Orchidectomy increases the formation of prostanoids and modulates their role in the acetylcholine-induced relaxation in the rat aorta

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Aims This study examines the effect of endogenous male sex hormones on thromboxane A₂ (TXA₂), prostaglandin (PG) I₂, PGF₂α, and PGE₂ release, as well as their role in acetylcholine (ACH)-mediated relaxation in the aorta.

Methods and results Aortic segments from orchidectomized and control male Sprague-Dawley rats were used to measure COX-2 protein expression. ACh-induced relaxation of these segments was also determined in the absence and presence of the COX-2 inhibitor NS-398, the TXA₂ synthesis inhibitor furegrelate, the PGI₂ synthesis inhibitor tranylcypromine (TCP), or the thromboxane-prostanoid (TP) receptor antagonist SQ-29 548. Furthermore, TXA₂, PGI₂, PGF₂α, and PGE₂ release as well as the vasomotor effect of exogenous TXA₂, PGI₂, PGF₂α, and PGE₂ were measured. COX-2 expression was increased in aortas from orchidectomized rats. NS-398 did not modify the ACh-induced relaxation in arteries from both control or orchidectomized rats. Furegrelate did not modify the ACh-induced relaxation in aortas from control animals but, in aortas from orchidectomized rats, it increased that response. TCP decreased the ACh-induced relaxation in both groups. The TP receptor antagonist, SQ29 548 failed to modify ACh-induced relaxation in aortas from either rat group. Pre-incubating arteries from orchidectomized rats with TCP plus furegrelate did not modify the decrease in the ACh response induced by TCP alone, but this response was restored by co-incubation of TCP plus SQ29 548. ACh-induced TXA₂, PGI₂, PGF₂α, and PGE₂ release were increased by orchidectomy. The presence of furegrelate plus TCP increased the ACh-induced PGE₂ release more in arteries from orchidectomized than in those from control rats. The contractile responses induced by the TXA₂ mimetic U-46619 or by exogenous PGF₂α were similar in arteries from control and orchidectomized rats, while those induced by exogenous PGE₂ were increased in arteries from orchidectomized rats; the vasodilator response induced by exogenous PGI₂ was decreased in arteries from orchidectomized rats.

Conclusion These data show that endogenous male sex hormone deprivation increases COX-2 expression, the release of TXA₂, PGI₂, PGF₂α, and PGE₂ and the contractile response induced by exogenous PGE₂ and TXA₂, while it decreases the relaxation induced by exogenous PGI₂. Despite the predominance of vasoconstrictor prostanoids derived from COX-2 in aortas from orchidectomized rats, the ACh-induced relaxation remains increased.

1. Introduction

Women develop cardiovascular diseases later in life than men. Although this gender difference involves more than sex hormones per se,¹ it has traditionally been attributed to the loss of female sex steroid hormones at the time of menopause. However, the fact that recent clinical trials have indicated doubts on the cardioprotective effects of estrogens,² coupled with studies demonstrating that low testosterone levels are associated with the development of cardiovascular diseases,³ has refocused interest on the role of androgens in cardiovascular function. In fact, some emerging data suggest that androgens are cardioprotective in males.⁴⁻⁶ Indeed, testosterone has been reported to have antiatherogenic actions⁷⁻¹⁰ and to improve myocardial...
ischaemia in men with coronary artery disease. Proposed beneficial factors are the antioxidant properties of androgens and the interaction between androgens and the endothelial nitric oxide (NO) system. Related to these issues, we previously reported that orchidectomy increased superoxide anion production in rat aorta, but did not affect either endothelial NO synthase (eNOS) expression or NO release.

Endothelial cells also release vasoconstrictor and vasodilator prostanoids, originated from the arachidonic acid metabolism through the cyclooxygenase (COX) pathway, to regulate vascular tone. One of the most frequently studied prostanoids is thromboxane A2 (TXA2), which has been implicated as a mediator in diseases such as myocardial infarction, hypertension, stroke, and bronchial asthma. However, little information is available on the role of androgens in the vascular effects of endogenous TXA2. Orchidectomy has been reported to either decrease or not modify TXA2 synthase expression. The contractile effect induced by the TXA2 mimetic, U-46619, was not modified by orchidectomy in mesenteric and cerebral rat arteries.

