Effect of Hydration on Doppler Velocity of Renal Arteries

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**Context:** Doppler sonography is a noninvasive method to evaluate the hemodynamic status of the kidney, and its parameters are used as direct and indirect predictors of certain parenchyma and renovascular diseases. However, the effect of hydration on kidney hemodynamics has not been explored via Doppler sonography.

**Objective:** To examine differences in arterial Doppler velocities of normal adult kidney before and after hydration.

**Methods:** A total of 60 native kidneys in 30 normal adult participants (mean age, 26 years) were assessed using Doppler sonography. Quantitative ultrasound Doppler parameters of peak systolic velocity (PSV), end diastolic velocity (EDV), and resistive index (RI) of the main renal artery and the intrarenal (interlobar) arteries were measured immediately before and 1 hour after ingestion of 500 mL of water. We tested differences in Doppler parameters before and after hydration using a paired *t* test, analyzed the correlation of the increase in PSV to the increase in EDV after hydration using Pearson correlation coefficient (PCC), and examined intraobserver reliability using intraclass correlation coefficient (ICC).

**Results:** Statistical analyses revealed that the differences in PSV and EDV values before and after hydration at the main renal artery and interlobar arteries of the kidney were significant (*P* <.001), whereas the RI at the main renal artery and interlobar arteries were not (*P* >.05). PCC for the correlation of the increase in PSV to the increase in EDV was greater than 0.80. ICC for intraobserver repeatability in performing kidney Doppler sonography was 0.92.

**Conclusion:** Our results suggest that Doppler sonography is able to demonstrate changes in kidney hemodynamics within 1 hour after hydration. The normal kidney reflects proportional increases in PSV and EDV at the main renal artery and interlobar arteries, while maintaining vascular resistance. Doppler flow velocities of renal arteries can be considered as noninvasive quantitative markers for evaluating the response of kidney hemodynamics to hydration.

*J Am Osteopath Assoc.* 2020;120(10):704-710. Published online August 5, 2020. doi:10.7556/jaoa.2020.113

**Keywords:** Doppler ultrasonography, hydration, kidney, renal artery, ultrasonography
adjustment have been reported for both healthy and disease states.1,3-5 Modification of fluid intake as a therapeutic intervention in chronic kidney disease is beneficial in preserving renal function,1 and hydration decreases the burden of urine production when the kidney is stressed with hypoxia.5 Furthermore, hypohydration (loss of fluid ~2% of body mass) induced by moderate exercise and water restriction may impair endothelial function in healthy adults.5 Therefore, it is important to understand the role of hydration in the examination of kidney vasculature.

Currently, clinical diagnosis of renal conditions largely relies on physiologic and biochemical markers, radiography, computed tomography (CT), magnetic resonance imaging (MRI), and ultrasonography.6 However, imaging methods like renal scintigraphy, contrast CT, MRI, and renal angiography are invasive due to the requirements of intravascular injection of radiotracers or contrast agents in order to evaluate dynamic function. Although hydration status is known to affect renogram patterns in normal adults,7 there is not yet a method to evaluate the effect of hydration on kidney hemodynamics without the use of tracers or contrast agents. Doppler sonography is a noninvasive imaging method, using Doppler parameters of peak systolic velocity (PSV), end diastolic velocity (EDV), and resistive index (RI) to quantify the speed of flow (cm/s) within vessels and the vascular resistance of the organ.8-10 Intrarenal Doppler evaluations of the interlobar arteries of the kidney are currently used in assessing hemodynamic status in the kidney as direct and indirect predictors associated with renovascular disease and kidney dysfunction, including chronic kidney disease, renal allograft rejection, acute kidney injury, and renal artery stenosis, among others.8-14 Currently, there is an ongoing effort to clarify the efficacy and sensitivities of Doppler sonography in the clinical setting.8,11,12 To our knowledge, there is no report of whether hydration influences renal Doppler parameters in normal kidneys.

The purpose of this study is to examine the effect of hydration on renal hemodynamics, specifically the main renal artery and intrarenal arteries, using Doppler sonography. We aim to understand how hydration affects renal Doppler parameters in normal adults and assess whether hydration status should be considered in routine Doppler sonography procedures and in the interpretation of the results.

Methods

Participants

A written informed consent was obtained from each participant, and the study was approved by the institutional review board at Rocky Vista University (IRB# 2018-00003). Participants were recruited at Rocky Vista University from February 2018 to September 2019.

