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Computed tomographic evaluation of experimental hydronephrosis treated with transarterial embolization of renal artery in Beagle dogs

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Abstract : This study was performed to evaluate the embolized kidney and contralateral normal kidney using computed tomography (CT) and enhanced computed tomography. Experimental hydronephrosis was induced by ligation of unilateral ureter in 2 Beagle dogs. Renal artery embolization was performed using selective catheterization in the hydronephrotic kidney of seven dogs and EKG, SpO_2, body temperature, pulse, and respiratory rate were within normal ranges during procedures. Iohexol-ethanol solution was used as embolic material. There were no dogs expired after TAE-RA and no side effects associated with regurgitation of iohexol-ethanol solution. Revascularization of renal artery was not found in angiography in dogs treated by TAE-RA at immediately after TAE-RA and 14 days after TAE-RA. CT showed dilation of urinary collecting system and ventral displacement of spleen at 14 days after TAE-RA in one dog not treated by TAE-RA and experimental group treated by TAE-RA. CT two month after TAE-RA showed the shrunken embolized kidney in experimental group. Transverse CT with contrast enhancement demonstrated the increase of signal intensity at thinned renal cortex in control group not treated by TAE-RA at 30 days and 60 days, however, there was no increase of signal intensity at shrunken embolized kidney at 60 days after TAE-RA. CT was useful modality for evaluation of the morphology and the size of embolized kidney and contralateral normal kidney. Enhanced CT was available for the detection of revascularization of renal artery after TAE-RA in dogs with hydronephrosis. It is concluded that CT is useful modality for the monitoring of the revascularization of the renal artery after TAE-RA.

Key words : dog, hydronephrosis, renal artery embolization, iohexol-ethanol, CT

Introduction

Simple nephrectomy has been routinely performed in patients with nonfunctioning kidneys and recurrent pain, infection or bleeding, however, this procedure is often technically demanding because recurrent infection or inflammation may be encased in dense adherent retroperitoneal tissues, leading to difficult dissection with the potential for serious injury. Patients with a poor general medical condition may also be treated with less invasive therapy, sparing them the additional morbidity associated with an operative procedure. TAE-RA was initially described in an experimental canine model with the intent of developing a therapeutic technique for treating neoplasia. This technique has been developed into an accepted method of treating advanced or unresectable renal cell carcinoma of human with persistent bleeding, pain or manifestations of the paraneoplastic syndrome[1]. TAE-RA has not been limited to oncological applications. It has also been used to infarct end stage kidneys in human patients with severe hypertension or proteinuria, native kidneys in transplant recipients as well as irreversibly rejected allografts and non functioning hydronephrotic kidneys[2].

In human patients, a novel nonsurgical treatment for nonfunctioning hydronephrosis with the sign of proteinuria, hypertension, and flank pain was developed based on TAE-RA with absolute ethanol[3]. Also, post-traumatic renal hypertension secondary to unilateral hydronephrosis was treated with TAE-RA[4]. Generally, renal artery embolization was considered to be a safe and less invasive alternative to surgical nephrectomy in human patients.

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However, in veterinary medicine, TAE-RA has not been performed to treat the nonfunctioning hydronephrosis of dogs nor has been the therapeutic effects of TAE-RA with iohexol-ethanol solution evaluated in dogs with unilateral nonfunctioning hydronephrosis.

The occlusive effects of embolic materials in TAE-RA have been evaluated mostly by follow-up arteriograms clinically as well as experimentally[1,5,6,7]. Also, enhanced CT has been used to evaluate the recanalization of embolized kidney after application of TAE-RA[8]. Although a role for the selective angiograms remains in the evaluation of TAE-RA, ultrasonography and CT scan have emerged as alternative primary screening tools. However, the recanalization after TAE-RA with iohexol-ethanol solution for the treatment of canine unilateral hydronephrosis using enhanced CT has not been performed, yet.

The purposes of this study is to evaluate the recanalization of obstructed renal artery, ipsilateral embolized kidney and contralateral normal kidney using selective angiography and enhanced CT.