On the other hand, the role of COX-derivatives other than TXA2, such as prostaglandin (PG) F2α, and PGE2, or PGF2α, which can induce a vasoconstrictor or vasodilator response is the subject of numerous studies. However, to the best of our knowledge studies analysing the effect of endogenous male sex hormones on the involvement of these prostanoids in vascular function are lacking.

Taking all these observations together, the aim of this study was to assess whether endogenous male sex hormones regulate the involvement of TXA2, PGF2α, and PGE2 in the acetylcholine (ACh)-induced response. Therefore, the expression of COX-2, the production and the vasomotor effect of these prostanoids derived from COX-2 were also analysed.

2. Methods

2.1 Animal housing and protocols

Male Sprague–Dawley rats (6 months old) were used. They were divided into two groups: control and orchidectomized males. All animals were housed in the Animal Facility of the Universidad Autónoma de Madrid (Registration number EX-021U) according to directives 609/86 CEE and R.D. 233/88 of the Ministerio de Agricultura, Pesca y Alimentación of Spain. Male sex hormone deprivation was induced by gonadectomy at 7 weeks of age, and 4 months later the animals were sacrificed. The observation of seminal vesicles’ atrophy confirmed successful surgery. Rats were sacrificed by CO2 inhalation; the thoracic aorta was carefully dissected out, cleaned of connective tissue, cut into 4 mm long segments and placed in Krebs–Henseleit solution (KHS) (containing, in mmol/L: NaCl 115; CaCl2 2.5; KCl 4.6; KH2PO4 1.2; MgSO4 1.2; NaHCO3 25; glucose 11.1; Na2EDTA 0.0D) at 4 °C. The investigation conforms to the Guide for the Care and Use of Laboratory Animals published by the USA National Institutes of Health (NIH publication no. 85.23 revised 1985). This study was also approved by the Ethical Committee of the Universidad Autónoma of Madrid.

2.2 Systolic blood pressure

Systolic blood pressure was indirectly measured in awake animals by the tail-cuff method, as previously reported (Letica, Digital Pressure Meter, LES0000, Barcelona, Spain).

2.3 Serum levels of testosterone

Serum was obtained at the time of decapitation by collecting trunk blood, followed by centrifugation, and testosterone levels were determined using the monoclonal enzyme immunoassay kit (Cayman Chemical). The assay was performed according to the manufacturer’s instructions.

2.4 Western blot analysis of COX-2

For western blot analysis of COX-2 protein expression, aortic segments were homogenized in a boiling buffer composed of 1 mM sodium vanadate (a protease inhibitor), 1% SDS, and 0.01 M pH 7.4 Tris–HCl. Homogenates containing 15 μg protein were electrophoretically separated on a 10% SDS–polyacrylamide gel (SDS–PAGE) and then transferred to polyvinyl difluoride membranes (Bio Rad Immun-Blot®) overnight at 4 °C, 230 mA, using a Bio-Rad Mini Protean III system (Bio-Rad Laboratories, Hercules, CA, USA) containing 25 mm Tris, 190 mM glycine, 20% methanol, and 0.05% SDS. Prestained SDS–PAGE broad range standards (Bio-Rad Laboratories) were used as molecular mass markers. The membrane was blocked for 2 h at room temperature in Tris-buffered-saline solution (100 mM, 0.9% w/v NaCl, 0.1% SDS) with 5% powdered fat-free milk before being incubated overnight at 4 °C with rabbit polyclonal antibody for COX-2 (1:200 dilution, Cayman Chemical). After washing, the membrane was incubated with a 1:1000 dilution of anti-rabbit immunoglobulin G antibody conjugated to horseradish peroxidase (Amersham International Plc). The membrane was thoroughly washed and the immunocomplexes were detected using an enhanced horseradish peroxidase/luminol chemiluminescence system (ECL Plus, Amersham International Plc, Little Chalfont, UK) and subjected to autoradiography (Hyperfilm ECL, Amersham International Plc). Signals on the immunoblot were quantified using a computer program (NIH Image V1.56, National Institute of Health, Bethesda, MD, USA). The same membrane was used to determine α-actin expression, and the content of the latter was used to correct COX-2 expression in each sample by means of a monoclonal antibody anti α-actin (1:2000 dilution, Sigma).

