

PULSED WAVE DOPPLER OF THE INFERIOR VENA CAVA IN ASSESSMENT OF RIGHT-SIDED CARDIAC FUNCTION IN CHRONIC RENAL FAILURE
Kronik böbrek yetmezliğinde sağ kalp fonksiyonlarının değerlendirilmesinde inferior vena cavanın dupleks Doppleri

Ediya A HASANOVA¹

Abstract: For the assesment of right-sided heart function the flow in the inferior vena cava was studied in 49 patients with chronic renal diseases using pulsed wave Doppler. Thirty-nine of these patients had chronic renal failure. The time-velocity waveform shape in patients with chronic renal diseases and normal renal function was similar to those seen in the control group. The vessels showed a triphasic flow pattern. There was a significant increase in flow velocity and volume flow rate at the initial and manifesting stages of chronic renal failure ($p < 0.05$). Doppler spectrum showed a biphasic waveform pattern, which was associated with impairment of right atrial function caused by its volumetric overload. In the severe and the end stages of chronic renal failure, a reduction of flow velocity and volume flow rate was seen. The signal showed a monophasic flow pattern. There was no significant dilatation of the inferior vena cava. In our opinion, pulsed wave Doppler may be a useful, noninvasive method of the estimation of right-sided cardiac function in chronic renal failure.

Key Words: Doppler ultrasound, Chronic renal failure

Özet: Sağ kalp yetmezliğinin değerlendirilmesinde, kronik böbrek hastalığı olan 49 hastada Doppler çalışıldı. Bu hastaların 39'unda kronik böbrek yetmezliği mevcuttu. Kronik renal hastalığı olan ve normal renal fonksiyonu olan hastalarda zaman-hız dalgasının şekli kontrol grubundakine benzeri idi. Damarlar trifazik bir akım paterni gösteriyordu. Kronik renal yetmezliğin başlangıç ve manifest dönemlerinde akım hızı ve akım debilerinde önemli bir artış mevcuttu ($p < 0.05$). Doppler spektrumu bifazik dalga paterni göstermekteydi; bu, volumetrik overload' un neden olduğu sağ atrial fonksiyon bozukluğu ile ilişkiliydi. Kronik böbrek yetmezliğinin şiddetli ve son dönemlerinde, akım hızı ve akım debisinde azalma görüldü. Sinyaller monofazik akım paterni göstermekteydi. İnfior vena cavada önemli bir dilatasyon yoktu. Dupleks Doppler'in, kronik böbrek yetmezliğinde sağ kardiyak fonksiyonlarının değerlendirilmesinde yararlı ve noninvazif bir metod olarak kullanılabileceği kanısındayız.

Anahtar Kelimeler: Doppler ultrasonografi, Kronik böbrek yetmezliği

The state of the cardio-vascular system has a great influence on the clinical picture and prognosis of chronic renal failure (CRF). As a few investigators reported, 55% of patients suffering from CRF died

of complications due to pathologic changes in the cardio-vascular system (1). These complications were the underlying cause of death in 30 to 50 % of patients on chronic hemodialysis. Extracorporeal circulation, occurring in hemodialysis, frequently leads to hemodynamic changes and makes the cardiac failure more likely (2). Thus, the study and assessment of the state of the cardio-vascular system in CRF are of great value in the prevention of potential complications.

Chair of Therapy and functional Diagnostics, Azerbaijan State Medical Advanced Trainin Institute Named after A. Aliyev Baku-Azerbaijan¹.

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The pathogenesis of right ventricular insufficiency in CRF remains relatively less studied. It is known that the increase of circulating blood volume and systolic pressure in the pulmonary artery plays a well-established role in the development of right-ventricular insufficiency as well as dystrophic changes in cardiac muscle (2).

Currently, the search for noninvasive techniques for the assessment of circulatory disturbances in right-ventricular insufficiency is continuing. The estimation of the caliber of the inferior vena cava (IVC) and its dependence on respiration is being assessed with both M-mode and two-dimensional ultrasound scanning which allows a judgment about circulating blood volume and right atrial diastolic pressure (3,4,5). Doppler ultrasonography, which is capable of giving objective characteristics based on the changes of velocity profile and flow direction, is a perspective method of assessment of hemodynamic disturbances in right-ventricular insufficiency (6).

The objective of the present study was to assess the ability of pulsed wave Doppler sonography of IVC in the evaluation of right-sided heart function in patients with CRF.

