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# Transarterial embolization of renal artery in dogs with experimental hydronephrosis

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**Abstract :** This study was performed to validate the procedure of transarterial embolization of the renal artery (TAE-RA) using iohexol-ethanol solution in dogs with unilateral experimental hydronephrosis and to evaluate the embolized kidney using B-mode ultrasonography and selective angiography. Experimental hydronephrosis was induced by ligation of unilateral ureter in 12 dogs. Ultrasonographic findings revealed that size of the kidney was significantly increased at 9 days and 17 days and the length of renal cortex was significantly decreased at 17 days after ligation of the unilateral ureter and it was in accordance with dilation of ipsilateral renal pelvis. No significant change of BUN, creatinine, ALT, calcium, and phosphorus was found immediately after unilateral experimental hydronephrosis. Therefore, it was concluded that unilateral hydronephrosis was established in 12 dogs at 17 days after ligation of ureter. 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. Average ethanol dose for renal artery embolization was 1.94± 1.24 ml/kg. 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. Ultrasonographically, the mean longitudinal length of the embolized kidney decreased significantly at 2 and 3 months after TAE-RA compared to that of contralateral normal kidney. In summary, marked shrinkage of the embolized kidney was observed in dogs with unilateral experimental hydronephrosis treated by TAE-RA with iohexol-ethanol and no adverse effects were observed throughout the observation period. It is concluded that TAE-RA with iohexol-ethanol solution is a viable alternative to nephrectomy in dogs with unilateral hydronephrosis.

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

## Introduction

Nonfunctioning hydronephrosis, even with very thin parenchyma such as a wall of simple renal cysts, expels substantially the urine, and these lesions are progressive and will become symptomatic in the future[1]. Also, in ureteral obstruction of recent onset when tubular function is intact, the renin-angiotensin mechanism may be activated because of an increased sodium reabsorption in the proximal tubule, which eventually produces the hypertension[2].

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[3]. TAE-RA has not been limited to oncological applications.

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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[4]. For the purpose of renal artery occlusion, several embolic materials have been tried clinically as well as experimentally. These include autologous clot, muscle tissue, gelfoam, cyanoacrylate, and stainless steel coils. The embolic effects of autologous blood clot are ranging from 48 to 72 hours. Isobutyl 2-cyanoacrylate (IBC), Gianturco Wallace coil, absolute ethanol and Ivalon showed permanent embolic effects, respectively[5,6,7,8,9,10,11]. Also, iohexol-ethanol solution can be used as a 'visible ethanol' to improve the safety and ease of ethanol embolization[12].

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[13]. Also, post-traumatic renal hypertension secondary to unilateral hydronephrosis was treated with TAE-RA[14]. Generally, renal artery embolization was considered to be a safe and less invasive alternative to surgical nephrectomy in human patients. 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 purposes of this study are to validate the procedure of TAE-RA using iohexol-ethanol solution in dogs with unilateral experimental hydronephrosis.

## Materials and Methods

### Experimental animals

Twelve mongrel dogs, ranging 2 to 4 years old, with body weight ranging from 3 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 (Table 1).

### Experimental unilateral hydronephrosis

Twelve 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

**Table 1.** Individual Characteristics of Dogs

| Animal No. | Body weight (kg) | Sex | Hydronephrosis | TAE-RA* |
|---|---|---|---|---|
| 1 | 3.9 | Female | O | O |
| 2 | 5.4 | Female | O | O |
| 3 | 3.1 | Male | O | O |
| 4 | 4.0 | Male | O | O |
| 5 | 7.5 | Male | O | O |
| 6 | 8.5 | Male | O | O |
| 7 | 9.7 | Female | O | O |
| 8 | 3.0 | Male | O | |
| 9 | 3.0 | Female | O | |
| 10 | 10.0 | Male | O | |
| 11 | 9.0 | Male | O | |
| 12 | 3.6 | Male | O | |
| Average± S. D | 6.0± 2.6 | | | |

* : Transarterial embolization of renal artery
O : The procedure is performed in the dog

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.

