Quantitative Measurement of Canine Renal Arterial Blood Flow Using Doppler Ultrasonography

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ABSTRACT. The aim of this study was to estimate the accuracy of the quantitative measurement of renal blood flow using the non-invasive method, Doppler ultrasonography. First, we determined a method of approach to the renal artery in order to detect the rate and pattern of flow, using 8 adult beagles under general anesthesia. Secondly, we examined the renal arterial blood flow using the Doppler method and electromagnetic flowmeter using 7 mongrel dogs. A significant correlation (r=0.879; p<0.01) was found between two methods, though the Doppler system tended to indicate high values than the electromagnetic flowmeter. Our study suggests that the Doppler method is a useful non-invasive technique of measuring renal blood flow in the dog.---KEY words: canine, Doppler ultrasonography, renal blood flow.


Renal blood flow is closely linked to physiological and pathological changes in the kidney. Therefore it is important to examine the blood flow under various conditions. Current methods used to estimate kidney function include clearance and radioisotope methods as well as electromagnetic flowmeter (EMF) and angiography. These methods, however, have many problems in clinical use, because these are very complex and invasive [1, 3, 7, 14]. Recently, trials have been made to measure renal blood flow using ultrasonography and echo-enhancing contrast media. However, suitable contrast media has not yet been developed and still involves the injection of contrast media into the aorta by catheter and the estimation of flow is limited to the renal cortex [2, 8]. The increasing accuracy and wide spread use of color Doppler ultrasonography allows the qualitative and quantitative measurement of blood flow in abdominal vessels [15, 16]. Cardiac output can also be accurately determined [5, 6]. In veterinary medicine, renal hemodynamic evaluation using Doppler ultrasonography was reported in kidney transplanted dogs and dogs with hydronephrosis [17, 27]. However, very few studies have been done in both humans and dogs to quantitatively measure renal blood flow [4, 9, 11, 19].

The purpose of this study was therefore to estimate the accuracy of quantitative measurement of canine renal arterial blood flow using Doppler ultrasonography in comparison to direct measurement with the EMF method.

Approach to the renal artery: Eight clinically normal beagles were used to establish a suitable method of approaching the renal artery.

After induction of the general anesthesia with 0.03 mg/kg atropine sulfate (i.m.) and 0.03 mg/kg flunisolide-pam (i.v.) and thymal sodium (i.v.), and anesthesia was maintained with a mask under halothane. The ultrasonographic equipment used was HITACHI EUB-565A (Hitachi Med. Co., Tokyo) with either a 7.5 MHz electronic linear probe (EUP-L33S, Hitachi Med. Co.) or 5.0 MHz electronic convex probe (EUP-C324, Hitachi Med. Co.).

The dogs were placed in dorsal recumbency to visualize the celiac and cranial mesenteric arteries as they branched from the abdominal aorta by scanning left paramidal.

Longitudinal, transverse and coronal sections were used. The identification of the renal artery was confirmed by following the suspected vessel into the kidney. Additionally, visualization of the renal artery was done by accompanying color Doppler ultrasonography. The detection of the blood flow by pulsed Doppler ultrasonography, was done with the sample volume 1 mm in length placed in the renal artery.

Simultaneous measurement of the renal blood flow by pulsed Doppler ultrasonography and the EMF method: Seven clinically normal adult mongrel dogs with a confirmed single left main renal artery were used. After induction of the general anesthesia, they were endotracheally intubated and then breathing movements arrested using 0.05 mg/kg vecuronium bromide (i.v.). The dogs were then mechanically ventilated by a ventilator (KV-2N, Kimuraikakiki Co., Ltd., Tokyo). The left main renal artery was exposed through a midline abdominal incision. The EMF (MEV-5200, Nihon Koden Co., Ltd., Tokyo) probe (FB Type, Nihon Koden Co., Ltd.) was placed around the exposed renal artery. After placing the EMF probe, a 6.5 MHz transvagal convex probe (EUP-V33, Hitachi Med. Co.) was fixed at the point where the renal artery could be visualized continuously. This point was derived from the transverse section in the previous study. The measurements were performed after 30 min, when the hemodynamic state of the dogs became stable.

The blood flow rate was increased using dopamin (5 mg/kg/min, i.v.) and decreased by using propranolol (0.3 mg/kg/min, i.v.). The measurements of blood flow by both methods were done simultaneously at the end of the inspiratory phase. The diameter of the renal artery was measured in systole by B-mode echo plane and the measurement by pulsed Doppler ultrasonography was done at that point, after which the measurement by EMF was performed and the values were recorded. The renal artery was treated as a circular structure and the area calculated using the formula for calculating the area of a circle. Next, the calculation was made by multiplying the area obtained by B-mode ultrasonography by the integral value of one blood flow velocity pattern [29]. In the pulsed Doppler ultrasonography, the angle between the Doppler
beam and the vessel was corrected. The sample point size was 1 mm in length. Simple regression was used for statistical analysis. The compatibility of the regression was examined with the analysis of variance. A difference was considered statistically significant when the p-value was below 0.01.

