Oncocytic tumors, which accounted for 20.5% of ablated lesions in our study were considered lesions of unclear malignant potential since a small proportion of malignant renal tumors can contain oncocytic cells as well[37]. Biopsy was nondiagnostic in 11.4% of the lesions. A nondiagnostic biopsy should not be used to rule out the possibility of malignant lesion[38], as a previous study has reported a proportion of 10.5% RCC in initially nondiagnostic lesions after the ablation[39]. Biopsy was only performed when it could be carried out safely, with pre-procedural planning. Complications related to the biopsy were noted in two (4.7%) patients only. Both complications were low grade (Clavien-Dindo grade 1), which is in accordance with previous research[40,41].

The mean procedure duration was shorter in the patients treated with MWA (5.5 minutes) compared to RFA (10.6 minutes), as was the mean length of hospital stay (2.6 days for MWA and 3.1 days for RFA), which was not statistically significant. Interestingly, even though the complications were more frequent in the group of patients treated with MWA, their mean hospitalization time remained shorter compared to the patients treated with RFA.

The primary strength of this study is a comparative design. A single operator performing all ablations also improved the strength of the study, since the interoperator variability was avoided. The main study limitations are retrospective design and small sample size, the latter contributing to the low power of the study, which may have been insufficient to show a statistically significant difference in the outcomes between patient groups treated with RFA and MWA. Another limitation of this study is selection bias, since the ablation was performed only in patients unfit for surgery and patients with a solitary kidney.

The results of this study suggest that both RFA and MWA are effective in the treatment of SRMs in a selected group of patients, with comparable short-term outcomes. Microwave ablation, which is a more recent method, yielded a slightly better efficacy rate but was also associated with a higher rate of low-grade complications. To confirm the equivalence of RFA and MWA in the treatment of small renal tumors, prospective studies with a larger number of participants and longer follow-up are required.

References

1. Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, Bray F. Global Cancer Statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin. 2021 May;71(3):209-49. doi: 10.3322/caac.21660. Epub 2021 Feb 4. PMID: 33538338.
2. Kumar V, Abbas AK, Aster, JC, Perkins JA. Robbins Basic Pathology, 10th edn. Philadelphia: Elsevier; 2018.
3. Padala SA, Barsouk A, Thandra KC, Saginala K, Mohammed A, Vakiti A, Rawla P, Barsouk A. Epidemiology of renal cell carcinoma. World J Oncol. 2020 Jun;11(3):79-87. doi: 10.14740/wjon1279. Epub 2020 May 14. PMID: 32494314; PMCID: PMC7239575.
4. Capitanio U, Bensalah K, Bex A, Boorjian SA, Bray F, Coleman J, Gore JL, Sun M, Wood C, Russo P. Epidemiology of renal cell carcinoma. Eur Urol. 2019 Jan;75(1):74-84. doi: 10.1016/j.eururo.2018.08.036. Epub 2018 Sep 19. PMID: 30243799; PMCID: PMC8397918.
5. Georgiades C, Rodriguez R. Renal tumor ablation. Tech Vasc Interv Radiol. 2013 Dec;16(4):230-8. doi: 10.1053/j.tvir.2013.08.006. PMID: 24238378.

6. Capitanio U, Montorsi F. Renal cancer. Lancet. 2016 Feb 27;387(10021):894-906. doi: 10.1016/S0140-6736(15)00046-X. Epub 2015 Aug 25. PMID: 26318520.

7. Volpe A, Jewett MA. The natural history of small renal masses. Nat Clin Pract Urol. 2005 Aug;2(8):384-90. doi: 10.1038/ncpuro0254. PMID: 16474735.

8. Stakhovskyi O, Yap SA, Leveridge M, Lawrentschuk N, Jewett MA. Small renal mass: what the urologist needs to know for treatment planning and assessment of treatment results. AJR Am J Roentgenol. 2011 Jun;196(6):1267-73. doi: 10.2214/AJR.10.6336. Erratum in: AJR Am J Roentgenol. 2012 May;198(5):1232.