**Selective angiography and renal artery embolization**

Dogs with unilateral hydronephrosis 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 7 dogs with unilateral hydronephrosis and saline was injected in 5 dogs with unilateral hydronephrosis. During renal artery embolization, to avoid the regurgitaion of embolic material into abdominal aorta, slow infusion (approximate 1 m*l*/min) was made under fluoroscopy. Then, angiogram was acquired immediately after TAE-RA through selected catheter by 2 m*l* 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.

**Ultrasonography**

Ultrasonograhy was performed using a Toshiba SSA-260A machine with a 7 MHz electronic sector probe at 0, 4, 9 and 17 days after surgery and 0, 1, 3, 5, 10, 30, 60 and 90 days after renal artery embolization. Both kidneys of experimental group (hydronephrosis + TAE-RA) and control group (hydronephrosis) were examined.

After shaving the right and left flank area, coupling gel was applied to the sites and the longitudinal and transverse scans were taken. In B-mode scan, the longitudinal, transverse, and cortical length of kidney were measured with built-in caliper.

**Serum profile**

Blood was collected on 0, 4, 9, 17 days after experimental hydronephrosis and 0, 1, 3, 5, 7, 10, 30, 60, 90 days after renal artery embolization. Serum BUN, creatinine, calcium, phosphorus, and ALT levels were measured using enzymatic methods by automatic blood chemical analyzer (Selectra2, Merck®, Netherland).

**Gross finding**

One dog of each group was euthanized by overdose injection of a pennobarbital sodium (50 mg/kg, Entobar®, Hanlim medical Co. Ltd., Seoul, Korea) at immediately after TAE-RA, 60 days and 90 days after TAE-RA, respectively. Both kidneys were dissected and removed and observed the internal structure of hydronephrosis and kidney treated with TAE-RA.

**Statistical analysis**

Statistical analysis was performed using the SPSS statistical computer program. According to property of

sample, one-way ANOVA and paired t-test were applied to data analysis.

## Results

### Experimental hydronephrosis

Hydronephrosis was found by the sonographic evaluation 4 days after unilateral ureter ligation in all dogs. The size of both kidneys after unilateral proximal ureter ligation in 12 dogs are shown in Fig 1 and 2. There is a statistically significant increase of longitudinal kidney length at 9 days ($p<0.05$) and 17 days ($p<0.005$) after unilateral obstruction and significant increase of transverse kidney length at 9 days ($p<0.05$) and 17 days ($p<0.005$) after unilateral obstruction (one-way ANOVA). The length of renal cortex is significantly decreased at 17 days ($p<0.005$) after unilateral obstruction (Fig 3) (one-way ANOVA). The fasting serum levels for BUN, creatinine, calcium, phosphorus, and ALT level remained within the normal range for 17 days after unilateral obstruction. All of the animals were in good general conditions throughout the study.

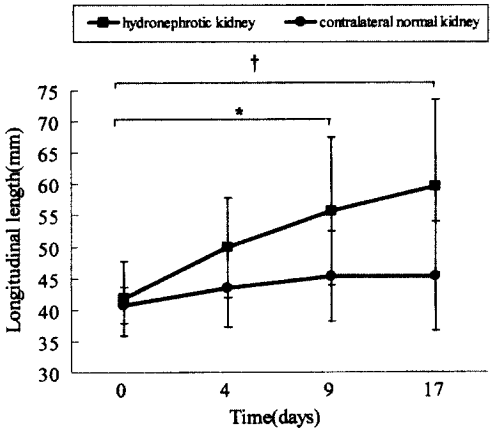


**Fig 1.** Longitudinal length of kidney with unilateral ureteral obstruction. There is a statistically significant increase of longitudinal kidney length 9 days ($p<0.05$) and 17 days ($p<0.005$) after unilateral ureter obstruction(one-way ANOVA).
* : $p<0.05$, † : $p<0.005$

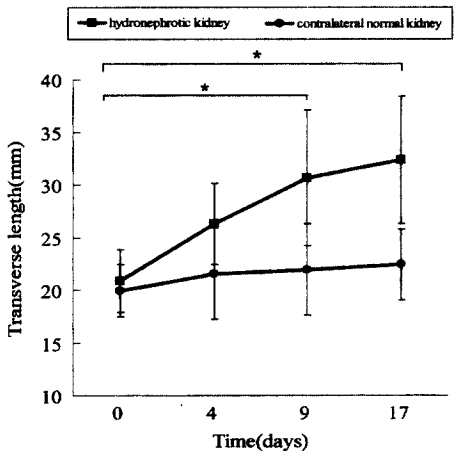


**Fig 2.** Transverse length of kidney with unilateral ureteral obstruction. There is a statistically significant increase of transverse kidney length 9 days ($p<0.005$) and 17 days ($p<0.005$) after unilateral ureter obstruction(one-way ANOVA).
* : $p<0.005$

