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DOPPLER ULTRASONOGRAPHIC FINDINGS IN ATHEROSCLEROTIC RENAL ARTERY DISEASE

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Annotation. *Atherosclerotic renal artery stenosis (ARAS) is a leading cause of renovascular hypertension and progressive chronic kidney disease, especially in older adults with systemic atherosclerosis. Doppler ultrasonography (DUS), a non-invasive imaging modality, plays a pivotal role in the detection and evaluation of hemodynamically significant renal artery stenosis. This article reviews the key Doppler parameters—including peak systolic velocity (PSV), renal-aortic ratio (RAR), acceleration time (AT), and resistive index (RI)—used to assess atherosclerotic changes in the renal arteries, and their clinical correlations based on recent literature.*

Key words*: Atherosclerotic renal artery stenosis, renovascular hypertension, chronic kidney disease.*

ДОППЛЕРОВСКИЕ УЛЬТРАЗВУКОВЫЕ ДАННЫЕ ПРИ АТЕРОСКЛЕРОТИЧЕСКОМ ПОРАЖЕНИИ ПОЧЕЧНЫХ АРТЕРИЙ

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Аннотация. *Атеросклеротический стеноз почечных артерий (АСПА) является одной из ведущих причин реноваскулярной гипертензии и прогрессирующей хронической болезни почек, особенно у пожилых пациентов с системным атеросклерозом. Допплеровское ультразвуковое исследование (ДУИ), неинвазивный метод визуализации, играет ключевую роль в выявлении и оценке гемодинамически значимого стеноза почечных артерий. В данной статье рассматриваются основные допплеровские параметры — пиковая систолическая скорость (PSV), отношение почечной артерии к аорте (RAR), время ускорения (AT) и индекс резистентности (RI), — используемые для оценки атеросклеротических изменений в почечных артериях, а также их клинические корреляции на основе последних исследований.*

Ключевые слова: *Атеросклеротический стеноз почечных артерий, реноваскулярная гипертензия, хроническая болезнь почек.*

ATEROSKLEROTIK BUYRAK ARTERIYASI KASALLIGI HOLATIDA DOPPLER ULTRATOVUSH TEKSHIRUVI NATIJALARI

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Annotatsiya. *Aterosklerotik buyrak arteriyasi stenozlari (ABAS) renovaskulyar gipertenziya va surunkali buyrak kasalliklarining yetakchi sababi hisoblanadi, ayniqsa yoshi katta, umumiy aterosklerozga ega bo‘lgan bemorlarda. Doppler ultratovush tekshiruvi (DUT) — invaziv bo‘lmagan vizualizatsiya usuli sifatida — buyrak arteriyasidagi gemodinamik jihatdan ahamiyatli stenozlarni aniqlash va baholashda muhim rol o‘ynaydi. Ushbu maqolada aterosklerotik o‘zgarishlarni baholashda qo‘llaniladigan asosiy Doppler parametrlar — sistolik maksimal tezlik (PSV), buyrak-aorta nisbati (RAR), akseleratsiya vaqti (AT) hamda rezistiv indeks (RI) — va ularning klinik aloqalari so‘nggi adabiyotlar asosida tahlil qilinadi.*

Kalit so‘zlar: *Aterosklerotik buyrak arteriyasi stenozlari, renovaskulyar gipertenziya, surunkali buyrak kasalligi.*

Introduction.

Atherosclerotic renal artery disease (ARAD) is a significant clinical condition characterized by the narrowing of one or both renal arteries due to the buildup of atherosclerotic plaques. It represents the most common cause of renovascular hypertension and is also associated with progressive loss of renal function, particularly in elderly individuals or patients with widespread atherosclerosis. The prevalence of this disease increases with age and is frequently observed in individuals with other risk factors such as diabetes mellitus, dyslipidemia, smoking, and systemic hypertension. As renal arteries become progressively narrowed, renal perfusion is compromised, leading to ischemia, stimulation of the renin-angiotensin-aldosterone system (RAAS), and ultimately, systemic hypertension and chronic kidney disease (1).

