Cardiovascular Effects of Clonidine-Like Drugs in Pithed Rabbits

Kenia Pompermayer, Maria Cristina O. Salgado, Josiane Feldman, Pascal Bousquet

Abstract—Administration (3 to 100 μg/kg IV) of clonidine, rilmenidine, and an imidazoline derivative, 2-(2-chlorophenylamino)imidazoline, in pithed nonstimulated rabbits caused a dose-dependent increase in mean arterial pressure without affecting heart rate. Prazosin (0.1 mg/kg IV) almost abolished the pressor responses to 2-(2-chlorophenylamino)imidazoline, partially inhibited those induced by clonidine, but failed to affect those elicited by rilmenidine. In contrast, yohimbine (1 mg/kg IV) blunted the pressor responses of the 3 drugs. In sympathetically stimulated pithed rabbits, 2-(2-chlorophenylamino)imidazoline induced only pressor effects, whereas clonidine and rilmenidine caused a transient pressure increase followed by a dose-dependent depressor effect. Yohimbine abolished the depressor effect of both drugs, which may have involved presynaptic α2-adrenoceptors. In conclusion, peripheral effects of 2-(2-chlorophenylamino)imidazoline and clonidine involved at least α1- and α2-adrenoceptor activation, whereas pressor and depressor effects of rilmenidine were mediated by α2-adrenoceptors. (Hypertension. 1999;34[part 2]:1012-1015.)

Key Words: adrenergic receptors ▪ sympathetic ▪ antihypertensive agents

Clonidine and rilmenidine are centrally acting antihypertensive drugs that contain an imidazoline or an oxazoline ring, respectively, in their chemical structures. The site of the hypotensive action of clonidine was first localized in the nucleus reticularis lateralis of the rostroventrolateral medulla. A structure-activity relationship study showed that imidazolines were able to induce hypotension when applied to this region, whereas catecholamines do not change blood pressure. These results suggest the existence of imidazoline-sensitive receptors involved in the hypotensive effect of imidazoline drugs and related substances.

Although the hypotensive effect of clonidine-like drugs involves central imidazoline receptors, many studies suggest the possibility of a peripheral presynaptic contribution to the depression of sympathetic tone produced by these drugs. In this regard, presynaptic α2-adrenoceptors have been shown to be involved in the inhibition of norepinephrine release. It was recently suggested that inhibitory presynaptic imidazoline receptors may also be involved in this response.

The aim of the present work was to investigate and to compare the presynaptic and postsynaptic effects of clonidine, rilmenidine, and an imidazoline derivative, 2-(2-chlorophenylamino)imidazoline, in the peripheral cardiovascular system of pithed rabbits with or without electrically stimulated sympathetic outflow.

Methods

The experiments were performed on pithed male rabbits (2.5 to 3 kg) with or without electrically stimulated sympathetic outflow as previously described by Szabo et al. All experiments were conducted in accordance with institutional guidelines on the use of animals in research. The animals were anesthetized with sodium pentobarbital (70 mg/kg IV), and the trachea was cannulated to allow artificial respiration. Catheters were placed into the right jugular vein and carotid artery for drug administration and arterial pressure measurement, respectively. Heart rate was calculated from the pressure signal recorded by a pressure transducer (HP-1280C) and connected to a computer measuring program (DATAQ-DI220-Windaq). Pancuronium bromide (2 mg/kg) was given intravenously to prevent skeletal muscle contraction. The rabbits were pithed by insertion of a steel rod (3.5 mm in diameter) through a hole in the parietal bone ~2 cm down the spinal canal. The rod destroyed the central nervous system and also served to electrically stimulate the peripheral sympathetic nerves with a stimulator (20 V, 2 Hz, 0.5 ms). An indifferent electrode was placed subcutaneously between the scapulae.

In all experiments, a 60-minute period was allowed before any drug injection. Vehicle administration produced no significant effect on hemodynamic parameters. Increasing doses of drugs were injected at 15-minute intervals. When antagonists were used, prazosin (0.1 mg/kg), yohimbine (1 mg/kg), or a combination of the two was injected 10 minutes before the injection of the agonists.