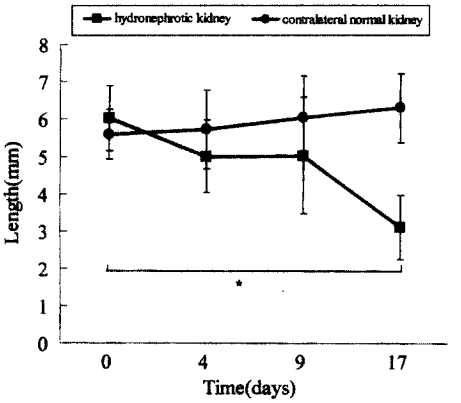


**Fig 3.** Renal cortex length of kidney with unilateral hydronephrosis. The length of renal cortex is significantly decreased 17 days ($p<0.005$) after unilateral ureter obstruction (one-way ANOVA).
* : $p<0.005$

### Renal artery embolization

A single ipsilateral renal artery of obstructed kidney was selectively catheterized in 7 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 7 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 mean dose of iohexol-ethanol solution was 28.3±25.6 ml ranging from 6 to 59.8 ml. The mean dose of absolute ethanol solution per body weight was 1.94± 1.24 ranging from 0.9 to 3.52 ml. The $SpO_2$, body temperature, pulse, and respiratory rate remained within the normal range during TAE-RA. The slight elevation of ALT was observed in 3 dogs at 1 day after renal artery embolization,

**Table 2.** Characteristics of the Dogs with Unilateral Hydronephrosis Treated by TAE-RA

| Animal No. | Body weight (kg) | Related to renal artery embolization | | |
|---|---|---|---|---|
| | | Serum profile** | Dose of iohexol-ethanol solution (ml) | Dose of pure ethanol (ml/kg) |
| 1 | 3.9 | ALT↑* | 7.0 | 0.9 |
| 2 | 5.4 | Normal | 11.0 | 1.0 |
| 3 | 3.1 | Normal | 6.0 | 1.0 |
| 4 | 4.0 | ALT↑* | 7.6 | 1.0 |
| 5 | 7.5 | Normal | 50.4 | 3.1 |
| 6 | 8.5 | ALT↑* | 59.8 | 3.5 |
| 7 | 9.7 | Normal | 56.2 | 2.9 |
| Average ± S. D | 6.0 ± 2.6 | | 28.3 ± 25.6 | 1.9 ± 1.2 |

* : Transiently elevated
** : It is measured 1 day after TAE-RA

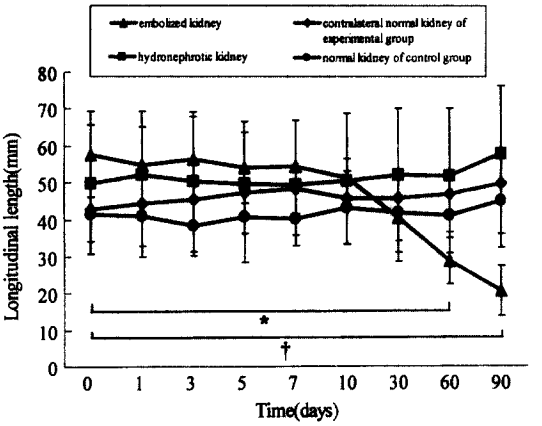


**Fig 4.** Longitudinal length of kidney treated by TAE-RA. The longitudinal length of embolized kidney is significantly decreased after 60 days ($p<0.05$) and 90 days ($p<0.005$) after TAE-RA compared to contralateral normal kidney (one-way ANOVA).
* : $p<0.05$, † : $p<0.005$

however, it was transient and disappeared within 3 days after renal artery embolization (Table 2). The fasting serum levels for BUN, creatinine, calcium, and phosphorus level remained within the normal range for 90 days after TAE-RA. The longitudinal length of embolized kidney was significantly decreased at 60 days (28.7 ± 6.3 mm) compared to that of contralateral normal kidney (46.6 ± 10.0 mm) and at 90 days (20.6 ± 6.8 mm) compared to that of contralateral normal kidney (49.5 ± 13.6 mm) after TAE-RA compared to contralateral normal kidney ($p<0.05$, one-way ANOVA, Fig 4).