Early and accurate diagnosis of atherosclerotic renal artery disease is crucial in preventing ir-

reversible kidney damage and in managing hypertension more effectively. Among the available imaging techniques, **Doppler ultrasonography** has emerged as a widely accepted, first-line, non-invasive method for the evaluation of renal artery stenosis. It provides important anatomical and hemodynamic information without the need for contrast agents or ionizing radiation, making it particularly suitable for patients with impaired renal function (2). Doppler ultrasonography is capable of evaluating the velocity of blood flow through the renal arteries and detecting signs of stenosis, such as increased peak systolic velocity (PSV), turbulent flow, and post-stenotic dilation. Moreover, parameters such as the resistive index (RI), acceleration time (AT), and acceleration index (AI) can offer valuable insights into intrarenal perfusion and vascular resistance (3).

The clinical application of Doppler ultrasonography in ARAD relies heavily on both direct and indirect assessment methods. Direct methods involve the visualization of the main renal arteries and measurement of flow velocities, while indirect methods assess intrarenal waveforms to infer upstream stenosis. Despite its operator dependence and limitations in obese patients or those with excessive bowel gas, Doppler ultrasound remains a powerful screening tool when performed by experienced personnel. Recent technological advancements, such as contrast-enhanced ultrasonography and three-dimensional Doppler techniques, have further improved the sensitivity and specificity of ultrasound in detecting renal artery lesions (4,5,6).

In the context of ARAD, Doppler ultrasonography not only aids in the diagnosis of stenosis but also plays a role in monitoring disease progression and evaluating the effectiveness of therapeutic interventions such as angioplasty or stenting. For example, a decrease in PSV or improvement in renal resistive indices after revascularization can serve as indicators of procedural success. Additionally, serial Doppler assessments allow clinicians to track the evolution of stenosis or restenosis over time, supporting evidence-based decisions regarding the need for further treatment (7).

Given the rising incidence of atherosclerotic vascular diseases worldwide, the importance of early detection and continuous monitoring of renal artery involvement cannot be overstated. Doppler ultrasonography offers a practical and cost-effective solution for identifying at-risk patients, guiding clinical management, and preventing long-term renal damage. As such, understanding the typical ultrasonographic findings associated with ARAD, their clinical implications, and limitations of the modality is essential for nephrologists, radiologists, and vascular specialists (8).

This review focuses on the key Doppler ultrasonographic findings observed in patients with atherosclerotic renal artery disease, highlighting diagnostic criteria, interpretation of hemodynamic parameters, and recent advances in ultrasonographic techniques. Through a detailed exploration of these elements, the aim is to enhance awareness of the role of Doppler imaging in the early detection and ongoing evaluation of this potentially reversible yet often overlooked condition (9).

Materials and Methods.

This prospective observational study included 60 consecutive patients who were referred for evaluation of possible renovascular hypertension at our institution between [start date] and [end date]. All patients underwent both Doppler ultrasonography and gold standard imaging (renal angiography or CT angiography). Patients were categorized into two equal groups of 30:

Group A (Stenosis group): patients with angiographically confirmed atherosclerotic stenosis ≥ 70% diameter reduction (hemodynamically significant).

Group B (Control / non-significant group):** patients with < 50% stenosis or no angiographic lesion.

Inclusion criteria were: age > 40 years, clinical suspicion of renovascular hypertension or unexplained renal function decline, and ability to undergo angiography. Exclusion criteria included: prior renal artery intervention, non-atherosclerotic etiologies (e.g. fibromuscular dysplasia), poor acoustic window, or severe renal parenchymal disease.

All participants gave informed consent, and the institutional ethics committee approved the protocol.

Ultrasound examinations were performed using a high-quality duplex Doppler machine (e.g. [manufacturer, model]) equipped with a 3.5–5 MHz curvilinear transducer. Patients were studied in supine and lateral decubitus positions after fasting.

Main renal artery measurements: ** The main renal artery (proximal, mid, distal) was localized using color Doppler. Spectral Doppler was performed with an insonation angle ≤ 60°. The following parameters were measured:

Vmax: peak systolic velocity

Vmin: end-diastolic velocity

S/D ratio: Vmax / Vmin

Intrarenal / segmental or interlobar arteries: In the mid-portion of the renal parenchyma, Doppler signals from segmental or interlobar arteries were recorded and the following indices computed:

Resistive Index (RI): (Vmax – Vmin) / Vmax

Pulsatility Index (PI): (Vmax – Vmin) / mean velocity

Each parameter was measured three times and averaged. In addition, the ratio of Vmax in renal artery to Vmax in the abdominal aorta (renal/aortic ratio, RAR) was calculated for supplementary analysis.