Materials and Methods

Experimental animals

Three Beagle dogs, ranging 2 to 4 years old, with body weight ranging from 7 to 10 kg were used. The dogs were housed in indoor cages and diet (Jerony, Che-il Jedang) and water were supplied *ad libitum*. Experimental animals were used without distinction of sex. All experimental procedures were done according to the time schedule (Fig 1).

Experimental unilateral hydronephrosis

Two dogs were anesthetized with 10 mg/kg of ketamine HCl (Ketalar®, Yu-han Yanghang Co. Ltd., Seoul, Korea) by intramuscular injection and maintained with isoflurane (Aerane®, Choongwae medical Co. Ltd., Seoul, Korea).

During surgery, SpO_2 probe was applied to dog's tongue and SpO_2 was monitored and lead II of EKG, rectal temperature were monitored with anesthesia monitoring system (Vet-Ox™ plus 4700, U. S. A). The mid-abdomen was shaved and the animal was fastened to an operating table. The surgical area was scrubbed with povidone-iodine solution then draped in a sterile fashion. Under sterile conditions, a 7 cm midline incision was made around the umbilicus. A segment of the unilateral ureter was located and freed by blunt dissection so as not to damage any of the associated vascular structures. Then, the proximal part of the unilateral ureter was ligated with 2-0 black-silk in two places adjacent to renal pelvis. Carprofen was administered before extubation to all dogs and was repeated at 4 to 6-hour intervals during the next 12 hours. After 17th days after ligation of the unilateral ureter, hydronephrosis was confirmed.

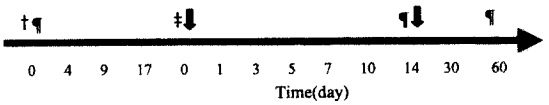

Fig 1. Time schedule of the experiment. † : surgery, ‡ : Renal artery embolization, ¶ : CT, ↓ : angiography.

Selective angiography and renal artery embolization

Dogs were anesthetized with 10 mg/kg of ketamine HCl (Ketalar®, Yu-han Yanghang Co. Ltd., Seoul, Korea) by intramuscular injection and maintained with isoflurane (Aerane®, Choongwae medical Co. Ltd., Seoul, Korea). During procedure, SpO_2 probe was applied to dog's tongue and SpO_2 was monitored and lead II of EKG, rectal temperature were monitored with anesthesia monitoring system (Vet-Ox™ plus 4700, USA). Under aseptic conditions, a stab incision was made on the inguinal region where pulsation was detected and a femoral artery was bluntly isolated. The distal portion of the artery was ligated while tension was applied to the proximal artery with 4-0 silk. The artery between the silk placement sites was punctured and an introducing sheath was introduced into the femoral artery. Then, the catheter (Fas-tracker® 18, length : 150 cm, outer diameter : 2.5F, Target therapeutics Inc., Fremont, CA, USA) and the 'J' shaped guide wire (Seeker®-16 Flexible guide wire, length : 175 cm, diameter : 0.016 inch, Target therapeutics Inc., Fremont, CA, USA) were introduced through the introducing sheath. Under fluoroscopy (Dong-a X-ray R/F TV System, Seoul, Korea), the catheter with guide wire was selectively introduced into ipsilateral artery of hydronephrosis. Iohexol (Optiray® 320, Mallinckrodt Medical, Inc., St. Louis, MO, USA) was used as the contrast agent. One thousand mgI/kg of contrast agent was used as a maximum dosage for selection of renal artery. During procedures, 0.5 m*l* of saline was administered to flush the remnant contrast agent in the catheter after every injection of contrast agent. The arteriogram of the renal artery was recorded with videotape.

