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Risk Factors for Renal Function Impairment Following Radiofrequency Ablation of Renal Tumors

신장 종양 고주파 절제술 이후 신장 기능 저하의 위험요소

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Purpose To evaluate the various factors that affect renal function following percutaneous radiofrequency ablation (RFA) therapy in patients with renal tumors.
Materials and Methods Between 2010 and 2018, 91 patients diagnosed with renal tumors using ultrasonography and CT-guided RFA were enrolled. We retrospectively investigated the serum creatinine (SCr) level and estimated glomerular filtration rates immediately prior to RFA and during post-treatment follow-up. The patients were divided into two groups based on the degree of change in SCr level (0.3 mg/dL). Group comparisons were performed using univariable and multivariable logistic regression analyses to determine the factors impacting renal function.
Results Impaired renal function was associated with solitary kidney, chronic kidney disease (CKD) over stage 3, and pyeloureteral injury. Sex, age, other cancers, tumor size, location, growth pattern, and proximity to the collecting system were not significantly associated with impaired renal function. There was a difference in the overall change over time between the association with and without solitary kidney, CKD stage 3, and pyeloureteral injury.
Conclusion Among the medical conditions present prior to RFA, solitary kidney and CKD over stage 3 could be considered as risk factors for impaired renal function. Post-procedural pyeloureteral injury can also be considered a risk factor.

Index terms Radiofrequency Ablation; Kidney Neoplasms; Kidney Function Tests

INTRODUCTION

Radical nephrectomy used to be considered as the choice of treatment for patients with renal cancer (1). In cases of small renal cancer, solitary kidney, or bilateral renal cancer, partial nephrectomy has shown to have comparable oncologic outcomes to that of an alternative treatment (1, 2). The nephron-preserving surgery can also be expected to prevent the overtreatment of radical nephrectomy in benign lesions (3). However, nephron- preserving surgery may significantly contribute to morbidity and mortality in patients with major comorbidities. Primarily, renal function impairment is a troublesome sequelae of renal cancer surgery, since the developing or aggravating chronic kidney disease (CKD) increases the risk of mortality, hospital stay, and risk of cardiovascular disorders (4, 5). The American Urological Association considers percutaneous radiofrequency ablation (RFA) as an alternative to surgery for poor surgical candidates with comorbidities (6).

Many studies show that RFA has minimal influence on renal function (7-11). In case of renal function loss following RFA, tumor predictors affecting renal function may be closely related to lesion size, location, number, and successful ablation rate (12). Apart from tumor predictors, the factors influencing renal function have not been elucidated. It is important to understand the risk factors for renal function impairment following RFA to aid patient management and guidance. The purpose of the present study is to evaluate various factors that affect renal function after RFA therapy in patients with renal tumors.

MATERIALS AND METHODS

This retrospective study was approved by our Institutional Review Board. Informed consent of patients was waived (IRB No. DAUHIRB-21-165).

PATIENTS

Between January 2010 and December 2018, 112 patients with renal tumors were treated using ultrasonography (US) and CT-guided RFA. The inclusion criteria comprised the presence of renal masses upon imaging for renal cell carcinoma (RCC) or sporadic Bosniak III or IV lesions on kidney CT or MRI, and at least 1 year of imaging and renal function test follow-up after RFA. Twenty one patients were excluded due to follow-up loss (n = 14), presence of a large renal tumor (8.8 cm, n = 1), renal metastases from lung cancer (n = 1) and bladder cancer (n = 1), RCC arising from a transplanted kidney (n = 1), bilateral multiple RCCs in a patient with von-Hippel-Lindau disease (n = 1), and subsequent nephrectomy for recurrence (n = 2).

Tables 1 and 2 show clinical and radiological data. A total of 91 patients (60 male and 31 female; mean age, 55.5 years; age range, 26–85 years; mean follow-up period, 66 months; follow-up range, 12–121 months) with 91 renal tumors were finally included in this study. All patients with CKD (7 of 91) were at stage 3. All patients with solitary kidney (9 of 91) underwent previous radical nephrectomy due to RCC.

