The residual non-adrenergic contractile response to nerve stimulation of the mouse prostate is mediated by acetylcholine not ATP, a comparison with the mouse vas deferens.


Medicinal Chemistry and Drug Action, Monash Institute of Pharmaceutical Sciences, Monash University, Parkville, VIC, Australia (C.W.W., J.L.S., J.M.H., S.V.), Department of Cell Physiology and Pharmacology, University of Leicester, Leicester, UK (R.J.E.)
Abstract

Neuronal release of noradrenaline is primarily responsible for the contraction of prostatic smooth muscle in all species and this forms the basis for the use of $\alpha_1$-adrenoceptor antagonists as pharmacotherapies for benign prostatic hyperplasia. Previous studies in mice have demonstrated that a residual non-adrenergic component to nerve stimulation remains after $\alpha_1$-adrenoceptor antagonism. In the guinea-pig and rat prostate and the vas deferens of guinea-pigs, rats and mice, ATP is the mediator of this residual contraction. This study investigates the mediator of the residual contraction in the mouse prostate. Whole prostates from wild-type, $\alpha_{1A}$-adrenoceptor and P2X1-purinoceptor knockout mice were mounted in organ baths, and the isometric force that tissues developed in response to electrical field stimulation or exogenously applied agonists was recorded. Deletion of the P2X1-purinoceptor did not affect nerve-mediated contraction. Furthermore, the P2-purinoceptor antagonist suramin (30 µM) failed to attenuate nerve-mediated contractions in wild-type, $\alpha_{1A}$-adrenoceptor or P2X1-purinoceptor knockout mice. Atropine (1 µM) attenuated contraction in prostates taken from wild-type mice. In the presence of prazosin (0.3 µM) or guanethidine (10 µM), or in prostates taken from $\alpha_{1A}$-adrenoceptor knockout mice the residual nerve-mediated contraction was abolished by atropine (1 µM), but not suramin (30 µM). Exogenously administered acetylcholine elicited reproducible concentration dependent contractions of the mouse prostate which were atropine (1 µM), but not prazosin (0.3 µM) sensitive. Acetylcholine not ATP mediates the non-adrenergic component of contraction in the mouse prostate. This cholinergic component of prostatic contraction is mediated by activation of muscarinic receptors.
Introduction

Benign prostatic hyperplasia (BPH) is a disease of the human prostate resulting from an age and androgen dependent non-cancerous proliferation of both the prostatic epithelium and stromal tissue (Wilson, 1980). The enlarged hyperplasic prostate places pressure on the urethra and the base of the bladder and leads to the manifestation of lower urinary tract symptoms. These symptoms arise from a dynamic component, caused by an increase in the prostatic smooth muscle tone, as well as a static component, caused by the proliferation of the prostatic tissue. Currently drugs that target the dynamic component by relaxing prostatic smooth muscle, such as the $\alpha_{1A}$-adrenoceptor antagonist tamsulosin, are the most effective treatments for relieving the symptoms associated with BPH (Lepor, 2007; Miano et al., 2008).

