

# HIGH BLOOD PRESSURE REDUCTION REVERSES AT<sub>2</sub> RECEPTOR-MEDIATED VASOCONSTRICTION INTO VASODILATION IN SPONTANEOUSLY HYPERTENSIVE RATS

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**Short title:** AT<sub>2</sub> receptor function in hypertension

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Acknowledgement: This work was supported in part by a grant from the French Foundation for Medical research (FRM, Paris, France)

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## **ABSTRACT**

**Background:** We have previously shown that angiotensin II type 2 receptor (AT2R) stimulation causes endothelium-dependent vasodilation which does not desensitize after chronic angiotensin II type 1 receptor (AT1R) blockade, suggesting a role for AT2R in antihypertensive treatment.

**Material and Results:** We recorded mean arterial pressure (MAP) and investigated AT2R by western blot analysis, immunohistochemistry and function in isolated mesenteric resistance arteries (205  $\mu$ m diameter) from Wistar-Kyoto (WKY) and spontaneously hypertensive rats (SHR) receiving for 4 weeks in drinking water: placebo, AT1R blockade (candesartan, 2 mg/kg/d), angiotensin converting enzyme inhibitor (perindopril, 3 mg/kg/d), non-selective vasodilator (hydralazine, 16 or 24 mg/kg/d) or candesartan + hydralazine (16 mg/kg/d).

In precontracted isolated arteries AT2R stimulation (Angiotensin II in the presence of candesartan) caused vasodilation in WKY rats (MAP=118 mmHg) and vasoconstriction in SHR (MAP=183 mmHg). In SHR treated with candesartan (MAP=146 mmHg) or hydralazine (16 mg/kg/d; MAP=145 mmHg) AT2R-induced contraction was reduced by 50%. In SHR treated with perindopril (MAP=125 mmHg), AT2R stimulation induced a vasodilation. In SHR treated with hydralazine (24 mg/kg/d; MAP=105 mmHg) and in SHR treated with hydralazine (16mg/kg/d) + candesartan (MAP=102 mmHg) an AT2R mediated-vasodilation was restored. Immunohistochemistry and Western-blot analysis showed that AT2R expression, lower in SHR than in WKY was restored to normal level by treatments reducing arterial pressure in SHR.

**Conclusions:** Our results suggest that in resistance arteries of SHR 1) AT2R is down regulated by hypertension and 2) specific and non-specific anti-hypertensive treatments restore AT2R expression and vasodilator functions.

**Keywords:** angiotensin; receptors, vascular; vasodilation; hypertension.

## INTRODUCTION

Angiotensin II (Ang II), the key effector of the renin-angiotensin-aldosterone system, has an important role in the control of blood pressure and blood volume. Angiotensin II activates at least two receptor types. (<sup>1,2</sup>), the Ang II type 1 receptors (AT<sub>1</sub>R) the Ang II type 2 receptors AT<sub>2</sub>R(<sup>3,4,5</sup>). Stimulation of AT<sub>2</sub>R undoubtedly induces relaxation in several vascular territories (<sup>6,7</sup>). In most blood vessels AT<sub>2</sub>R-dependent relaxation is associated with activation of the bradykinin (BK) and/or nitric oxide (NO)/Guanosine 3', 5'-cyclic monophosphate (cGMP) pathway (<sup>8,9,10,11</sup>). In vitro, the vasodilator role of AT<sub>2</sub>R is supported by evidence based on enhance Ang II-mediated vasoconstriction in the presence of AT<sub>2</sub>R blockade or in AT<sub>2</sub>R knockout mice (<sup>12,13,14</sup>). AT<sub>2</sub>R mRNA and protein expression was demonstrated in resistance arteries from normotensive rats (<sup>15,16</sup>). We have previously shown in mesenteric resistance arteries from WKY, that AT<sub>2</sub>R is involved in NO-dependent flow-mediated dilation (<sup>16</sup>), whereas in SHR flow (shear stress) stimulation of the endothelium is associated to an AT<sub>1</sub>R and endothelin-1 type A receptor activation, thus counteracting endothelium-dependent dilation (<sup>17</sup>). Furthermore, acute administration of an AT<sub>2</sub>R inhibitor reversed both the acute antihypertensive effects and elevated level of BK, NO and cGMP in renal interstitial fluid caused by AT<sub>1</sub>R blockade in renal wrap and salt-restricted rats (<sup>18,19</sup>). Finally, we have recently shown the reproducibility of the vasodilator effect of AT<sub>2</sub>R stimulation under acute and chronic AT<sub>1</sub>R blockade (<sup>20</sup>), further supporting the assumption that AT<sub>2</sub>R stimulation might play a role in the antihypertensive effect of AT<sub>1</sub>R blocking drugs. Thus, we speculate that AT<sub>2</sub>R-stimulation, and hence vasodilation, might play a role in antihypertensive treatments, especially when AT<sub>1</sub>R blocking agents are used. Indeed, AT<sub>1</sub>R antagonists induce an important rise in circulating angiotensin II. AT<sub>2</sub>R might then be chronically overstimulated, participating to the maintenance of a vasodilation, particularly since this effect was not easily desensitized (20).

Thus, in the present study, we evaluated the vasomotor role of AT<sub>2</sub>R in resistance arteries isolated from SHR (hypertensive conditions) and after various chronic antihypertensive treatments, including angiotensin-converting enzyme inhibition, AT<sub>1</sub>R blockade or a non-selective treatment, as well as AT<sub>2</sub>R expression and immunolocation. We hypothesized that AT<sub>2</sub>R-mediated dilation, which was impaired in untreated SHR, would be re-established in mesenteric arteries taken from treated SHR in parallel with reductions in blood pressure.