Renal tumor size was measured on contrast enhanced kidney CT or MRI, and the median tumor size was 1.7 cm (range, 0.8–5.6 cm). Measurement of the longest diameter in the axial or coronal plane was selected as the tumor size. Tumor radiologic features were categorized based on the tumor classification algorithms suggested by the Radius, Exophytic/Endophytic properties, Nearness of tumor, Anterior/posterior, Location relative to polar lines (R.E.N.A.L) nephrometry score (13). Renal tumors were classified as exophytic or endophytic according to the lesion location. Exophytic tumors were classified based on the extent to which the tumor bulged out from the kidney surface (≥ 50% or < 50%). Entirely endophytic tumors were considered as enclosed renal masses by uninvolved normal renal parenchyma (13).

Various criteria have been used to define a significant worsening of the renal function. Re-

Table 1. Patient Characteristics

Features	Values
Age, year	
Mean	55.5
Range	26–85
Sex	
Male	60 (65.9)
Female	31 (34.1)
Follow-up period, month	
Mean	66
Range	12–121
Underlying diseases	
CKD stage ≥ 3*	7 (7.7)
Single kidney	9 (9.9)
Cancer	21 (23.1)
HTN	61 (67.0)
DM	52 (57.1)

Values in parentheses are percentages unless specified otherwise.
*All CKD patients were stage 3.
CKD = chronic kidney disease, DM = diabetes mellitus, HTN = hypertension

Table 2. Radiologic Features of the Tumors

Features	Values
Size, cm	
Mean	2.8
Median	1.7
Range	0.8–5.6
Laterality	
Right	54 (59.3)
Left	37 (40.7)
Location	
Anterior	41 (45.1)
Posterior	41 (45.1)
Neither	9 (9.8)
Growth pattern	
Exophytic	58 (63.7)
Endophytic	33 (36.3)

Values in parentheses are percentages unless specified otherwise.

nal function results were categorized into continuous [serum creatinine (SCr) or estimated glomerular filtration rates (eGFRs) change] and categorical (CKD stages ≥ 3, ≥ 3b, ≥ 4, and end-stage renal disease) outcomes (14-23). The Acute Kidney Injury Network's working group proposed an absolute increase in the SCr level of at least 0.3 mg/dL as the diagnostic criteria for stage 1 of acute kidney injury (24). Although the patient group in this study included those with acute and chronic renal injury, the definition of the renal functional impairment after

RFA has not been specifically established. We defined an SCr level change of at least 0.3 mg/dL between pre-RFA and post-RFA as a significant change, indicative of renal function impairment. The patients were divided into two groups based on the degree of change in the SCr level. The 15 patients who presented an increase in SCr level of more than 0.3 mg/dL, three times consecutively in a year, compared with pre-RFA SCr level, constituted group A. The other 76 patients with an SCr level change of less than 0.3 mg/dL constituted group B.

RFA PROCEDURE

RFA was conducted by a uroradiologist with 14 years of experience in percutaneous US and CT-guided ablation in the kidney. CT-guided RFA was performed using a CT scanner (Sensation, Siemens Medical Solutions Inc., Malvern, PA, USA).

All cases were performed with a single (with one 2.0–3.0 cm tip) internally cooled radiofrequency electrode (Radionics, Burlington, MA, USA) with impedance-modulated pulsed current.

The patients lay in a modified lateral position on the CT table based on the tumor location. US and CT-guided RFA procedure composed of planning, targeting, monitoring, controlling, and assessment of treatment response (25).

US or CT was performed to measure the angle and depth of the electrode insertion. While checking the location of the renal tumor under US, an electrode was inserted into the boundary of the tumor. Subsequently, CT was performed to confirm whether the electrode was placed within the tumor. Following this, RFA was performed using the electrode for 12 minutes. When residual tumors were found on an additional CT, the position of the electrode was adjusted with the help of the CT and an additional procedure was performed for 6–12 minutes (26, 27). When renal tumor ablation of 0.5 cm or more of the tumor margin was considered appropriate by the uroradiologist, the RFA session was completed (12).

DATA ANALYSIS

Contrast-enhanced multiphasic CT imaging was performed immediately after the procedure to serve as a basis for comparison of follow-up images. The purpose of 1-day follow-up CT was to check for immediate complications. Patients were followed up with contrast-enhanced CT or dynamic contrast-enhanced MRI at 1 day, 1 month, 3 months, and 6 months and were then followed up twice a year.

