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● *Technical Note*

MEAL INGESTION AND HEMODYNAMIC INTERACTIONS REGARDING RENAL BLOOD FLOW ON DUPLEX SONOGRAPHY: POTENTIAL DIAGNOSTIC IMPLICATIONS

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Abstract—Splanchnic blood flow changes dramatically after meal ingestion. The present study evaluated physiologic interactions between meal ingestion and hemodynamics with respect to renal blood flow on duplex sonography, assessing the possible influence on Doppler parameters used as diagnostic criteria for renal artery stenosis. Subjects comprised 26 healthy young men (mean age: 22 ± 2 y). Sonographic measurements were made shortly after breakfast and every 1 h thereafter and were compared with values measured before the meal. Peak systolic velocity in the renal artery was elevated post-prandially, peaking at 1 h (90 ± 12 cm/s), compared with pre-prandially (73 ± 10 cm/s, $p < 0.01$). Similarly, acceleration time at the intra-renal segmental artery shortened to a minimum at 1 h (45 ± 5 ms) compared with baseline (51 ± 6 ms, $p < 0.01$). The present study indicates that renal blood flow is altered for a few hours after meal ingestion. Attention should be paid to the interpretation of data measured after meals on duplex sonography for diagnosis of renal artery stenosis. (E-mail: kishino@ks.kyorin-u.ac.jp)

Key Words: **Duplex sonography, Hemodynamics, Meal ingestion, Renal artery stenosis, Renal blood flow.**

INTRODUCTION

Splanchnic blood flow is dynamically changed by meal ingestion (Dauzat et al. 1994; Perney et al. 2001; Sabbá et al. 1991; Taourel et al. 1998), along with an increase in cardiac output (Iwao et al. 1998; Waaler and Eriksen 1992). The superior mesenteric artery (SMA) undergoes dilation, leading to an increase in mesenteric blood flow that benefits digestion. To make up for this, the renal arteries contract after a meal, as reported in previous studies using duplex Doppler sonography (Iwao et al. 1998; Perney et al. 2001). Examinations for renal blood flow are often performed with no limitations on meal ingestion in the actual clinical setting, although it is recommended that ordinary abdominal sonography be performed in the fasting state. This is because sonographic images are likely to be disturbed by gastrointestinal gas after meal ingestion, but the Doppler parameters for renal blood flow can be obtained relatively easily even after meal ingestion. However, renal blood flow measurements are used as one of the diagnostic criteria for renal artery stenosis (RAS), which is a major cause of renovascular hypertension (Baumgartner and Lerman 2011; Granata et al. 2009; Hoffmann et al. 1991; Lee and Grant 2002; Rundback et al. 2002; Zeller et al. 2008; Zubarev 2001). Diagnosis of RAS might therefore be influenced by the timing of measurement after meal ingestion, assuming that renal blood flow is altered post-prandially. The present study investigated physiologic interactions between meal ingestion and hemodynamics with respect to renal blood flow on duplex Doppler sonography in healthy subjects, assessing the possible influence on sonographic criteria on the diagnosis of RAS.

METHODS

Subjects

The study population comprised 26 healthy young men (mean age ± standard deviation: 22 ± 2 y).

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Subjects had no history of cardiovascular disease, gastroenterological disease and abdominal surgery, and were not currently using any medications. Absence of hypertension was confirmed by measuring blood pressures before enrollment into the study. Written informed consent for inclusion in the study was obtained from each subject. All study protocols described below were approved by the ethics committee at our institution. All procedures were performed in accordance with the ethical standards formulated in the Declaration of Helsinki and its revisions.