## **METHODS**

### ***Animal model***

7-8 weeks old male WKY and SHR rats were separated into 8 groups receiving for 4 weeks in drinking water: WKY: placebo or AT1R antagonist (candesartan cilexetil, 2mg/kg/d), SHR: placebo, ACEI (perindopril, 3mg/kg/d), candesartan (2mg/kg/d), the non-selective antihypertensive drug (hydralazine, 2 groups: 16 or 24 mg/kg/d) or candesartan + hydralazine (16 mg/kg/d).

The protocol used was in accordance with the European Community standards on the care and use of laboratory animals (authorization no.00577).

### ***MAP Measurement***

After 4 weeks of treatment, rats were anesthetized with sodium pentobarbital (50mg per kg, i.p.). Mean arterial pressure (MAP) was measured in the right carotid artery using a catheter connected to a GOULD transducer and an analog-digital signal recording system (Biopac)(16,17)

### ***Isolated mesenteric artery***

A 3-4 mm-long segment of mesenteric artery ( $205 \pm 11 \mu\text{m}$ , internal diameter measured at 75 mmHg in the absence of tone) was dissected, cannulated at both ends and mounted in a video monitored perfusion system (<sup>21</sup>) as we have previously described (16,17,20). Briefly, arteries were bathed in a physiological salt solution (PSS) maintained at 37°C, pH 7.4. The pO<sub>2</sub> was 160 mmHg and the pCO<sub>2</sub> 37 mmHg (16,17,20). The artery was superfused (4 ml/min) and flow through the vessel was maintained at a rate of 100  $\mu\text{l}/\text{min}$ , with intraluminal pressure set at 75 mmHg (20). Arterial diameter was measured (Living Systems Instrumentations, Burlington, VT, USA) and recorded continuously (Biopac, Lajolla, CA, USA). Vessels were allowed to stabilize for at least 30 minutes before drugs were added to the PSS superfusion. The integrity of the endothelium was assessed by testing the relaxing effect of acetylcholine (Ach, 1  $\mu\text{mol}/\text{L}$ ) after precontraction with phenylephrine (PE, 1  $\mu\text{mol}/\text{L}$ ). The arteries were then exposed to candesartan (100 nmol/L) for at least 30 minutes before exposure to Ang II while they were precontracted with PE (1  $\mu\text{mol}/\text{L}$ ) and serotonin (0.1  $\mu\text{mol}/\text{L}$ ) in order to induce a stable reduction in diameter. When this response had reached a plateau, a concentration-response curve to Ang II (0.1 nmol/L to 100 nmol/L) or Ang II (100 nmol/L)

was performed and changes in diameter were measured. Ach (1  $\mu\text{mol/L}$ ) was used to completely dilate the vessels. A number of 8 rats was used in each group.

In separate series of experiments (n=5 per group), AT<sub>2</sub>R stimulation was repeated before and after application of one of the following drug: the cyclooxygenase inhibitor indomethacin (10  $\mu\text{mol/L}$ ), the thromboxane A<sub>2</sub>-PGH<sub>2</sub> receptor blocker SQ29548 (10  $\mu\text{mol/L}$ ), the bradykinin B<sub>2</sub> receptor blocker HOE140 (0.1  $\mu\text{mol/L}$ ), the endothelin receptor blocker bosantan (10  $\mu\text{mol/L}$ ).

Stimulation of AT<sub>2</sub>R was also performed before and after endothelium removal (5 second of air perfusion, n= 4 rats per group) in WKY rats, untreated SHR and in SHR treated with candesartan plus hydralazine (16 mg/kg/d).

### ***Western Blot Analysis of AT<sub>2</sub> Receptors***

Western blot analysis of AT<sub>2</sub>R was performed in mesenteric resistance arteries of WKY rats and SHR (n=8 per group). Mesenteric arteries were also isolated from SHR treated with hydralazine (24mg/kg/d, for 18, 23, or 48 days, n=5 per group) or with candesantan + hydralazine (16mg/kg/d, n=5 per group). Mesenteric arteries were homogenized using a lysis buffer (1% sodium dodecyl sulfate SDS, 10 mmol/L Tris-HCl [pH 7.4], 1 mmol/L sodium orthovanadate , 2.5 mg/L leupeptin and 5 mg/L aprotin). Extracts were incubated at 25 °C for 30 minutes and then centrifuged (1 000g, 15 minutes, 14°C). Proteins concentration was determined using the Micro BCA Protein Assay Kit (Pierce). After denaturation at 100°C for 5 minutes, equal amounts of proteins (15  $\mu\text{g}$ ) were loaded on a 9% polyacrylamide gel and transferred to nitrocellulose membranes for 12 hours (40 V, 4°C). Membranes were blocked with 10% albumin bovine (BSA) in TBST (20 mmol/L Tris [pH 8.0], 150 mmol/L NaCl, and 0.1% Tween-20) for 1 hour and were then incubated with AT<sub>2</sub>R rabbit polyclonal antibody (dilution 1:100, Santa Cruz, California, USA) in washing solution at room temperature for 20 hours. The membranes were then washed and incubated with the anti-rabbit horseradish peroxidase antibody (dilution 1 : 5000, Amersham Pharmacia Biotech, Orsay, France) for 1 h at room temperature. After 3 washes with TBS-T, immunocomplexes were detected by chemiluminescent reaction (ECL-kit; Amersham Pharmacia Biotech) using a computer based imaging system (Fuji LAS 1000 plus; Fuji Medical System). Quantification was performed by densitometric analysis.