RFA sessions, residual tumor, technical efficacy, and local tumor progression were recorded based on the International Working Group of Image-Guided Tumor Ablation (IWG-IGT) criteria. Residual tumor was considered to have a focal enhancing lesion observed on the first follow-up CT scan 1 month after RFA. Technical efficacy was defined as no focal enhancing lesion on images taken at the first follow-up. Local tumor progression was defined as a focal enhancing lesion on images taken at the second follow-up or increased size of ablation zone or suspicious findings in MR images (decreased T1 signal intensity, increased T2 signal intensity, or increased diffusion weighted signal with decreased apparent diffusion coefficient) (25).

After the procedure, periodic SCr levels and eGFRs were recorded for the previous day and post RFA (1 day, 3 days, 1 week, 1 month, and 6 months, followed by twice a year) to confirm renal function impairment. eGFRs were estimated using the diet modification in renal disease equation (28). Time points for follow-up periods in previous studies vary. In this study, renal function outcomes within a year were used to prevent inclusion of other competitive factors of renal function deterioration and to check the long-term renal function changes rather than acute kidney injury (22).

Post-procedural complication types (major or minor) were recorded based on the IWG-IGT criteria (25). A major complication is defined as one that may result in significant morbidity (e.g., unexpected organ loss or permanent adverse sequelae) requiring pharmacological, radiological, or surgical treatment. It can increase the level of care required, result in hospital admission, or substantially lengthen the hospital stay. All complications other than the major ones are considered minor complications requiring supportive care.

STATISTICAL ANALYSIS

Group comparisons were performed using univariable and multivariable logistic regression analysis to evaluate the risk factors for renal function impairment after RFA. Paired *t* test was used to compare the SCr level and eGFRs evaluated pre-RFA and upon 1-year follow up. Differences in repeatedly recorded SCr levels and eGFRs were evaluated using repeated-measures ANOVA. When the Mauchly's sphericity assumptions were not met ($p < 0.05$), either Greenhouse-Geisser ($\varepsilon < 0.75$) or Huynh-Feldt ($\varepsilon \geq 0.75$) corrections were performed to rectify the ANOVA F statistic for main and interaction effects. All statistical analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). A p value < 0.05 was considered statistical significant.

RESULTS

Residual tumors were detected in 9 of the 91 patients on the first follow-up CT images; hence the technical efficacy rate was 90.1% (82/91). Among the nine tumors, eight additional RFAs were performed successfully for eight; one rejected the additional RFA. Local tumor progression was found in 12 of the 91 patients (local tumor progression rate: 13.2%) at various follow-up intervals within 5 years after RFA procedures. Eight patients with local tumor progression were treated with repeated RFA. Of these, one patient experienced recurrence since the second procedure. The patient underwent subsequent RFA and no sign of recurrence was observed for 12 months since the last RFA. Two patients having local tumor progression refused further treatment. One patient was diagnosed with biopsy proven oncocytoma, and the other showed lung and bone metastases 16 months after RFA and was treated with chemotherapy and radiotherapy.

The overall complication rate in the 108 RFA sessions was 29.6% (32/108). Most of the complications (30/32; 93.8%) were minor, including 24 perinephric or subcapsular hematomas, and 6 mild hydronephrosis due to pyeloureteral injuries. All hematoma cases were managed with supportive care and resolved within 3 months. Two major complications occurred (2/32; 6.3%), which were pyeloureteral injuries that required percutaneous nephrostomy and insertion of a double J ureteral catheter, respectively, and resulted in a ureteropelvic junction stricture (Fig. 1).