**Approach to the renal artery**

*Longitudinal section (Fig. 1):* In all cases, we were able to visualize the celiac and cranial mesenteric artery branching from the abdominal aorta, by scanning left paramedial. In this section, it was difficult to depict the renal artery itself, but these vessels became good landmarks for finding it.

*Transverse section (Fig. 2):* Both renal arteries were made visible by scanning from the branching point of the cranial mesenteric artery in caudal direction.

*Coronal section (Fig. 3):* By scanning from coronal direction at the level of the renal artery in transverse section, the renal artery, branching from the abdominal aorta toward the probe, was visible. In lateral recumbency, the coronal section visualized the vessel well. Combined with the color Doppler method, the rate of visualization and identification of the renal artery, in transverse or coronal section, was 8/8 and 7/8 on the left, and was 7/8 and 7/8 on the right side, respectively.

*Pulsed Doppler findings (Fig. 4):* On transverse and coronal sections, the blood flow was clearly detected in all cases. The renal arterial flow pattern detected composed of a fast systolic flow followed by a gradually slowing diastolic flow to end diastole.

*Simultaneous measurement of the renal blood flow by pulsed Doppler ultrasonography and the EMF method*

Measurement of the renal blood flow under various hemodynamic states, were performed at 227 points with 7 dogs. Between the two methods, a significant correlation was recognized (Fig. 5). The compatibility of the regression was statistically significant at p<0.01.

The increasing number of renal transplants in humans led to the need of an easy, non-invasive method of studying possible complications [20–23]. Some estimation of renal blood flow by the Doppler system have been done [4, 9, 11, 19]. However some problems still remain like the difficulty in the approach to the main renal artery, the large angle of the Doppler beam against the renal artery, and the difficulty in flow estimation where there is more
than one renal artery. The intrarenal vessels, especially
the peripheral vessels can be easily visualized using the
color Doppler method. Their hemodynamics reflect renal
function. The correlation between the velocity of blood
flow in segmental and interlobar arteries and the value of
creatinine clearance, and the correlation of pulsatility
index and resistance index, have been examined in various
renal diseases [13, 18, 25, 26, 28]. It is however, important
to measure not only the intrarenal hemodynamics but also
to estimate the total renal blood flow volume in order to
determine the synthetical function of the kidney.

Suitable approach to the renal artery: Though each
section yielded significant information, some advantages
and disadvantages were recognized. The longitudinal
section had an advantage in that we could visualize the
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celiac and cranial mesenteric artery which were then
anatomical landmarks in the visualization of the renal
artery. It was difficult to depict the renal artery itself. On
transverse sections, both renal arteries were easy to
visualize and identify by following them into the kidney.
In humans, this section is mainly used to depict the renal
artery [23]. However, it was recognized that this section
had an disadvantage in that a large Doppler beam angle
against the renal artery induced an error of measurement
in both humans and dogs. The coronal section tended to
be visualized less clearly than the transverse section, so
that accurate measurement of vessel diameter was diffi-
cult. This section visualized the renal artery in both
dorsal and lateral recumbency, and had an advantage in
that it established a smaller Doppler beam angle. The
error of measurement induced by the beam angle, was
therefore minimal. The measurement of the renal blood
flow was possible by combining the longitudinal, coronal
and transverse section.

Simultaneous measurement of the renal blood flow by
pulsed Doppler ultrasonography and the EMF method:
Reid et al. reported a good correlation between the pulsed
Doppler ultrasonography and EMF measurement of renal
blood flow in the canine model using only one dog [19].
Comparative studies between the Doppler method and
EMF measurement in the cranial mesenteric and carotid
artery have been reported in the dog and human [16]. In
these reports, the change of blood flow with the cardiac
cycle was observed by recording the Doppler spectrum
and the change of vessel diameter by M-mode ultrasono-
graphy. The value of the flow volume measured by
EMF/the flow volume measured by Doppler \(Q_{\text{EMF}}/Q_{\text{DOPPLER}}\) was 0.50 in systole, 0.67 in diastole, and 0.62 in
time average of the cardiac cycle. In our study, the value
of \(Q_{\text{EMF}}/Q_{\text{DOPPLER}}\) was 0.53. This was almost the same
result as the one obtained by Nakamura et al. (0.50) in
systole [16]. In humans, pulsatile changes in the cross-sectional area of the ascending aorta and superior mesenteric artery, were 11% and 13%, respectively [10, 16]. This indicates the necessity of the accurate measurement of the diameter using the time average diameter and not the instant diameter obtained by B-mode. In measurement of cardiac output, the time average diameter in systole is used, because most blood is ejected in systole [5, 6]. The normal renal artery has continuous flow throughout the entire cardiac cycle, similar to that seen in the inferior carotid artery, as a result of the low vascular resistance in the kidney [12].

The major problem in this work was the difficulty in the transsurface approach because the EMF probe disturbed the echo beam and also manipulation of the echo probe caused a change in the position of the EMF probe which occasionally led to compression of the renal artery. Therefore, in this experiment, we used intraabdominal measurement which made the method not really noninvasive but produced comparatively better results. This study shows the possibility that the Doppler method could in future become a useful non-invasive technique for the quantitative evaluation of renal arterial blood flow in the dog.

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