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Original

# Significance of posture and workload in exercise renography

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## Abstract

BACKGROUND: Exercise-induced alteration in renal function has been described in patients with essential hypertension. The aim of our study was to assess the significance of adopting a supine posture and the degree of workload required to induce these changes in patients with essential hypertension. The second aim was to assess whether the severity of hypertension had any influence on the development of exercise related renal dysfunction.
MATERIAL AND METHODS: Fifteen patients were studied (nine patients with mild and untreated hypertension and six patients with drug resistant hypertension). Exercise renography was carried out using a cycloergometer with the patient lying in supine posture and a target exercise rate of 20 bpm over baseline rate. Each patient was injected with 100 MBq of $^{99m}$Tc-MAG3 and renography was carried out for 20 minutes. Renography was repeated in rest condition only when an abnormality was observed in exercise scans.
RESULTS: Exercise renography was normal in 12 patients, while in 3 patients minor abnormalities were observed during exercise related to a minimal degree of pelvic dilatation. These changes remained substantially unmodified at rest. In none of the 15 patients did we find positive studies (i.e. reversible exercise induced prolongation of tracer transit caused by cortical retention). There was no difference in the results between patients with mild or severe hypertension.
CONCLUSIONS: Our results are different from previous reports on exercise renography since different groups have demonstrated exercise-induced renal dysfunction in the majority of patients with essential hypertension. The main differences between our protocol and that adopted in the literature relate to posture during exercise (upright vs. supine) and degree of workload (minor in supine exercise with less workload). These differences may have contributed to our results but further and larger studies are required to address the pathophysiological basis of exercise-induced alteration in renal function in association with essential hypertension.
**Key words: renography, hypertension, 99mTc-MAG3, exercise**

## Introduction

Hypertension is one of the most common worldwide diseases afflicting humans [1]. Because of the associated morbidity and mortality and the cost to society, hypertension is an important public health challenge. Arterial blood pressure is a product of cardiac output and systemic vascular resistance [1] and therefore, determinants of blood pressure include factors that affect both cardiac output and arteriolar vascular physiology. There is potential relevance of blood viscosity, vascular wall sheer conditions (rest and stress) and blood flow velocity (mean and pulsatile components) on vascular and endothelial function regulating blood pressure in humans. Furthermore, changes in vascular wall thickness affect the amplification of peripheral vascular resistance in hypertensive patients and result in reflection of waves back to the aorta, increasing systolic blood pressure.

Hypertensive patients may suffer from one of two categories:
- essential (primary) hypertension when the cause is unknown despite all necessary investigations (95% of cases);
- secondary hypertension when the cause is known, such as renal disease or endocrine disturbances (5% of cases) [2].

Exercise renography is an investigative procedure used to investigate alterations in renal function in patients with hypertension

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**Table 1. Blood pressure and heart rate (at baseline and peak exercise) with corresponding exercise Tmax and PTT in left and right kidneys in group A**

| Patient | Baseline BP | Exercise BP | Baseline HR | Exercise HR | TMAX (L-R) Exercise | TMAX (L-R) Rest | PTT (L-R) Exercise | PTT (L-R) Resr |
|---|---|---|---|---|---|---|---|---|
| 1 | 130/95 | 150/100 | 60 | 88 | 190–190 | | 160–160 | |
| 2 | 150/90 | 170/100 | 68 | 84 | 140–150 | | 210–220 | |
| 3 | 155/90 | 175/100 | 72 | 84 | 330–350 | 350-350 | 315–350 | 300–310 |
| 4 | 150/90 | 175/95 | 78 | 92 | 230–290 | | 170–180 | |
| 5 | 145/90 | 155/100 | 66 | 84 | 260–210 | | 170–220 | |
| 6 | 140/95 | 200/110 | 76 | 104 | 210–210 | | 210–220 | 210–220 |
| 7 | 150/90 | 175/100 | 70 | 86 | 380–380 | 430-560 | 240–260 | 240–240 |
| 8 | 140/90 | 155/100 | 72 | 86 | 140–140 | | 140–150 | |
| 9 | 140/90 | 170/105 | 64 | 84 | 180–200 | | 150–160 | |