Tables 3 and 4 show the variables significantly associated with renal function impairment

Fig. 1. A 67-year-old male with an injury at the ureteropelvic junction.
A. Pre-RFA kidney CT image during the corticomedullary phase shows a 1-cm endophytic renal tumor (arrow) in the medial portion of the right kidney lower pole and in close proximity to the upper ureter (arrowhead). Pre-RFA SCr and eGFR were 0.73 mg/dL and 115 mL/min/1.73 m^2, respectively.
B. CT-guided RFA was done with the patient in the left lateral decubitus position on the CT table. RF electrode (arrow) abuts on the upper ureter (arrowhead).
C. The next-day post-RFA kidney CT image shows complete ablation of the renal tumor (arrow), but enhancing wall thickening of the ureteropelvic junction is newly detected (arrowhead).
D. Four-month post-RFA kidney CT image shows ureteropelvic junction stricture (arrowhead) and hydronephrosis. Abscess pockets and inflammatory thickening (arrow) are detected at the right perinephric space. Post-RFA SCr increased to 1.24 mg/dL and eGFR decreased to 69.2 mL/min/1.73 m^2, respectively.
eGFR = estimated glomerular filtration rates, RFA = radiofrequency ablation, SCr = serum creatinine

upon univariable and multivariable logistic regression analysis. In univariable analysis, age, solitary kidney, CKD stage 3, R.E.N.A.L score, and pyeloureteral injury were found to be significantly associated (p < 0.05). Among these, solitary kidney [odds ratio (OR) = 176.723, p = 0.026], CKD stage 3 (OR = 43.583, p = 0.024), and pyeloureteral injury (OR = 36.848, p = 0.043) remained significantly associated (p < 0.05) upon multivariable analysis. The R.E.N.A.L. score (OR = 5.872, p = 0.071) and age (OR = 1.56, p = 0.086), followed a trend toward significance. Other variables such as sex, other previously diagnosed cancers, tumor size, location, growth

Table 3. Univariable Analysis of Renal Function Impairment (Impaired = Group A, Unimpaired = Group B)

Clinical and Radiologic Features	Group A (*n* = 15)	Group B (*n* = 76)	*p*-Value	OR
Clinical features				
Sex			0.279	1.399
Male	10 (66.6)	50 (65.8)		
Female	5 (33.3)	26 (34.2)		
Mean age, year	70.9	55	0.047	1.140
CKD stage 3	5 (33.3)	2 (2.6)	0.031	25.569
Single kidney	5 (33.3)	4 (5.2)	0.017	25.489
Cancer	3 (20.0)	17 (18.7)	0.409	0.224
HTN	10 (66.6)	51 (67.1)	0.591	0.985
DM	8 (53.3)	44 (57.9)	0.416	1.518
Radiologic features				
Mean size, cm	2.4	2.8	0.828	1.017
Mean ablation diameter, cm	4.7	3.9	0.950	1.004
Laterality			0.633	1.871
Right	8 (53.3)	46 (60.5)		
Left	7 (46.7)	30 (39.5)		
Mean R.E.N.A.L score	8	7	0.042	6.783
Low (score 4–6)	4 (26.7)	26 (34.2)		
Intermediate (score 7–9)	9 (60.0)	43 (56.6)		
High (score 10–12)	2 (13.3)	7 (9.2)		
Postprocedural features				
Pyeloureteral injury	3 (20.0)	5 (6.6)	0.040	10.846
Hematoma	2 (13.3)	21 (27.7)	0.235	0.166
RFA session				
1 session	11 (73.3)	63 (82.9)	0.519	3.252
2 session	3 (20.0)	13 (17.1)	0.601	1.946
3 session	1 (6.7)	0	0.261	1.248

Values in parentheses are percentages unless specified otherwise. Group A: SCr three consecutive increase of more than 0.3 mg/dL compared with pre-RFA SCr. Group B: serum creatinine change of less than 0.3 mg/dL. CKD = chronic kidney diseae, DM = diabetes mellitus, HTN = hypertension, OR = odds ratio, R.E.N.A.L. = Radius, Exophytic/Endophytic properties, Nearness of tumor, Anterior/posterior, Location relative to polar lines, RFA = radiofrequency ablation, SCr = serum creatinine

pattern, nearness to the collecting system, and pathologic types were not positively associated with decreased renal function ($p > 0.1$).

Renal function test results regarding SCr levels and eGFRs at pre-RFA were significantly different from those obtained at the 1-year follow-up. The mean pre-RFA SCr level was 1.11 mg/dL, which significantly increased to 1.57 mg/dL at the 1-year follow-up ($p < 0.0001$) in group A (Table 5). The mean pre-RFA eGFR was 72.2 mL/min/1.73 m^2, which significantly decreased to 43.3 mL/min/1.73 m^2 ($p < 0.0001$) in group A (Table 5). Group B showed insignificant changes in renal function tests before and after RFA (Table 5).