The smooth muscle tone of the prostate gland is predominantly controlled by neuronally released noradrenaline acting at $\alpha_{1A}$-adrenoceptors in humans, as well as in guinea-pigs, rats (Haynes and Ventura, 2005) and mice (Gray and Ventura, 2006). This therefore forms the basis for the use of selective $\alpha_{1A}$-adrenoceptor antagonists for the treatment of BPH (Cooper et al., 1999; Lepor, 2007). While $\alpha_{1A}$-adrenoceptors are seen as the principle mediator of nerve-mediated prostatic smooth muscle contraction, a residual nerve-mediated non-adrenergic contraction is observed after pharmacological $\alpha_1$-adrenoceptor blockade and more prominently after genetic $\alpha_{1A}$-adrenoceptor deletion in mice (Gray et al., 2008). We have previously shown that adenosine 5′-triphosphate (ATP), released as a co-transmitter with noradrenaline, acting at P2X1-purinoceptors, mediates the residual non-adrenergic nerve-mediated contraction in the prostates of guinea-pigs (Buljubasich and Ventura, 2004) and rats (Ventura et al., 2003). We have also shown however, that this is not the case in the mouse prostate (Gray and Ventura, 2005).
A large muscarinic receptor population has been identified in the prostates of humans, rats and guinea-pigs (Ventura et al., 2002). These receptors are mostly confined to the epithelium and are therefore thought to be responsible for the production and secretion of prostatic fluid. Little is known about the contribution of muscarinic receptor and cholinergic innervation to contraction in the mouse prostate. Binding studies of whole prostates indicate the presence of muscarinic receptors (Oki et al., 2006) of the M1 and M3 subtypes (Ito et al., 2009), however, the location or function of these receptors was not described. Nevertheless muscarinic receptor expression is not entirely confined to the glandular epithelium, and has been observed in the stromal tissue of prostate glands taken from humans (Lepor and Kuhar, 1984), dogs (Fernandez et al., 1998), rats (Lau and Pennefather, 1998) and guinea-pigs (Lau et al., 2000). Furthermore, cholinesterase positive nerves have been shown histochemically in the mouse prostatic smooth muscle (Gray and Ventura, 2005), and functional studies have indicated that muscarinic receptors play a role in nerve-mediated prostatic contraction of other species (Haynes and Hill, 1997; Najbar-Kaszkiel et al., 1997; Lau et al., 2000). The aim of this study was to investigate whether the mediator of the non-adrenergic non-purinergic residual component of nerve-mediated contraction in the mouse prostate is cholinergic in nature.
Methods

Animals

Adult $\alpha_{1A}$-adrenocceptor knockout mice were purchased from JAX Mice (Jackson Laboratory, Bar Harbor, ME, USA) and P2X1-purinoceptor knockout mice were generated in the laboratory of Professor R.J. Evans (University of Leicester, Leicester, UK). Colonies of knockout mice were maintained on a C57Bl/6 background by heterozygous breeding pairs and were routinely genotyped by PCR using genomic DNA from tail samples obtained at weaning (21 days) as previously described (Mulryan et al., 2000; Rokosh and Simpson, 2002). All mice were bred and housed at the Monash Animal Services facility, exposed to a 12 hr light/dark photoperiod, and had free access to food and water. Adult male mice ($\geq 8$ weeks) for experimentation were killed by cervical dislocation. Prior approval for animal experimentation was granted by the Monash University Standing Committee on Animal Ethics, ethics numbers VCPA 2006/08 RSV.4 2006 and VCPA 2006/09 RSV.5 2006, for the use of genetically modified and wild-type mice respectively. All studies conformed to the National Health and Medical Research Council, Australian code of practice for the care and use of animals for scientific purposes.

Tissue Dissection

An incision along the midline of the lower abdomen was made and the urogenital tract was exposed. The penile muscles, excess fat and connective tissue were cut away to reveal the prostate and vas deferens. The whole prostate and one vas deferens from alternating sides were carefully dissected out and placed in a specimen jar containing Krebs-Henseleit solution (NaCl 118.1mM, NaHCO$_3$ 25.0mM, glucose 11.7mM, KCl 4.69mM, KH$_2$PO$_4$ 1.2mM, MgSO$_4$ 0.5mM, CaCl$_2$ 2.5mM; pH 7.4).
Isolated organ bath studies

The dissected prostate and as a comparator the vas deferens were mounted in 10 ml water jacketed organ baths containing Krebs-Henseleit solution maintained at 37°C and bubbled with 95% O₂ / 5% CO₂. One end of the tissue was attached to a perspex tissue holder and the other to a Grass FT03 force displacement transducer (Grass Instruments, Quincy, MA) for the measurement of isometric contractions. The force of contraction was recorded using a PowerLab 4/SP data acquisition system (ADInstruments Pty. Ltd., Castle Hill, NSW, Australia) and LabChart software version 5 (ADInstruments Pty. Ltd.) run on a personal computer. Tissues were maintained under a resting force of approximately 0.7 g. Prior to experimentation tissue preparations were equilibrated for a period of 1 hour, during which time tissues were stimulated with electrical pulses of 0.5ms duration, 60V at 0.01Hz. Electrical stimulation occurred via two parallel platinum electrodes incorporated into the tissue holder, connected to a Grass S88 stimulator (Grass Instruments, Quincy, MA).