9. European Association of Urology. EAU Guidelines. Edn. presented at the EAU Annual Congress Amsterdam 2022. Arnhem, Tthe Netherlands: EAU Guidelines Office; 2022. 28-36 p. ISBN: 978-94-92671-16-5.

10. Choi SH, Kim JW, Kim JH, Kim KW. Efficacy and safety of microwave ablation for malignant renal tumors: an updated systematic review and meta-analysis of the literature since 2012. Korean J Radiol. 2018 Sep-Oct;19(5):938-49. doi: 10.3348/kjr.2018.19.5.938. Epub 2018 Aug 6. PMID: 30174484; PMCID: PMC6082757.

11. Lin Y, Liang P, Yu XL, Yu J, Cheng ZG, Han ZY, Liu FY. Percutaneous microwave ablation of renal cell carcinoma is safe in patients with a solitary kidney. Urology. 2014 Feb;83(2):357-63. doi: 10.1016/j.urology.2013.05.071. Epub 2013 Dec 8. PMID: 24321484.

12. Xiaobing W, Wentao G, Guangxiang L, Fan Z, Weidong G, Hongqian G, Gutian Z. Comparison of radiofrequency ablation and partial nephrectomy for tumor in a solitary kidney. BMC Urol. 2017 Sep 6;17(1):79. doi: 10.1186/s12894-017-0269-4. PMID: 28877693; PMCID: PMC5588723.

13. Park BK, Kim CK. Percutaneous radio frequency ablation of renal tumors in patients with von Hippel-Lindau disease: preliminary results. J Urol. 2010 May;183(5):1703-7. doi: 10.1016/j.juro.2010.01.022. Epub 2010 Mar 17. PMID: 20299060.

14. Park BK, Kim CK, Park SY, Shen SH. Percutaneous radiofrequency ablation of renal cell carcinomas in patients with von Hippel Lindau disease: indications, techniques, complications, and outcomes. Acta Radiol. 2013 May;54(4):418-27. doi: 10.1177/0284185113475441. Epub 2013 Apr 30. PMID: 23446745.

15. Park SY, Park BK, Kim CK, Lee HM, Jeon SS, Seo SI, Jeong BC, Choi HY. Percutaneous radiofrequency ablation of renal cell carcinomas in patients with von Hippel Lindau disease previously undergoing a radical nephrectomy or repeated nephron-sparing surgery. Acta Radiol. 2011 Jul 1;52(6):680-5. doi: 10.1258/ar.2011.100435. Epub 2011 Apr 27. PMID: 21525107.

16. Camisassi N, Mauri G, Vigna PD, Bonomo G, Varano GM, Maiettini D, Orsi F. Local recurrence of renal cell carcinoma successfully treated with fusion imaging-guided percutaneous thermal ablation. Ecancermedicalscience. 2020 Jul 13;14:1070. doi: 10.3332/ecancer.2020.1070. PMID: 32728386; PMCID: PMC7373648.

17. Shakeri S, Raman SS. Trends in percutaneous thermal ablation therapies in the treatment of T1a renal cell carcinomas rather than partial nephrectomy/radical nephrectomy. Semin Intervent Radiol. 2019 Aug;36(3):183-93. doi: 10.1055/s-0039-1694714. Epub 2019 Aug 19. PMID: 31435126; PMCID: PMC6699960.

18. Zhou W, Herwald SE, McCarthy C, Uppot RN, Arellano RS. Radiofrequency ablation, cryoablation, and microwave ablation for T1a renal cell carcinoma: a comparative evaluation of therapeutic and renal function outcomes. J Vasc Interv Radiol. 2019 Jul;30(7):1035-42. doi: 10.1016/j.jvir.2018.12.013. Epub 2019 Apr 5. PMID: 30956075.

19. Abboud SE, Patel T, Soriano S, Giesler J, Alvarado N, Kang P. Long-term clinical outcomes following radiofrequency and microwave ablation of renal cell carcinoma at a single VA Medical Center. Curr Probl Diagn Radiol. 2018 Mar-Apr;47(2):98-102. doi: 10.1067/j.cpradiol.2017.05.006. Epub 2017 May 17. PMID: 28648469.