BP — blood pressure; HR — heart rate; TMAX — time to maximum; PTT — parenchymal transit time

**Table 2. Blood pressure and heart rate (at baseline and peak exercise) with corresponding exercise Tmax and PTT in left and right kidneys in group B**

| Patient | Baseline BP | Exercise BP | Baseline HR | Exercise HR | TMAX (L-R) Exercise | TMAX (L-R) Rest | PTT (L-R) Exercise | PTT (L-R) Rest |
|---|---|---|---|---|---|---|---|---|
| 10 | 160/105 | 195/120 | 74 | 86 | 230–300 | | 210–220 | |
| 11 | 170/100 | 120/120 | 88 | 110 | 290–300 | 210–250 | 400–360 | 250–290 |
| 12 | 165/100 | 175/105 | 78 | 102 | 240–320 | | 170–190 | |
| 13 | 145/95 | 155/100 | 72 | 92 | 230–250 | | 170–180 | |
| 14 | 165/100 | 190/105 | 58 | 76 | 230–230 | | 170–160 | |
| 15 | 165/95 | 180/110 | 76 | 94 | 200–210 | | 190–200 | |

BP — blood pressure; HR — heart rate; TMAX — time to maximum; PTT — parenchymal transit time

[3–10], particularly those with essential hypertension (EH). In 1983 Clorius et al. introduced exercise renography as a tool in the investigation of hypertension [3], and extended their work by describing exercise-induced renal function disturbance in 62% of patients with EH [8]. These findings were further investigated by the same group [4–9] and confirmed by other authors [10–11]. Exercise renography, however, has not gained widespread popularity despite the potential of revealing a possible pathogenic link to essential hypertension. The aim of our study was to further assess exercise-induced renal dysfunction, with patients in supine posture during exercise as all previous studies have performed exercise in upright posture [9].

## Material and methods

Fifteen patients referred to the department of nuclear medicine, S. Orsola-Malpighi Hospital, Bologna, for assessment of hypertension, were included in this study. All known causes of hypertension were ruled out by biochemical screening and imaging, including Doppler ultrasound scans to assess renal arteries. On selecting patients, different clinical settings were taken into consideration in order to evaluate the possible role of the severity of hypertension. The patients were split into two groups:

- group A — nine patients (5 females and 4 males, age range: 39-56 years, mean age: 51 years) with recent onset, mild and untreated hypertension;
- group B — six patients (3 females and 3 males, age range: 28–57 years, mean age: 48 years) with chronic drug resistant hypertension.

When patients were on antihypertensive medications, therapy was uninterrupted. To ensure good hydration, 350–500 ml of liquids were orally administered 30 minutes prior to the examination. Blood pressure and heart rate were measured in all patients at baseline and during exercise.

Exercise renography was carried out using a cycloergometer with the patient lying in the supine posture. Exercise started at a workload of 25W and increased within 4 minutes to obtain a target heart rate of 20 bpm over baseline rate or the maximum workload that the patient was able to sustain for 20 minutes.

Acquisition started immediately after exercise using a LFOV gamma camera (Elscint, APEX 415, Haifa, Israel) equipped with a low--energy general-purpose (LEGP) collimator. Studies were acquired in a 64 × 64 matrix with a frame rate of 10 seconds/frame for a total of 20 minutes. In addition to visual inspection, time/activity curves (TAC) were generated and individual renal function, time to maximum (Tmax) and parenchymal transit time (PTT) were obtained. For the purpose of this study, the normal values for individual renal function, Tmax and PPT were 44–56%, $< 300$ seconds and $< 220$ seconds respectively.

Renography was repeated in the rest condition only in cases of an abnormality observed on the exercise scan.