Measurements of sonographic parameters used as diagnostic criteria for RAS

Examinations were performed using a UF-870AG ultrasound system (Fukuda Denshi, Tokyo, Japan) with a 2- to 5-MHz convex-array transducer. Absence of morphologic abnormalities was confirmed in the renal arteries or kidneys bilaterally on sonography before measurements in all subjects. Blood flow turbulence indicative of the presence of RAS was likewise not observed on color-coded duplex sonography. Hemodynamic measurements were thus obtained only from the right renal artery and kidney. Examinations were performed using the same sonographic machine in all subjects. Subjects were asked to breathe normally and then to hold their breath after non-forced expiration during the examination. For these measurements, a 6-mm spectral Doppler gate was placed at the center of the sampled arterial lumen of the renal artery or the intra-renal segmental artery described below. Doppler signals were always obtained at an angle $\leq 60^{\circ}$ using Doppler angle correction to obtain reliable velocity measurements. A combination of representative diagnostic criteria for RAS on sonography is shown in Table 1 (Baumgartner and Lerman 2011; Granata et al. 2009; Hoffmann et al. 1991; Lee and Grant 2002; Rundback et al. 2002; Zeller et al. 2008; Zubarev 2001). First, Doppler waveforms were obtained from the right renal artery and aorta. In the right renal artery, the Doppler gate was set at a proximal to middle site of the vessel as close to the proximal side as possible, as long as the optimal Doppler angle could be obtained. Peak systolic velocity (PSV) was measured, and renal/aortic ratio (RAR, defined as PSV of the right renal artery divided by PSV of the aorta) was calculated, as both are direct criteria for the diagnosis of RAS. Next, the Doppler waveform was obtained in the intra-renal segmental artery to evaluate indirect criteria for the diagnosis of RAS. Resistive index (RI) was calculated from PSV and end-diastolic velocity (EDV), using the equation (PSV − EDV)/PSV. Acceleration (Acc) and acceleration time (AT) were also measured. Presence or absence of early systolic peak (ESP) was evaluated in the Doppler waveform. Although only absence of ESP is required for diagnosis, height of the ESP was actually measured in this study.

Table 1. Combination of representative diagnostic criteria for renal artery stenosis on duplex Doppler sonography

Direct criteria (renal arteries)
Peak systolic velocity >180 (or 200) cm/s
Renal/aortic ratio* >3.5 (or 3.0)
Indirect criteria (intra-renal segmental arteries)
Right−left difference in resistive index >0.05 (or 0.15)
Acceleration <300 m/s^2
Acceleration time >70 ms
Loss of early systolic peak
Tardus parvus waveform

* Peak systolic velocity of renal artery/peak systolic velocity of aorta.

Meal ingestion and follow-up sonography

Subjects were evaluated using the sonographic measurements described above the morning after overnight fasting for ≥12 h. Subjects were then asked to eat a prepared breakfast. Although each examination was performed on a different day for each subject, the breakfast meal was always the same, comprising 130 g of fried chicken, 200 g of rice and 280 mL of mineral water (total caloric intake: 576 Cal). Subjects then underwent Doppler sonography to obtain the parameters described above shortly after breakfast and every 1 h thereafter until 7 h. Subjects were prohibited from eating other meals, but *ad libitum* access to mineral water and calorie-free sports drinks was allowed during this period to avoid dehydration.

Statistical analyses

Descriptive results are presented as the mean ± standard deviation. First, the statistical significance of results from the time course analysis of each parameter on sonography was tested using one-way repeated-measures analysis of variance or the Kruskal-Wallis test after confirming the presence or absence of a normal distribution at all time points of pre- and post-prandial states. Next, for multiple comparisons, Dunnett's test for parametric values or Steel's test for non-parametric values was used to estimate differences in Doppler parameters between time points before and after meal ingestion; p values < 0.05 were deemed to indicate statistical significance.

RESULTS

Representative spectral Doppler images taken before and after meal ingestion are provided in Figure 1. Parameter values obtained by sonography exhibited significant changes over the time course as a whole. PSV in the renal artery was significantly elevated after meal ingestion for at least 3 h, peaking at 1 h (90 ± 12 cm/s),