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Effect of anesthetics and diuretics on Doppler measurements of intrarenal resistive index in dogs

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Abstract : Intrarenal resistive index (RI) was determined in normal, sedated and diuretic kidneys. The mean RI values of normal dogs were 0.64±0.03 without statistically significant difference between left and right kidney. Interrenal RI difference (Δ RI) was 0.03±0.01. No significant relationship was found between mean intrarenal RI versus body weight.

The mean intrarenal RI values after administration of acepromazine, xylazine, thiopental, and ketamine were 0.66±0.03, 0.64±0.03, 0.56±0.05, and 0.50±0.05, respectively. After administration of acepromazine or xylazine, a significant change of the RI was not found. But, a significant decrease of the RI following thiopental or ketamine administration could be observed as compared with the normal RI.

The mean intrarenal RI values were 0.63±0.06 and 0.62±0.04 at 10 minutes and 30 minutes after injection of furosemide, respectively. No significant change of intrarenal RI was found after administration of furosemide. But, mannitol significantly decreased mean intrarenal RI to 0.57±0.02 and 0.58±0.03 at 30 minutes and 60 minutes, respectively.

Based on the obtained results, values of 0.72 and 0.05 may be proposed as the reasonable upper limits of RI and Δ RI of normal average. Acepromazine or xylazine are recommended as anesthetics for renal diseases because they have less effect on the RI. Further study using mannitol injection to increase Δ RI may be suggested in unilateral urinary tract obstruction since mannitol more effectively changed mean RI than furosemide.

Key words : resistive index, anesthetics, diuretics, Doppler, dog.

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Introduction

Conventional ultrasonographic evaluation of the kidneys has become a routine procedure in veterinary medicine, because important anatomic information can be obtained without use of ionizing radiation[1]. But, B-mode gray scale sonography lacks the ability to provide significant physiological data. Duplex Doppler sonography has the potential to provide physiological information regarding renal arterial blood flow and resistance[2]. Duplex Doppler evaluation of intrarenal blood flow is commonly performed using the resistive index (RI), an expression of the resistance to intrarenal blood flow.

Motion of the insonated vessel relative to the Doppler sample volume, such as patient motion and excessive respiration may hinder obtaining adequate intrarenal Doppler-flow spectra[3]. Similar difficulties may be more often encountered in dogs than human beings. Sedation can be utilized to avoid these difficulties and expedite obtaining adequate Doppler-flow spectra in such dogs[4].

Anesthetic agents may alter systemic and renal hemodynamics, which may affect intrarenal RI values. Rivers *et al* found that the RI statistically significantly decreased in sedated normal dogs compared with RI values reported for nonsedated, normal dogs[4].

In human patients, Duplex Doppler examination using RI was especially employed in the diagnosis of obstructed uropathy. Hemodynamic changes with acute, complete obstruction have been well demonstrated[2,5]. Three phases of renal blood flow alteration occurring after the onset of obstruction have been described. Diuretic Doppler procedure was reported to be useful in the pediatric kidney and more accurate (95%) in differentiation of obstructed from nonobstructed kidneys[6].

Obstruction of urinary tract is relatively commonly observed in dogs and cats[7]. Nyland *et al* reported that an RI greater than 0.70 was not significantly useful standards of obstruction and comparison of both kidneys did not significantly improve the detection rate for obstruction in dogs[8]. But, several recent studies have reported that diuretic Doppler examination was useful diagnostic method of experimentally-induced unilateral partial obstruction in dogs.

Duplex Doppler sonography using intrarenal RI has been proposed as a reliable technique for assessing possibly obstruction. But, the intrarenal RI was affected by drugs used during examination, such as anesthetics, or diuretics. So, the present study was performed with the purposes of (1) to determine the RI of normal canine kidneys, (2) to assess the effect of anesthetics on the RI, and (3) to determine the RI change following administration of diuretics.

Materials and Methods

Experimental animals and Materials : Sixteen mature, clinically healthy, mixed-breed dogs (weighing 1.8 to 6.5kg) were utilized without distinction of sex for the study of normal intrarenal RI. The animals were normal on the basis of physical examination, urine dip stick test, and real-time B-mode gray scale renal ultrasonography. The dogs were provided with water and food *ad libitum*.