20. Hinshaw JL, Lubner MG, Ziemlewicz TJ, Lee FT Jr, Brace CL. Percutaneous tumor ablation tools: microwave, radiofrequency, or cryoablation – what should you use and why? Radiographics. 2014 Sep-Oct;34(5):1344-62. doi: 10.1148/rg.345140054. PMID: 25208284; PMCID: PMC4319523.

21. Kim C. Understanding the nuances of microwave ablation for more accurate post-treatment assessment. Future Oncol. 2018 Jul;14(17):1755-64. doi: 10.2217/fon-2017-0736. Epub 2018 Feb 14. PMID: 29441813.

22. Laeseke PF, Lee FT Jr, Sampson LA, van der Weide DW, Brace CL. Microwave ablation *versus* radiofrequency ablation in the kidney: high-power triaxial antennas create larger ablation zones than similarly sized internally cooled electrodes. J Vasc Interv Radiol. 2009 Sep;20(9):1224-9. doi: 10.1016/j.jvir.2009.05.029. Epub 2009 Jul 18. PMID: 19616970; PMCID: PMC3309457.

23. Carrafiello G, Laganà D, Mangini M, Fontana F, Dionigi G, Boni L, Rovera F, Cuffari S, Fugazzola C. Microwave tumor ablation: principles, clinical applications and review of preliminary experiences. Int J Surg. 2008;6 Suppl 1:S65-9. doi: 10.1016/j.ijsu.2008.12.028. Epub 2008 Dec 14. PMID: 19186116.

24. Ahmed M, Solbiati L, Brace CL, Breen DJ, Callstrom MR, Charboneau JW, Chen MH, Choi BI, de Baère T, Dodd GD 3rd, Dupuy DE, Gervais DA, Gianfelice D, Gillams AR, Lee FT Jr, Leen E, Lencioni R, Littrup PJ, Livraghi T, Lu DS, McGahan JP, Meloni MF, Nikolic B, Pereira PL, Liang P, Rhim H, Rose SC, Salem R, Sofocleous CT, Solomon SB, Soulen MC, Tanaka M, Vogl TJ, Wood BJ, Goldberg SN; International Working Group on Image-guided Tumor Ablation; Interventional Oncology Sans Frontières Expert Panel; Technology Assessment Committee of the Society of Interventional Radiology; Standard of Practice Committee of the Cardiovascular and Interventional Radiological Society of Europe. Image-guided tumor ablation: standardization of terminology and reporting criteria – a 10-year update. Radiology. 2014 Oct;273(1):241-60. doi: 10.1148/radiol.14132958. Epub 2014 Jun 13. PMID: 24927329; PMCID: PMC4263618.

25. Virtanen P, Gommers R, Oliphant TE, Haberland M, Reddy T, Cournapeau D, Burovski E, Peterson P, Weckesser W, Bright J, van der Walt SJ, Brett M, Wilson J, Millman KJ, Mayorov N, Nelson ARJ, Jones E, Kern R, Larson E, Carey CJ, Polat İ, Feng Y, Moore EW, VanderPlas J, Laxalde D, Perktold J, Cimrman R, Henriksen I, Quintero EA, Harris CR, Archibald AM, Ribeiro AH, Pedregosa F, van Mulbregt

P; SciPy 1.0 Contributors. SciPy 1.0: fundamental algorithms for scientific computing in Python. Nat Methods. 2020 Mar;17(3):261-72. doi: 10.1038/s41592-019-0686-2. Epub 2020 Feb 3. Erratum in: Nat Methods. 2020 Feb 24; PMID: 32015543; PMCID: PMC7056644.

26. Matin SF, Ahrar K, Cadeddu JA, Gervais DA, McGovern FJ, Zagoria RJ, Uzzo RG, Haaga J, Resnick MI, Kaouk J, Gill IS. Residual and recurrent disease following renal energy ablative therapy: a multi-institutional study. J Urol. 2006 Nov;176(5):1973-7. doi: 10.1016/j.juro.2006.07.016. Erratum in: J Urol. 2008 Jun;179(6):2490.