### ***Immunofluorescence Analysis of AT2 Receptors***

Segments of mesenteric resistance arteries (n= 6 rats per group) were mounted in embedding medium (Miles, Inc), frozen in isopentane pre-cooled in liquid nitrogen, and stored at -80°C on transverse cross sections 7 µm thick. Sections were incubated with candesartan (30 min, 10 nmol/L, 25°C), then with fluorescent Angiotensin II (FITC-bound angiotensin II, 30 min, 10 pmol/L, 25°C, Molecular Probes). Fluorescence staining was visualized using confocal microscopy (Biorad MRC-600). Control experiments were performed after incubation with non-fluorescent Angiotensin II. Image analysis was performed using Histolab (Microvision, France). Briefly, pixels quantification was performed after separating the media and the endothelial layer. Data is given as percentage of control (fluorescence in WKY taken as 100%).

### ***Statistical analysis***

Results are expressed as means ± s.e. mean. The significance of the different treatments was determined by ANOVA or two tailed Student's paired t-test. P values less than 0,05 were considered to be significant. Number of rats was used for the analysis.

### ***Drugs***

Candesartan cilexetil was kindly provided by Astra-Zeneca (Sweden). Other products were purchased from Sigma.

## **RESULTS**

### ***Mean Arterial Pressure and AT2R Mediated dilation in isolated arteries***

Figure 1 shows typical recordings obtained with mesenteric arteries isolated from a WKY rat (fig. 1A) and from SHR (fig. 1B). Mean arterial blood pressure was  $118 \pm 8$  mmHg (n=8) in WKY rats and  $183 \pm 11$  mmHg (n=8) in SHR. Isolated arteries were first incubated with

candesartan (100 nmol/L, 30 min) and pre-contracted with phenylephrine ( $54\pm 4$   $\mu\text{m}$ , diameter decrease). Then, addition of Ang II (100 nmol/L) induced a significant dilation ( $24\pm 3$   $\mu\text{m}$ , diameter increase) in control WKY. By contrast, in SHR the stimulation of AT<sub>2</sub>R led to a significant contraction ( $8\pm 3$   $\mu\text{m}$ , diameter decrease, Fig. 1B). In both WKY and SHR the arteries were able to fully dilate when acetylcholine was added after ang II. Diameter changes in response to AT<sub>2</sub>R stimulation (dilation in WKY rats or contraction in SHR) were suppressed by the AT<sub>2</sub>R antagonist PD123319 (1  $\mu\text{mol/L}$ ). In the presence of candesartan and PD123319 Ang II produced no significant change in diameter ( $2\pm 3$   $\mu\text{m}$ , n=5 in WKY and  $-1\pm 2$   $\mu\text{m}$ , n=4 in SHR).

The contraction induced by ang II (100 nmol/L) in arteries isolated from SHR was significantly reduced by indomethacin (10  $\mu\text{mol/L}$ ,  $6\pm 2$  versus  $12\pm 3$   $\mu\text{m}$  reduction in diameter, n=5), SQ29548 (10  $\mu\text{mol/L}$ ,  $6\pm 3$  versus  $14\pm 3$   $\mu\text{m}$  reduction in diameter, n=5) and by bosantan (10  $\mu\text{mol/L}$ ,  $7\pm 3$  versus  $16\pm 3$   $\mu\text{m}$  reduction in diameter, n=5). The combination of indomethacin (10  $\mu\text{mol/L}$ ) and bosantan (10  $\mu\text{mol/L}$ ) suppressed ang II-induced contraction in SHR ( $2\pm 3$  versus  $14\pm 3$   $\mu\text{m}$  reduction in diameter, n=5). The bradykinin B<sub>2</sub> receptor blocker HOE140 (0.1  $\mu\text{mol/L}$ ) did not significantly affect angII-induced contraction in SHR ( $13\pm 3$  versus  $15\pm 4$   $\mu\text{m}$  reduction in diameter). In WKY rats angII-induced dilation was significantly reduced by L-NAME ( $4\pm 2$  versus  $24\pm 4$   $\mu\text{m}$ ) and by HOE140 ( $6\pm 3$  versus  $26\pm 5$   $\mu\text{m}$ ).

The stimulation of AT<sub>2</sub>R produced a concentration dependent dilation in arteries isolated from WKY rats and a concentration dependent contraction in arteries isolated from SHR (fig. 1C, n=8 per group).

**Concentration dependent stimulation of AT<sub>2</sub>R (angII 0.01 to 100 nmol/L)** was repeated in arteries isolated from WKY rats and SHR submitted to various treatments. Maximal responses to AT<sub>2</sub>R stimulation and mean arterial blood pressure determined in the different groups are shown in figure 2.

There was no significant difference in MAP and AT<sub>2</sub>R mediated dilation between control WKY rats ( $118\pm 8$  mmHg;  $24\pm 3$   $\mu\text{m}$ , diameter increase, n=8) and WKY rats treated with candesartan ( $108\pm 9$  mmHg,  $19\pm 5$   $\mu\text{m}$  diameter increase, n=4).

In SHR, candesartan partly depressed MAP ( $146\pm 8$  mmHg, n=4 versus  $183\pm 11$  mmHg, n=8;  $P<0.01$  versus SHR and  $P<0.01$  versus WKY rats) and tended to reduce AT<sub>2</sub>R mediated

contraction, although this did not reach significance ( $8\pm 3$   $\mu\text{m}$  versus  $3\pm 2$   $\mu\text{m}$  diameter decrease).

In SHR, treatment with perindopril reduced MAP ( $n=4$ ,  $125\pm 6$  mmHg,  $P<0.01$ ) and AT2R stimulation induced a significant vasodilation ( $6\pm 2$   $\mu\text{m}$ , diameter increase) which was significantly lower than AT2-induced dilation in WKY rats.

