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THE INFLUENCE OF ADRENAL VEIN OCCLUSION ON WHOLE-KIDNEY HEMODYNAMICS IN THE SPONTANEOUSLY HYPERTENSIVE RATS

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It has been shown that occlusion of the adrenal vein causes an increase in renal vascular resistance in the ipsilateral kidney in Wistar Kyoto rats (WKY). The most probable mechanism of this phenomenon is the direct inflow of adrenal catecholamines to the kidney by the adrenal renal portal circulation (ARPC). As the number of vessels of the ARPC is bigger and the tonic sympathetic activity is higher in spontaneously hypertensive rats (SHR), the aim of the current study was to compare the effect of adrenal vein occlusion on renal vascular resistance between SHR and WKY. Mean arterial blood pressure and renal blood flow (RBF) were measured and renal vascular resistance (RVR) was calculated before and after closure of the adrenal vein. Occlusion of the adrenal vein significantly reduced RBF and increased RVR in both strains of rats. The rise of the RVR was significantly higher in SHR than in WKY. Therefore we assume that the hemodynamic responsiveness of the kidney due to increase in blood flow through ARPC is greater in SHR and may contribute to the development of arterial hypertension in this strain of rat.

Key words: spontaneously hypertension rat, arterial hypertension, kidney, adrenal gland, adrenal renal portal circulation.

INTRODUCTION

The role of the kidney and adreno-sympathetic overactivity in the development of arterial hypertension are widely discussed. The kidney as a target for the sympathetic inflow may be affected in three different ways: by the renal nerves, by catecholamines diluted in the blood and by the adrenal renal portal circulation (ARPC). The role of this direct route for adrenal hormones in the development of primary arterial hypertension has been suggested (1). Comparing to normotensive rats, in spontaneously hypertensive rats (SHR), the increased number of vessels of the ARPC has been described (2). The elimination of the above connection in young SHR leads to the delay of
the development and diminution of the arterial hypertension in this strain of rat (3). Therefore the ARPC may be the functional link between the overactive adrenal medulla (4) and the kidney in SHR.

The exact mechanism by which the above connection influences on the kidney is still unclear. As early as in 1914, Cow demonstrated that occlusion of the adrenal vein, causing augmentation of blood flow through the direct vascular pathway from the adrenal gland to the kidney, significantly limited the excretory function of the affected kidney in the cat (5). Blood samples, collected from vessels of the ARPC demonstrated marked elevation of the catecholamines concentration (6). An augmented blood flow through the ARPC, caused by occlusion of the adrenal vein, results in an increase in the renal vascular resistance in the ipsilateral kidney in Wistar Kyoto rats (WKY) (7). It is abolished by α-adrenergic receptor antagonist which suggests that the adrenal catecholamines that reach the kidney directly through the ARPC are the responsible factor.

On the base of the evidences for more developed ARPC and the overactive adrenal gland in SHR we hypothesized that the direct impact of the adrenal hormones on the kidney in SHR would be greater than in their normotensive counterparts.

The aim of the present study was a comparison of influence of the occlusion of the adrenal vein on the whole-kidney hemodynamic changes between SHR and WKY.

METHODS

Experiments were performed on 6 male spontaneously hypertensive rats (SHR) and 6 male Wistar Kyoto rats weighing 300—400 g, obtained from the Medical University animal house (Warsaw, Poland). The anesthesia was induced with chloral hydrate at the dose of 0.36 g/kg b.w. i.p. and was then maintained by additional doses of chloral hydrate as necessary. Mean arterial blood pressure (MAP) was monitored using a pressure transducer module (MP-100, WPI, USA) attached to a cannula inserted into the femoral artery. The left femoral vein was cannulated for drugs and fluids administration. Rectal temperature was maintained at 37.5°C by means of a thermostatically controlled heating blanket. The trachea was cannulated and rats were paralysed with 0.1 mg/kg BW, i.v., pancuronium (Pavulon; Organon Teknika B.V. Boxtel, Holland); rats were artificially ventilated using the Harvard pump (L) for small animals (Harvard Apparatus Ltd, Edenbridge, Kent, UK). Ventilation was adjusted according to arterial blood gasometry (Blood Gas System-AVL 995 Hb, AVL List GmbH, Graz, Austria) in order to maintain pH, pCO₂ and pO₂ values within normal limits. After laparotomy, the left renal artery and vein were dissected free and the kidney was denervated by cutting renal nerves which was later followed by brushing of the kidney hilum with 10% alcohol solution of fenol. The flow-probe of a Doppler-flowmeter (Transonic-System, USA) was placed on the left renal vein for measurement of the renal blood flow (RBF). RBF and MAP were recorded with MP-100 data acquisition system (WPI, USA). The left central adrenal vein was closed using bicoagulation. After the experiments the kidneys were weighted.

