Original Article | Intervention

http://dx.doi.org/10.3348/kjr.2014.15.4.472
pISSN 1229-6929 · eISSN 2005-8330
Korean J Radiol 2014;15(4):472-480

Korean Journal of Radiology
KJR

Safety and Efficacy of Transarterial Nephrectomy as an Alternative to Surgical Nephrectomy

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Objective: To evaluate the safety and efficacy of transarterial nephrectomy, i.e., complete renal artery embolization, as an alternative to surgical nephrectomy.
Materials and Methods: This retrospective study included 11 patients who underwent transarterial nephrectomy due to a high risk of surgical nephrectomy or their refusal to undergo surgery during the period from April 2002 to February 2013. Medical records and radiographic images were reviewed retrospectively to collect information regarding underlying etiologies, clinical presentations and embolization outcomes.
Results: The underlying etiologies for transarterial nephrectomy included recurrent hematuria (chronic transplant rejection [n = 3], arteriovenous malformation or fistula [n = 3], angiomyolipoma [n = 1], or end-stage renal disease [n = 1]), inoperable renal or ureteral injury (n = 2), and ectopic kidney with urinary incontinence (n = 1). The technical success rate was 100%, while clinical success was achieved in eight patients (72.7%). Subsequent surgical nephrectomy was required for three patients due to an incomplete nephrectomy effect (n = 2) or necrotic pyelonephritis (n = 1). Procedure-related complications were post-infarction syndrome in one patient and necrotic pyelonephritis in another patient. Of four patients with follow-up CT, four showed renal atrophy and two showed partial renal enhancement. No patient developed a procedure-related hypertension.
Conclusion: Transarterial nephrectomy may be a safe and effective alternative to surgical nephrectomy in patients with high operative risks.
Index terms: *Kidney; Embolization; Nephrectomy*

Received December 20, 2013; accepted after revision April 12, 2014.
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INTRODUCTION

Renal artery embolization is a minimally invasive procedure which is being increasingly used for the treatment of a wide range of conditions (1-13). The indications for renal artery embolization overlap with those for surgical nephrectomy, although the less invasive nature of the former is a major advantage. Renal artery embolization can be performed partially or completely for the preoperative embolization of renal tumors, management of angiomyolipoma or vascular malformation, palliation of unresectable renal malignancy and the control of renal bleeding (1, 14).

Transarterial nephrectomy, i.e., complete renal artery embolization, has the potential to be used as an alternative to surgical nephrectomy with an expectation of complete infarction and non-function of the embolized kidney (2-8). There have been studies demonstrating transarterial nephrectomy as an alternative to surgery for patients with renal graft intolerance, end-stage kidneys associated with severe hypertension or proteinuria or non-functioning hydronephrotic kidneys (2-5). However, there are only a limited number of reports regarding detailed clinical and/or imaging follow-up data for a variety of clinical indications. Therefore, the purpose of our study was to retrospectively evaluate the safety and efficacy of transarterial nephrectomy as an alternative to surgical nephrectomy in our 11 clinical series of patients.

MATERIALS AND METHODS

Patients

We retrospectively analyzed our database for patients who underwent transarterial nephrectomy from April 2002 to February 2013 and identified a total of 11 patients (seven men and four women; mean age 48.4 years; range 6–73 years). A transarterial nephrectomy was performed in nine cases during the period from April 2009 to February 2013, while it was performed from April 2002 to February 2009 in only in two cases. All of these patients underwent embolization with one or more permanent embolic materials used for the purpose of nephrectomy. We reviewed their medical records and computed tomography (CT) images to gather information regarding underlying etiologies, clinical presentations, coagulation status, baseline renal function (blood urea nitrogen and creatinine) and outcomes after transarterial nephrectomy.

Transarterial Nephrectomy Technique

Transarterial nephrectomy was performed by one of four board-certified radiologists with five to 26 years of clinical experience in the performance of endovascular therapy. The right common femoral artery was routinely accessed and then renal arteriography was performed after selecting the renal artery using a 0.035-inch hydrophilic guide wire (Radifocus®, Terumo, Tokyo, Japan) and a standard 5-Fr catheter (Cobra catheter, Cook, Bloomington, IN, USA). Local anesthesia with lidocaine was used before arterial puncture. For one pediatric patient was (No. 10), chloral hydrate (Pocral®, Hanlim Pharm. Co., Seoul, Korea) used for sedation during the procedure.