Ultrasound examinations were performed with a Toshiba SSA-260A unit(Toshiba corporation Medical Systems Division, Tokyo, Japan) using 7 MHz electronic sector scanner. The Doppler spectra were recorded on thermal printing paper (UPP-110HD, SONY corporation, Tokyo, Japan) using thermal printer (SONY HD200, SONY corporation, Tokyo, Japan).

Doppler ultrasound technique : Doppler flow spectra was obtained by the usual method recommended in human beings. Anatomic sites of pulsed-Doppler interrogation were interlobar arteries along the borders of the medullary pyramids or arcuate arteries at the corticomedullary junction[10]. These vessels were visualized by color-flow Doppler ultrasonographic imaging. A representative B-mode, color Doppler image with pulsed Doppler flow spectrum is shown in Fig 1. The machine wall filter was set as 50 Hz and the smallest possible frequency range was utilized to maximize Doppler scale.

The RI is defined as follows[9].

$$\frac{\text{peak systolic shift} - \text{end diastolic shift}}{\text{peak systolic shift}}$$

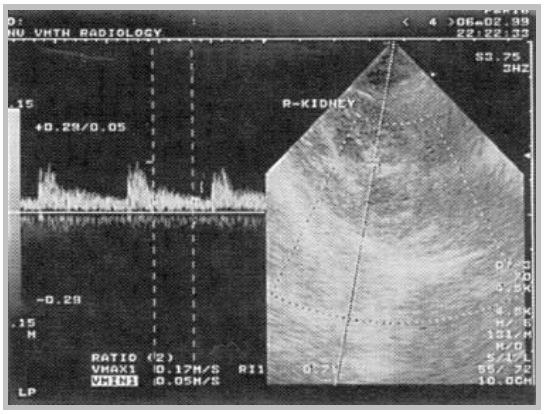

Fig 1. Duplex Doppler image illustrating B-mode sonogram of kidney accompanying Doppler flow spectra.

Peak systolic shift and end diastolic shift were acquired from recorded flow spectra by measurement with internal calipers of the sonography unit. The RI was calculated for each kidney as an average value obtained from three-to-five similar-appearing wave forms from three distinct vessels. Systolic and diastolic shift measurements and resulting RI values were obtained from the flow spectra by measurement with ultrasonographic unit internal calculation software.

Anesthetics : In 8 dogs, acepromazine maleate was given in 0.03ml/kg doses IV, ketamine hydrochloride in 10mg/kg IV, thiopental sodium in 10mg/kg IV, and xylazine hydrochloride in 2mg/kg IM. Withdrawal periods between each medications were over 7 days. After the animals were sedated, the mean intrarenal RI was measured.

Diuretics : The other 8 dogs were subjected to Doppler ultrasonography at 10 and 30 minutes after administration of furosemide (1mg/kg). A period of 7 days was allowed to elapse following an administration of furosemide. Then, mannitol (0.5g/kg) was administered as a 20 percent solution over 10 minutes. Intrarenal RI measurement was performed at 30 and 60 minutes after infusion of mannitol.

Statistical analysis : The ANOVA test was used to analyze the significance of any difference.

Results

Satisfactory Doppler examinations were obtained in 32 kidneys of 16 dogs. The normal intrarenal RI were 0.63±0.04 for the left kidney, 0.64±0.03 for the right kidney. The mean RI of both kidney was 0.64±0.03. A statistically significant difference was not found between the values obtained for the right versus the left kidney (Fig 2). Also, the absolute difference in intrarenal RI between right and left kidney was 0.03±0.01.

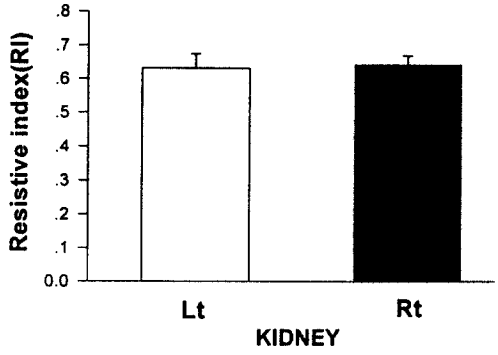

Fig 2. Mean RI value for right and left kidneys in normal dogs.