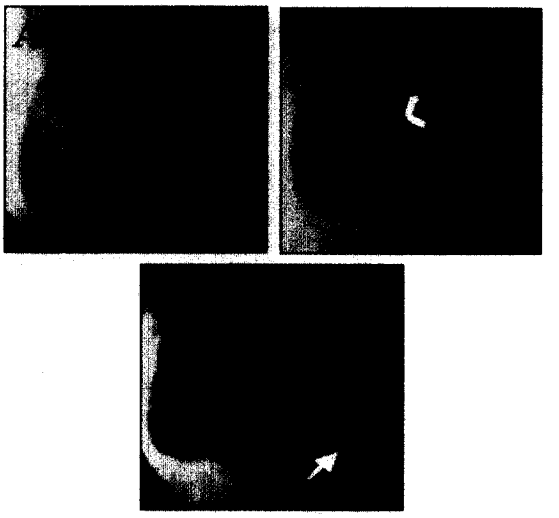

**Fig 5.** Transarterial embolization of renal artery and angiographic findings immediately after TAE-RA. A. The hydronephrotic kidney with thinned renal cortex (black arrow-head) is opacified by the contrast media injected during selective angiogram. There is a radiopaque catheter (black arrow) within the renal artery. B. Iohexol-ethanol solution is injected through selected catheter into renal artery. Iohexol-ethanol solution is visible at the interlobar artery (curved arrow) during injection of embolic material. C. After TAE-RA, contrast agent injected into the renal artery is regurgitated into the abdominal aorta and vertebral artery (white arrow) due to obstruction of the renal artery.

### Selective angiography

All 7 dogs underwent successful complete obstruction of the renal artery, as demonstrated by the absence of blood flow to the embolized kidneys on immediate

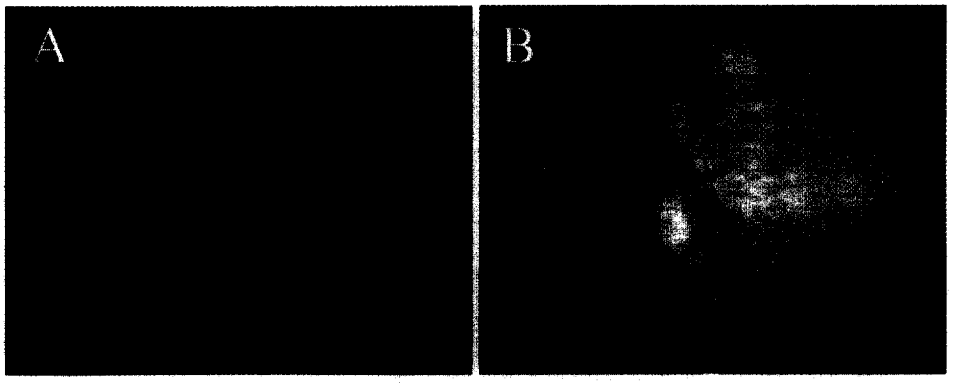


**Fig 6.** Angiographic findings 14 days after TAE-RA. A. After injection of contrast media through selected catheter, ipsilateral renal artery (black arrow) of hydronephrotic kidney not treated by TAE-RA is opacified. Also, the thinned renal cortex (arrow head) is visualized. B. The renal artery (black arrow) treated by TAE-RA is occluded and injected contrast media is regurgitated into the abdominal aorta (arrow head).