PATIENTS AND METHODS

The study was performed at the Republic Urology Hospital in Baku. Forty-nine patients aged 16 to 60 with renal diseases participated in the study. The first group consisted of 10 patients with renal diseases and normal renal function (2 had chronic glomerulonephritis, 2 had nephrolithiasis and 6 had chronic pyelonephritis). Twenty patients with renal disease complicated by subclinical, initial, and manifesting stages of CRF according to the M.J.Javad-zade and P.S.Malkov's classification, (7) were included in the second group (5 had chronic glomerulonephritis, 1 interstitial nephritis, 2 nephrolithiasis, and 12 chronic pyelonephritis). The third group consisted of 19 patients with severe and end stages of CRF (10 had chronic

glomerulonephritis, 2 polycystic kidney disease, 1 nephrolithiasis, and 7 chronic pyelonephritis). Ten healthy volunteers aged between 16 to 60 years were included in the control group.

The mean value of serum creatinine was $0,102 \pm 0,025$ mmol/l in the first group, $0,347 \pm 0,220$ mmol/l in the second group, and $1,249 \pm 0,415$ mmol/L in the third group. In the control group, the mean value of serum creatinine was $0,117 \pm 0,016$ mmol/l. Mean systolic blood pressure was $124,5 \pm 112,2$ mm Hg in the first group, $163,9 \pm 43,0$ mm Hg in the second group, and $176,3 \pm 40,3$ mm Hg in the third group. Mean diastolic blood pressure was $76,5 \pm 12,0$ mm Hg in the first group, $97,1 \pm 22,4$ mm Hg in the second group, and $99,5 \pm 29,2$ mm Hg in the third group. None of the patients had an impairment of cardiac rhythm. One of the patients in the second group as well as 1 in the third group had the clinical picture of cardiac insufficiency.

The flow in the IVC was assessed with pulsed wave Doppler using duplex scanner "Combison-320-5" with "Doppler-300" unit ("Kretztechnik", Austria). Imaging was performed with a sector transducer at 2,5 MHz and Doppler at 2,25 MHz. The diameter of the IVC was measured with a two-dimensional ultrasound image using an epigastric approach. The waveform shape of Doppler shift frequencies was assessed. Quantitative analysis of Doppler spectra was performed using computer processing by means of built-in programs on the screen of the scanner. The cross-sectional area (cm^2), mean velocity (cm/sec), and volume flow rate (ml/min.) were estimated (8). All the examinations were performed in the first three days of the patients' admission to the hospital. Drugs were not administered before the investigations. The patients were scheduled for their examinations for the morning after an overnight fast.

Data are presented as mean value \pm SE. The difference between the groups was evaluated by analysis of variance (F test). Comparisons with the control group were made using unpaired t-test.

Table I. Pulsed wave doppler data of the inferior vena cava flow values in patients with chronic renal failure

parameters	n=10	n=10	n=20	n=19	F	p
Diameter (mm)	12.2±0.8	12.5±0.7	12.1±0.5	12.9±0.5	0.16	>0.05
Cross-sectional area (cm ²)	1.18±0.15	1.26±0.15	1.18±0.11	1.34±0.11	0.53	>0.05
Mean velocity (cm/sec)	11.7±3.3	14.9±3.1	19.6±2.6	15.3±2.1	4.93	<0.05
Flow volume (ml/min.)	835.6±304.2	1126.5±243.6	1300.4±161.7	1213.5±161.7	2.79	<0.05

RESULTS

Results are summarized in Table I

As shown on Table I, there was no significant difference in the diameter and the cross-sectional area of the IVC between the groups. Only 2 patients (one from the second group with the diagnosis of chronic glomerulonephritis at the manifesting stage of CRF and with presence of edema and ascitic syndrome, and the other from the third group with the diagnosis of chronic glomerulonephritis at the end stage of CRF and with exudative pericarditis) had the IVC diameter achieving 17 mm and cross-sectional area rising to 2,43 cm².

In the first group mean flow velocity was 14,9±3,1 cm/sec, and volumetric flow rate was 1126,5±243,6 ml/min., which was higher than that in the control group, but the difference was not statistically significant (p>0,05).