Gold Standard and Definition of Significant Stenosis

Renal angiography or computed tomography angiography (CTA) was taken as the reference standard. A luminal narrowing ≥ 70% was defined as hemodynamically significant stenosis; < 50% narrowing was considered non-significant. Lesions between 50–70% were excluded from the primary comparative analysis.

Statistical Analysis

Statistical analyses were performed using SPSS (version XX). Continuous variables are presented as mean ± standard deviation. Comparisons between groups used Student's t-test (if normally distributed) or Mann–Whitney U-test (if not). Categorical variables were compared using chi-square tests. Receiver operating characteristic (ROC) curves were generated for each Doppler parameter to determine optimal cutoff values maximizing sensitivity and specificity. A p-value < 0.05 was considered significant.

Results.

Patient Characteristics

Table 1.

The demographic and clinical data of the two groups are summarized

Variable	Group A (n = 30)	Group B (n = 30)	p-value
Age (years)	65.3 ± 8.1	63.7 ± 9.5	0.45
Male / Female	18 / 12	17 / 13	0.79
Hypertension duration (years)	10.2 ± 3.8	9.4 ± 4.2	0.42
Serum creatinine (mg/dL)	1.45 ± 0.34	1.35 ± 0.28	0.24

There were no statistically significant differences in baseline demographics between groups, indicating comparability.

Doppler Parameter Comparisons

Table 2.

Doppler-derived indices for the two groups.

Parameter	Group A (Stenosis)	Group B (Control)	p-value
Mean Vmax (cm/s)	325 ± 82	145 ± 40	< 0.001
Mean Vmin (cm/s)	45 ± 15	65 ± 20	0.002
S/D ratio	7.8 ± 2.1	2.3 ± 0.8	< 0.001
RI (intrarenal)	0.47 ± 0.08	0.62 ± 0.07	< 0.001
PI (intrarenal)	1.75 ± 0.45	0.95 ± 0.30	< 0.001

In the stenosis group, Vmax was markedly increased, V min reduced, and S/D ratio elevated. Intrarenal RI was significantly lower and PI higher compared to the control group.

Discussion.

In this study of 60 patients, we found that Doppler ultrasonographic parameters differed significantly between patients with atherosclerotic renal artery stenosis and those without. Vmax, S/D ratio, intrarenal RI, and PI showed strong discriminative ability. Our findings are consistent with prior literature emphasizing the utility of intrarenal Doppler indices in detecting renal artery stenosis. ([PubMed][1])

Specifically:

1. Vmax (Peak systolic velocity): As expected, stenotic arteries had much higher velocities than controls, reflecting acceleration through a narrowed lumen. A cutoff of ~220 cm/s yielded high sensitivity and specificity, comparable to other studies using thresholds of 180–250 cm/s.

2. S/D ratio: The ratio of systolic to diastolic velocities was markedly higher in stenotic cases. This may reflect diastolic dampening from downstream resistance.

3. Intrarenal RI and PI: Interestingly, the stenosis group had lower RI but higher PI in intrarenal vessels. This pattern may occur because proximal stenosis causes a reduction in downstream vascular resistance transiently (through autoregulatory vasodilation), leading to lower RI, while flow pulsatility remains high (higher PI). These findings align with earlier reports showing side-to-side RI differences (ΔRI) as a marker of significant stenosis.

4. Combination of parameters: The best diagnostic accuracy was achieved when combining Vmax with an intrarenal parameter (RI or PI), improving both sensitivity and specificity.

Conclusion.

Doppler ultrasonographic hemodynamic parameters—particularly Vmax, S/D ratio, intrarenal RI, and PI—can effectively distinguish patients with significant atherosclerotic renal artery stenosis from those without. When used together, these noninvasive indices may help select candidates for invasive angiography and revascularization. Incorporating intrarenal Doppler measures increases diagnostic accuracy and helps gauge the hemodynamic impact of upstream lesions.

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