2.5 Vascular reactivity

The method used for isometric tension recording has been described in full elsewhere. Briefly, two parallel stainless steel pins were introduced through the lumen of the vascular segment: one was fixed to the bath wall, and the other connected to a force transducer (Grass FT03C; Grass Instruments Co., Quincy, MA, USA); this in turn was connected to a model 7D Grass polygraph. Segments were suspended in an organ bath containing 5 mL of KHS at 37 °C, continuously bubbled with a 95% O2–5% CO2 mixture (pH 7.4). The segments were subjected to a tension of 1 g which was re-adjusted every 15 min during a 90 min equilibration period before drug administration. After this, the vessels were exposed to KCl (75 mmol/L) to check the functional integrity. After a washout period, the presence of vascular endothelium was confirmed by the ability of 10 μmol/L ACh to relax segments precontracted with 1 μmol/L 5-hydroxytryptamine (5-HT). The segments were rinsed several times with KHS for 1 h, and then cumulative ACh concentration–response curves (0.1 mmol/L–10 μmol/L) were obtained in 5-HT precontracted segments. Only one cumulative ACh concentration–response curve was performed in each aortic segment to avoid desensitization and misinterpretation of the results.

To investigate the possible participation of products derived from COX-2, some aortic segments were incubated for 30 min with the COX-2 inhibitor N-(2-cyclohexyloxy-4-nitrophenyl) methansulfonamide (NS-398; 10 μmol/L) before generating the ACh concentration–response curves. In another set of experiments, to analyse the possible involvement of TXA2 in the ACh-induced relaxation, some segments were incubated with either the TXA2 synthase inhibitor, furegrelate.
dilutions were made in KHS on the day of the experiment. To investigate possible interactions between TXA₂ and PGI₂, concentration–response curves to ACh were performed in the presence of the PGI₂ synthase inhibitor, tranylcypromine (TCP, 10 μmol/L), TCP plus furegrelate, or TCP plus SQ29548. To assess possible differences in the responses induced by TXA₂, PGI₂, PGF₂ₐ, or PGE₂ in arteries from both groups, concentration–response curves for the TXA₂ mimetic 15-hydroxy-11α,9α-(epoxymethano)prosta-5,13-dienoic acid (U-46619, 1 nmol/L–10 μmol/L), endogenous PGI₂ (0.1 nmol/L–1 μmol/L), PGF₂ₐ (1 nmol/L–1 μmol/L), or PGE₂ (1 nmol/L–10 μmol/L) were performed in arteries from control and orchidectomized rats.

3.2 Serum testosterone 

The effectiveness of orchidectomy was analysed by measuring the concentration of testosterone in the serum from control and orchidectomized rats. We found that orchidectomy decreased the level of serum testosterone (control: 2404 ± 323 pg/mL; orchidectomized: 220 ± 49 pg/mL; n = 6; P < 0.001).

3.3 COX-2 expression 

The effect of orchidectomy on the expression of COX-2 protein was assessed by western blot analysis. Orchidectomy increased the expression of COX-2 protein. In arteries from control and orchidectomized rats, furegrelate did not reverse the effect of TCP, while SQ29 548 reversed the effect of TCP in arteries from orchidectomized rats, furegrelate did not reverse the effect of TCP, while SQ29 548 did (Figure 3A, Table 1). These results indicate the participation of other prostanoids in addition to TXA₂ in the ACh-induced response.

3.4 Vascular reactivity 

The vasodilator response induced by ACh was greater in aortic segments from orchidectomized rats than those of controls (ANOVA, P < 0.01; Table 1), as previously described. Incubation with the specific COX-2 inhibitor NS-398 (10 μmol/L, 30 min) did not alter the ACh-induced response in either group of rats (Figure 2). However, the absence of differences in the ACh-induced response, it is possible to hypothesize that the two groups differed in terms of the products derived from COX-2. Therefore, the arteries were incubated with specific prostanoid synthase inhibitors or receptor blockers. Pre-incubation with the TXA₂ synthase inhibitor, furegrelate (1 μmol/L, 30 min) did not modify the relaxation induced by ACh in segments from control rats, although it increased the relaxation induced by ACh in arteries from orchidectomized rats (Figure 2A and B, Table 1). Pre-incubation with the TP receptor antagonist, SQ29 548 (1 μmol/L, 30 min) did not modify the response to ACh in arteries from either group of rats (Figure 2A and B, Table 1). These results indicate the participation of other prostanoids in addition to TXA₂ in the ACh-induced response.

