Potentiation of the bronchoprotective effects of vasoactive intestinal peptide, isoprenaline, and theophylline against histamine challenge in anaesthetised guinea pigs by adrenomedullin

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Abstract

Background – Adrenomedullin is a hypothalamic peptide recently discovered in human pheochromocytoma which has been found to inhibit bronchoconstriction induced by histamine and acetylcholine. This study was designed to determine the manner in which adrenomedullin and other bronchodilators interact in modulating airway function.

Methods – A study was undertaken to determine whether adrenomedullin potentiates the bronchoprotective effects of isoprenaline, vasoactive intestinal peptide (VIP), and theophylline against histamine-induced bronchoconstriction in anaesthetised guinea pigs in vivo.

Results – Adrenomedullin in a concentration of 10⁻⁷M significantly inhibited histamine-induced bronchoconstriction but in a concentration of 10⁻⁸M it did not exhibit the bronchoprotective effect against histamine. VIP (10⁻⁷M) did not affect histamine-induced bronchoconstriction but it markedly inhibited the bronchoprotective effect against histamine in the presence of adrenomedullin (10⁻⁸M). VIP (10⁻⁷M) significantly inhibited histamine-induced bronchoconstriction but this effect was short lived. Adrenomedullin in a concentration of 10⁻⁶M potentiated bronchoprotection induced by VIP (10⁻⁴M) and prolonged it. Isoprenaline (10⁻⁴M) also significantly inhibited histamine-induced bronchoconstriction and this effect was enhanced in the presence of adrenomedullin (10⁻⁸M). Similarly, adrenomedullin (10⁻⁷M) significantly potentiated theophylline-induced bronchoprotection, and a sub-bronchoprotective dose of theophylline (20 mg/kg i.p.) was effective in preventing histamine-induced bronchoconstriction in the presence of adrenomedullin (10⁻⁸M).

Conclusions – This study shows that adrenomedullin potentiates the bronchoprotective effects of different classes of bronchodilators against histamine challenge in anaesthetised guinea pigs.

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Adrenomedullin is a hypotensive peptide recently discovered in human pheochromocytoma. The peptide, consisting of 52 amino acids, has one intramolecular disulphide bond and 17% amino acid sequence homology with calcitonin gene-related peptide. A cDNA clone encoding the porcine adrenomedullin precursor has been isolated and sequenced from rat and human tissue. With the use of RNA blot analysis, porcine adrenomedullin mRNA was shown to be highly expressed in lung tissue, and adrenomedullin was synthesised by several cell populations of the lung including epithelium and airway smooth muscle cells. We have already shown that exogenous adrenomedullin induces long lasting bronchodilatation. Adrenergic agonists and theophylline are used clinically for treatment of bronchial asthma. They directly stimulate the production of cyclic adenosine monophosphate (cAMP) in airway smooth muscle cells, and theophylline prevents the degradation of cAMP to 5'AMP, thus increasing intracellular cAMP and causing relaxation. Vasoactive intestinal peptide (VIP), a 28 amino acid peptide, is the neuropeptide found in highest concentrations in human lung and is localised to efferent nerves. VIP immunoreactive nerve fibres are associated with airway smooth muscle, mucous glands, airway blood vessels, and parasympathetic ganglia. VIP is a potent relaxant of airway smooth muscle in vitro, and this relaxation is independent of adrenergic receptors. Torphy et al have already shown that phosphodiesterase inhibitors significantly potentiate isoprenaline-induced relaxation of human isolated receptors. However, the manner in which adrenomedullin and these bronchodilators interact in modulating airway function has not yet been determined. In this study we have examined whether adrenomedullin potentiates the bronchoprotective effects of isoprenaline, VIP, and theophylline against histamine-induced bronchoconstriction in anaesthetised guinea pigs.

Methods

MEASUREMENT OF PULMONARY RESISTANCE

Hartley male guinea pigs (400–500 g) were used in the study. They were anaesthetised with sodium pentobarbitone (50 mg/kg intraperitoneally; Abbott Laboratories) and then ventilated artificially with a tracheal cannula
using a constant volume ventilator (Model 680; Harvard Apparatus Co) at a frequency of 60 breaths/min. The tidal volume was set at 6 ml/kg. Airflow was monitored continuously using a pneumotachograph (TV-241T, Nihon Koden Co) connected to a differential pressure transducer (TP-602T, Nihon Koden Co). The tidal volume was determined by electrical integration of airflow. A fluid-filled polyethylene catheter was introduced into the oesophagus to measure oesophageal pressure as an approximation of pleural pressure. Intratracheal pressure was measured using a polyethylene catheter inserted into a short tube connecting the tracheal cannula to the pneumotachograph. The transpulmonary pressure (defined as the pressure difference between the intratracheal and oesophageal pressures) was measured with a differential pressure transducer. Pulmonary resistance was calculated as previously described. Aerosols of test agents (mass median aerodynamic diameter 1.8 μm; geometric standard deviation 2 μm; output 1.5 ml/min) were generated with an ultrasonic nebuliser (TUR-3200, Nihon Koden Co) and delivered to the airways by the ventilator. The mean blood pressure and heart rate were monitored from the cannula in the right jugular artery with a Statham pressure transducer (model P231D; Gould, Saddle Brook, New Jersey, USA) connected to a polygraph (Polygraph System, Nihon Koden Co).