Frequency response curves

Frequency response curves to electrical field stimulation were constructed using frequencies of 1, 2, 5, 10 and 20 Hz (0.5 ms duration, 60 V) and electrical stimulation was delivered at 10 min intervals in trains of pulses lasting 10 s.

An initial control frequency response curve was constructed to determine the contractile response of the tissue at each frequency. A second frequency response curve was then constructed after the tissue had been washed with 3-4 times the volume of the organ bath and had been exposed to the test drug for a period of one hour. Where a third frequency response curve was constructed, the same washing and dosing protocol as previously described was used. Appropriate time control curves were constructed concurrently where no test drug(s) was administered. The volume of test drug(s) added to the organ bath was ≤ 200 µl.
In a subset of electrical field stimulation experiments, prazosin (0.3 µM) or guanethidine (10 µM) was present for the equilibration period and construction of the initial frequency response curve. The second frequency response curve was then constructed after the tissues had been washed with 3-4 times the volume of the organ bath and had been exposed for 1 hour to the re-added initial test drug and atropine (1 µM). An appropriate time control curve was also constructed in the presence of prazosin (0.3 µM), whereby the tissues were exposed to prazosin (0.3 µM) alone for both the first and second frequency response curves.

**Agonist concentration-response studies**

To assess sites of action, contractions of the isolated tissues were elicited by the application of exogenous acetylcholine on unstimulated tissues. After a 1 hour equilibration period where tissues were stimulated with electrical pulses of 0.5ms duration, 60V at 0.01Hz. An initial discrete concentration response curve to acetylcholine (10 nM-1 mM) was constructed without electrical stimulation using a log unit concentration-progression ratio.

For each agonist concentration, the contractile response of the tissue was allowed to reach a maximum and plateau before the tissue was washed with 3-4 times the volume of the organ bath. The tissue was then allowed to recover for 15 minutes before the addition of a subsequent concentration. After the initial concentration response curve, a second concentration response curve was constructed in the same manner; however in this instance, the tissue was exposed to an antagonist for 1 hour prior to the addition of the first agonist concentration and after each wash-out the antagonist was replaced. Antagonists used were prazosin (0.3 µM) or atropine (1 µM). An appropriate time control curve was constructed in a parallel experiment, without the addition of antagonists.
Data Analysis

The peak force (g), prostate, or integral force (g.s; where s = 30 seconds), vas deferens, of electrical field stimulation or agonist mediated contraction was measured at each frequency or concentration. Baseline variance was removed from the peak contractile response by subtraction of the baseline height from the contractile response peak height. Mean frequency and concentration response curves were constructed using GraphPad Prism version 5.00 for windows (GraphPad Software, San Diego, CA). The mean curves were formed from the average of data from n experiments, where n is equal to the number of mice used. Results are expressed as mean ± S.E.M.

In mean frequency and concentration response curves, differences between the initial and subsequent drug exposed curve(s) were analysed by GraphPad Prism version 5.00 using a two way repeated measure analysis of variance (ANOVA), followed by a Bonferroni post-test where required. The P-values stated were used to evaluate the statistical significance of any difference between the two curves and represent the probability of the drug treatment causing a significant change. P<0.05 was considered significant. GraphPad Prism version 5.00 was also used to calculate EC$_{50}$ and pK$_B$ values from concentration response curves. All receptor nomenclature conforms to the IUPHAR nomenclature guidelines (Harmar et al., 2009)

Reagents

Acetylcholine chloride, atropine sulphate, prazosin hydrochloride, suramin sodium salt and tetrodotoxin were obtained from Sigma-Aldrich (St. Louis, MO). Guanethidine sulphate was attained from Ciba-Geigy (Australia). All drugs were dissolved and diluted in distilled water.
Results

Contractile response to electrical field stimulation

Electrical field stimulation (1-20 Hz) of the mouse prostate, produced frequency dependent contractions which were abolished by tetrodotoxin (1 µM; P<0.001, data not shown). The noradrenergic component of contraction was attenuated to a similar degree by pharmacological $\alpha_1$-adrenoceptor blockade with prazosin (0.3 µM; Fig. 1a, P<0.001), the genetic deletion of the $\alpha_{1A}$-adrenoceptor (Fig. 2a, P<0.001) or noradrenergic neuron blockade with guanethidine (10 µM; P<0.001, data not shown). Maximum attenuation of contraction by prazosin (0.3 µM) was observed at 5 Hz and at 10 Hz for $\alpha_{1A}$-adrenoceptor deletion with a reduction in contraction of 60% and 44% respectively.