## Results

The mean baseline systolic/diastolic blood pressure and heart rate in groups A were 144/91 mm Hg and 70 bpm changing during exercise to 161/101 mm Hg and 88 bpm respectively (Table 1). In group B the baseline values were 162/99 mm Hg and 74 bpm changing during exercise to 167/94 mm Hg and 93 bpm respectively (Table 2)

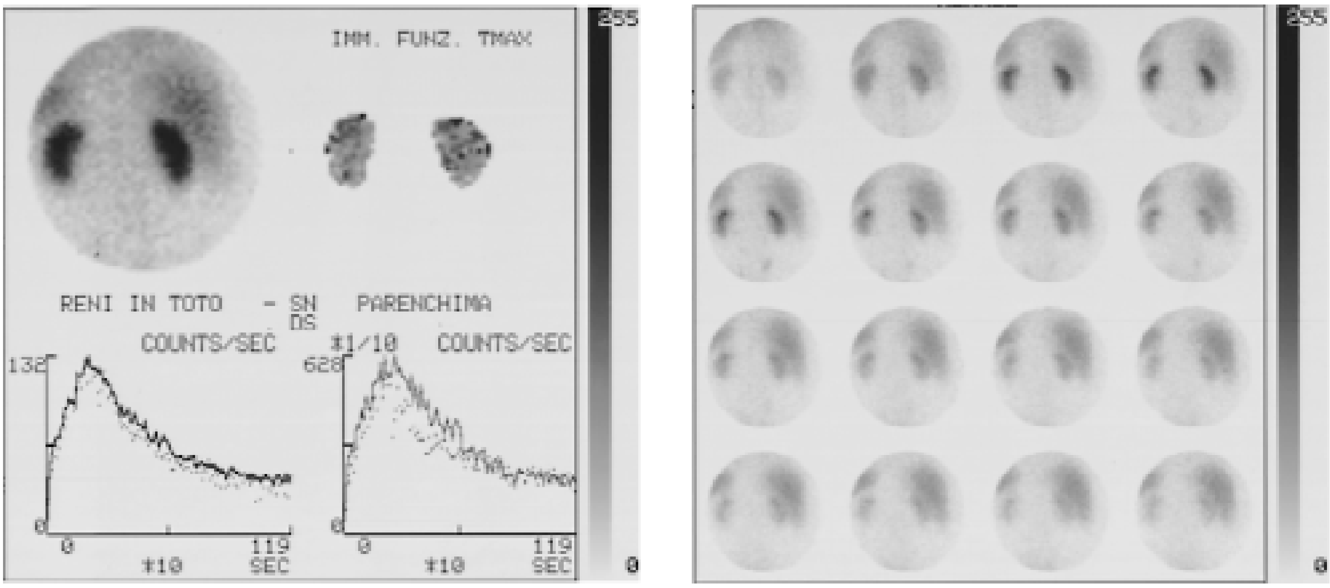

Figure 1. Exercise renography (renogram and sequential images): bilateral normal findings.