Volunteers were selected based on kidney health (no previous history of hypertension, renal dysfunction, or kidney disease of any kind) and age between 20 and 40 years. All participants with hypertension (resting brachial artery blood pressure greater than 140/90 mmHg)15 and reported medical history of renal dysfunction or disease were excluded from the study. To exclude hypertension, resting brachial blood pressures were recorded onsite by a single observer after 10 minutes of rest with a sphygmomanometer and a stethoscope. Previous medical history, age, gender, height, and weight were self-reported upon arrival to the study.

Doppler Sonography

Participants were asked to refrain from drinking water or other fluids 1 hour prior to the first scan (before hydration). Upon completion of the first scan, participants were then instructed to drink 500 mL of water and returned 1-hour post-ingestion of water for the second scan (after hydration). Otherwise, no special preparation was necessary for ultrasonography. The first and second scans used the same technical procedure.

Participants were scanned in the left and right lateral decubitus positions for imaging the right and left kidney, respectively. Transmitting gel was placed on the skin over the kidneys, and no pressure was applied.
to the skin upon application of the transducer, avoiding mechanical compression of the kidney. All ultrasonography parameters were measured at renal arteries in all participants twice by a single observer, testing intraobserver variability.

Doppler sonography was performed using an Aplio i800 scanner (Canon Medical Systems) equipped with a curved linear array transducer (3.5 MHz). We used color Doppler as the guidance to optimize the localization of the main and intrarenal vasculature of the kidney. The aorta flow velocity was sampled at the level of the main renal arteries, the main renal artery flow velocities were measured at the hilum of the kidney, and the intrarenal artery Doppler parameters were measured at the junction of the renal pyramids within the renal medulla. We sampled arterial flow velocity of the aorta, main renal artery (MRA), and interlobar arteries (twice at each artery) using the manufacturer’s machine settings for kidney spectral Doppler (Doppler gate: 2 mm). The Doppler angle was corrected by aligning the spectrum along the direction of blood flow (<60° and approximating 0° angle, if possible). Participants held their breath at the completion of expiration; PSV (maximum systolic velocity, cm/s) and EDV (minimum diastolic velocity, cm/s) of the interlobar artery were manually measured at the upper, middle, and lower poles of the kidney (Figure 1). All velocity parameters in the interlobar artery in the upper, middle, and lower poles were averaged for data analysis. The RI of main renal and interlobar arteries, PSV ratio of aorta to main renal artery (RAR), and PSV ratio of main renal artery to interlobar artery (RIR) were calculated using the following equations. The threshold for normal RAR and RIR were set at 3 and 5, respectively. RAR greater than 3 and RIR greater than 5 indicate a renal artery stenosis.9

RI=(PSV-EDV)/PSV10,11
RAR=MRA PSV/Aorta PSV9
RIR=MRA PSV/Interlobar PSV9

Statistical Analysis
All quantitative Doppler values are expressed by mean and standard deviation (Table 1). PSV, EDV, RI, RAR, and RIR were tested using a paired t test for statistical differences before hydration and after hydration. Correlations of the percent increase of PSV and EDV after hydration were analyzed using Pearson correlation coefficient (PCC). Intraobserver reliability in performing Doppler sonography was examined using intraclass correlation coefficient (ICC). Criterion for statistical
significance was a $P$ value of less than 0.05. All statistical analyses were performed using SPSS software (SPSS 25.0, IBM, Armonk, NY).

**Results**

A total of 30 adults (mean [SD] age, 26 [3] years; range, 23-37 years) composed of 17 men and 13 women participated in the study. The mean (SD) body mass index of the participants was 25.1 (3.79), and the mean (SD) systolic and diastolic blood pressures were 115 (10) and 76 (8), respectively.

There were no statistically significant differences between the prehydration and posthydration measurements in renal RI values at the main renal artery (MRA) or at the intrarenal (interlobar) arteries (all $P > 0.05$). However, significant increases in the PSV (all $P < 0.001$) and EDV (all $P < 0.001$) were found at the MRA and the interlobar arteries after hydration (Figure 2). The correlation (PCC) of the percent increase in PSV to the percent increase in EDV after hydration was 0.80 ($P < 0.001$) (Figure 3).

All Doppler parameters were nonsignificant when comparing the right with left kidneys (all $P > 0.05$). There were no differences between men and women in all Doppler parameters before or after hydration (all $P > 0.05$). RAR and RIR were within normal values (RAR < 3; RIR < 5) before hydration and after hydration (Table 1).

