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PHARMACEUTICAL FORMULATION

This invention relates to new compounds, mixtures and methods for their preparation.

Nedocromil sodium, the sodium salt of 9-ethyl-6,9-dihydro-4,6-dioxo-10-propyl-4H-pyrano[3,2-g]quinoline-2,8-dicarboxylic acid has been recommended for use in the treatment of allergic and other conditions, in particular of reversible obstructive airway disease.

Bronchodilators and steroids have also been recommended for use in the treatment of reversible obstructive airway disease. However therapy using a combination of active ingredients, particularly fixed dose combinations, can cause problems and consequently there is a considerable prejudice against the use of such combinations. In many patients treatment with a bronchodilator on a regular basis over a prolonged period, eg six weeks, leads to a diminution in response to the therapeutic agent, leaving the patient unprotected. In some cases, prolonged administration of a bronchodilator can even lead to rebound bronchoconstriction. In other cases, one of the components of the mixture may, on its own, be sufficient to control the disease, rendering the other components superfluous.

We have now found that mixtures of nedocromil sodium with agents suitable for inhalation selected from

bronchodilators and steroids, salts of 9-ethyl-6,9-dihydro-4,6-dioxo-10-propyl-4H-pyrano[3,2-g]quinoline-2,8-dicarboxylic acid with these agents, and mixtures of these salts with nedocromil sodium or the agent at the appropriate therapeutic ratio, possess the advantage that they are both palliative and prophylactic, are more effective, suffer less from loss of responsiveness, produce fewer side effects, reduce bronchial hyperactivity, can be used at lower doses, can be administered directly to the site of the disease, eg by inhalation, can be administered less frequently, eg 1-2 times per day, can be administered as a long term therapy, are longer acting, reduce steroid induced candidiasis, are more stable, are synergistic, cause better patient compliance, have a less offensive taste or possess other desirable properties as compared to the steroids or bronchodilators when used on their own, nedocromil sodium when used on its own or certain other mixtures when tested in relevant pharmacological models.

According to the invention there is provided a pharmaceutical mixture comprising

a) one or more of 9-ethyl-6,9-dihydro-4,6-dioxo-10-propyl-4H-pyrano[3,2-g]quinoline-2,8-dicarboxylic acid or a pharmaceutically acceptable salt thereof, as 'active ingredient A' in combination with

b) one or more agents suitable for inhalation selected from bronchodilators, steroids and pharmaceutically acceptable derivatives thereof as 'active ingredient B'.

We prefer to use the disodium salt of 9-ethyl-6,9-dihydro-10-propyl-4H-pyrano-[3,2-g]quinoline-2,8-dicarboxylic acid, which is known as nedocromil sodium. We also prefer to use only one active ingredient A in admixture with either one bronchodilator or one steroid as active ingredient B.

Bronchodilators that ingredient B may represent include isoprenaline. However, we prefer the bronchdilator to be B_2 selective.

A B_2-selective bronchodilator is a beta adrenoceptor agonist which has a greater affinity for B_2 adrenoceptors, stimulation of which results in relaxation of bronchial (and also arterial and uterine) muscle, than for B_1 adrenoceptors, agonists of which produce cardiac stimulation (and lipolysis). For the determination of B_2 selectivity, a comparison is made of the activity of the compound, (a) as a relaxant of isolated guinea pig tracheal preparations with spontaneous tone (EC_{50} = molar concentration giving 50% of maximum relaxation response to isoprenaline), and (b) in increasing atrial beat frequency of isolated spontaneously beating atria from guinea-pig hearts (EC_{50} = molar concentration

causing 50% of maximum increase in rate induced by isoprenaline). A B_2 selective compound will have a lower EC_{50} on the trachea than on the atria. A selectivity ratio can be determined which is the anti log of the difference between the negative log EC_{50} (trachea) and negative log EC_{50} (atria). The greater this selectivity ratio the more selective is the compound for B_2 adrenoceptors.