The proximal renal artery of the diseased kidney was embolized using various embolic materials such as N-butyl-2-cyanocrylate (NBCA; Histoacryl, B. Braun, Sempach, Switzerland), a microcoil (Tornado or Micronester, Cook, Bloomington, IN, USA), vascular plug (AGA Medical, Golden Valley, MN, USA), gelatin sponge particles (Gelfoam®, Upjohn, Heppenheim, Germany) or their combinations. Embolic materials were selected during the procedure on a case-by-case basis at the discretion of the interventional radiologist. In every case, complete renal arteriography was performed in order to confirm a successful occlusion of the proximal renal artery after embolization.

Definitions of Terms and Study End Points

Technical success was defined as a complete occlusion of the proximal renal artery which was no longer seen to be opacified on the immediate post-embolization angiography. Clinical success was defined as resolution of the patients' presenting symptoms without the need for further interventions or surgical procedures. Complications were classified as major or minor according to the guidelines of the Society of Interventional Radiology Standards of Practice Committee (15). Major complications were defined as follows: those requiring major therapy, an unplanned increase in the level of care or prolonged hospitalization (more than 48 hours), permanent adverse sequelae or death. Minor complications were defined as follows: those requiring no nominal therapy, including overnight admission for observation only.

The procedure outcomes were evaluated by reviewing changes in the patients' clinical status, such as presenting symptoms and their hemodynamic status, the serum creatinine level after transarterial nephrectomy and any procedure-related complications. Also, follow-up CT scans obtained more than four months later, if available, were evaluated in order to assess possible renal atrophy and partial renal enhancement.

RESULTS

The clinical characteristics and outcomes of the 11 patients are summarized in Table 1. Underlying etiologies and the clinical presentation of these patients included chronic transplant rejection with hematuria (n = 3), huge

Table 1. Patient Characteristics and Outcomes in Eleven Patients

No.	Age	Sex	Underlying Etiologies	Clinical Presentation	Angiographic Findings	Embolic Agents	Technical Success	Clinical Success	Complication	Follow-Up Length*	Remarks
1	72	M	Transplanted kidney rejection	Hematuria	Pseudoaneurysm	Coil, NBCA	Yes	Yes	None	45	
2	61	F	AVM with recurrent bleeding	Hematuria	Multiple feeders from proximal RA	NBCA	Yes	Yes	None	694	4-month FU: atrophy, no enhancement on CT
3	73	F	Postoperative ureter injury	Wound discharge	Normal	Coil, NBCA, gelfoam	Yes	Yes	None	797	14-month FU: atrophy, enhancement on CT
4	49	M	Transplanted kidney rejection	Hematuria, pain	No bleeding focus	AVP, NBCA, gelfoam	Yes	Yes	Post-infarction syndrome	826	6-month FU: atrophy, no enhancement on CT
5	63	M	ESRD with refractory bleeding	Hematuria	No bleeding focus	AVP, gelfoam	Yes	Yes	None	30	
6	60	M	Transplanted kidney rejection	Hematuria	Multifocal active bleeding	NBCA	Yes	Yes	None	85	
7	50	M	AVM	No symptom	AVM with single artery and single draining vein	AVP, coil, NBCA	Yes	Yes	None	198	
8	31	F	AML	Hematuria, pain	Multiple pseudo-aneurysms	Coil, NBCA	Yes	No	Necrotic pyelonephritis, ARF	8	SN due to uncontrolled infection following 7 days
9	45	M	Aneurysm with AVF	Hematuria	RA aneurysm with rupture	Coil, NBCA	Yes	No	None	11	SN due to bleeding following 10 days
10	6	F	Ectopic kidney	Urinary incontinence	Ectopic kidney with RA from right CIA	Coil, gelfoam	Yes	No	None	130	SN due to recurrent incontinence following 3 months
11	23	M	Traumatic shattered kidney, AAST grade IV	Hematuria	Multiple parenchymal defect	AVP	Yes	Yes	None	337	12-month FU: atrophy, enhancement on CT

Note.— *Follow-up length (days). AAST = American Association for the Surgery of Trauma, AML = angiomyolipoma, ARF = acute renal failure, AVF = arteriovenous fistula, AVM = arteriovenous malformation, AVP = Amplatzer vascular plug, CIA = common iliac artery, ESRD = end-stage renal disease, FU = follow-up, NBCA = N-butyl-2-cyanoacrylate, RA = renal artery, SN = surgical nephrectomy

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and multiple arteriovenous malformations or fistulas (n = 3), angiomyolipoma with recurrent bleeding (n = 1), inoperable traumatic injury to the kidney and/or ureter (n = 2), end-stage renal disease with uncontrollable renal bleeding (n = 1) and ectopic kidney with urinary incontinence in a pediatric patient (n = 1).