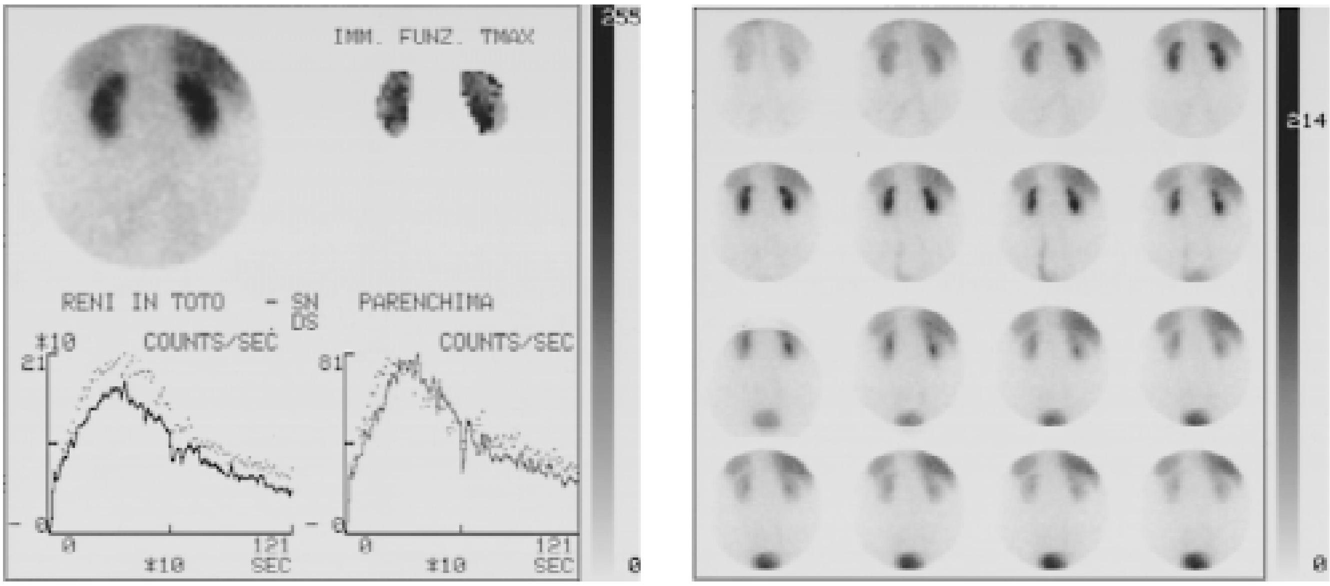

Figure 2. Exercise renography (renogram and sequential images) showing bilateral delay in Tmax and PTT due to pelvic-calyceal dilatation.

Exercise renography was completely normal in 12 cases with normal values for Tmax, PTT and divided renal function (Figure 1). In 3 cases, prolongation of Tmax and/or PTT (with normal individual renal function) was observed during exercise (patients 3 and 7, group A, Table 1 and patient 11, group B, Table 2). An example, relating to patient number 7, is shown in Figures 2 and 3.

Visual assessment showed that these changes were caused by minor pelvic-calyceal dilatation (Figure 3) and were not related to prolonged retention in the cortex. The prolongation of Tmax and/or PTT remained substantially abnormal at rest. In none of the 15 patients, therefore, did we observe reversible exercise-induced prolongation of tracer transit caused by cortical retention.

## Discussion

Early work by Clorius and Shmidlin demonstrated transient posture- and exercise-related alteration of renal cortical blood flow and tracer transit in patients with hypertension [3]. The changes were noted in 24% of their patients during the change from prone to standing postures and in 57% during exercise. The same group looked at the outcome of operative revascularisation of patients with renovascular hypertension (RVHT), and found that 11% of those who had pre-operative exercise-related alteration of renal cortical transit benefited from revascularisation compared to 83% of those who had no such alteration [5]. The exercise related al-