27. Wells SA, Wheeler KM, Mithqal A, Patel MS, Brace CL, Schenkman NS. Percutaneous microwave ablation of T1a and T1b renal cell carcinoma: short-term efficacy and complications with emphasis on tumor complexity and single session treatment. Abdom Radiol (NY). 2016 Jun;41(6):1203-11. doi: 10.1007/s00261-016-0776-x. PMID: 27167230.

28. Park BK, Shen SH, Fujimori M, Wang Y. Asian Conference on Tumor Ablation guidelines for renal cell carcinoma. Investig Clin Urol. 2021 Jul;62(4):378-88. doi: 10.4111/icu.20210168. PMID: 34190433; PMCID: PMC8246015.

29. Ito K, Soga S, Seguchi K, Shinchi Y, Masunaga A, Tasaki S, Kuroda K, Sato A, Asakuma J, Horiguchi A, Shinmoto H, Kaji T, Asano T. Clinical outcomes of percutaneous radiofrequency ablation for small renal cancer. Oncol Lett. 2017 Jul;14(1):918-24. doi: 10.3892/ol.2017.6262. Epub 2017 May 26. PMID: 28693252; PMCID: PMC5494732.

30. Yu J, Zhang G, Liang P, Yu XL, Cheng ZG, Han ZY, Zhang X, Dong J, Li QY, Mu MJ, Li X. Midterm results of percutaneous microwave ablation under ultrasound guidance *versus* retroperitoneal laparoscopic radial nephrectomy for small renal cell carcinoma. Abdom Imaging. 2015 Oct;40(8):3248-56. doi: 10.1007/s00261-015-0500-2. PMID: 26288264.

31. Gao Y, Liang P, Yu X, Yu J, Cheng Z, Han Z, Duan S, Huang H. Microwave treatment of renal cell carcinoma adjacent to renal sinus. Eur J Radiol. 2016 Nov;85(11):2083-9. doi: 10.1016/j.ejrad.2016.09.018. Epub 2016 Sep 19. PMID: 27776662.

32. Kunkle DA, Uzzo RG. Cryoablation or radiofrequency ablation of the small renal mass: a meta-analysis. Cancer. 2008 Nov 15;113(10):2671-80. doi: 10.1002/cncr.23896. PMID: 18816624; PMCID: PMC2704569.

33. Johnson BA, Sorokin I, Cadeddu JA. Ten-year outcomes of renal tumor radio frequency ablation. J Urol. 2019 Feb;201(2):251-8. doi: 10.1016/j.juro.2018.08.045. PMID: 30634350.

34. Loloi J, Shingleton WB, Nakada SY, Zagoria RJ, Landman J, Lee BR, Matin SF, Ahrar K, Leveillee RJ, Cadeddu JA, Raman JD. Management of residual or recurrent disease following thermal ablation of renal cortical tumors. J Kidney Cancer VHL. 2020 Jun 9;7(2):1-5. doi: 10.15586/jkcvhl.2020.133. PMID: 32665886; PMCID: PMC7331942.

35. Tsang Mui Chung MS, Maxwell AW, Wang LJ, Mayo-Smith WW, Dupuy DE. Should renal mass biopsy be performed prior to or concomitantly with thermal ablation? J Vasc Interv Radiol. 2018 Sep;29(9):1240-4. doi: 10.1016/j.jvir.2018.04.028. Epub 2018 Jul 31. PMID: 30075976.

36. DeRoche T, Walker E, Magi-Galluzzi C, Zhou M. Pathologic characteristics of solitary small renal masses: can they be predicted by preoperative clinical parameters? Am J Clin Pathol. 2008 Oct;130(4):560-4. doi: 10.1309/YR7P42XUVQHPHDWL. PMID: 18794048.

37. Gorin MA, Rowe SP, Allaf ME. Oncocytic neoplasm on renal mass biopsy: a diagnostic conundrum. Oncology (Williston Park). 2016 May;30(5):426-35. PMID: 27188673.