Technical success was achieved in all 11 patients (100%). The proximal renal artery was embolized using embolic

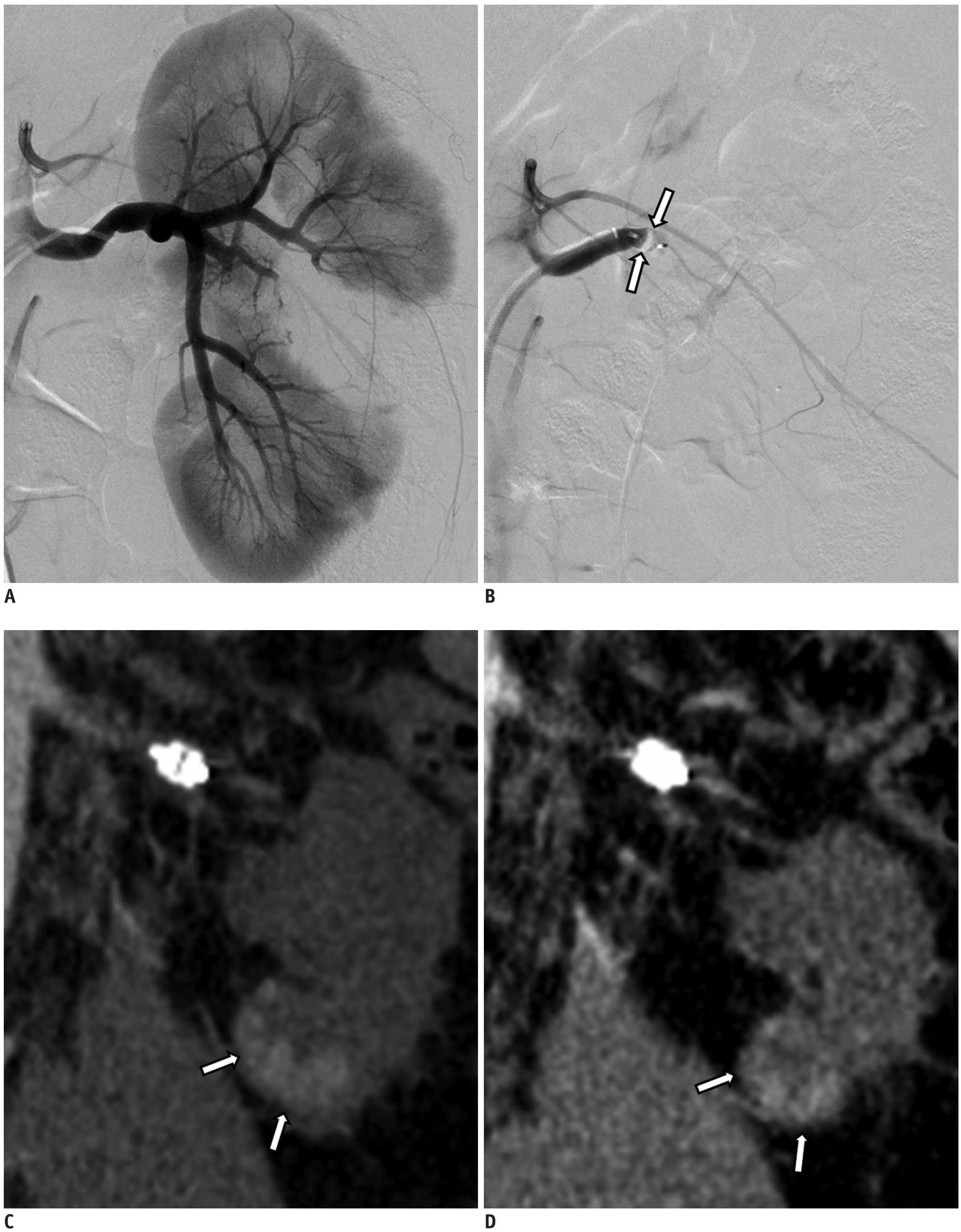

Fig. 1. 23-year-old male patient (No. 11) with hematuria caused by traumatic left kidney rupture.
A. Renal arteriography shows parenchymal defect due to his shattered kidney (AAST grade IV). **B.** Arteriogram obtained after embolization reveals successful occlusion of left renal artery (arrows) using two vascular plugs. **C, D.** Follow-up CT scans obtained four **(C)** and ten **(D)** months following embolization show progressive renal atrophy with residual partial enhancement at lower pole (arrows).