Drugs used were clonidine (RBI), rilmenidine (Servier), 2-(2-chlorophenylamino)imidazoline (synthesized in the Strasbourg laboratory), prazosin hydrochloride (Sigma), yohimbine hydrochloride (Sigma), sodium pentobarbital (Nembutal, Sigma), and pancuronium bromide (Cristalia). Drugs were dissolved in normal saline.

Results were expressed as mean±SEM. Differences between groups were determined by 2-factor ANOVA with repeated measures followed by Student’s t test with Bonferroni corrections. Differences within each group were determined by ANOVA for repeated measures followed by Student’s t test. A value of P<0.05 was considered statistically significant.
Results

Pithed Rabbits Without Electrical Stimulation
Basal mean arterial pressure and heart rate were 33±1 mm Hg and 205±4 bpm (n=47), respectively. Injections (3 to 100 μg/kg IV) of clonidine, rilmenidine, or 2-(2-chlorophenylamino)imidazoline induced dose-dependent increases in mean arterial pressure with different maximal pressor activity (Figure 1). At the highest dose, 100 μg/kg, rilmenidine induced the lowest pressor effect (84±10% increase in pressure, n=11), followed by 2-(2-chlorophenylamino)imidazoline (160±1%, n=10) and clonidine (221±19%, n=11). In these conditions, heart rate was not affected by these drugs. Basal arterial pressure and heart rate were not significantly affected by administration of prazosin or yohimbine. Pressor responses to clonidine (Figure 1A) were partially reduced by yohimbine, whereas prazosin reduced these responses only when high doses were used. Pressor responses induced by rilmenidine (Figure 1B) were unaffected by prazosin but were significantly reduced by yohimbine or a combination of the two antagonists. In contrast, pressor responses to 2-(2-chlorophenylamino)imidazoline (Figure 1C) were almost abolished by prazosin alone, whereas yohimbine only partially reduced these responses.

Pithed Rabbits With Electrical Stimulation
Peripheral effects of clonidine, rilmenidine, and 2-(2-chlorophenylamino)imidazoline were also studied in pithed rabbits with preganglionic electrical stimulation of sympathetic nerves. Stimulation induced a significant increase in basal mean arterial pressure (63±3 mm Hg) and heart rate (266±8 bpm) compared with the nonstimulated group (P<0.05, n=26). Clonidine (15 to 1000 μg/kg) and rilmenidine (15 to 1000 μg/kg) caused a transient increase in mean arterial pressure, followed by a dose-dependent depressor effect (Figure 2A and 2B) and reduction in heart rate (Table). In contrast, 2-(2-chlorophenylamino)imidazoline (15 to 1000 μg/kg) induced only a dose-dependent pressor effect (Figure 2C), without significant changes in heart rate (Table).

To determine the contribution of α₂-adrenoceptors to the biphasic effect of clonidine and rilmenidine, yohimbine (1 mg/kg IV) was administered 10 minutes before the tested drugs. Yohimbine did not change heart rate but induced a
significant decrease in mean arterial pressure (from 79±4 to 65±4 mm Hg and from 55±2 to 42±3 mm Hg in the rilmenidine- and clonidine-treated groups, respectively). In the presence of yohimbine (Figure 3), clonidine (n=5) or rilmenidine (n=6) elicited only long-lasting dose-dependent pressor effects. Although the magnitude of the pressor responses to clonidine was not significantly affected after yohimbine, those elicited by rilmenidine were attenuated. Surprisingly, the bradycardic effects of clonidine were not prevented by yohimbine, whereas those elicited by rilmenidine were prevented by yohimbine (Table).

**Discussion**

In the present study, we compared the cardiovascular effects of clonidine, rilmenidine, and the imidazoline derivative 2-(2-chlorophenylamino)imidazoline given systemically to pithed rabbits with or without electrically stimulated sympathetic outflow.