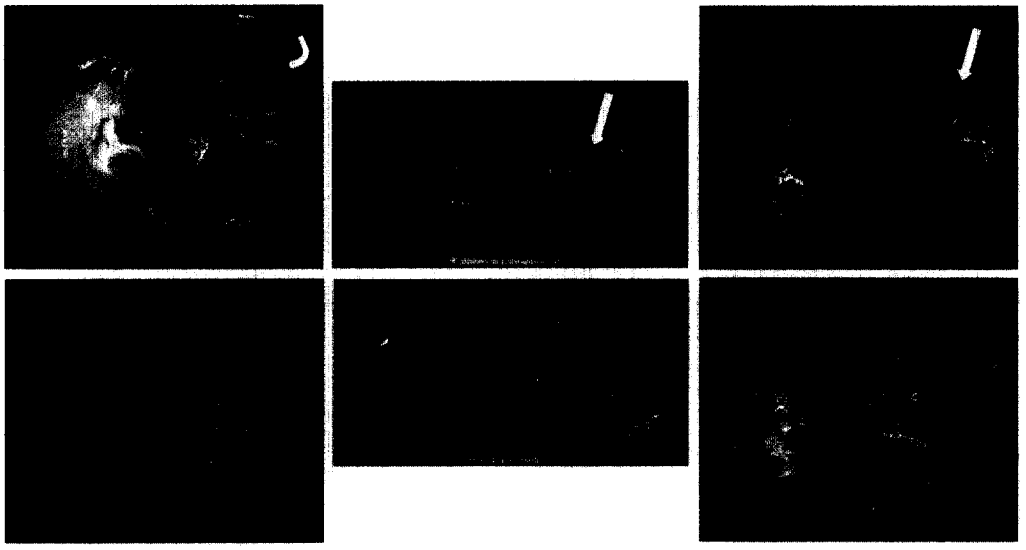

**Fig 7.** Gross findings of the kidney treated by TAE-RA (A: experimental group immediately after TAE-RA, B: experimental group 2 month after TAE-RA, C: experimental group 3 month after TAE-RA, D: control group immediately after TAE-RA, E: control group 2 month after TAE-RA, F: control group 3 month after TAE-RA). Gross findings demonstrated the hemorrhage, edematous changes of renal cortex and dilated urinary collecting system at immediately after TAE-RA of unilateral hydronephrosis (curved arrow). However, two and three month after TAE-RA showed the decrease of kidney size (white arrow) compared to that of control group.

postoperative angiograms (Fig 5) and 14 days after renal artery embolization (Fig 6).

### Gross findings

Gross findings demonstrated hemorrhage, edematous changes of renal cortex and dilated urinary collecting system at immediately after TAE-RA of unilateral hydronephrosis. However, two and three month after TAE-RA showed the decrease of kidney size compared to the control group (Fig 7).

## Discussion

Obstruction of the urinary tract can be defined as a narrowing such that the proximal pressure must be raised to transmit the usual flow through it[15]. If a

narrowing exists in the collecting system and the flow of urine is to be maintained, the collecting system pressure must be increased in order to maintain a given volume of urine through the point of narrowing. Hence, in the acute setting of obstruction there exists elevated intrarenal collecting system pressure. This pressure ultimately can cause ischemia throughout the kidney and can lead to irreversible renal damage[16,17,18,19].

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.

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[5,6,7,8,9,10,11]. One of the techniques available for permanent vascular occlusion seems to be the use of the Gianturco stainless steel coil[6,11,20]. Ekelund *et al.* (1981)[21] used steel coils for therapeutic embolic occlusion of the renal artery in nine human patients with inoperable renal carcinoma, and no complications were seen without any evidence of recanalizaton at follow-up arteriograms. However, they reported the risk of peripheral embolization, pseudoaneurysm formation and drawback of Gianturco coils and therefore, obliteration of the renal artery by ethanol injection was very safe and convenient in experimental model. Miyazono *et al.* (1996)[12] reported that infusion of pure ethanol into the adrenal artery was difficult because of its radiolucency through their initial experience with TAE of aldosteronomas, therefore, iohexol-ethanol solution could be an alternative to pure ethanol in experimental study. In this study, technique of renal artery ablation by iohexol-ethanol solution was very easy to perform in the experimental hydronephrosis of dogs. Reflux into the aorta may be prevented by a slow injection of the solution, and even if small amount of solutions occurs, this would not seem to be harmful. Also, there was a slight elevation of serum ALT levels in 3 dogs after TAE-RA, however it was transient and disappeared three days after TAE-RA.