Arteriogram being finished, ethanol mixture (iohexol : pure ethanol = 1 : 1) was injected through the catheter in 2 dogs with unilateral hydronephrosis and saline was injected in 1 dog with unilateral hydronephrosis. During renal artery embolization, to avoid the regurgitaion of embolic material into abdominal aorta, slow infusion (approximate 1 ml/min) was made under fluoroscopy. Then, angiogram was acquired immediately after TAE-RA through selected catheter by 2 ml bolus injection of iohexol. After selective angiography and renal artery embolization were performed, the catheter was retrieved and the femoral artery was ligated with 4-0 silk. Selective angiography was performed in experimental group and control group by selective catheterization via femoral artery cut-down at 14 days after TAE-RA. Femoral artery access for follow-up angiography at 14 days after renal artery embolization was accomplished by using proximal part of ligature site in the same artery.

Computed tomography

Two dogs with renal artery embolization after experimental hydronephrosis and one dog with experimental hydronephrosis were examined at before experimental hydronephrosis, 14 days and 60 days after TAE-RA. CT and enhanced CT were performed using Hitachi®, W2000. The dogs were anesthetized with 10 mg/kg of zoletil (Zoletil®, Yu-han Yanghang Co. Ltd., Seoul, Korea) by intramuscular injection and maintained with spontaneous breathing. The dogs were positioned in sternal recumbency. Dorsoventral scout and transverve 5 mm contiguous slices of the mid abdomen were obtained. Scan settings were 120 kV, 175 mA, 35 cm field diameter, and a 512 image matrix.

Water soluble iodinated contrast medium was then administered intravenously as a bolus at a dose of 880 mgI/kg using a manual pressure for 1 minutes. A 11 post contrast images were acquired using same protocol used in unenhanced CT.

The interval between the contrast medium injection and first image acquisition were 20 seconds.

Results

Renal artery embolization

A single ipsilateral renal artery of obstructed kidney was selectively catheterized in 2 dogs and immediate interruption of arterial flow was obtained in all cases.

Iohexol-ethanol solution was infused slowly at an approximate rate of 2.0 ml/kg into the renal artery in 2 dogs. The iohexol-ethanol solution was visualized faintly and distributed at thinned renal cortex under fluoroscopy when it was infused into the artery in all animals. The SpO_2, body temperature, pulse, and respiratory rate remained within the normal range during TAE-RA.

Selective angiography

Two dogs underwent successful complete obstruction of the renal artery, as demonstrated by the absence of blood flow to the embolized kidneys on immediate postoperative angiograms and 14 days after renal artery embolization (Table 1).

Image analysis of computed tomography

Unenhanced CT showed dilated urinary collecting system and ventral displacement of spleen at 30 days after the ligation of unilateral ureter in one dog not treated with TAE-RA and two dogs treated with TAE-RA and unenhanced CT two month after renal ablation showed the shrunken embolized kidney in two dogs (Fig 2). Transverse CT with contrast enhancement demonstrated increase of signal intensity at thinned renal

Table 1. Individual data of dogs treated with TAE-RA. Both angiography and enhanced CT show the ablation of renal artery in two dogs treated with TAE-RA

Animal No.	TAE-RA	Angiography		Enhanced CT	
	Dose of embolic material (ml/kg)	Patency of renal. a		Opacification of hydronephrotic kidney	
		Before TAE-RA	14 days	14 days	2 months
1	6.72	Patent	Occluded	Absent	Absent
2	5.79	Patent	Occluded	Absent	Absent
3	N/A	Patent	Patent	Opacified	Opacified