A repeated-measures ANOVA measured at preset times (pre-RFA and post-RFA at 1day, 3 days, 1 week, 1 month, 6 months, and 1 year) was used to evaluate any interaction between

Table 4. Multivariable Analysis of Renal Function Impairment (Impaired = Group A, Unimpaired = Group B)

Clinical and Radiologic Features	Group A (*n* = 15)	Group B (*n* = 76)	*p*-Value	OR
Mean age, year	70.9	55	0.086	1.560
CKD stage 3	5 (33.3)	2 (2.6)	0.024	43.583
Single kidney	5 (33.3)	4 (5.2)	0.026	176.723
Mean R.E.N.A.L score	8	7	0.071	5.872
Low (score 4–6)	4 (26.7)	26 (34.2)		
Intermediate (score 7–9)	9 (60.0)	43 (56.6)		
High (score 10–12)	2 (13.3)	7 (9.2)		
Radius, maximal diameter, cm			0.119	0.004
1, ≤ 4	14 (93.3)	72 (94.7)		
2, > 4 but < 7	1 (6.7)	4 (5.3)		
3, ≥ 7	0	0		
Exophytic/endophytic			0.932	0.918
1, ≥ 50%	4 (26.7)	18 (23.7)		
2, < 50%	3 (20.0)	33 (43.4)		
3, endophytic	8 (53.3)	25 (32.9)		
Nearness of tumor to collecting system, mm			0.796	0.776
1, ≥ 7	5 (33.3)	33 (43.4)		
2, > 4 but < 7	3 (20.0)	14 (18.4)		
3, ≤ 4	7 (46.7)	29 (38.2)		
Anterior/posterior			0.216	3.910
Anterior	6 (40.0)	35 (46.1)		
Posterior	8 (53.3)	33 (43.4)		
Neither	1 (6.7)	8 (10.5)		
Location relative to polar lines			0.231	1.540
1, above or below	4 (26.7)	32 (42.1)		
2, crosses	4 (26.7)	10 (13.2)		
3, between*	7 (46.7)	34 (44.7)		
Pyeloureteral injury	3 (20.0)	5 (6.6)	0.043	36.848

Values in parentheses are percentages unless specified otherwise. Group A: SCr three consecutive increase of more than 0.3 mg/dL compared with pre-RFA SCr. Group B: serum creatinine change of less than 0.3 mg/dL.
*More than 50% of the mass is across the polar line, mass crosses the axial renal midline, or mass is entirely between the polar lines.
CKD = chronic kidney diseae, OR = odds ratio, R.E.N.A.L. = Radius, Exophytic/Endophytic properties, Nearness of tumor, Anterior/posterior, Location relative to polar lines, SCr = serum creatinine

the risk factors (solitary kidney, CKD stage 3, and pyeloureteral injury) and renal function impairment (Fig. 2). Within-patient main effects between the predetermined times were significant for solitary kidney (SCr: F = 9.005, $p < 0.0001$, eGFR: F = 5.573, $p < 0.0001$), CKD stage 3 (SCr: F = 10.031, $p < 0.0001$, eGFR: F = 1.924, $p = 0.046$), and pyeloureteral injury (SCr: F = 4.969, $p < 0.0001$, eGFR: F = 2.533, $p = 0.027$). Thus, SCr and eGFR showed statistically significant changes with the passing of time. Significant within-patient differences in interactions between the risk factors (solitary kidney, CKD stage 3, and pyeloureteral injury) and decreased renal function outcome were detected for solitary kidney (SCr: F = 3.522, $p = 0.004$, eGFR: F = 2.611, $p =$