In the isolated vas deferens taken from wild-type mice, tetrodotoxin (1 µM; P<0.001, data not shown) and the noradrenergic neuron blocker guanethidine (10 µM; Fig. 3d) abolished contraction. Contraction was attenuated by the $\alpha_1$-adrenoceptor antagonist prazosin (0.3 µM; Fig. 1b, P<0.001) and to the same degree by genetic deletion of the $\alpha_{1A}$-adrenoceptor (Fig. 2b, P<0.001). A reduction in contraction of 74% at 10 Hz was observed in both cases. Furthermore in vasa deferentia taken from P2X1-purinoceptor knockout mice prazosin (0.3 µM; Fig. 4d, P<0.001) abolished contraction.

In isolated prostates taken from wild-type mice, suramin (30 µM) had no effect on the magnitude of contraction in the absence (Fig. 1c; P=0.552) or presence (Fig. 4a; P=0.121) of prazosin (0.3 µM). Moreover in the presence of prazosin (0.3 µM) and atropine (1 µM), suramin (30 µM) did not affect the magnitude of the small residual contraction (Fig. 5b). Nor did suramin (30 µM) affect the residual non-adrenergic contraction in prostates taken from $\alpha_{1A}$-adrenoceptor knockout mice (Fig. 6a; P=0.347). Furthermore, genetic deletion of the
P2X1-purinoceptor did not result in reduction of electrical field stimulation induced contractions of the isolated mouse prostate (Fig. 2c; P= 0.768).

In the isolated vas deferens, pharmacological blockade by the P2-purinoceptor antagonist suramin (30 µM; Fig. 1d, P<0.001,) or genetic deletion of the P2X1-purinoceptor attenuated contraction (Fig. 2d; P<0.001). In the vas deferens taken from α₁A-adrenoceptor knockout mice suramin (30 µM) abolished contraction (Fig.6b; P<0.001).

In isolated prostates taken from wild-type mice, atropine (1 µM) attenuated electrical field stimulation induced contractions (Fig. 1e; P<0.001). Atropine (1 µM) produced a maximum inhibition of contraction of 84% at 1 and 2 Hz. Furthermore, atropine (1 µM) abolished the residual non-adrenergic contractile response to electrical field stimulation observed in the presence of prazosin (0.3 µM; Fig. 3a, P<0.001) or guanethidine (10 µM; Fig. 3c, P<0.001). The contractile response to electrical field stimulation was also attenuated by atropine in prostates taken from α₁A-adrenoceptor knockout mice (Fig. 4a; P<0.001). Similarly, in isolated prostates taken from P2X1-purinoceptor knockout mice, electrical field stimulation induced contractions were inhibited by prazosin (0.3 µM), and the residual non-adrenergic contraction was then abolished by atropine (1 µM; Fig. 4c, P<0.001).

In the isolated vas deferens the muscarinic receptor antagonist atropine (1 µM; Fig. 1f, P<0.001) attenuated contraction. Similarly in the presence of prazosin (0.3 µM; Fig. 3b, P<0.001) or in vas deferens taken from α₁A-adrenoceptor knockout mice (Fig. 4b; P<0.001) contraction was further attenuated by atropine (1 µM). However in the presence of prazosin (0.3 µM) in vas deferens taken from P2X1-purinoceptor knockout mice, atropine (1 µM; Fig. 6d) had no effect.

Representative traces illustrating the different effects of suramin (30 µM) and atropine (1 µM) on the residual responses of the mouse prostate and vas deferens to trains of electrical field stimulation (10 Hz) in the presence of prazosin (0.3 µM) are shown in Fig. 7.
Agonist-induced contractile response

Administration of exogenously applied acetylcholine produced a reproducible concentration dependent contractile response ($-\log_{10}[EC_{50}] = 6.33$, 95% confidence limits: 5.88 – 6.71). Second discrete concentration response curves constructed without the application of a test drug were not different from the original curve ($P=0.794$).