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[14]. 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[22]. 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[1].

However, the procedure of treatment for hydronephrosis with TAE-RA with Iohexol-ethanol solution has not been reported yet. In this experiment, the dogs with bodyweight ranging from 3 to 10 kg are used and due to its small diameter of the renal artery and the femoral artery, balloon catheter and Gianturco-Wallace coil designed for human use can not be introduced into the femoral artery of dogs. However, a small catheter such as the Fas-tracker® 18 with outer diameter of 2.5F which is designed for interventional procedures of human cerebral diseases can be introducible into the renal artery of dogs. Iohexol-ethanol solution is employed for the treatment of hydronephrosis because it is easy to deliver through small catheters. Also, it is inexpensive, easy to handle, and it provides complete infarction with both cellular death and secondary vascular thrombus without evidence of collateralization, and shows a low risk of complications such as reflux to other organs[21,23].

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. Also, this procedure may be applied to other renal diseases, including renal hemorrhage and renal tumors in order to ablate the affected kidney.

## Conclusion

This study was performed to validate the procedure of TAE-RA using iohexol-ethanol solution in dogs with

unilateral experimental hydronephrosis and to evaluate the recanalization of obstructed renal artery, ipsilateral embolized kidney and contralateral normal kidney using selective angiography.

The mean dose of iohexol-ethanol solution was 28.29 ±25.62 m*l* ranging from 6 m*l* to 59.8 m*l*.

Marked shrinkage of the treated kidney was observed in 7 dogs with unilateral experimental hydronephrosis treated by TAE-RA with iohexol-ethanol and no adverse effects were observed throughout the observation period.

Ultrasonography was useful modality for evaluation of the morphology and the size of embolized kidney and contralateral normal kidney. Selective angiography 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.

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# 개의 실험적 수신증에 실시한 신동맥 색전술

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**국문초록** : 개에서 실험적으로 편측성 신수종증을 유발한 후, 이오헥솔-에탄올 용액을 신장동맥내로 주입하여 신수종증이 유발된 신장으로의 혈류를 차단하는 신동맥 색전술을 확립하고자 본 실험을 실시하였다. 실험적 수신증은 12두의 개의 편측 근위 요관을 이중결찰하여 유발하였다. 편측의 수뇨관을 결찰한 후, 초음파상으로 동측 신장의 장축길이가 유발전에 비하여 9일째($p<0.05$)와, 17일째($p<0.005$)에 유의적으로 증가하였으며, 동측 신장의 피질길이가 17일째에 유의적으로 감소하며, 아울러 확장된 신우내에 액체가 저류하는 것을 관찰할 수 있었다. BUN, creatinine, ALT, calcium, phosphorus는 변화하지 않았다. 이를 통하여 12두의 개에서 요관 결찰 17일째에 편측성 수신증이 유발되었음을 확인할 수 있었다. 신장동맥 색전술은 7두의 신수종증이 유발된 신장측의 신장동맥에 대퇴동맥을 통하여 선택적으로 카테터를 삽입한 후 이오헥솔-에탄올 용액을 주입하였으며, 시술 중 심전도, 산소포화도, 체온, 맥박, 호흡수는 모두 정상범위에 있었다. 주입한 평균 에탄올 용량은 1.94±1.24 ml/kg 였다. 신장동맥 색전술 후 사망한 개체는 없었으며, 색전물질의 유출로 인한 부작용도 관찰할 수 없었다. 색전술 직후 그리고 14일째에 실시한 선택적 동맥촬영술을 통하여 색전술을 시행한 7두의 개의 신장동맥에서 재맥관화가 발생하지 않았음을 확인할 수 있었다. 초음파 검사를 통하여 신장동맥 색전술을 시행한 7두의 개의 색전된 신장은 평균 장축길이가 반대편 정상 신장에 비하여 2달째와 3달째에 유의적으로 감소하였음을 확인할 수 있었다. 이오헥솔-에탄올 용액을 이용하여 실시한 신장동맥 색전술은 개의 수신증을 치료하는 안전하며, 비교적 비침습적인 치료법으로 기존의 신장절제술의 대안이 될 수 있을 것으로 사료된다.

**핵심어** : 개, 수신증, 신장동맥 색전술, 이오헥솔-에탄올