In hydralazine (16 mg/kg/d,  $n=4$ )-treated SHR, MAP decreased to a level that was still higher than in WKY rats ( $145\pm 11$  mmHg,  $n=6$ ;  $P<0.01$  versus SHR and  $P<0.05$  versus WKY rats) and stimulation of AT2R induced a vasoconstriction ( $3\pm 1$   $\mu\text{m}$  diameter decrease,  $n=6$ ).

In SHR treated with a higher dose of hydralazine (24 mg/kg/d,  $n=4$ ) MAP was reduced to a normal value ( $105\pm 10$  mmHg, NS versus WKY rats) and AT2R induced a significant vasodilation ( $27\pm 7$   $\mu\text{m}$ , diameter increase, NS versus WKY rats).

In SHR treated with candesartan plus hydralazine (16 mg/kg/d) MAP was reduced to normal level ( $n=4$ ,  $102\pm 9$  mmHg, NS versus WKY rats) and AT2R induced a significant vasodilation ( $22\pm 5$   $\mu\text{m}$  diameter increase, NS versus WKY rats).

Endothelium removal did not affect AT2R-dependent contraction in untreated SHR ( $12\pm 3$   $\mu\text{m}$  with endothelium versus  $14\pm 3$   $\mu\text{m}$  contraction without endothelium,  $n=4$ ). On the other hand, AT2R-dependent dilation was abolished by endothelium removal in both untreated WKY ( $24\pm 4$  versus  $3\pm 2$   $\mu\text{m}$  dilation,  $n=4$ ) and SHR treated with candesartan plus hydralazine (16 mg/kg/d:  $26\pm 4$  versus  $4\pm 2$   $\mu\text{m}$  increase in diameter,  $n=4$ ).

### ***Western Blot Analysis of AT2R***

In resistance arteries isolated from untreated WKY ( $n=8$ ) rats and untreated SHR ( $n=8$ ), as well as from SHR treated with hydralazine alone (24 mg/kg/d,  $n=5$ ) or hydralazine (16 mg/kg/d,  $n=5$ ) combined with candesartan, AT2R expression was quantified. Western-blot analysis showed that AT2R was significantly less expressed in SHR than in WKY rats (46%) in isolated mesenteric resistance arteries (fig. 3). Hydralazine (24mg/kg/d) gradually raised AT2R expression in SHR treated for 18, 23 and 48 days. After 48 days, AT2R expression was significantly higher than in SHR, but it remains significantly lower than in WKY (70%, Fig. 3). However, after 44 days of treatment, candesartan plus hydralazine (16 mg/kg/d) restored AT2R expression in SHR to a level equivalent to that found in WKY (96,7% versus 100%, Fig. 3).

### ***Immunohistology analysis of AT2R***

In WKY, immunofluorescence analysis of mesenteric resistance arteries, using confocal microscopy, indicated that AT2R was present in the endothelium, in the smooth muscle and in the adventitia. In the endothelium AT2R immunofluorescence was lower in SHR than in WKY rats ( $5\pm 3\%$  of WKY, NS,  $n=6$  per group). In the media a significant fluorescence could be detected although it was lower than in WKY rats ( $32\pm 6\%$ ,  $P<0.01$   $n=6$ ). In SHR treated with candesartan + hydralazine (16mg/kg/d) immunofluorescence of AT2R was restored to a level equivalent to that found in WKY rats (compared to WKY:  $88\pm 11\%$  in the endothelium and  $81\pm 18\%$  in the media) (Fig. 4).

## **DISCUSSION**

The present study demonstrates that AT2R stimulation induced a vasoconstriction in untreated SHR resistance arteries associated with a decrease in AT2R expression. Specific or non-specific anti-hypertensive treatments restored AT2R expression and its vasodilator function when the decrease in pressure was sufficient.

Recent evidence suggests that AT2R stimulation causes vasodilation in small resistance arteries in normotensive rats (6,7,11,16,17,20,<sup>22</sup>). This vasodilation may play an important role in the regulation of arterial blood pressure by increasing resistance arteries diameter. Vasodilation induced by AT2R stimulation has been described in several vascular territories and is usually associated to NO production by endothelial cells and cGMP production by smooth muscle cells (<sup>23</sup>). In some, but not all arteries investigated bradykinin B2 receptor activation is involved in AT2R-dependent dilation (9-11,22). Importantly, AT2R-mediated dilation does not desensitize, by contrast with AT1R-dependent contraction, supporting the assumption that AT2R dilation might have a role in the treatment of hypertension (20,<sup>24</sup>). Furthermore, in agreement with previous studies (21<sup>25</sup>) AT2R were found in resistance arteries using western blot and RT-PCR analysis. Using immuno-fluorescence AT2R were localized in endothelial and smooth muscle cells, as in previous studies in rat mesenteric arteries (16) and skeletal muscle arterioles (<sup>26</sup>).

We found that AT2R stimulation in SHR induced a vasoconstriction, in agreement with previous studies showing that in young hypertensive rats AngII-induced contraction was decreased by AT2R blockade (25). Interestingly, this effect involved stimulation of ET-1 and

probably thromboxane A<sub>2</sub>. We found that AT<sub>2</sub>R expression was lower in SHR resistance arteries than in WKY rats. However, a decreased expression cannot readily explain a reversal of dilation into contraction. The mechanism of this reversal remains to be discovered, but may involve a switch in signaling from constrictor to dilator mechanisms due to increased endothelial AT<sub>2</sub>R expression. Indeed, our immunohistological analysis of AT<sub>2</sub>R in mesenteric arteries from SHR showed undetectable AT<sub>2</sub>R labeling in the endothelium that was re-established with antihypertensive treatment that normalized blood pressure. In addition, AT<sub>2</sub>R-dependent contraction in SHR is not affected by endothelium removal whereas AT<sub>2</sub>R-dependent dilation is abolished in the absence of endothelium. Thus the difference in the type of response might reflect a change in AT<sub>2</sub>R expression between the endothelium and the smooth muscle. Nevertheless, due to the small size of the resistance arteries AT<sub>2</sub>R expression and mRNA level were not significantly decreased by endothelium removal in either SHR or WKY rats (unpublished data). In addition, cultured endothelial cells rapidly lose AT<sub>2</sub>R phenotype, thus preventing a study of AT<sub>2</sub>R expression in cultured endothelial cells from WKY rats or SHR.