The IVC time-velocity waveform shape in most of the patients from the first group was similar to those seen in the control group. The vessels showed a triphasic flow pattern. The first negative phase of the Doppler spectrum reflected blood movement from the IVC towards the right atrium during its diastole. The second negative phase corresponded to atrial emptying during the period of early filling of right ventricle, accompanied by the intensive flow from the caval veins. The flow was away from the probe and therefore appears below the zero line. The

positive phase coincides with the reverse flow in the IVC during right atrial systole (Fig.-1). The patient from the first group with chronic glomerulonephritis and nephrotic syndrome had a spectrum which showed a broader band of Doppler shift frequencies associated with turbulence. In a given case the phases of the spectrum were not differentiated (Fig.-2). Mean flow velocity in this patient achieved 29 cm/sec and volumetric flow rate was equal to 1605 ml/min.

In the second group, mean flow velocity was 19.62±2,6 cm/sec and volumetric flow rate was equal to 1300,4±161,7 ml/min., which was significantly higher than that in the control group (p<0,05). In patients in the second group, the border between two negative phases of spectrum was eliminated. The signal showed biphasic flow pattern with marked negative phase and small positive component (Fig.-3). The flow in three of the patients of the second group showed a spectral broadening, associated with turbulence (Fig.-4). These patients had a mean flow velocity which ranged from 30 to 45 cm/sec and a volume flow rate which ranged from 1302 to 2687 ml/min.

In the third group, the mean flow velocity decreased to 15,3±2,1 cm/sec, and the volume flow rate reduced to 1213,5±164,8 ml/min similar to those seen in the first group. In this case, almost all the patients had a monophasic waveform pattern of Doppler spectrum below the zero line (Fig.-5).

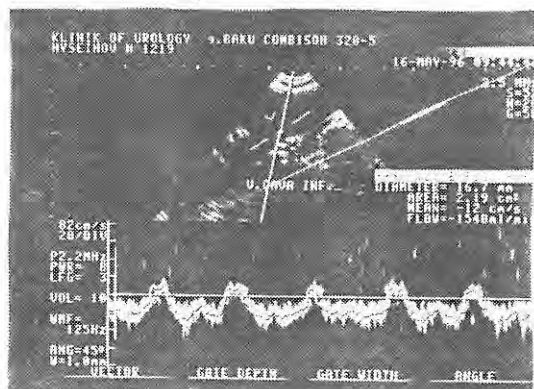


Figure 1. Duplex scanning of the inferior vena cava shows B-mode ultrasound image (longitudinal section) and corresponding normal triphasic Doppler spectrum in a patient with chronic pyelonephritis

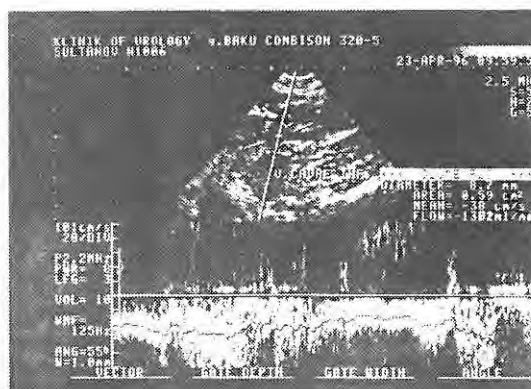


Figure 4. Time-velocity spectrum shows spectral broadening in a patient with chronic pyelonephritis, complicated by manifesting stage of chronic renal failure

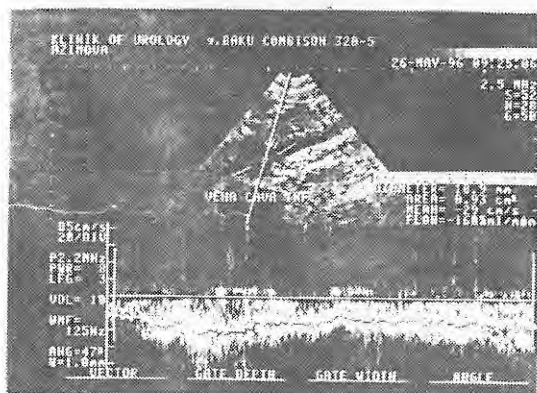


Figure 2. Spectrum shows the broader band of Doppler shift frequencies in a patient with chronic glomerulonephritis