RBF was calculated per 1 g of kidney weight (k.w.). Renal vascular resistance (RVR) was calculated as mean arterial pressure (mm Hg)/renal blood flow (ml min⁻¹ g⁻¹), and expressed as RRU — Renal Resistance Units.
The Student's *t*-test was used to compare values with relevant controls. Statistical comparison between groups was performed by ANOVA. *P* < 0.05 was considered to be statistically significant. Values are presented as the mean ± SEM.

RESULTS

The mean blood pressure was significantly higher in SHR than in WKY rats (101.3 ± 9.2 mm Hg vs. 76.5 ± 8.9 mm Hg) and was not significantly affected by the occlusion of the adrenal vein.

The initial values of RBF were significantly lower in the SHR as compared to the WKY (1.19 ± 0.009 ml min⁻¹ g⁻¹ vs. 2.44 ± 0.21 ml min⁻¹ g⁻¹, *p* < 0.05) and RVR significantly higher (69.6 ± 6.3 RPU vs. 22.4 ± 1.57 RRU, *p* < 0.01). Occlusion of the adrenal vein significantly reduced RBF and increased RVR in both strains of rats. The changes in RBF and RVR occurred with a delay of 4 min and reached a plateau after 12 min. Fifteen minutes after occlusion of the adrenal vein the values of RBF were 0.94 ± 0.11 ml min⁻¹ g⁻¹ in SHR and 1.92 ± 0.15 ml min⁻¹ g⁻¹ in WKY (*p* < 0.05), and the values of RVR were 90.59 ± 4.3 RRU and 25.69 ± 1.2 RRU respectively (*p* < 0.01). The changes in RVR were significantly higher in SHR than in WKY (Fig. 1).

![Graph showing comparison of renal vascular resistance (ΔRVR) between WKY and SHR after occlusion of the adrenal vein.](image)

*Fig. 1.* Comparison of the changes in renal vascular resistance (ΔRVR) between WKY and SHR after occlusion of the adrenal vein. *means *p* < 0.01 as compared to the WKY. # means *p* < 0.01 as compared to the control values in SHR, & means *p* < 0.01 as compared to the control values in WKY.
DISCUSSION

The augmented blood flow through the ARPC as a result of an increase in blood pressure in the adrenal microcirculation is the most probable mechanism for the decrease in RBF after occlusion of the adrenal vein. It may be assumed on the base of the previous study (7) that the above process is mediated by the increased inflow of adrenal catecholamines to the kidney. Katholi et al. (8) found that reflex stimulation of the sympathetic system, induced by a short period of atrial fibrillation, results in a dilation of the vessels of the ARPC and a decrease in RBF in dog. The role of the ARPC in the hemodynamic changes in the kidney during hypotension has also been proved in rat (9).

The histological structure of the ARPC suggests that the blood flow inside the vessels is under low pressure. An unidirectional blood flow (from the adrenal gland to the kidney) is preserved by the valves of the vessels of the ARPC (10). These findings suggest that the ARPC connects the adrenal gland with the intrarenal vein system. The adrenal catecholamines may reach the renal arterioles by diffusion from the intrarenal ending of the ARPC, which is suggested by the long latency of the renal vascular response after the adrenal vein occlusion.

The higher renal vascular resistance in the SHR than in the WKY which occurs in the present experiment is in an accordance with the previous study (11). It is the result of the higher tonic sympathetic activity and structural changes in the renal arterioles in the SHR (12, 13).

The main finding of the present study is the greater response of the renal vascular bed in SHR than in WKY to the augmented blood flow through ARPC. Though, the reduction of the RBF is similarly in both strains (about 20%), the greater increase in RVR (in absolute values) after adrenal vein occlusion is the result of the initial higher RVR in SHR. Renal α-adrenergic receptor density is greater in SHR than in WKY (14). It has been reported that administration of α-adrenergic receptor agonist produced increased afferent and efferent arteriolar hyperresponsiveness in the SHR (15). Therefore each of the three elements of the adrenal-kidney axis (the adrenal medulla, the vessels of the ARPC and the number of the adrenergic receptors on the kidney) is more developed in SHR than in the normotensive rats.

Higher responsiveness of the kidney to an increase of the blood flow through the ARPC (occurring in these experiments, but also in the physiological situation) may result in reducing of the kidney excretory function. At least two mechanisms are involved in this process: increased renal tubular sodium reabsorption and decrease in glomerular filtration rate (GFR). According to Guyton's theory of hypertension, such defects of the kidney function may shift the curve of the arterial blood pressure and natriuresis relationship to higher blood pressure values. An elimination of any direct
inflow of the sympathetic nervous system to the kidney in SHR completely prevents the development of arterial hypertension (3).

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REFERENCES


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