materials such as NBCA, microcoils, vascular plugs, gelfoam pledgets or their combinations. Gelfoam pledgets were used as adjunct embolic materials in four patients. The most commonly used embolic material was NBCA (72.7%, 8/11) as a single agent (n = 2) or with other embolic materials (n = 6). Microcoils and gelfoam pledgets were used with other

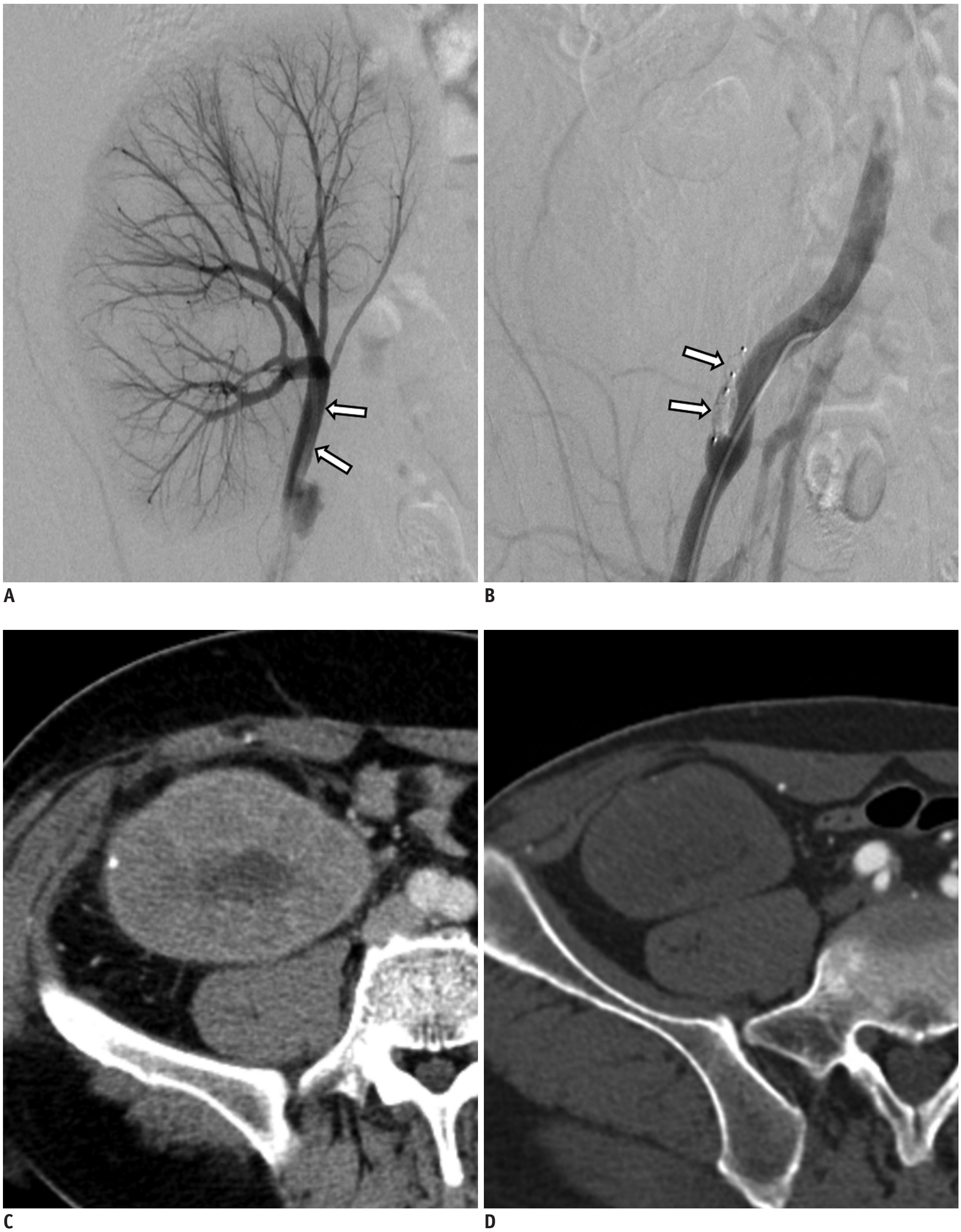

Fig. 2. 49-year-old male patient (No. 4) with chronic transplanted kidney rejection presenting with hematuria and pain.
A. Arteriogram of graft renal artery (arrows) arising from right external iliac artery shows normal angiogram without bleeding focus. **B.** Arteriogram obtained following embolization reveals successful occlusion of graft renal artery using two vascular plugs (arrows), gelfoam pledgets and NBCA. **C, D.** CT scans obtained before **(C)** and six months after **(D)** embolization show decrease in size of graft kidney. There was no residual renal enhancement seen on six-month follow-up CT scan.

materials in six and four patients, respectively. A vascular plug was used as a single agent (n = 1) (Fig. 1) or with other embolic materials (n = 3).