Stimulation of the NO-cGMP pathway by AT<sub>2</sub>R has been initially shown in aortic cells (<sup>27</sup>). In the dog coronary circulation NO production by ang II is activated through both AT<sub>1</sub>R and AT<sub>2</sub>R stimulation (<sup>28</sup>). Several other evidences suggest that AT<sub>1</sub>R and AT<sub>2</sub>R may not always oppose each other, at least concerning NO production (23). In the mesenteric circulation we found that AT<sub>2</sub>R-dependent flow-mediated dilation requires NO production and that exogenous stimulation of AT<sub>2</sub>R in the same arteries produces dilation (16).

In WKY rats, candesartan did not significantly change MAP and AT<sub>2</sub>R mediated dilation was preserved, as we have previously reported (20). By contrast, candesartan partly decreased MAP and AT<sub>2</sub>R mediated vasoconstriction in SHR. Similarly, a low dose hydralazine, also partly reducing MAP, inhibited AT<sub>2</sub>R mediated vasoconstriction. Obviously, these treatments were not able to normalize MAP and to restore AT<sub>2</sub>R vasodilator function. Indeed, it was only when MAP was sufficiently reduced in SHR that AT<sub>2</sub>R mediated vasodilation was observed. First, using an ACEI inhibitor, MAP was decreased to a level similar to that observed in WKY. In this case, stimulation of AT<sub>2</sub>R induced a vasodilation. A further decrease in MAP, using a higher dose of hydralazine or candesartan plus hydralazine, was also associated with a vasodilator effect of AT<sub>2</sub>R stimulation.

Interestingly, the different groups studied allowed a correlation to be drawn between MAP and the type and amplitude of the response to AT<sub>2</sub>R-stimulation (figure 2). Thus, from high to low MAP, AT<sub>2</sub>R-stimulation moved progressively from contraction to dilation. In addition,

this effect was associated with a different AT2R expression. In SHR, AT2R expression was low in the wall of mesenteric arteries, compared to WKY. After MAP reduction in SHR, AT2R expression was restored to the level of WKY. However, it is difficult to determine if AT2R-mediated dilation is a cause or a consequence of the reduction in blood pressure. In the combined candesartan/ hydralazine group of SHR, the time course for AT2R expression, assessed by Western blots, was in parallel with the restoration of maximal AT2R-mediated dilation and normotension, which may indicate a primary role for AT2R. On the other hand, equivalent reductions in MAP caused by hydralazine were associated with maximal AT2R-mediated dilation despite suppressed AT2R expression. These discrepancies in AT2R abundance between treatments may reflect distinct AT2R locations within the vasculature. Indeed, more precise immunohistological analysis demonstrated that AT2R expression was located in the endothelial and smooth muscle cells in WKY, whereas, in SHR AT2R was not detectable in the endothelium. On the other hand, in SHR treated with candesartan plus hydralazine, MAP was restored, AT2R stimulation induced a vasodilation and AT2R expression was equivalent to that found in WKY. In this group, immunohistology of AT2R showed the presence of the receptor in both endothelia and smooth muscle cells. Thus we can speculate that the presence or absence of AT2R on endothelial cells has a key role in determining the type of response, at least in part, as the inhibition of the vasodilation in WKY by L-NAME does not uncover a vasoconstriction due to receptors located on the muscle, as revealed by immunohistology. We can also assume that MAP per se is the effector determining the type of response induced by AT2R stimulation (figure 2C).

In conclusion, in resistance arteries of SHR 1) AT2R is down regulated by hypertension and 2) specific and non-specific anti-hypertensive treatments restore AT2R expression and vasodilator functions. Whether or not this AT2R plasticity directly contributed to the blood pressure reduction, this AT2R dilator mechanism is likely to contribute to the maintenance of a vasodilator state during chronic treatment.