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3.3 COX-2 expression

The effect of orchidectomy on the expression of COX-2 protein was analysed by using western blot analysis. Orchidectomy increased the expression of COX-2 protein detected in homogenates from aortic segments (Figure 1).

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Table 1: 

<table>
<thead>
<tr>
<th>Substance</th>
<th>Concentration</th>
<th>Effect on ACh-induced response</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCP</td>
<td>10 μmol/L</td>
<td>Reduced relaxation</td>
</tr>
<tr>
<td>Furegrelate</td>
<td>1 μmol/L</td>
<td>No effect on relaxation</td>
</tr>
<tr>
<td>SQ29 548</td>
<td>1 μmol/L</td>
<td>Reduced relaxation</td>
</tr>
</tbody>
</table>

For prostanoid release experiments, the effectiveness of orchidectomy was analysed by measuring the concentration of testosterone in the serum from control and orchidectomized rats. We found that orchidectomy decreased the level of serum testosterone (control: 2404 ± 323 pg/mL; orchidectomized: 220 ± 49 pg/mL; n = 6; P < 0.001).
PGI₂, TXA₂, PGF₂α, and PGE₂ was analysed, as well as their vasomotor effect. The TXA₂ mimetic U-46619 (1 nmol/L–10 μmol/L) induced a contractile response, which was similar in arteries from control and orchidectomized rats (Figure 4A). The vasodilator response induced by exogenous PGI₂ (1 nmol/L–1 μmol/L) was decreased by 36% in arteries from orchidectomized rats with regard to those of control rats (Figure 4B). The contractile response induced by exogenous PGF₂α was similar in arteries from control and orchidectomized rats (Figure 4C). The contractile response elicited by exogenous PGE₂ (1 nmol/L–10 μmol/L) was increased in arteries from orchidectomized rats (Figure 4D). Specifically, the contractile response induced by the highest concentration of exogenous PGE₂ in arteries from orchidectomized rats exceeded that induced in arteries from control rats by 206%.

The effect of orchidectomy on the E₉₅ to the exogenous prostanoids used and EC₅₀ are summarized in Table 2.

### 3.5 Prostanoid production

Orchidectomy increased the ACh-stimulated aortic production of TXB₂, 6-keto-PGF₁α, 13,14-dihydro-15-keto PGF₂α, and PGE₂ (Figure 5A–D). Pre-incubation with TCP plus furegrelate produced a greater increase in PGE₂ production in arteries from orchidectomized rats than in those of control rats (Figure 5D).

### 4. Discussion

Recent studies have reported several mechanisms behind the beneficial effects of androgens on cardiovascular function in males. One of the proposed mechanisms is the interaction between androgens and endothelial cells. It is known that endothelial cells possess androgen receptors whose activation could modify intracellular signalling pathways, among them the NO pathway. Endothelial NO plays a crucial role in cardiovascular protection through its regulatory effects on platelet aggregation, oxidative stress, leukocyte adherence, and vascular smooth muscle cell proliferation, all of which ultimately modulate vascular tone. In this respect, we have previously reported that orchidectomy did not alter either eNOS expression or endothelial NO release in rat aorta or mesenteric arteries; however the ACh-induced relaxation in aortas from orchidectomized rats was greater than in those of control male rats due to superoxide-induced vasodilatory action through calcium-dependent potassium channels (KᵥCa) activation. In the present study, we provide evidence that orchidectomy also regulates the release and function of prostanoids derived from COX-2, indicating the complexity of physiological systems in which multiple signalling pathways are simultaneously working.