Table 5. Changes in Renal Function Tests Between Pre- and Post-RFA

Renal Function Tests	Pre RFA	1 Year Follow Up	*p*-Value
Total (*n* = 91)			
Creatinine, mg/dL	0.96 (1.30–1.88)	1.06 (0.60–2.40)	< 0.0001
eGFRs, mL/min/1.73 m^2	82.9 (30.8–128.4)	75.9 (19.8–138.0)	< 0.0001
Group A (*n* = 15)			
Creatinine, mg/dL	1.11 (0.60–1.80)	1.57 (0.94–2.40)	< 0.0001
eGFRs, mL/min/1.73 m^2	72.2 (30.8–117.2)	43.3 (19.8–69.2)	< 0.0001
Group B (*n* = 76)			
Creatinine, mg/dL	0.93 (1.30–1.88)	0.97 (1.20–1.71)	0.161
eGFRs, mL/min/1.73 m^2	85.1 (41.6–128.4)	82.3 (42.0–138.0)	0.235

Parenthesis indicates data range.
eGFRs = estimated glomerular filtration rates, RFA = radiofrequency ablation

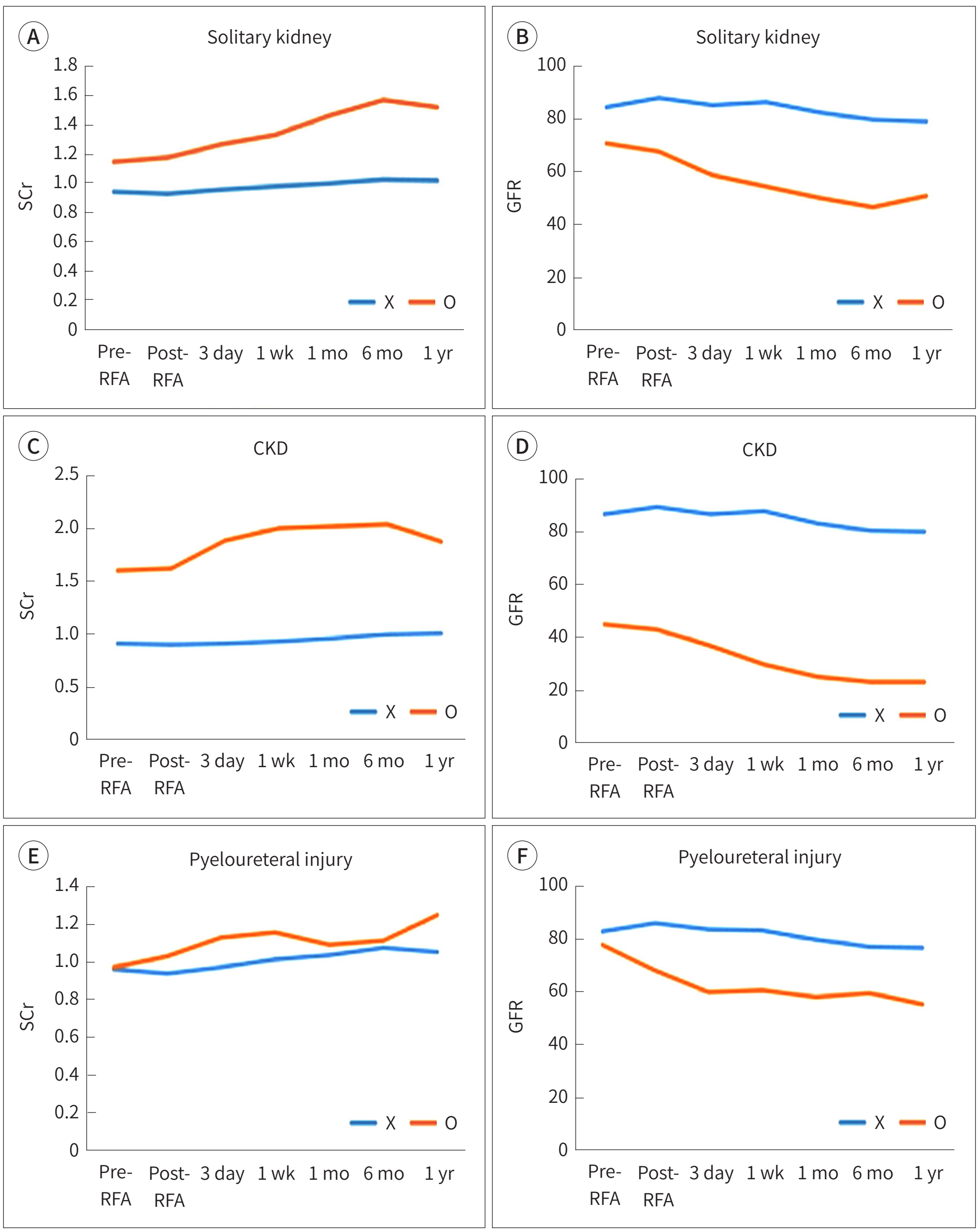
0.023), CKD stage 3 (SCr: F = 6.053, p < 0.0001, eGFR: F = 1.545, p = 0.043), and pyeloureteral injury (SCr: F = 3.376, p = 0.005, eGFR: F = 1.866, p = 0.024). There was a difference in overall change over time between the variables: with- and without solitary kidney, CKD stage 3, and pyeloureteral injury.