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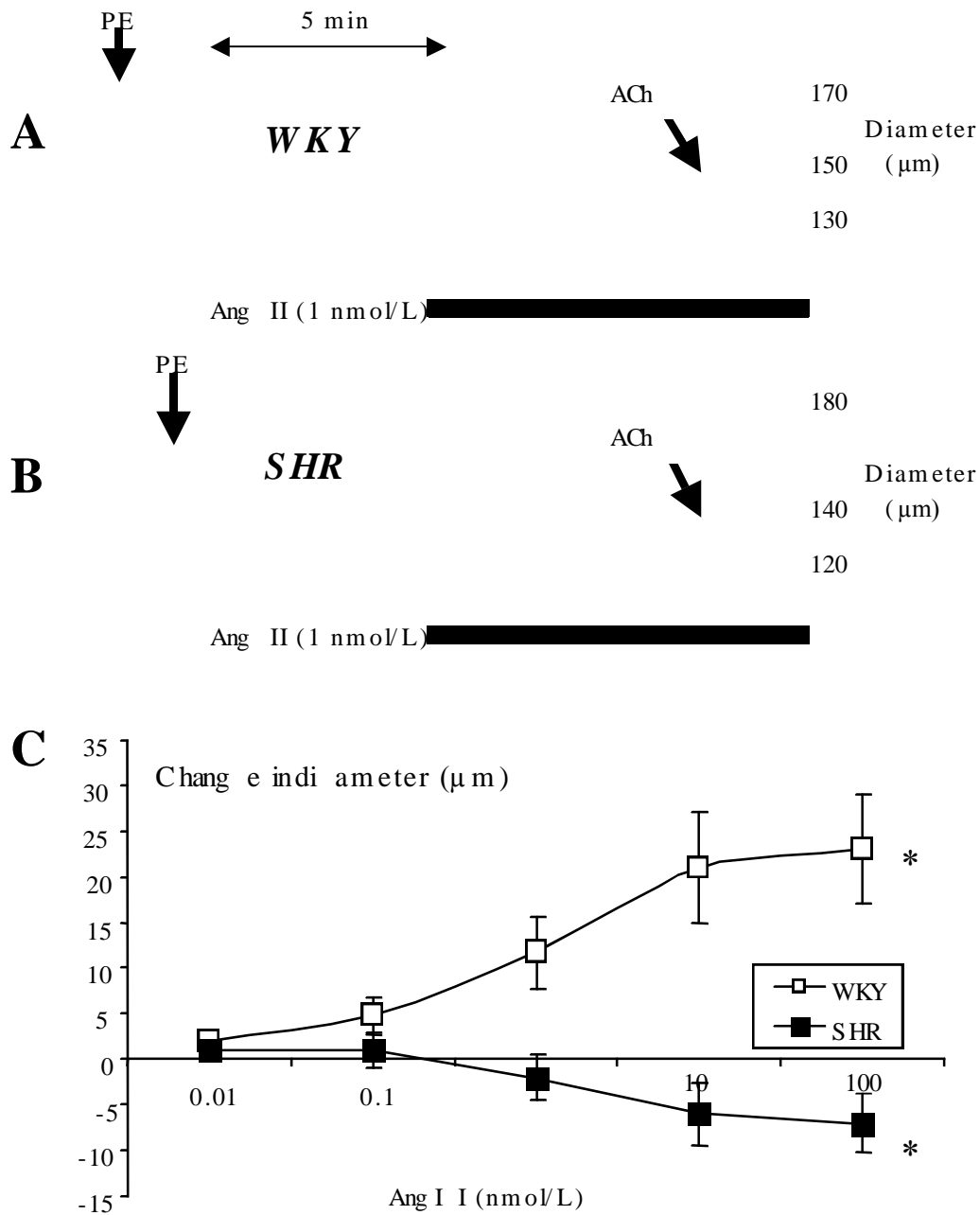
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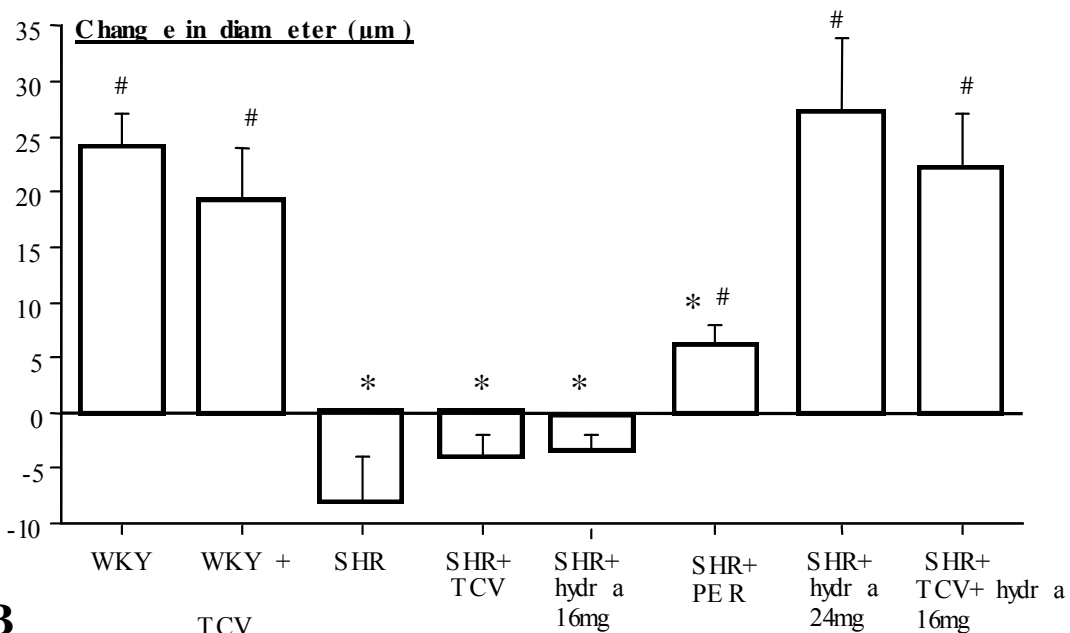
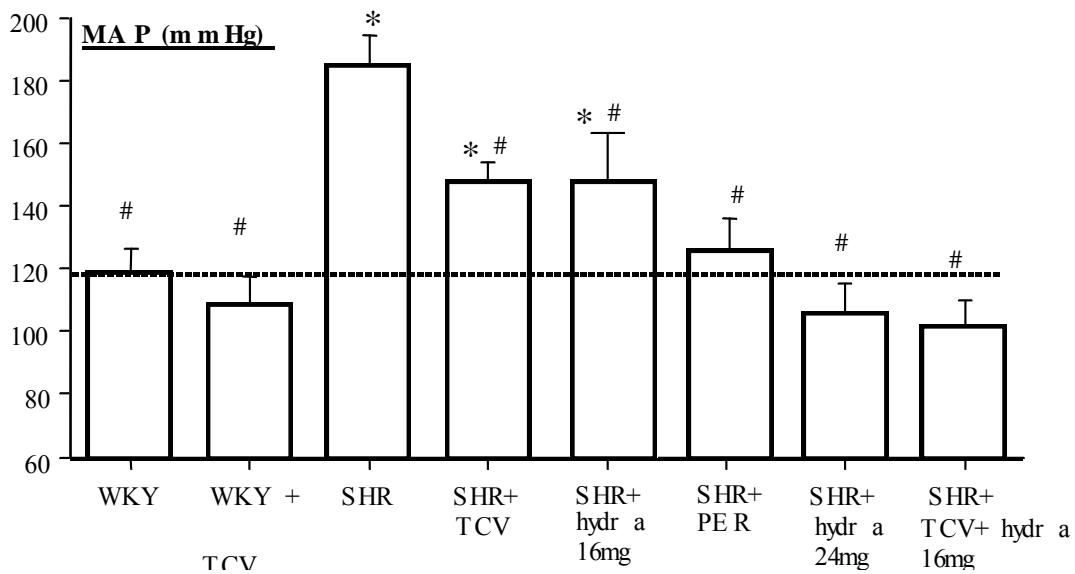
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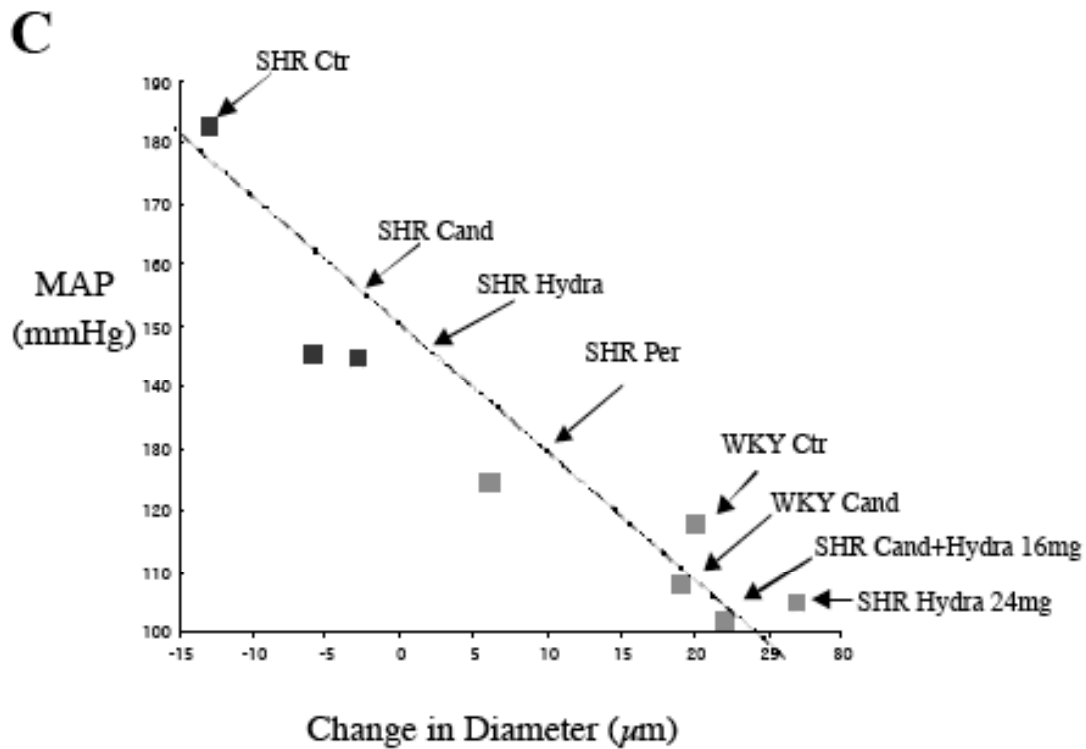
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**Figure 1:** Typical recordings obtained in mesenteric arteries isolated from WKY (A) and SHR (B) rats and perfused under a pressure of 75 mmHg, a flow of 100  $\mu\text{l}/\text{min}$  and in the presence of candesartan (100 nmol/L). After a precontraction with phenylephrine (PE), angiotensin II (Ang II, 100 nmol/L) was added to the bath containing the artery. Finally acetylcholine (1  $\mu\text{M}$ ) was added in order to fully relax the artery (n=8 per group).