The effects described earlier seem to be independent of previous blood pressure levels, since orchidectomy did not modify blood pressure; moreover, since endogenous hormone deprivation is the only variable used in our

### Table 1 Changes in the maximum response (E₉₅, expressed as a percentage of relaxation) and log EC₅₀ to acetylcholine in aorta from control and orchidectomized rats

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>E₉₅ (%)</th>
<th>log EC₅₀</th>
<th>Orchidectomized</th>
<th>E₉₅ (%)</th>
<th>log EC₅₀</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control condition</td>
<td>88.15 ± 2.5</td>
<td>−7.14 ± 0.06</td>
<td></td>
<td>93 ± 2.67</td>
<td>−7.3 ± 0.07</td>
<td></td>
</tr>
<tr>
<td>NS-398</td>
<td>89.53 ± 2.4</td>
<td>−7.45 ± 0.07</td>
<td></td>
<td>88.20 ± 3.09</td>
<td>−7.37 ± 0.09</td>
<td></td>
</tr>
<tr>
<td>Furegrelate</td>
<td>92.95 ± 5.7</td>
<td>−7.14 ± 0.14</td>
<td></td>
<td>100 ± 3.99</td>
<td>−7.59 ± 0.11**</td>
<td></td>
</tr>
<tr>
<td>SQ29 548</td>
<td>92.89 ± 8.5</td>
<td>−7.08 ± 0.21</td>
<td></td>
<td>97.28 ± 3.96</td>
<td>−7.09 ± 0.09</td>
<td></td>
</tr>
<tr>
<td>TCP</td>
<td>71.02 ± 3.5</td>
<td>−7.30 ± 0.12</td>
<td></td>
<td>67.19 ± 3.2*</td>
<td>−7.41 ± 0.12</td>
<td></td>
</tr>
<tr>
<td>TCP+Furegrelate</td>
<td>80.76 ± 4.9</td>
<td>−7.34 ± 0.15</td>
<td></td>
<td>77.5 ± 3.6*</td>
<td>−7.42 ± 0.12</td>
<td></td>
</tr>
<tr>
<td>TCP+SQ29 548</td>
<td>83.31 ± 3.4</td>
<td>−7.19 ± 0.09</td>
<td></td>
<td>86.13 ± 3.62</td>
<td>−6.69 ± 0.18</td>
<td></td>
</tr>
</tbody>
</table>

*P < 0.05 vs. control rats.
**P < 0.01 vs. control rats.
P < 0.05 vs. control condition in control rats.
*P < 0.01 vs. control condition in orchidectomized rats.
studies, the results obtained would have to be androgen-related, as confirmed by the decreased testosterone levels. In addition to NO, endothelial cells also release vasoconstrictor and vasodilator prostanoids that are involved in the modulation of vascular tone. Therefore, it is possible to speculate that androgens could also modulate the release and/or function of prostanoids. Since prostanoids are derived from COX-2, we analysed the possible differences in COX-2 expression in arteries from control and orchidectomized rats. We found that COX-2 expression, in contrast to observations in mesenteric artery, was increased in aortas from orchidectomized rats indicating that endogenous male sex hormones act differently depending on the specific vessel. Our results also show that, in aorta from orchidectomized rats, COX-2 derivatives could also be increased and play a role in the regulation of vascular function. To test this hypothesis, we analysed the effect of the COX-2 inhibitor NS-398 on the ACh-induced response. In contrast to our assumptions, we found that NS-398 did not modify the ACh-induced relaxation in either group of rats, apparently indicating the lack of participation of COX-2-derived products in the ACh response. However, it has been recently reported that COX-2 selective inhibitors amplify NO/cGMP signalling by phosphodiesterase inhibition, this allows us to speculate that the contribution of different prostanoids to the vasodilator response mediated by ACh could be regulated by endogenous male sex hormones.

It is known that TXA₂ is one of the most important vasoconstrictor prostanoids produced by the vascular wall to
participate in the endothelial dysfunction associated with different cardiovascular risk factors.\cite{41,42,43} Most of the studies analysing the influence of androgens on the vascular effects of TXA2 have been focused on describing its action on TP receptors, as well as on the contractile response elicited by TXA2 analogues. Thus, testosterone was shown to increase the density of TP receptors in platelets\cite{44,45} and vascular smooth muscle cells cultured from the rat aorta.\cite{46,47} Regarding the influence of androgens on constrictor response to the TXA2 mimetic, U-46619, both increases\cite{44,48,49} and a lack of change\cite{25,26} have been reported, but in different vessels. As we have previously reported that orchidectomy increased TXA2 production and its vascular involvement in the clonidine-induced contraction, in rat mesenteric artery,\cite{26} and since there is a lack of studies analysing the effect of endogenous male sex hormones on the whole TXA2 pathway under the same experimental conditions, we began by analysing, in aortic segments from control and orchidectomized rats. Results (means ± SEM) are expressed as percentage of the previous tone elicited by 75 mmol/L KCl (A–D) or as percentage of inhibition of contraction induced by 1 μmol/L 5-HT (B). Number of animals is indicated in parenthesis. *P < 0.05, **P < 0.001 compared with control rats.