A scatter plot of the mean intrarenal RI values versus the body weights is shown in Fig 3. No statistically significant relation was found.

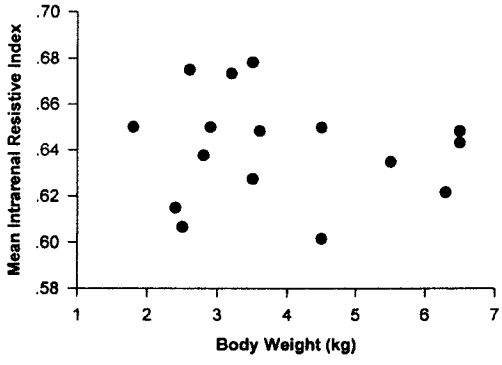

Fig 3. Scatterplot of averaged value of right and left mean resistive index versus respective body weight (kg) for normal dogs.

After administration of acepromazine or xylazine, a significant change of the RI was not found. But, a significant decrease of the RI following thiopental ($p < 0.01$) or ketamine ($p < 0.01$) administration could be observed as compared with the normal RI (Fig 4).

The mean intrarenal RI was 0.63±0.06 and 0.62±0.04

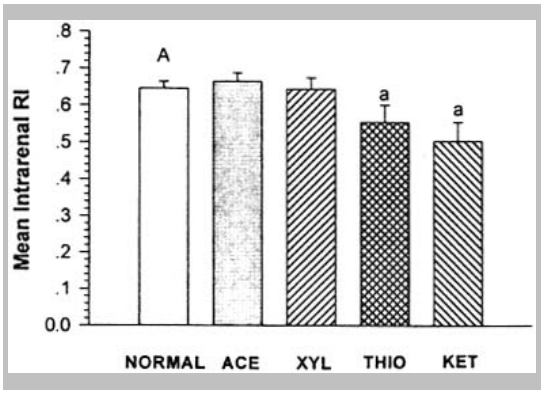

Fig 4. Mean intrarenal RI after administration acepromazine (ACE). xylazine (XYL), thiopental (THIO), ketamine (KET). (Comparison significant are indicated by A : a, $p < 0.01$).

at 10 minutes and 30 minutes after injection of furosemide, respectively (Fig 5). Intravenous administration of furosemide didn't cause any significant change for the mean intrarenal RI.

The mean intrarenal RI was 0.57 ± 0.02 and 0.58 ± 0.03 at 30 minutes and 60 minutes after infusion of mannitol, respectively (Fig 5). Infusion of mannitol significantly decreased the mean intrarenal RI ($p < 0.01$).

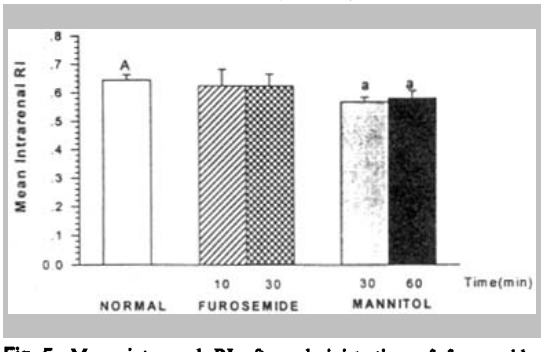

Fig 5. Mean intrarenal RI after administration of furosemide and mannitol. (Comparison significant are indicated by A : a, $p < 0.01$)

Discussion

The principles of Doppler effect is quite simple. Movement of the reflector with respect to the sound source, such as flowing red blood cells, results in a change in frequency at the receiver. These frequency shift was displayed as spectral cyclic waveforms. The frequency shift is affected by velocity of blood flow, transducer frequency, and the angle between vascular flow and the axis of Doppler beam. Resistive index(RI) refers to the resistance of renal blood flow and described with systolic and diastolic blood flow velocity of renal vasculatures. The RI depends on ratios involving the systolic peak velocity and the end diastolic peak velocity. Thus, the angular correction and vessel size cancel each other out and do not need to be known. This is important in evaluating small and tortuous vessels, such as intrarenal arteries[9].