The lower panel (C) shows concentration-response curves to ang II obtained in the conditions described above.

**A****B**



**Figure 2:**

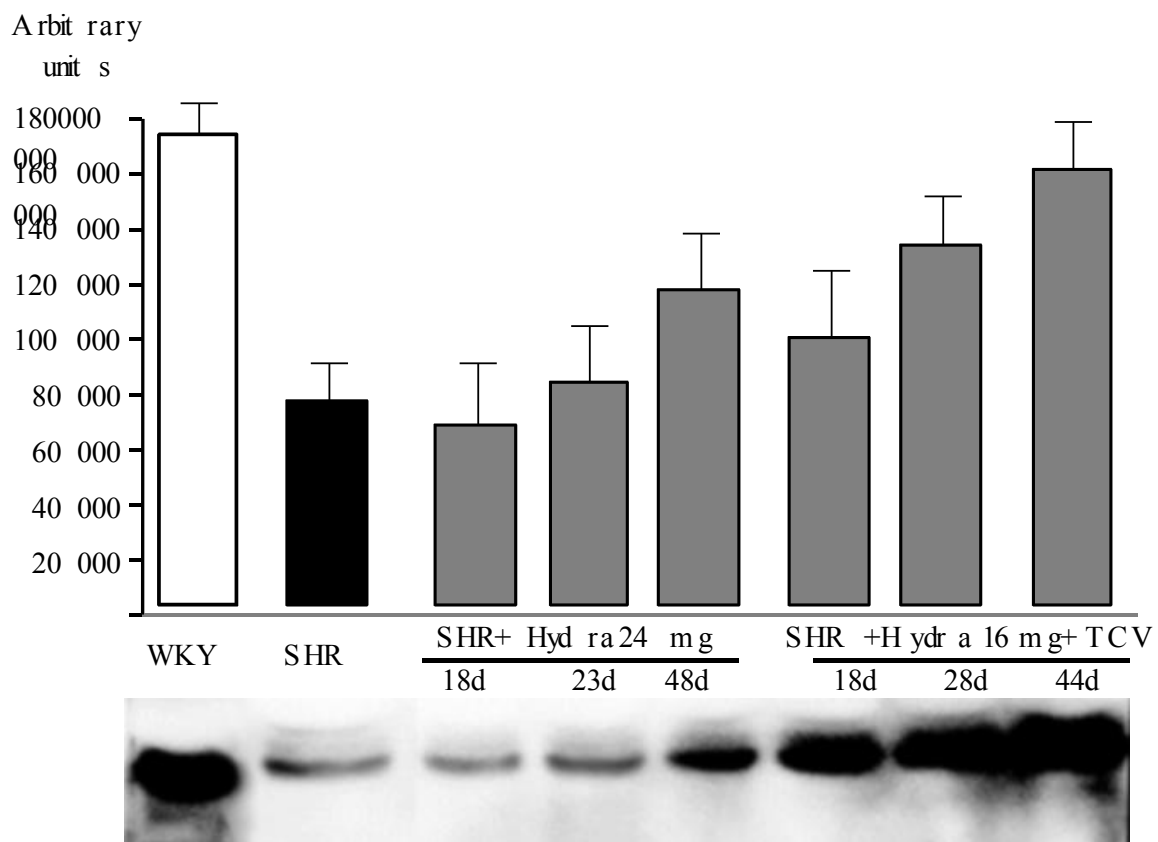
Upper panel (A): Angiotensin II (Ang II, 100 nmol/L) mediated-dilation (diameter increase) or contraction (diameter decrease) in the presence of candesartan (100 nmol/L), obtained in isolated mesenteric arteries of the normotensive rats (WKY) or spontaneously hypertensive rats (SHR) perfused in an arteriograph under a pressure of 75 mmHg and a flow of 100  $\mu$ l/min). Rats were treated for 4 weeks with candesartan (TCV, 2mg/kg/d), perindopril (PER, 3mg/kg/d), hydralazine (Hydra, 16 or 24 mg/kg/d), or candesartan + hydralazine (TCV 2mg/kg/d +Hydra 16mg/kg/d).

Middle panel (B): Mean arterial pressure measured in the groups of rats described above. Mean  $\pm$  SEM is presented (n=8 per group).

Lower panel (C): Relationship between mean arterial pressure (MAP) and AT<sub>2</sub>R mediated-diameter-changes in resistance arteries (from data shown on panel A and B).

\*P<0,05, versus control WKY;

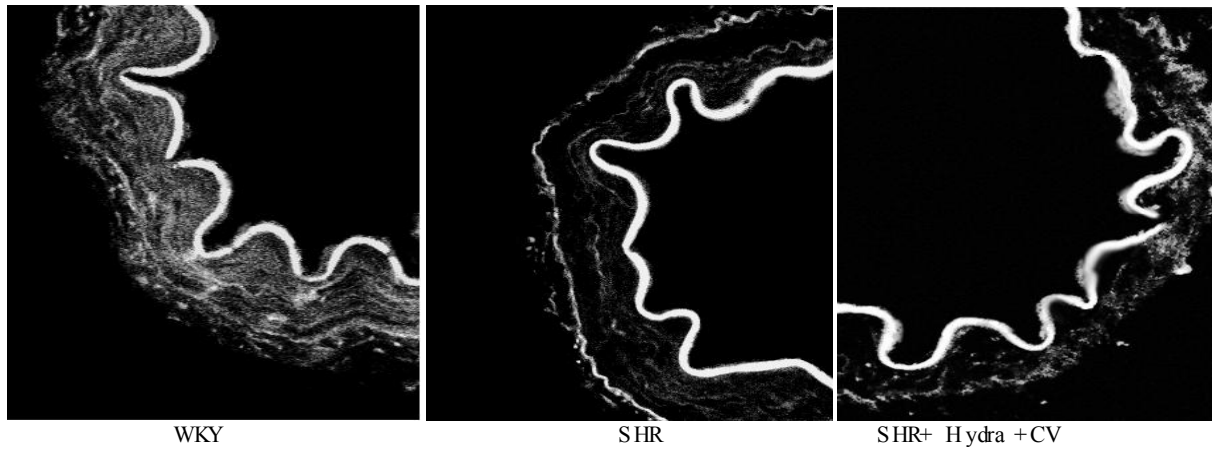
#P<0,05, versus control SHR.



**Figure 3:** Western blot analysis of AT<sub>2</sub>R in mesenteric resistance arteries of normotensive (WKY, white bar, n=8) rats or spontaneously hypertensive rats (SHR, black bar, n=8). One group of SHR were treated with hydralazine (hydra, 24mg/kg/d) for 18, 23, or 48 days (n=5 per group). Another group of SHR was treated with candesantan + hydralazine (TCV + Hydra 16mg/kg/d, n=5 per group). Representative blots are shown below.

\*P<0,05, versus control WKY;

#P<0,05, versus control SHR.



**Figure 4:** Confocal immuno-histological analysis of AT<sub>2</sub>R in mesenteric resistance arteries of the normotensive (WKY) rats, spontaneously hypertensive rats (SHR) or SHR treated with cadesantane (TCV, 2mg/kg/d) and hydralazine (Hydra, 16mg/kg/d). Each image is representative of 4 different arteries (6 rats).