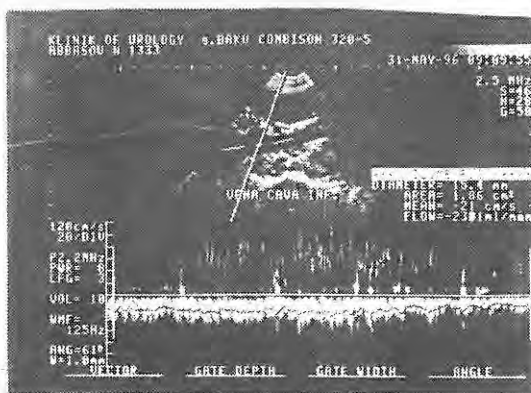


Figure 5. Duplex scanning of a patient with chronic glomerulonephritis, severe stage of chronic renal failure: time-velocity spectrum showing continuous monophasic flow pattern the inferior vena cava

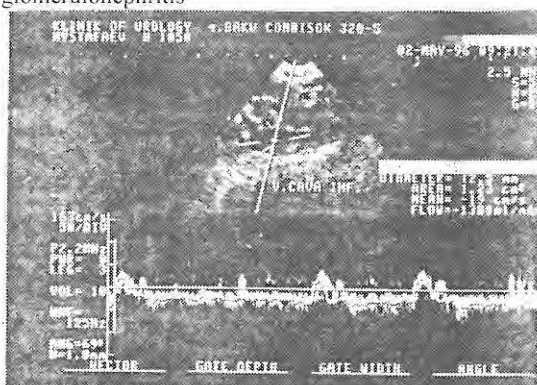


Figure 3. Duplex sonogram of the inferior vena cava in a patient with chronic pyelonephritis complicated by initial stage of chronic renal failure: the border between negative phases is eliminated

DISCUSSION

The changes in the character of pulsed wave Doppler velocity obtained from the IVC throughout the cardiac cycle in patients with chronic renal diseases have their origin in the reflection of right heart contractions. Since renal failure appeared, the flow velocity in the IVC has been increasing (second group of patients). This is thought to be due to the hyperhydration and an increase of circulating blood volume (2). We suggest, blood shunting via intrahepatic and portocaval anastomosis, which could be observed in nitrogen metabolism and the product retention may be a reason for such flow rate

elevation. All of them might cause the right atrial volumetric overload and might lead to its diastolic function impairment. Maybe it is an underlying cause of disappearance of the border between the negative components of Doppler velocity waveform in patients of the second group.

Further development of CRF and right atrial volumetric overload are followed by an impairment of its diastolic as well as systolic functions. Time-velocity spectrum shows an absence of marked positive phase of waveform. The flow presents a monophasic waveform pattern. As previously noted, the similar changes of waveform shape were also found in few patients of first and second groups, when flow velocity increased. These changes were associated with turbulent flow. This suggests that marked right atrial volumetric overload could be followed by impairment of its functions even in the absence of CRF as well as in its initial stages.

As reported so far, the fact of right atrial volumetric overload was confirmed by the increase of secretion of atrial natriuretic factor (9).

The onset of right-ventricular insufficiency leads to the decrease of IVC flow velocity. The cause is tricuspid regurgitation, which has a reverse direction to the normal flow in IVC. This results in the decrease of mean velocity and flow volume in IVC in patients of the third group.

It draws our attention to the fact that there was no expressed dilatation of IVC that was considered to be expected in right-ventricular insufficiency (10).

Probably, such an absence of the IVC dilatation is associated with reduction of passive extension due to metabolic calcification of vessels in CRF. This change tends to reduce the venous capacity and results in the increase of venous return in IVC. Therefore, the reduction of venous capacity could be the another cause of blood flow increase in IVC in patients of the second group.

Thus, the waveform shape of Doppler shift frequencies obtained from IVC in CRF is characterized by changes of flow due to disturbances

of right-sided heart function. It confirms the results of the authors, which showed the increase of central venous pressure in 80,9% of patients with CRF (2). Pulsed wave Doppler of the IVC may be a useful noninvasive method of assessment of right-sided cardiac function in CRF, even in the absence of a clinical picture of right-ventricular insufficiency. It can also be used to assess the efficacy of treatment of right-ventricular insufficiency.

Conclusion

1. Pulsed wave Doppler of the IVC may be considered as an important non-invasive method of assessment of right-sided heart function in CRF.
2. At the initial and the manifesting stages of CRF, changes of time-velocity spectra were associated with impairment of diastolic function of the right atrium, which was caused by its volumetric overload and was accompanied by a statistically significant increase of flow velocity and volume flow rate in the IVC.
3. At the severe and the end stages of CRF, as right-ventricular insufficiency appeared, the reduction of flow velocity and volume flow rate was accompanied by respective changes of waveform shape of Doppler spectrum. The significant dilatation of the IVC was not revealed in the given case.

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