Atropine (1 µM), shifted the acetylcholine concentration response curve to the right approximately 250-fold (Fig. 8a, $P<0.001$; $-\log_{10}[EC_{50}]= 3.91$, 95% confidence limits: 3.55 – 4.27) with a $pK_B$ of 8.42 (95% confidence limits: 7.84 – 9.01), whereas prazosin (0.3 µM) had no effect (Fig. 8b, $P=0.624$).
Discussion

Previous studies of the mouse prostate have identified that after pharmacological α₁-adrenoceptor blockade or genetic deletion of the α₁A-adrenoceptor, a residual nerve-mediated contraction remains (Gray and Ventura, 2005; Gray et al., 2008). The mediator of this component is not purinergic (Gray and Ventura, 2005), as has been shown in the guinea-pig and rat prostate (Ventura et al., 2003; Buljubasich and Ventura, 2004), and the vas deferens of the guinea-pig, rat and mouse (Burnstock and Verkhratsky, 2010). The objective of this present study was to characterize the residual non-adrenergic component, using both pharmacological antagonists and genetically modified receptor knockout mice.

In the present study we confirmed our earlier observation that genetic deletion of the α₁A-adrenoceptor attenuated but did not abolish nerve mediated contraction when compared to wild-type mice from the same breeding colony (Gray et al., 2008). The possibility exists that compensatory up-regulation of the remaining α₁B, α₁D-adrenoceptor subtypes occurs, as has been reported in the hepatocytes of α₁B-adrenoceptor knockout mice (Deighan et al., 2004). However, this appears unlikely in the mouse prostate as the non-subtype selective α₁-adrenoceptor antagonist prazosin failed to attenuate nerve-mediated contraction in prostates taken from α₁A-adrenoceptor knockout mice. Similarly, prazosin and guanethidine attenuated but did not abolish nerve-mediated contractions of prostates taken from wild-type mice. This is in agreement with previous studies and it is therefore reasonable to conclude that contraction of the mouse prostate is not solely mediated by noradrenergic mechanisms.

The guanethidine insensitive residual nerve-mediated contraction indicates that while the mouse prostate is innervated by noradrenergic nerves, non-adrenergic possibly cholinergic nerves capable of eliciting contraction also exist. Compared to adrenergic
blockade, we observed that inhibition of cholinergic mechanisms consistently reduced nerve-mediated contraction to a larger extent at lower frequencies (1, 2 and 5 Hz). Whereas adrenergic blockade produced a marked inhibition at 10 and 20 Hz. This suggests that cholinergic nerves contribute to a greater proportion of contraction at lower frequencies and are more sensitive than adrenergic nerves in the mouse prostate.

Immunohistochemical studies of the mouse prostate have identified P2X1-purinoceptors in the smooth muscle (Gray and Ventura, 2005). However, activation of P2X1-purinoceptors by neuronally released ATP does not appear to play a physiological role in contraction of the mouse prostate. The mouse prostate is different in this regard to the guinea-pig and rat prostate (Ventura et al., 2003; Buljubasich and Ventura, 2004) where ATP acts as a co-transmitter with noradrenaline at P2X1-purinoceptors in the prostatic smooth muscle to elicit contraction. In contrast ATP mediates contraction in the mouse vas deferens via P2X1-purinoceptors (Mulryan et al., 2000) as it does in the guinea-pig and rat vas deferens (Burnstock and Verkhratsky, 2010) as well as human vas deferens (Banks et al., 2006). The P2-purinoceptor antagonist suramin, inhibited contraction in the vas deferens of wild-type and $\alpha_{1A}$-adrenoceptor knockout mice but did not inhibit nerve-mediated contraction in prostates taken from wild-type or $\alpha_{1A}$-adrenoceptor knockout mice. Despite the presence of other P2-purinoceptors in the mouse prostate (Gray and Ventura, 2005) it would appear unlikely that we have targeted the wrong purinoceptor with the P2X1-purinoceptor knockout mouse as the non-specific P2-purinoceptor antagonist suramin, is without effect on contraction in prostates taken from wild-type mice. Therefore we have demonstrated that ATP is not a neuronally released mediator of contraction in the mouse prostate.