Table 2 Effect of orchidectomy in the maximum response (E\textsubscript{max}) and log EC\textsubscript{50} to the vasomotor response elicited by the analogue of TXA\textsubscript{2}, U-46619, and the exogenous PGI\textsubscript{2}, PGF\textsubscript{2α}, or PGE\textsubscript{2}

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Orchidectomized</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>E\textsubscript{max} (%)</td>
<td>log EC\textsubscript{50}</td>
</tr>
<tr>
<td>U-46619</td>
<td>213.1 ± 6.4</td>
<td>–7.74 ± 0.05</td>
</tr>
<tr>
<td>PGI\textsubscript{2}</td>
<td>39.07 ± 2.4</td>
<td>–7.4 ± 0.2</td>
</tr>
<tr>
<td>PGF\textsubscript{2α}</td>
<td>12.8 ± 2.15</td>
<td>–7.25 ± 0.3</td>
</tr>
<tr>
<td>PGE\textsubscript{2}</td>
<td>30.12 ± 1.3</td>
<td>–5.58 ± 0.2</td>
</tr>
</tbody>
</table>

*P < 0.05.
**P < 0.001 vs. control rats.
segments, the possible modulation of ACh-induced TXA2 production by endogenous male sex hormones and the involvement of TXA2 in ACh-induced relaxation. The results showed that the formation of TXA2 induced by ACh was increased in aortas from orchidectomized rats, a finding that is similar to those in mesenteric arteries from comparable animals stimulated with ACh37 or with the $\alpha_2$-receptor agonist clonidine.26

Once we had established that orchidectomy increased TXA2 release, we analysed the possible role of this prostaglandin in the response to ACh by analysing the effect of the TXA2 synthase inhibitor, furegrelate, and the TP receptor antagonist, SQ29 548, on the vasodilator response to ACh. We observed that neither furegrelate nor SQ29 548 had any effect on the ACh-induced response in arteries from control animals, indicating that TXA2 did not participate in that response, in agreement with reports in other rat strains.28,29 However, in arteries from orchidectomized rats, furegrelate enhanced the vasodilator response to ACh, showing a functional involvement of TXA2. The fact that the contractile response to the TXA2 mimetic U-46619 was similar in arteries from control and orchidectomized rats demonstrated that sensitivity to TXA2 is not modified by orchidectomy, which agrees with reports in cerebral 25 and mesenteric26 arteries; additionally, it also shows that differences in the TXA2 involvement in the ACh-response are due to increased synthesis rather than increased sensitivity to TXA2. However, the incubation with SQ29 548 did not affect the ACh-induced relaxation. This observation seems to contradict the results obtained with furegrelate. However, since interactions among different prostanoids have been reported,50,51 it is possible to hypothesize that when TXA2 synthesis is inhibited, the production of other prostanoids, which counterbalance the TXA2 effect, could be increased. Therefore, we investigated the effect of inhibiting PGI2 synthesis on the ACh-induced response. We found that the presence of the PGI2 synthesis inhibitor TCP decreased the vasodilator response to ACh to a greater extent in arteries from orchidectomized than in those of control rats, which would indicate a greater involvement of this vasodilator prostaglandin in the former arteries, a circumstance that could be due to alterations in PGI2 synthesis and/or the vasomotor effect. We observed that the ACh-induced PGI2 release was increased in arteries from orchidectomized rats, probably due to the superoxide anion overproduction observed in aortas from orchidectomized rats,18 supporting the concept of redox regulation of vascular prostaglandin synthesis proposed by Bachschmid et al.51 Moreover, the increased production of PGI2 is in line with that reported in human syndromes involving platelet activation in which PGI2 biosynthesis is elevated along with TXA2.52,53 It is known that PGI2 can induce both vasodilation, through activation of prostacyclin receptors (IP) and thereby increasing cyclic-AMP, and vasoconstriction through activation of TP receptors.21 In the present study, we found that exogenous PGI2 induced relaxation in rat aorta, and that it was decreased in arteries from orchidectomized rats, which could be due to differences in the expression of IP receptors rather than differences in cell signalling operating after receptor activation; we have observed that
the relaxation induced by the activator of adenylate cyclase, forskolin, was similar in arteries from control and orchidectomized rats (unpublished data).