38. Leveridge MJ, Finelli A, Kachura JR, Evans A, Chung H, Shiff DA, Fernandes K, Jewett MA. Outcomes of small renal mass needle core biopsy, nondiagnostic percutaneous biopsy, and the role of repeat biopsy. Eur Urol. 2011 Sep;60(3):578-84. doi: 10.1016/j.eururo.2011.06.021. Epub 2011 Jun 24. PMID: 21704449.

39. Permpongkosol S, Link RE, Solomon SB, Kavoussi LR. Results of computerized tomography guided percutaneous ablation of renal masses with nondiagnostic pre-ablation pathological findings. J Urol. 2006 Aug;176(2):463-7; discussion 467. doi: 10.1016/j.juro.2006.03.039. PMID:16813865.

40. Marconi L, Dabestani S, Lam TB, Hofmann F, Stewart F, Norrie J, Bex A, Bensalah K, Canfield SE, Hora M, Kuczyk MA, Merseburger AS, Mulders PFA, Powles T, Staehler M, Ljungberg B, Volpe A. Systematic review and meta-analysis of diagnostic accuracy of percutaneous renal tumour biopsy. Eur Urol. 2016 Apr;69(4):660-73. doi: 10.1016/j.eururo.2015.07.072. Epub 2015 Aug 29. PMID: 26323946.

41. Morris CS, Baerlocher MO, Dariushnia SR, McLoney ED, Abi-Jaoudeh N, Nelson K, Cura M, Abdel Aal AK, Mitchell JW, Madassery S, Partovi S, McClure TD, Tam AL, Patel S. Society of Interventional Radiology Position Statement on the Role of Percutaneous Ablation in Renal Cell Carcinoma: Endorsed by the Canadian Association for Interventional Radiology and the Society of Interventional Oncology. J Vasc Interv Radiol. 2020 Feb;31(2):189-94.e3. doi: 10.1016/j.jvir.2019.11.001. Epub 2020 Jan 6. PMID: 31917025.

Sažetak

USPOREDBA KRATKOROČNIH ISHODA PERKUTANE RADIOFREKVENTNE I MIKROVALNE ABLACIJE U LIJEČENJU MALIH TUMORA BUBREGA

L. Grbanović, A. M. Alduk, N. Knežević, Ž. Kaštelan, T. Hudolin i *M. Prutki*

Iako je zlatni standard u liječenju tumora bubrega kirurško liječenje, metode termalne ablacije dobar su izbor za bolesnike s malim (<4 cm) tumorima bubrega koji nisu kandidati za operativni zahvat. Cilj ovoga rada je usporediti tehnički uspjeh, odgovor na terapiju i učestalost komplikacija perkutane radiofrekventne i mikrovalne ablacije u liječenju malih tumora bubrega. Učinjena je retrospektivna analiza uzastopnih bolesnika s malim tumorima bubrega liječenih radiofrekventnom ili mikrovalnom ablacijom između prosinca 2017. i siječnja 2022. godine. Odgovor na terapiju procijenjen je na temelju pregleda kompjutoriziranom tomografijom 3 mjeseca nakon zahvata. Ablacijom su liječene 44 lezije kod 43 bolesnika, pri čemu je 16 lezija liječeno radiofrekventnom, a 28 mikrovalnom ablacijom. Kod obje metode postignuta je visoka razina tehničkog uspjeha (100%). Potpun odgovor na terapiju zabilježen je kod 81,3% lezija liječenih radiofrekventnom i 89,3% lezija liječenih mikrovalnom ablacijom. Komplikacije vezane uz ablaciju zabilježene su samo kod bolesnika liječenih mikrovalnom ablacijom (18,5%), no sve su bile niskog gradusa (Clavien-Dindo 1 i 2). Radiofrekventna i mikrovalna ablacija podjednako su uspješne u liječenju malih tumora bubrega, pri čemu je mikrovalna ablacija povezana s usporedbeno većim brojem komplikacija.

Ključne riječi: *Tumor bubrega; Termalna ablacija; Radiofrekventna ablacija; Mikrovalna ablacija*