**Discussion**

Our results demonstrate that hydration increases the PSV and EDV values at the main renal artery and interlobar arteries. It is important to note that there was no significant difference in the renal RI before and after hydration, and the value of RI remained within normal range (0.47-0.70)$^{11-12}$ despite significant increases in PSV and EDV after hydration. The normal adult kidney has compliant vasculature that proportionately increases the PSV and EDV ($r = 0.80$) of the main renal and interlobar arteries, resulting in maintenance of a stable RI value across the kidney after hydration.

The present study reveals that hydration’s effect on renal hemodynamics can be quantified with Doppler sonography within 1 hour of ingesting water (500 mL); thus, Doppler sonography could be informative in monitoring responses to hydration therapy. Certain renal diseases, such as chronic kidney disease (CKD), renal artery stenosis, allograft rejection of kidney transplantation, and acute kidney injury are routinely monitored by renal Doppler sonography.$^{8-14}$ There is

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**Table 1. Renal Artery Doppler Sonography Parameters Before and After Hydration**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Before hydration</th>
<th>After hydration</th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main renal artery PSV (cm/s)</td>
<td>84.5 (15.4)</td>
<td>112.5 (25.2)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Main renal artery EDV (cm/s)</td>
<td>31.9 (6.8)</td>
<td>41.5 (9.5)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Main renal artery RI</td>
<td>0.63 (0.07)</td>
<td>0.63 (0.05)</td>
<td>&gt;.05</td>
</tr>
<tr>
<td>Interlobar artery PSV (cm/s)</td>
<td>34.1 (5.2)</td>
<td>42.7 (7.7)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Interlobar artery EDV (cm/s)</td>
<td>14.7 (3.3)</td>
<td>17.9 (3.8)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Interlobar artery RI</td>
<td>0.57 (0.05)</td>
<td>0.58 (0.05)</td>
<td>&gt;.05</td>
</tr>
<tr>
<td>RAR</td>
<td>0.92 (0.28)</td>
<td>0.99 (0.29)</td>
<td>&gt;.05</td>
</tr>
<tr>
<td>RIR</td>
<td>2.78 (0.37)</td>
<td>2.83 (0.63)</td>
<td>&gt;.05</td>
</tr>
</tbody>
</table>

*Abbreviations:* EDV, end diastolic velocity; $P$, paired t-test; PSV, peak systolic velocity; RAR, renal-aortic ratio, peak systolic velocity ratio of main renal artery to aorta; RI, resistive index; RIR, renal-interlobar ratio, peak systolic velocity ratio of main renal artery to interlobar artery.
evidence that hydration therapy improves CKD in preserving renal function, and low hydration may be related to higher incidence of CKD. Hydration is also indicated in prophylaxis for renal medullary hypoxia. Future research may elaborate on the role of Doppler sonography in hydration procedures. Importantly, we observed a good repeatability in performing kidney Doppler sonography (ICC=.92).
Doppler sonography has been available in portable scanners that can be used not only in imaging centers, but also in emergency rooms and intensive care units. There were several limitations to this study. First, the sample size was small and the sample was fairly homogeneous in age. Future reproducibility, upon expansion of the age range (young, middle-aged, and senior adults), would improve the general results and validation of the method. Second, we categorized normal participants within the euhydrated (not dehydrated) state via self-reporting. The euhydrated state of the participant and the healthy kidney function could be verified with additional methods, such as urine specific gravity, which may help quantify the degree of hydration in relation to changes in the Doppler parameters. Furthermore, correlation analysis of ultrasonography with established CT, MRI, and angiogram would improve the clinical applicability of our findings, and these imaging modalities may be addressed in future studies. Third, the study enrolled only healthy adults. The feasibility of Doppler sonography in assessing the effect of hydration on kidney hemodynamics in patients with kidney disease needs further evaluation. Finally, a single observer performed all kidney sonography; therefore, interobserver variation needs further examination.

Conclusion

Hydration affects kidney hemodynamics, which can be quantitatively measured by Doppler sonography parameters of the main renal artery and the intrarenal arteries. In the normal adult kidney, renal blood flow measured by PSV and EDV increases proportionately, which maintains normal RI values after hydration. The effect of hydration status on renal artery blood flow velocities should be considered when evaluating the kidney hemodynamics in physiologic and pathologic conditions with Doppler sonography.

Author Contributions

Both authors provided substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; both authors drafted the article or revised it critically for important intellectual content; both authors gave final approval of the version of the article to be published; and both authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

References


Figure 3.

The scatter plot shows a strong positive correlation between the increase in blood flow PSV and the increase in EDV after hydration (Pearson correlation coefficient, r = 0.80, P < .0001). Abbreviation: EDV, end diastolic velocity; PSV, peak systolic velocity.


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