The potent vasopressor effects of clonidine and 2-(2-chlorophenylamino)imidazoline in nonstimulated rabbits were significantly inhibited by yohimbine and prazosin, indicating that these compounds produced vasoconstriction by stimulation of postsynaptic vascular α1- and α2-adrenoceptors. The pressor effects of low doses of clonidine were mainly due to stimulation of α2-adrenoceptors, whereas additional stimulation of α1-adrenoceptors occurred at higher doses. This observation confirmed previous observations in pithed rats.11,12 The weak pressor effects of rilmenidine were significantly inhibited by yohimbine and were unaffected by prazosin, suggesting that rilmenidine exhibited some selectivity for postsynaptic vascular α2-adrenoceptors.

The presynaptic α2-adrenergic activity of clonidine and rilmenidine was confirmed in stimulated pithed rabbits; in these conditions, these compounds produced a hypertensive effect, followed by depressor and bradycardic effects. Yohimbine prevented the depressor effects of both drugs, suggesting that these effects were probably mediated by presynaptic α2-adrenoceptor. The pressor effects of clonidine were not affected by yohimbine, whereas those induced by rilmenidine were significantly reduced. These results confirmed the selectivity for α2-adrenoceptors of rilmenidine observed in the nonstimulated animals. The fact that the maximal depressor effect of rilmenidine, observed in stimulated animals, was much weaker than that of clonidine strongly suggests that rilmenidine acted on presynaptic α2-adrenoceptors as a partial agonist.13 Such an effect might also explain that rilmenidine caused α2-adrenoceptor–mediated vasoconstriction that was also weaker than that of clonidine. Surprisingly, bradycardia induced by clonidine was insensitive to yohimbine. In contrast, studies performed in pithed rats have shown that clonidine inhibited electrically induced tachycardia and that this effect was sensitive to α2-adrenoceptor antagonists.12,14 Recently, the presence of a presynaptic imidazoline receptor has been suggested in the human heart,15 as well as in rabbit aorta and pulmonary arteries16 and rat vena cava.9 Our results do not exclude the possibility that rilmenidine and clonidine elicit effects through a putative presynaptic imidazoline receptor in sympathetic stimulated pithed rabbits. Experiments with selective

<table>
<thead>
<tr>
<th>Dose, μg/kg</th>
<th>Control</th>
<th>Yohimbine</th>
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<tbody>
<tr>
<td>Basal</td>
<td>254±16</td>
<td>250±22</td>
</tr>
<tr>
<td>15</td>
<td>236±13</td>
<td>240±8</td>
</tr>
<tr>
<td>30</td>
<td>232±13</td>
<td>232±16</td>
</tr>
<tr>
<td>100</td>
<td>228±10*</td>
<td>232±16</td>
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<tr>
<td>300</td>
<td>218±10*</td>
<td>220±13</td>
</tr>
<tr>
<td>1000</td>
<td>210±9*</td>
<td>216±10</td>
</tr>
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Values are bpm, mean±SEM (n=5 or 6).

*P<0.05 vs basal value.

Figure 3. Effect of clonidine and rilmenidine on mean arterial pressure in control conditions (n=5 each) and after yohimbine (n=5 and n=6, respectively). Data are mean±SEM. *P<0.05 vs control.
antagonists are needed to further clarify our observations in pithed rabbits.

In nonstimulated rabbits, the vasoconstrictive effect of 2-(2-chlorophenylamino)imidazoline was more sensitive to prazosin than to yohimbine. Consistent with this observation is the fact that this derivative, like phenylephrine (data not shown), produced neither depressor nor bradycardic effects in stimulated pithed rabbits. Our results show that a very weak chemical change, the absence of a chloride atom in position 6 on the aromatic ring, largely altered the pharmacological profile of the drug.

In conclusion, peripheral effects of clonidine and 2-(2-chlorophenylamino)imidazoline involve \( \alpha_1 \)- and \( \alpha_2 \)-adrenoceptor activation. The weak pressor and depressor effects of rilmenidine in pithed rabbits with or without stimulation suggest that this drug acts as a partial agonist on peripheral \( \alpha_2 \)-adrenoceptors.

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