Histochemical observation of cholinesterase containing nerves in the prostatic smooth muscle and glandular epithelium has been observed in human (Higgins and Gosling, 1989; Dixon et al., 2000), guinea-pig, rat (Lau et al., 1998) and mouse prostates (Gray and Ventura,
In contrast to our previous study of the mouse prostate (Gray and Ventura, 2005), the current study shows inhibitory effects of atropine on nerve-mediated contractions. On closer examination the noted difference between the two studies appears to be due to statistical analysis rather than experimental origin. However in agreement with this study, atropine has previously been observed to inhibit nerve-mediated cholinergic contractile responses in the rabbit, guinea-pig and rat prostates (Haynes and Hill, 1997; Najbar-Kaszkiel et al., 1997; Lau et al., 1998).

In the mouse prostate when the adrenergic component of the nerve-mediated contractile response was blocked by guanethidine, prazosin or $\alpha_{1A}$-adrenoceptor deletion, muscarinic receptor antagonism abolished the residual response. Previously this residual non-adrenergic response has been observed in the mouse prostate (Gray et al., 2008), but its mediator was not identified, except to state that it is also non-purinergic. In the guinea-pig and rat it has also been reported that contraction can be abolished by a combination of guanethidine and atropine (Najbar-Kaszkiel et al., 1997). The use of guanethidine may be misleading as ATP is the major non-adrenergic transmitter but is co-stored with noradrenaline and the contractile effects of both are abolished by guanethidine (see figure 3d). Our results imply that acetylcholine, rather than ATP, is the major non-adrenergic transmitter and is released from non-noradrenergic, cholinergic nerves which innervate the prostatic smooth muscle and mediate contraction via muscarinic receptors in addition to noradrenaline released from noradrenergic nerves.

Exogenous muscarinic agonists have previously been shown to mediate contraction in prostates of the dog, rabbit, guinea-pig, and rat (Normandin and Lodge, 1996; Najbar-Kaszkiel et al., 1997; Fernandez et al., 1998; Lau and Pennefather, 1998), albeit at a decreased magnitude when compared to the adrenergic response. Some studies have also reported that muscarinic receptor agonists mediate contraction in the human prostate (Caine
et al., 1975; Gup et al., 1989; Kester et al., 2003). Whereas in other human studies no contraction was observed (Hedlund et al., 1985). When observed, cholinergic receptor agonist mediated contraction appears to be localised to the prostatic capsule. Acetylcholine is reported to potentiate the adrenergic component of nerve mediated prostatic contraction in the guinea-pig (Lau et al., 1998; Lau et al., 2000), whilst inhibiting noradrenaline mediated contraction in the prostates of dogs (Arver and Sjostrand, 1982). Acetylcholine has also been shown to enhance noradrenaline mediated contraction in the human prostate (Roosen et al., 2009) indicating a possible synergism.

It has been shown that there are functional muscarinic receptors mediating contraction in vasa deferentia taken from the mouse (Cuprian et al., 2005) and guinea-pig (Solanki et al., 2007) and we also observed that atropine attenuated contraction in vasa deferentia taken from wild-type mice. However after purinergic and adrenergic blockade we did not observe a cholinergic residual response. This is in contrast to the mouse prostate where adrenergic and purinergic blockade still left a substantial residual response which could be abolished by atropine.

Traditionally, theoretical concerns over acute urinary retention have limited the use of anti-cholinergic drugs for the treatment of patients with BPH. Nevertheless, a recent review of clinical trial data indicated that anti-cholinergics are a safe treatment option for the lower urinary tract symptoms associated with BPH and that patients may benefit from a combination therapy of $\alpha_1$-adrenoceptor and muscarinic receptor antagonists (Gallegos and Frazee, 2008). Although Gallegos and Frazee (2008) suggested that the mechanism of action was localised in the bladder, evidence of cholinergically mediated contraction of the prostatic smooth muscle suggests that the mechanism of action of solifenacin for relief of the lower urinary tract symptoms associated with BPH may be achieved by relaxing prostatic smooth muscle as suggested by Roosen et al (2009). This prostatic relaxation would alleviate the
urethral blockade caused by the hyperplastic prostate allowing for an easier flow of urine. In conclusion, the present study indicates that cholinergic rather than purinergic innervation is predominantly responsible for the non-adrenergic component of nerve-mediated contraction in the mouse prostate. Therefore, if the same were true for humans, anti-cholinergic drugs in combination with existing $\alpha_1$-adrenoceptor antagonists may provide a more effective treatment for lower urinary tract symptoms associated with BPH.
References