In human beings, duplex Doppler arterial flow spectra for intrarenal blood flow were obtained from arcuate arteries because prior animal renal vascular studies suggest that many pathological processes produce the most marked alterations in resistance to blood flow in the most distal arterial branches within the kidney[10]. A study of 120 subjects found the resistive index at the level of the interlobar-arcuate arteries to be most consistent as compared with the RI at the level of segmental, or interlobar arteries[11].

During Doppler examination, the smallest wall filter setting was employed to detect low flow velocities through small intrarenal vessels. The larger the spectrum, the smaller will be the relative error produced by any error when positioning cursors or calipers. To maximize Doppler scale, smallest possible frequency range that does not produce aliasing was used[10].

Color Doppler extracts velocity information from the returning echoes and adds the information to the conventional gray-scale image as color information. Thus, color Doppler make it easy to interrogate of arcuate or interlobar arteries, which are not actually seen with conventional gray scale ultrasonography[9].

Patient motion and excessive respiration may hinder obtaining technically satisfactory Doppler flow spectra in dogs as well as human beings[3,12]. Anesthetics may alter systemic and renal hemodynamics. Acepromazine may cause a decrease in systemic vascular resistance and blood pressure[13]. Ketamine produces an increase in heart rate, cardiac output, and arterial pressure. Invasive study on the renal hemodynamics showed that renal resistance was not significantly altered by 10mg/kg of thiopental, but significantly increased

by 5mg/kg of ketamine[14]. Intramuscular injection of xylazine did not increase vascular resistance as compared with intravenous injection[13]. Rivers *et al* reported that intrarenal RI values of sedated dogs by clinically routine protocol (combination of atropine, acepromazine, diazepam and ketamine) were significantly lower than values of normal[4]. When used in such combination, the cardiovascular responses generally reflect the pharmacological actions of ketamine[12].

In the present study, acepromazine and xylazine did not cause significant change on the intrarenal RI because acepromazine may have less affection on the cardiovascular system except bradycardia and xylazine was injected intramuscularly. Intrarenal RI after administration of ketamine was statistically significantly decreased. In human beings, Mostbeck *et al*[15] found a statistically significant inverse relationship between the intrarenal RI and heart rate[15]. Therefore, this result may be caused by increase of heart rate after administration of ketamine. Although heart rates was not monitored during Doppler examination, subjective increase of heart rate was prominent after administration of ketamine.

Conventional ultrasound provides anatomic information regarding obstruction, primarily a dilated collecting system. In some cases it may show the level and cause of obstruction. Traditional ultrasound does not, however, provide physiological or functional data regarding obstruction. Recently, numerous investigations have attempted to address these limitations with the addition of duplex Doppler ultrasound.

In human beings, Doppler assessment of increased intrarenal resistance may be an accurate marker for significant obstruction. To identify an elevated RI, different criteria have been suggested. These include elevation above threshold value (0.70 in human and 0.73 in dogs), a right-to-left interrenal RI difference greater than 0.06 to 0.10 (with unilateral obstruction), and abnormal RI response to a diuretic challenge[7,16~20]. The latter two criteria appear most helpful in the pediatric age group, in equivocal partial obstruction, and in patients with underlying renal medical disease[2,5,10,21~23]. Because abnormal renal Doppler suggests clinically significant mechanical obstruction (e.g. ureteral calculus), Doppler examination of intrarenal RI was useful in distinction between obstructive and nonobstructive pyelocaliectasis[2,22,23].

Many studies noted that infusion of furosemide and normal saline caused a further significant increase of the RI in the obstructed kidney and a further significant decrease of the RI in the nonobstructed kidney resulting in increase of delta RI[18]. However, furosemide only did not cause alteration of intrarenal RI[24]. Similarly, intrarenal RI in the present study was not affected after injection of furosemide. However, mannitol only caused statistically significant decrease of intrarenal RI. Therefore, mannitol may be expected to cause more increase of interrenal difference rather than furosemide.

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