EFFECT OF ADRENOMEDULLIN ON HISTAMINE-INDUCED BRONCHOCONSTRICTION
After measuring baseline (100%) pulmonary resistance the guinea pigs were first exposed to adrenomedullin (10⁻¹⁰ M or 10⁻⁸ M, 30 breaths at each concentration) and five minutes later to histamine (10⁻³ M, 20 breaths). The time of exposure to histamine was defined as time 0.

EFFECT OF ADRENOMEDULLIN ON THE BRONCHOPROTECTIVE EFFECTS OF VIP OR ISOPRENALINE
The guinea pigs were first exposed to adrenomedullin (10⁻¹⁰ M, 30 breaths). Five minutes later they were exposed to VIP (10⁻⁶ M or 10⁻⁴ M, 30 breaths at each concentration) or isoprenaline (10⁻⁸ M, 30 breaths) and then after a further five minutes they were exposed to histamine (10⁻³ M, 20 breaths). The time of exposure to histamine was defined as time 0. All data were standardised by the baseline pulmonary resistance and the percentage inhibitory effects of VIP and isoprenaline were calculated.

EFFECT OF ADRENOMEDULLIN ON THE BRONCHOPROTECTIVE EFFECTS OF THEOPHYLLINE
The guinea pigs were injected with theophylline (20 mg/kg, 40 mg/kg, 60 mg/kg i.p.) or saline. Ten minutes after theophylline they were exposed to adrenomedullin (10⁻¹⁰ M, 30 breaths) followed by histamine (10⁻³ M, 20 breaths) five minutes later. The percentage maximal inhibitory effects of theophylline were calculated.

DRUGS
Histamine, isoprenaline, and theophylline were obtained from the Sigma Chemical Company (St Louis, Missouri, USA) and human adrenomedullin and VIP were purchased from the Peptide Institute Inc (Japan). Stock solutions of histamine, adrenomedullin, VIP, isoprenaline, and theophylline were prepared in distilled water. All stock solutions were stored at −70°C and dilutions from stock were all prepared fresh daily in 0.9% NaCl to the final concentrations.

DATA ANALYSIS
Values are expressed as mean (SE). Statistical analysis was performed by one way analysis of variance followed by the Fisher test, and a p value of less than 0.05 was considered significant.

RESULTS
Baseline pulmonary resistance after aerosolised control solvent (0.16 (0.02) cm H₂O/ml/s) was no different from that observed in control animals (0.15 (0.01) cm H₂O/ml/s) and it had no effect on histamine-induced bronchoconstriction. Adrenomedullin (10⁻¹⁰ M) significantly inhibited histamine-induced bronchoconstriction but in a concentration of 10⁻⁸ M it did not exhibit a bronchoprotective effect against histamine (fig 1).

Inhaled VIP (10⁻⁹ M) did not affect histamine-induced bronchoconstriction but markedly inhibited histamine-induced bronchoconstriction in the presence of adrenomedullin (10⁻¹⁰ M) (highest maximal inhibition 50 (15%); fig 2). Higher doses of VIP (10⁻⁸ M)
Potentiation of vasoactive intestinal peptide, isoprenaline and theophylline by adrenomedullin

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**Discussion**

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### Table 1: Synergistic effects of adrenomedullin on theophylline-induced bronchoprotection against histamine

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Highest maximal inhibition (%)</th>
</tr>
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<tbody>
<tr>
<td>Theophylline (20 mg/kg)</td>
<td>4 (3)</td>
</tr>
<tr>
<td>Theophylline (40 mg/kg)</td>
<td>22 (12)</td>
</tr>
<tr>
<td>Theophylline (60 mg/kg)</td>
<td>50 (8)</td>
</tr>
<tr>
<td>Adrenomedullin (10⁻¹⁰ M)</td>
<td></td>
</tr>
<tr>
<td>+Theophylline (20 mg/kg)</td>
<td>25 (9)</td>
</tr>
<tr>
<td>+Theophylline (40 mg/kg)</td>
<td>48 (13) **</td>
</tr>
<tr>
<td>+Theophylline (60 mg/kg)</td>
<td>80 (12) **</td>
</tr>
</tbody>
</table>

** p<0.01 compared with theophylline alone.
† p<0.05; ‡ p<0.01 compared with adrenomedullin + theophylline (20 mg/kg).

Each group represents the mean (SE) for six guinea pigs.
the bronchoconstrictor effects of histamine and prostaglandin F₂ in dogs. In asthmatic patients, however, inhaled VIP had no bronchodilator effect although β₂ adrenergic agonists were markedly effective in the same subjects. Inhaled VIP has only a small protectice effect against histamine and has no effect against exercise-induced bronchoconstriction. The lack of potency of inhaled VIP may be explained by limitation of diffusion of VIP across the airway epithelium to reach receptors in the airway smooth muscle or by enzymatic degradation of VIP. We suggest that adrenomedullin might potentiate VIP receptor agonist-induced bronchoprotection, since recently designed VIP analogues were found not to be susceptible to peptidases and to have a high metabolic stability.

The precise mechanism responsible for the synergism in the bronchoprotective effects of adrenomedullin and VIP or isoprenaline is unclear. Adrenomedullin induces vasodilatation by increasing cAMP levels in vascular smooth muscle cells, where cAMP levels are drastically increased. Adrenomedullin might cause cAMP levels to be susceptible to peptidases and to have high metabolic stability. Isolated porcine peptide, a newly discovered hypotensive peptide, is a potent bronchodilator. Biochem Biophys Res Commun 1994;205:251–4.


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