DISCUSSION

RFA has emerged as an alternative treatment to partial nephrectomy for patients with small renal tumors (T1a) and can also be performed in larger tumors (T1b) (29-32). RFA has been regarded as having long-term oncologic outcomes comparable to that of partial nephrectomy. Given the comparable and favorable survival outcomes of each treatment, significant measures are often taken for renal function preservation (14). Many studies reported better renal function outcomes after RFA than that after partial nephrectomy among patients with solitary kidney (15, 16). With the exception of patients with solitary kidney, the changes in renal function after performing each of the treatments remain unclear. The European Association of Urology, the National Comprehensive Cancer Network, and the American Urological Association do not have firm suggestion for the treatment of choice based on renal function impact. Many studies evaluated continuous renal function tests, showing no significant differences between RFA and partial nephrectomy (17-21). However, some studies reported that RFA might protect renal function better when compared to partial nephrectomy (11, 22, 23).

In univariable and multivariable logistic regression analysis, renal function impairment was positively associated with solitary kidney, CKD stage 3, and pyeloureteral injury. Better renal function outcome was reported following RFA compared to partial nephrectomy in patients with solitary kidney (15, 16); however, solitary kidney by itself was independently associated with CKD development (33). Among the nine patients with solitary kidney, impaired renal function was reported in five. Two of them had preexisting stage 3 CKD, and the other two had a history of colon cancer surgery at an advanced age (over 70-year-old). Lucas et al. (34) reported a significant decrease in renal function of patients with preoperative CKD stage

Fig. 2. Repeated-measures ANOVA to evaluate the interaction between risk factors and renal function impairment. Visual analog scales for renal function outcomes (SCr and eGFR) are shown for with or without single kidney, CKD, and pyeloureteral injury at various times.
A-F. As time passed, SCr (A, C, E) and eGFR (B, D, F) show statistically significant changes. There was a difference in overall change over time between with and without solitary kidney, CKD stage 3, and pyeloureteral injury.
CKD = chronic kidney disease, eGFR = estimated glomerular filtration rates, mo = month, RFA = radiofrequency ablation, SCr = serum creatinine, wk = week, yr = year



3 who had undergone partial nephrectomy compared to RFA. Wehrenberg-Klee et al. (10) demonstrated that RFA of renal tumors did not affect the renal function of patients with pre-existing CKD over stage 3. However, this study (10) showed that 7 of 48 patients had more than 25% decrease in the eGFRs. In the present study, five of seven patients with pre-existing

CKD stage 3 showed decreased renal function outcome. Among them, four patients' condition worsened from CKD stage 3 to a stage 4 and one patient from CKD stage 3a to stage 3b. Eight hydronephroses were detected on the follow-up CT scans. Three patients showed renal function impairment and the other five patients showed renal function preservation. Radiological interventions were performed in two of them; however, continuous ureteropelvic junction strictures were detected on follow-up CT along with worsened renal function. The two cases had tumors in the medial portion of the kidney and in close proximity to the collecting system. Prior to RFA, the SCr levels and eGFRs of the two patients were 0.73, 0.8 mg/dL and 115, 90.6 mL/min/1.73 m^2, respectively. Post-RFA, the SCr levels increased to 1.24, 1.22 mg/dL and eGFRs decreased to 69.2, 64.8 mL/min/1.73 m^2, respectively; these were measured at 4 months after RFA just prior to the interventional procedure for the ureteropelvic junction stricture. Although the tumor location did not show statistically significant results, the medial portion of the lower pole may be a significant predictor of ureteropelvic junction injury (12, 23, 35). The renal mass arising from the medial portion of the lower pole can be located closer to the ureter; hence the operator should perform an RFA carefully, considering invasive or non-invasive prevention methods such as hydrodissection, levering electrode, preprocedural ureter catheterization, or position change. The other case who had impaired renal function showed continuously mild hydronephrosis on follow-up CT scans. Radiological intervention was not performed. Prior to RFA, the SCr levels and eGFRs was 1.12 mg/dL and 68.1 mL/min/1.73 m^2. The SCr level increased to 1.61 mg/dL and eGFRs decreased to 32 mL/min/1.73 m^2 after a year. Five patients without decreased renal function showed mild caliectasis on follow-up CT scans. There was no need to take further treatment in relation to mild caliectasis.