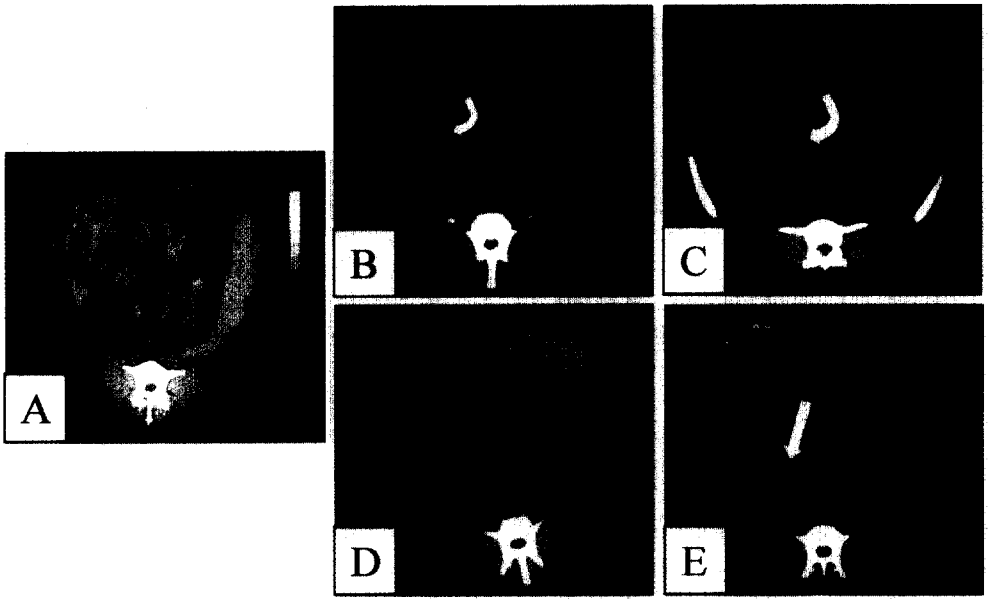

Fig 2. Unenhanced computed tomographic findings of the kidney treated by TAE-RA (A: normal kidney, B: hydronephrotic kidney 14 days after TAE-RA, C: hydronephrotic kidney of 60 days after TAE-RA, D: Embolized kidney 14 days after TAE-RA, E: Embolized kidney 60 days after TAE-RA). CT showed dilated urinary collecting system (curved arrow) compared to normal kidney (black arrow) and displacement of spleen (arrow head). CT 60 days after TAE-RA showed the shrunken embolized kidney (white arrow).

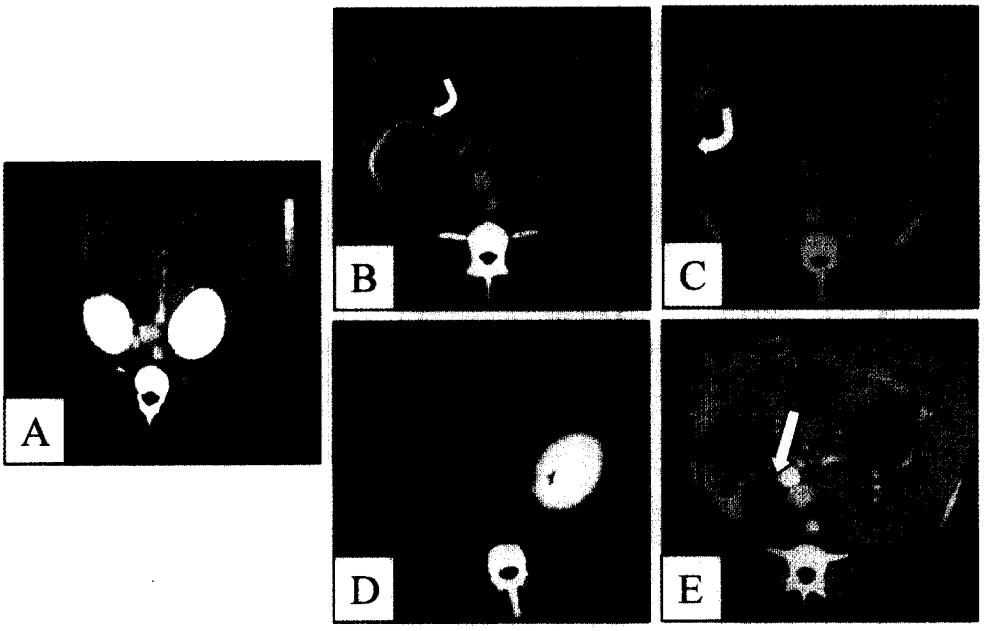

Fig 3. Enhanced computed tomographic findings of the kidney treated by TAE-RA(A: normal kidney, B: hydronephrotic kidney 14 days after TAE-RA, C: hydronephrotic kidney 60 days after TAE-RA, D: Embolized kidney 14 days after TAE-RA, E: Embolized kidney 60 days after TAE-RA). Enhanced CT demonstrated increase of signal intensity at thinned renal cortex (curved arrow). There were no increase of signal intensity at shrunken embolized kidney (white arrow) compared to normal kidney (black arrow).