Since considerable evidence exists for cross-talk between the TXA₂ and PGI₂ systems,⁵⁰ we analysed the functional effect of inhibiting the synthesis of both prostanoids. We observed that co-incubation of arteries with TCP plus furegrelate, or TCP plus SQ29 548, reversed the decreased response to ACh caused by TCP in arteries from control rats, showing the existence of a balance between TXA₂ and PGI₂ in these arteries. However, in arteries from orchidectomized rats, the co-incubation with TCP plus furegrelate did not modify the decreased ACh response caused by TCP, indicating the participation of prostanoids other than PGI₂ and TXA₂ that could induce contraction. Moreover, these other prostanoids would activate TP receptors since co-incubation with TCP and SQ29 548 completely reversed the decrease in the ACh response induced by TCP.

Among COX-2 derivatives, other than TXA₂ and PGI₂ systems,⁵⁰ we analysed the functional effect of inhibiting the synthesis of both prostanoids. We observed that co-incubation of arteries with TCP plus furegrelate, or TCP plus SQ29 548, reversed the decreased response to ACh caused by TCP in arteries from control rats, showing the existence of a balance between TXA₂ and PGI₂ in these arteries. However, in arteries from orchidectomized rats, the co-incubation with TCP plus furegrelate did not modify the decreased ACh response caused by TCP, indicating the participation of prostanoids other than PGI₂ and TXA₂ that could induce contraction. Moreover, these other prostanoids would activate TP receptors since co-incubation with TCP and SQ29 548 completely reversed the decrease in the ACh response induced by TCP. Among COX-2 derivatives, other than TXA₂ and PGI₂, that can activate TP receptors, PGE₂ is the most plausible candidate,²⁹ ⁵⁴ since the ACh-induced PGE₂ production and its vasoconstrictor effect were both very limited. Therefore, we investigated the ACh-induced PGE₂ release, as well as its vasoconstrictor effect. We found that both ACh-induced PGE₂ production and PGE₂-induced vasoconstrictor response were greater in arteries from orchidectomized than in those of control rats. Consequently, we analysed the effect of TXA₂ and PGI₂ synthesis inhibition on the ACh-induced PGE₂ release. We found that, under this experimental condition, the ACh-induced PGE₂ production further increased, probably as a consequence of increased PGH₂ production and subsequent transformation into PGE₂;⁵⁴ ⁵⁵ and, what is more important, the PGE₂ increase was more pronounced in arteries from orchidectomized rats. This result probably is a consequence of compensatory mechanisms such as the dual effect of superoxide anion (O₂⁻), whose formation is increased in orchidectomized rats, by decreasing endothelial nitric oxide (NO) bioavailability¹⁸ and by activating calcium-dependent potassium channels (KᵥCa).³² NS-398, specific COX-2 inhibitor; SQ29 548, TP-receptor antagonist.

In summary, this study demonstrates that orchidectomy enhances COX-2 expression, and induces an imbalance in the production and function of vasodilator and vasoconstrictor prostanoids, in such a way that the vasoconstrictor prostanoids predominate in the latter group. This situation per se, could indicate a disadvantage in cardiovascular function in the absence of male sex hormones. Additionally, we have previously reported a decreased NO bioavailability in aortas from orchidectomized rats¹⁸ that would also counteract the vasodilator response to ACh. However, despite these findings, the vasodilator response to ACh is increased in aortas.
from orchidectomized rats, probably as a consequence of compensatory mechanisms, such as the activation of BK$_{Ca}$ channels by superoxide anion, the formation of which is increased in orchidectomized rats$^{32}$ (see Figure 6).

This intriguing information makes it essential to perform studies in vascular function taking into account different cell signalling pathways that are working simultaneously.

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