Dixon JS, Jen PY and Gosling JA (2000) The distribution of vesicular acetylcholine
transporter in the human male genitourinary organs and its co-localization with neuropeptide

Fernandez JLG, Rivera L, Lopez PG, Recio P, Vela-Navarrete R and Garcia-Sacristan A
*J Auton Pharmacol* **18**:205-211.


Gray KT, Short JL and Ventura S (2008) The α1A-adrenoceptor gene is required for the α1L-

Gray KT and Ventura S (2005) Evaluation of the mouse prostate as a suitable model for the

Gray KT and Ventura S (2006) α1L-Adrenoceptors mediate contractions of the isolated mouse


Footnotes

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Reprint requests

Dr. Sabatino Ventura, 381 Royal Parade, Parkville, Vic 3052, Australia

Sab.Ventura@monash.edu
Legends for figures

**Figure 1** Mean contractile responses to electrical field stimulation (0.5ms, 60V, 1-20 Hz, 10 s pulses) in the prostate (a,c,e) and vas deferens (b,d,f) in the absence (open bars) and presence of (solid bars): (a,b) prazosin (0.3 µM), (c,d) suramin (30 µM) and (e,f) atropine (1 µM). Bars represent mean force ± S.E.M., n=6-7. ANOVA p-values determined by a two-way repeated-measures of ANOVA represent the probability of the drug treatment causing a significant change. *, p<0.05, **, p<0.01 and ***, p<0.001 solid bar versus control calculated by Bonferroni post-tests.

**Figure 2** Comparison of mean contractile responses to electrical field stimulation (0.5ms, 60V, 1-20 Hz, 10 s pulses) in prostates (a,c) and vas deferens (b,d) taken from wild-type mice (open bars) and (a,b) α1A-adrenoceptor knockout mice (solid bars) or (c,d) P2X1-purinoceptor knockout mice (solid bars). Bars represent mean force ± S.E.M., n=5-11. ANOVA p-values determined by a two-way repeated-measures of ANOVA represent the probability of the drug treatment causing a significant change. **, p<0.01 and ***, p<0.001 solid bar versus control calculated by Bonferroni post-tests.

**Figure 3** Mean contractile responses to electrical field stimulation (0.5ms, 60V, 1-20 Hz, 10 s pulses) in the prostate (a,c) and vas deferens (b,d) following the administration of: (a,b) prazosin (0.3 µM) (open bars) and prazosin (0.3 µM) plus atropine (1 µM) (solid bars) and (c,d) guanethidine (10 µM) (open bars) and guanethidine (10 µM) plus atropine (1 µM) (solid bars). Bars represent mean force ± S.E.M., n=5-6. ANOVA p-values determined by a two-way repeated-measures of ANOVA represent the probability of the drug treatment causing a
significant change. **, p<0.01 and ***, p<0.001 solid bar versus control calculated by Bonferroni post-tests.

**Figure 4** Mean contractile responses to electrical field stimulation (0.5ms, 60V, 1-20 Hz, 10 s pulses) in prostates (a) and vas deferens (b) taken from α_{1A}-adrenoceptor knockout mice, following the administration of: no drug (open bars), prazosin (0.3 µM) (solid bars) and prazosin (0.3 µM) plus atropine (1 µM) (grey bars). Mean contractile responses to electrical field stimulation (0.5ms, 60V, 1-20 Hz, 10 s pulses) in prostates (c) and vas deferens (d) taken from P2X1-purinoceptor knockout mice following the administration of: no drug (open bars), prazosin (0.3 µM) (solid bars) and prazosin (0.3 µM) plus atropine (1 µM) (grey bars). Bars represent mean force ± S.E.M., n=6. ANOVA p-values determined by a two-way repeated-measures of ANOVA represent the probability of the drug treatment causing a significant change. **, p<0.01 and ***, p<0.001 solid bar versus control, ††, p<0.01 and †††, p<0.001 grey bars versus control calculated by Bonferroni post-tests.