cortex in one dog not treated with TAE-RA at 30 and 60 days, however, there was no increase of signal intensity at shrunken embolized kidney at 60 days after TAE-RA (Fig 3).

Discussion

The treatment for hydronephrosis includes surgical resection. However, this procedure is quite invasive and requires long periods for recovery after surgery. In veterinary medicine, percutaneous radiologic interventions, such as TAE-RA for the treatment of hydronephrosis have not been performed, yet. However, transarterial embolization of renal artery is accepted in the ablation of diseased kidney in human patients. It includes the Gianturco steel coil, gelfoam, Ivalon particles, polyvinyl alcohol, autologous clot, detachable balloon catheters. Also, there have been many experimental studies done about the embolization of kidneys in dogs with various embolic materials[5,6,7,9,10,11,12]. One of the techniques available for permanent vascular occlusion seems to be the use of the Gianturco stainless steel coil[9,12,13].

The number of reports of interventional treatment for nonfunctioning hydronephrosis is relatively small in human patients. A case of posttraumatic renal hypertension secondary to unilateral hydronephrosis who underwent ablative TAE-RA with Gianturco-Wallace coils presented successful control of renal hypertension over 24 months; however, the fate of the hydronephrosis was not mentioned[4]. Another case of nonfunctioning hydroureteronephrosis who received TAE-RA with 90% ethanol underwent percutaneous nephrectomy resulting in the removal of a total 16 g of renal parenchyma. In this case, the renal volume estimated by ultrasound was reduced from 129.7 m*l* at the time of operation to 17.1 m*l* at 90 days after the procedures[14]. Total ablative treatment for nonfunctioning hydronephrosis combined with TAE-RA and percutaneous sclerotherapy of the renal pelvis and ureter with absolute ethanol has been reported to be safe and less invasive alternative to surgical nephrectomy in human patients[15].

For nonsurgical interventional treatments, a precise follow-up evaluation is needed. Follow-up studies of non-functioning hydronephrosis in human patients treated with TAE-RA using absolute ethanol were performed periodically by enhanced CT and found that marked shrinkage of hydronephrosis without any enhancement of the parenchyma[15]. In case of traumatic renal hypertension secondary to unilateral hydronephrosis in human patients treated TAE-RA using Gianturco-Wallace coil, revascularization were evaluated with abdominal aortogram and selective left renal arteriogram and they demonstrated the total occlusion of the left renal artery distal to the coils[4].

Also, digital subtraction of angiograpy was employed to evaluate the TAE-RA with alcohol for proteinuria in patients with end-stage renal disease[3]. In our study, selective angiography and enhanced CT were performed after TAE-RA for follow-up examination of TAE-RA and observed the obstruction and shrinkage of embolized kidney. However, although enhanced CT and selective angiogram are useful for evaluation of the configuration of the kidney and the revascularization of the embolized kidney, enhanced CT requires general anesthesia and injection of iodinated contrast medium and selective angiogram is an invasive procedure that requires a percutaneous puncture of the femoral artery. Despite this, it seems that because the differentiation of revascularization is not possible in MR scanning, MR will not serve a primary function in the evaluation of TAE-RA after hydronephrosis of dogs. Color Doppler ultrasonography can evaluate the treatment response to nonsurgical interventions for the vascular diseases. In our study, the embolized kidney was evaluated using enhanced CT and no blood flow signals in the embolized kidney in 2 dogs treated by TAE-RA were detected with general anesthesia.