Clinical success was achieved during the mean post-procedure follow-up of 287 days (8–826 days) in eight patients (72.7%). In these patients was hemodynamic stability and resolution of the clinical presentations achieved by transarterial nephrectomy. Subsequent surgical nephrectomy was performed in three other patients (27.3%) due to an incomplete transarterial nephrectomy (n = 2) or necrotic pyelonephritis (n = 1) occurring within three months following transarterial nephrectomy.

One (patient No. 9) of the two patients with incomplete transarterial nephrectomy showed a persistent hypotension with ongoing hypovolemic shock after a technically successful embolization as evaluated by the immediate post-procedural renal arteriography. A follow-up angiography, performed the day after the first embolization showed a persistent flow into arteriovenous fistula and both the right renal artery and vein were additionally embolized using microcoils and NBCA resulting in no residual opacification. One week later, the patient presented with blood pressure drop and flank bulging again. Then, an aneurysmal rupture with bleeding was confirmed during surgical nephrectomy performed 10 days following the initial embolization. The other patient (patient No. 10) with ectopic kidney with urinary incontinence caused by an ectopic ureterovaginal fistula showed a recurrent urinary incontinence one week after the technically successful embolization. This patient underwent a surgical nephrectomy three months following the embolization. One patient (patient No. 8) developed spiking fever and elevation of serum creatinine the day after the embolization. In this case, a necrotic pyelonephritis was proven during surgical nephrectomy seven days following the embolization. Coagulopathy was noted in one patient (patient No. 6) with prolongation of the international normalized ratio (1.66) and an activated partial thromboplastin time (40.3 seconds). However, the patient exhibited both, a technically and clinically successful transarterial nephrectomy. In five patients with normal renal function before transarterial nephrectomy, four showed no significant increase in serum creatinine levels following transarterial nephrectomy, while the remaining patient (patient No. 8) showed an acute renal failure with continuously increasing serum creatinine level after embolization due to unknown cause.

Major complications developed in two patients. One patient (patient No. 4) presented with post-infarction syndrome consisting of fever and leukocytosis lasting for more than 48 hours and progressing to a respiratory failure with systemic inflammatory reaction. However, this patient recovered after conservative treatment. The worsening of his symptoms is presumed to have been secondary to his low immune status caused by the renal graft rejection. The other patient (patient No.8) showed the aforementioned necrotic pyelonephritis and acute renal failure. However, no minor complications were observed in any of the patients.

In three patients (patient No. 2, 3, and 11) (Fig. 1) were their native kidneys being treated and followed with CT for more than four months, and all of them showed a renal atrophy and two showed a partial renal enhancement on the follow-up. Another patient (patient No. 4) (Fig. 2) with a chronically rejected transplanted kidney was being treated and followed with CT for six months and showed a renal atrophy with no residual renal enhancement on the follow-up. None of the patients developed a procedure-related hypertension.

DISCUSSION

Transarterial nephrectomy seems to be a viable alternative to surgical nephrectomy, although surgical nephrectomy remains as the first-line therapy (1, 2, 4-9). Therefore, transarterial nephrectomy could be considered especially in patients with a poor condition for surgery or in patients who refuse a surgery. In addition to the previously reported underlying etiologies of transarterial nephrectomy, such as end-stage renal disease, irreversible transplant rejection, arteriovenous fistula and ectopic kidney with urinary incontinence (1, 4-7, 12, 16, 17), there were also cases of traumatic renal injury [Grade IV by using American Association for the Surgery of Trauma renal injury grading system, AAST (18)] or iatrogenic ureteral injury in our study. Although advances in less invasive surgery, such as laparoscopic surgery, has diminished the indications for transarterial nephrectomy, the decision to choose surgery or transarterial nephrectomy has to be made according to the relative invasiveness of the procedure and the postoperative course (2).