There were certain limitations to our study. First, this study was conducted using a retrospective method. Hence, selection bias for the study population may be inevitable. Second, the small sample size in this study may lead to a less reliable conclusion. Third, we set the criteria for a significant decrease in renal function as a 0.3 mg/dL increase in SCr level without proven evidence.

Partial nephrectomy may cause significant morbidity and mortality in patients with major comorbidities. RFA may be an alternative in not only poor surgical candidates but also healthy patients unwilling to undergo surgery. Among the medical conditions present prior to RFA, solitary kidney and CKD over stage 3 may be considered as risk factors for impaired renal function. Post-procedural pyeloureteral injury may also be considered a risk factor. High-risk comorbidities may require great care to avoid aggravating remnant renal function.

Author Contributions

Conceptualization, all authors; data curation, P.I.C., K.D.W.; formal analysis, all authors; funding acquistion, Y.S.K.; investigation, P.I.C., K.D.W.; methodology, all authors; project administration, Y.S.K.; resources, P.I.C., K.D.W.; supervision, Y.S.K.; validation, Y.S.K., K.D.W.; visualization, P.I.C., K.D.W.; writing—original draft, all authors; and writing—review & editing, all authors.

Conflicts of Interest

Seong Kuk Yoon has been a Section Editor of the Journal of the Korean Society of Radiology since 2014; however, he was not involved in the peer reviewer selection, evaluation, or decision process of this article. Otherwise, no other potential conflicts of interest relevant to this article were reported.

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신장 종양 고주파 절제술 이후 신장 기능 저하의 위험요소

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목적 본 연구는 신장종양 환자에서 시행한 고주파절제술 이후 신장 기능에 영향을 미치는 다양한 요소들에 대한 평가를 통해서 이들의 상관관계와 임상적 가치를 평가하기 위한 것이다.

대상과 방법 2010년 1월부터 2018년 12월까지 본원에서 ultrasonography, CT 유도하에 고주파절제술을 시행 받은 91명을 대상으로 선정하였다. 신기능을 평가하는 방법으로 시술 직전과 시술 이후 혈청 크레아티닌, 사구체 여과율을 측정하였다. 시술 전과 비교하여 혈청 크레아티닌 수치가 0.3 mg/dL 이상 증가하는 것을 유의미한 것으로 정하고, 이에 근거하여 두 그룹으로 분류하였다. 신장 기능 손상에 영향을 미치는 요소를 평가하기 위해서 다변수 로지스틱 회귀분석을 이용해서 그룹 간에 비교를 시행하였다.

결과 단일 신장, 3단계 이상의 만성 콩팥병, 요관 손상은 신장 기능 손상에서 통계적으로 유의한 의미가 있었다. 성별, 연령, 다른 암, 종양 크기, 위치, 성장 형태, 집합계와의 근접성 등은 통계적으로 유의하지 않았다. 신장 기능 수치의 시간에 따른 변화는 단일 신장, 3단계 이상의 만성 콩팥병, 요관 손상 유무에 따라서 통계적으로 유의하게 달랐다.

결론 고주파절제술 시행 전의 의학적 상태 중 단일 신장, 3단계 이상의 만성 콩팥병, 시술 이후 발생한 합병증 중 요관 손상은 시술 이후 발생하는 신장 기능 손상의 위험요소로 생각할 수 있다.

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