**Figure 5** Mean contractile responses to electrical field stimulation (0.5ms, 60V, 1-20 Hz, 10 s pulses) in the prostate following the administration of: (a) prazosin (0.3 µM) (open bars) and prazosin (0.3 µM) plus suramin (30 µM) (solid bars) and (b) no drug (open bars), prazosin (0.3 µM) plus atropine (1 µM) (solid bars) and prazosin (0.3 µM) plus atropine (1 µM) plus suramin (30 µM) (grey bars). Bars represent mean force ± S.E.M., n=5-6. ANOVA p-values determined by a two-way repeated-measures of ANOVA represent the probability of the drug treatment causing a significant change. ***, p<0.001 solid bar versus control, †††, p<0.001 grey bar versus control calculated by Bonferroni post-tests.
Figure 6 Mean contractile responses to electrical field stimulation (0.5ms, 60V, 1-20 Hz, 10 s pulses) in prostates (a) and vas deferens (b) taken from α1A-adrenoceptor knockout mice, in the absence (open bars) and presence of suramin (30 µM) (solid bars). Bars represent mean force ± S.E.M., n=6. ANOVA p-values determined by a two-way repeated-measures of ANOVA represent the probability of the drug treatment causing a significant change. *, p<0.05 and ***, p<0.001 solid bar versus control calculated by Bonferroni post-tests.

Figure 7 Representative traces of the contractile responses to electrical field stimulation (0.5 ms, 60 V, 10 Hz, 10 s trains) in isolated preparations of prostate and vas deferens from wild type mice in the absence and presence of prazosin (0.3 µM), prazosin (0.3 µM) and suramin (30 µM) or prazosin (0.3 µM) and atropine (1 µM). ‘___’ indicates period of electrical field stimulation (10 s). Traces are representative of six experiments.

Figure 8 Normalised mean log concentration response curves to acetylcholine of prostates before and after the administration of (a) atropine (1 µM) and (b) prazosin (0.3 µM). Bars represent mean force ± S.E.M., n=6. P values determined by a two-way repeated-measures of ANOVA represent the probability of a significant interaction between concentration and treatment.
Figure 1

**Prostate**

A

- Control
- Prazosin (0.3 μM)

ANOVA: P<0.001
n=6

B

- Control
- Prazosin (0.3 μM)

ANOVA: P<0.001
n=6

**Vas deferens**

C

- Control
- Suramin (30 μM)

ANOVA: P=0.552
n=7

D

- Control
- Suramin (30 μM)

ANOVA: P<0.001
n=6

E

- Control
- Atropine (1 μM)

ANOVA: P<0.001
n=6

F

- Control
- Atropine (1 μM)

ANOVA: P<0.001
n=6
Figure 3

Prostate

A

- Prazosin (0.3 μM)
- Prazosin (0.3 μM) + Atropine (1 μM)

ANOVA: P<0.001
n=6

B

- Prazosin (0.3 μM)
- Prazosin (0.3 μM) + Atropine (1 μM)

ANOVA: P<0.001
n=6

Vas deferens

C

- Guanethidine (10 μM)
- Guanethidine (10 μM) + Atropine (1 μM)

ANOVA: P<0.001
n=6

D

- Guanethidine (10 μM)
- Guanethidine (10 μM) + Atropine (1 μM)

ANOVA: P<0.001
n=6
Figure 5

**A**

- Prazosin (0.3 μM)
- Prazosin (0.3 μM) + Suramin (30 μM)

ANOVA: P=0.121
n=6

**B**

- Control
- Prazosin (0.3 μM) + Atropine (1 μM)
- Prazosin (0.3 μM) + Atropine (1 μM) + Suramin (30 μM)

ANOVA: P<0.001
n=5
Figure 8

A

- Control
- Atropine (1 μM)

P < 0.001
n = 6

B

- Control
- Prazosin (0.3 μM)

P = 0.624
n = 6

\[
\log_{10}[\text{Acetylcholine}]
\]