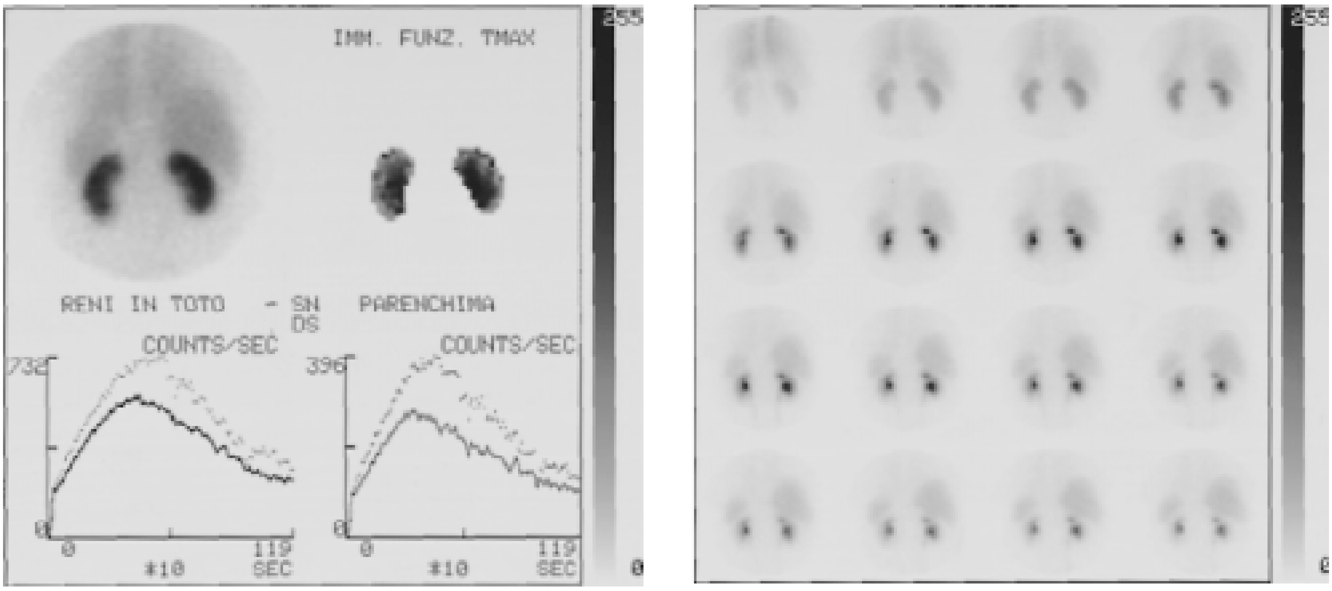

**Figure 3.** Rest renography (renogram and sequential images) of same patient as in Figure 2 showing no significant difference in Tmax and PPT.

terations in function were associated with reductions in glomerular filtration rate (GFR) and effective renal plasma floe (ERPF) using concomitant $^{131}$I-hippurate and $^{111}$In-DTPA, and were found in patients with RVH as well as EH [6]. In a more recent work [9], the same group investigated patients with EH and hypothesised that afferent-efferent glomerular vessel dysfunction disrupts the relationship between GFR and ERPF in EH and this is detected by exercise renography. The observation that patients with EH had exercise-related changes in renal function was documented by others [10]. All studies relating to exercise renography were performed in sitting or upright posture.

Our results are clearly different from previous reports on exercise renography, as we were unable to document any abnormal exercise-induced disturbance in renal function that would induce prolongation of Tmax and/or PTT. This discrepancy may have resulted from adopting different posture during exercise (upright *vs.* supine), or applying a reduced degree of workload (minor in supine exercise).

Regarding posture, all previous studies were carried out by imaging patients exercising in the upright posture. Posture dependent abnormalities of renal scintigraphy were described by Clorius et al [12], but it is unlikely that the sitting posture alone will account for renal dysfunction in hypertension, but rather it would activate and enhance such disturbances through sympathetic nervous system stimulation. Exercise in orthostatic upright posture causes a physiological vasoconstriction of renal vessels in favour of increasing muscular blood flow [13]. At first, renal vasoconstriction is mediated by sympathetic nervous stimulation only, followed by the additional effect of circulating catecholamines on vascular a2 receptors [14] and on adenosine [15] (a product of muscular metabolism).

In hypertensive patients, renal vasoconstriction during exercise may be worsened by two factors: activation of renin-angiotensin-aldosterone system (RAAS) [16, 17] and endothelial dysfunction [18], which is, at the same time, a cause and an effect of hypertension. Our data indicate that hypertensive patients exercising in supine posture maintain a good renal blood flow resulting in normal renal scintigraphy. On the basis of these pathophysiological considerations, we assume that adopting a supine posture may reduce the effect of vasoconstrictive factors, in particular RAAS and sympathetic stimulation.

As regards degree of workload, in our study patients were subjected to a lower workload compared to previous studies. We started with a low workload (25 W) with gradual increments, while the original protocol of Clorius et al. started and continued at 60 W (female) and 80 W (male). This implies a lower degree of muscular metabolism and a lower production of circulating adenosine.

Furthermore, supine posture allows a better venous backflow to the heart, which results in increased systolic out-flow and renal blood flow.

Because of the above reasons, we were likewise unable to demonstrate any significant difference in the response to exercise between patients with mild EH as compared to those with severe and drug resistant EH.

In conclusion, the adoption of supine posture and low workload during exercise renography reduces the chances of development of alteration of renal function in patients with essential hypertension and should be avoided to reduce incidence of false negative results.

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