Nevertheless, there could be incomplete embolization and still unsolved clinical problems, although the goal of transarterial nephrectomy is the complete elimination of the blood supply to the kidney and a resolution of related clinical problems. Complete embolization is important in order to lower the risk of hypertension caused by the increased renin production of the ischemic renal parenchyma (19-21). Therefore, a recanalization of the renal artery or collateral circulation could be considered as cause of an incomplete embolization. A recanalization was suspected in one patient with aneurysmal rupture with rebleeding 10 days following the initial embolization as cause of incomplete embolization, because 10 days seemed too short as time to generate collaterals.

Collateral formation is also an important cause of incomplete embolization. Although it was not confirmed in our study, a partial renal enhancement was seen on the follow-up CT scans of at least four months in two patients and a collateral circulation to the embolized kidney was suggested. The remaining renal enhancement corresponded to the remaining renal parenchyma, even though there were no related symptoms seen in our study patients. This suggests that a remnant renal enhancement does not always accompany a clinical failure. An additional embolization could be considered if a remnant renal enhancement is detected together with related clinical symptoms.

In one published report, as many as 62% of the 32 study patients showed collaterals on follow-up angiograms obtained following renal artery embolization for inoperable renal cancer (22). An extrarenal arterial blood supply for renal tumor via gonadal capsular arteries, lumbar arteries and inferior adrenal arteries has been suggested (11, 22-24). Typically, a renal capsular artery may enlarge to carry blood to the renal parenchyma through branches to the periureteric, peripelvic and pericapsular complexes (22-24). It was suggested that an additional angiographic examination at that time would be beneficial as collaterals could develop 6–12 months following embolization (22-24). Although their results cannot be directly applied to our study, the possibility of a collateral arterial supply should be considered in failed cases.

In clinical practice, it is difficult to strictly divide the types of embolization into three categories, such as proximal, peripheral and capillary artery embolization (2). In our 11 cases, transarterial nephrectomy was aimed at the proximal renal artery embolization by using several embolic materials. However, other embolic materials, for example, particulate or liquid embolic materials, could cause a peripheral artery embolization. Although proximal embolization has the risk of collateral circulation and resultant incomplete renal infraction, it has an advantage of avoiding the risk of complete renal necrosis or infarction secondary to capillary embolization (2).

In our study, a renal atrophy was observed in all of the four patients with available follow-up CT scans obtained after more than four months, which is consistent with the study by Ubara et al. (12) reporting the size reduction of kidneys seen for up to two years on the follow-up CT scans. In our study, this size reduction was evident not only in native kidneys, but also in a chronically rejected kidney. Although partial renal enhancement remained in two patients, an overall renal size reduction indicated a sufficient devascularization obtained by renal artery embolization.

A devastating complication in our study was a necrotic pyelonephritis of an infarcted kidney. Although the incidence is low, infectious complications have been reported which can require surgical nephrectomy (4, 16, 25, 26). However, the nephrectomy was relatively bloodless secondary to the previous embolization in this patient. An increased infection risk could also be associated with a compromised immunity and renal calculi which may cause an ascending infection of the embolized tissues from the urinary tract. Although this is the most probable source of infection, those risk factors were not seen in our patients (7, 16, 26). We were unable to determine whether the infection occurred before or as a consequence of the embolization procedure. Regardless of the causes, the need for blood and urine sampling prior to a renal embolization to exclude a preexisting urinary infection as well as the possible need for the prophylactic administration of antibiotics before a nephrectomy may be suggested due to this observation as it was addressed in previous studies also (27, 28).

After transarterial nephrectomy, a post-infarction syndrome may develop which is characterized by flank pain lasting 24 to 48 hours, fever up to 40°C associated with negative urine and blood cultures, elevated white blood count, ileus and transient hypertension (29). This syndrome usually resolves with conservative management, including hydration, pain medication and antipyretics. It is caused by an acute infarction of a large amount of renal parenchyma and can manifest to a lesser degree, if there is less cortical tissue as it is the case in hydronephrotic nonfunctioning or end-stage kidneys (7). In the post-infarction syndrome, symptoms could become worse, if tissue thromboplastins and other chemicals, triggering an inflammation, are suddenly released from the necrotic kidney (30).

Our study has some limitations. First, the number of patients in this series was relatively small. However, the data collection time was approximately 11 years. Second, interventional devices and materials as well as the operators varied and no standardized follow-up protocol was available for all patients, as this study was a retrospective case series for a long study period.

In conclusion, a transarterial nephrectomy may be a safe and effective alternative to surgical nephrectomy for patients in various conditions, especially for those who are candidates in poor condition for a surgery.

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