In summary, TAE-RA is a resonable alternative to surgical nephrectomy with satisfactory results in experimental hydronephrosis of dogs. Dogs in poor health that are at increased risk for operative complications are ideal candidates for this minimally invasive procedure. We believe that enhanced CT is useful technique for the follow-up examination of hydronephrosis treated by TAE-RA using iohexol-ethanol solution. Also, CT examination may be suitable for evaluation of revascularization and size change, however, it requires general anesthesia that there is limitation for serial follow up study of TAE-RA.

Conclusion

This study was performed to evaluate the recanalization of obstructed renal artery, ipsilateral embolized kidney and contralateral normal kidney using selective angiography and enhanced CT.

Marked shrinkage of the treated kidney was observed in 2 dogs with unilateral experimental hydronephrosis

treated by TAE-RA with iohexol-ethanol and no adverse effects were observed throughout the observation period.

CT was useful modality for evaluation of the morphology and the size of embolized kidney and contralateral normal kidney. Enhanced CT was available for the detection of revascularization of renal artery after TAE-RA in dogs with hydronephrosis.

We may concluded that TAE-RA with iohexol-ethanol solution is a viable alternative to nephrectomy in dogs with unilateral hydronephrosis and enhanced CT is a useful modality for the monitoring of the revascularization of the renal artery after TAE-RA.

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신장동맥 색전술을 실시한 실험적 수신증의 전산화 단층촬영

장동우 · 윤정희

서울대학교 수의과대학

(2001년 8월 28일 게재승인)

국문초록 : 개에서 실험적으로 편측성 신수종증을 유발한 후, 이오헥솔-에탄올 용액을 신장동맥내로 주입하여 신수종증이 유발된 신장으로의 혈류를 차단하는 신동맥 색전술을 실시하고, 선택적 동맥촬영술, 조영증강 전산화 단층촬영, 이용하여 색전술이 실시된 신수종증의 신장과 반대편 정상신장을 평가하고자 본 실험을 실시하였다. 실험적 수신증은 2두의 비글견의 편측 근위 요관을 이중결찰하여 유발하였으며 개에서 요관 결찰 17일째에 편측성 수신증이 유발되었음을 확인할 수 있었다. 신장동맥 색전술은 2두의 신수종증이 유발된 신장측의 신장동맥에 대퇴동맥을 통하여 선택적으로 카테터를 삽입한 후 이오헥솔-에탄올 용액을 주입하였으며, 시술 중 심전도, 산소포화도, 체온, 맥박, 호흡수는 모두 정상범위에 있었다. 신장동맥 색전술 후 사망한 개체는 없었으며, 색전물질의 유출로 인한 부작용도 관찰할 수 없었다. 색전술 직후 그리고 14일째에 실시한 선택적 동맥촬영술을 통하여 색전술을 시행한 2두의 개의 신장동맥에서 재맥관화가 발생하지 않았음을 확인할 수 있었다. 실험군의 2두와 대조군의 1두에서 실시한 전산화단층촬영상에서는 색전술 실시 후 14일째에 실험군과 대조군의 신장의 신우부가 확장되고 확장된 신장에 의해 비장이 복측으로 변위된 것을 확인할 수 있었으며, 색전술 실시 후 두 달째의 소견에서는 색전된 신장의 크기가 감소한 것을 확인할 수 있었다. 조영제 증강 전산화단층촬영에서는 색전술을 실시하지 않은 신장피질의 신호강도가 증가하는 것을 관찰할 수 있었으나, 색전술을 실시한 신장피질의 신호강도는 증가하지 않았다. 따라서, 조영 증강 전산화 단층촬영은 개의 수신증에 실시한 신장동맥 색전술 후의 신장동맥의 재맥관화를 평가할 수 있는 유용한 검사법으로 사료된다.

핵심어 : 개, 수신증, 신장동맥 색전술, 이오헥솔-에탄올, 전산화단층촬영