Endothelin-1 Antagonises Beta-Adrenergic Stimulation in Human Right Atrial Myocardium

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Plasma concentrations of endothelin-1 (ET-1) are elevated in chronic heart failure (CHF) and correlate with a poor prognosis [1]. Short-term systemic ET blockade in CHF patients causes potentially beneficial haemodynamic effects; increasing cardiac output and reducing vascular resistance [2]. However, the initial results from longer term clinical trials have been disappointing. In the ENABLE and EARTH clinical trials preliminary reports indicate that there was no major benefit when an endothelin receptor antagonist (ETRA) was added to conventional heart failure therapy. Beta-blockers improve mortality in CHF patients and while the mechanisms for these benefits are not fully understood they may involve beta-1-adrenoceptor upregulation. Beta1-adrenergic stimulation increases adenylate cyclase (AC), increasing cAMP, activating protein kinase A, resulting in phosphorylation of several intracellular proteins ultimately leading to an increase in intracellular calcium. The positive inotropic effect of ET-1 is mediated predominantly via the ETA receptor resulting in activation of protein kinase C via G proteins. However, in isolated myocardial membrane studies ET-1 also inhibits AC and may therefore inhibit beta-adrenergic stimulation [3, 4]. This potentially important antagonism between the two systems has not been previously studied at a functional level.

Methods

12 right atrial appendage biopsies were harvested at the time of coronary artery bypass surgery and placed in cold cardioplegic solution (mM): NaCl 130, KCl 5.4, NaHPO4 0.56, MgCl2H2O 3.5, CaCl2 2, Glucose 10, HEPES 5, 2,3-butane-dione-monoxime 30 (mM) corrected to pH 7.4 with NaOH. Free running trabeculae were mounted for electrical stimulation at 3 Hz at a voltage $\approx 10\%$ above threshold and allowed to stabilise for 1 hour in a vertical 7 ml chamber (World Precision Instruments, UK) containing modified Tyrodes (NaCl 130, KCl 5.4, NaHPO4 0.56, MgCl2H2O 3.5, CaCl2 2, Glucose 10, HEPES 5 [mM]) corrected to pH 7.4 with NaOH and continuously bubbled with 100% O2 at 35 °C. ET-1 (Neosystem, SNPE England, UK) was reconstituted in 0.9% saline and isoprenaline (Sigma-Aldrich Chemicals, UK), a beta1-adrenoreceptor agonist, was dissolved in physiological solution with ascorbic acid (1 mM) to reduce oxidation. Drug concentrations were chosen from previous dose ranging studies. Trabeculae were exposed to either isoprenaline (10 nM), ET-1 (10 nM) or isoprenaline followed by ET-1. When possible two trabeculae were dissected from a single atrial appendage.

Statistical difference was tested by Student’s t-test (Excel 5.0, Microsoft). A value of p < 0.05 was considered to be statistically significant. All values are expressed as mean ± SEM.

Results

ET-1 (10 nM) increased force by 12.6 ± 5.0%, n = 5, p = 0.04. This was preceded by a transient non-significant decrease in force (-3.6 ± 1.9%, p = ns). Isoprenaline (10 nM) increased force from baseline 65.7 ± 29.2%, n = 5, p = 0.01. The increase in force with isoprenaline was of more rapid onset, with a maximal effect seen after 5 min (Fig. 1). When added to maximally beta-adrenergic stimulated trabeculae, ET-1 significantly attenuated the effect of isoprenaline causing a reduction in force (96 ± 39%, n = 5, p < 0.01) (Fig. 2).

Discussion

Both ET-1 and isoprenaline increased isometric force in human RA myocardium. ET-1 increased force following a transient negative inotropic response, and although this has been described by other groups [4, 5] the mechanism remains unclear. Isoprenaline increased force, which was of faster onset and larger magnitude than ET-1. We have observed, for the first time, that ET-1 functionally attenuates the inotropic effects of isoprenaline in human myocardium. This reduction in force was observed after maximal stimulation of the beta-adrenergic system. The underlying mechanism is likely to be interaction at the level of AC as seen in isolated membrane studies where ET-1 was shown to inhibit AC.

Figure 1. Effect of isoprenaline (10 nM) and endothelin-1 (10 nM) on force of contraction of human right atrial trabeculae
to inhibit the effect of beta1-adrenoreceptor activation on
this enzyme.

This study has some limitations in that we were unable to
study normal human ventricular myocardium due to a lack
of suitable samples. Previous isolated membrane studies have
confirmed differences between atrial and ventricular tissue so
ET-1 may not inhibit AC in ventricular tissue [5]. In addi-
tion, the concentrations of ET-1 used were higher than those
in the plasma of CHF patients but may be similar to those
occurring at a local level in myocardium.

The interaction between endothelin and adrenergic sys-
tems in the human myocardium may be significant in
patients with CHF where both systems are activated. ET-1
may protect from catecholamines over-stimulation and may
be anti-arrhythmic. With the possible introduction of ETRAs
for the treatment of CHF the physiological and patho-
physiological interactions between these two systems may be of
clinical importance as unintended deleterious effects may
occur with ET blockade in the absence of beta1-adreno-
receptor blockade.

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