We prefer the B_2 selective bronchodilator to be long acting. By the term 'long acting' we mean that the compound has a longer duration of action as a relaxant of bronchial smooth muscle in pharmacological tests than does isoprenaline or orciprenaline. For duration of action studies, a comparison is made of the effect of equiactive i.v. doses as inhibitors of acetyl choline or histamine induced bronchospasm in anaesthetised guinea-pigs. The duration of action of isoprenaline in such a test is relatively short (control response back to normal in 10 to 25 minutes). In the case of a compound with a longer duration of action, the control response would only return to normal over a several-fold longer period of time.

Specific bronchodilators which may be mentioned are terbutaline, fenoterol, reproterol, pirbuterol, rimiterol, orciprenaline and in particular salbutamol.

Steroids suitable for use as active ingredient B

include hydrocortisone, and more active compounds such as betamethasone valerate, clobetasone butyrate, fluocinolone acetonide, fluocortolone hexanoate, beclomethasone dipropionate, hydrocortisone butyrate, diflucortolone valerate, triamcinolone acetonide, flucinonide, desonide, flurandrenalone, flumethasone pivalate, methylprednisolone, clobetasol propionate, halcinonide, tixocortol, prednisolone and fluprednylidene-21-acetate. We prefer active ingredient B to be beclomethasone dipropionate.

According to the invention there is also provided a salt of 9-ethyl-6,9-dihydro-4,6-dioxo-10-propyl-4H-pyrano[3,2-g]quinoline-2,8-dicarboxylic acid with a basic agent suitable for inhalation selected from B_2 selective bronchodilators and steroids.

The salt may be made by a metathetical process, eg by reacting a suitable salt, such as the disodium salt, of 9-ethyl-6,9-dihydro-4,6-dioxo-10-propyl-4H-pyrano[3,2-g] quinoline-2,8-dicarboxylic acid with an appropriate salt, eg the hydrochloride or sulphate, of the base of the agent suitable for inhalation. However the salt is preferably produced by reacting the free acid, 9-ethyl-6,9-dihydro-4,6-dioxo-propyl-4H-pyrano[3,2-g]quinoline-2,8-dicarboxylic acid with the free base of the agent suitable for inhalation, as such a process does not produce a

bi-product inorganic salt. The reaction may be carried out in a solvent which is inert under the reaction conditions. The solvent is preferably one in which the desired salt is soluble, eg water. The desired salt may be isolated and purified, for example, by crystallisation or by freeze drying.

The salt may be in substantially dry form, or may be in admixture with insufficient liquid, eg water, to dissolve it all.

The salt may, if desired, be used in conjunction with one or more other salts of 9-ethyl-6,9-dihydro-4,6-dioxo-10-propyl-4H-pyrano[3,2-g]quinoline-2,8-dicarboxylic acid, notably the disodium salt thereof.

The ratio of active ingredients A and B in the composition will vary with the particular active ingredients, and the specific purpose for which the composition is intended. When active ingredient A is itself a salt of 9-ethyl-6,9-dihydro-10-propyl-4H-pyrano[3,2-g]quinoline-2,8-dicarboxylic acid with a basic agent suitable for inhalation, eg a B_2 selective bronchodilator, it may be necessary to use, none, or only a very small proportion of 'free' basic agent or of another salt thereof as active ingredient B.

A suitable dose of active ingredient A for inhalation

is in the range 1 to 100mg and preferably 1 to 20mg, (measured as nedocromil sodium).

A suitable dosage of active ingredient B for inhalation and a suitable number of parts by weight of active ingredient A (measured as nedocromil sodium) to one part by weight of active ingredient B are specified below:

Compound	Dose in micro g	Ratio A:B (pressurised aerosol formulation)
Salbutamol (as the sulphate)	50 to 300, preferably 50 to 200	4 to 20 : 1
Terbutaline (as the sulphate)	100 to 600 preferably 100 to 500	2 to 10 : 1
Fenoterol (as the hydrobromide)	100 to 500	2 to 10 : 1
Pirbuterol (as the hydrochloride)	100 to 500	2 to 15 : 1
Reproterol (as the hydrochloride)	150 to 750	1.3 to 6.7 : 1
Beclomethasone dipropionate	10 to 500 preferably 25 to 200	2 to 40 : 1

It is much preferred that the dose of ingredient B be such as to give a sustained rather than a transitory action. The mixture may be administered as divided doses from 1 to 6, and preferably 2 to 4, times per day. Each dose may comprise one or more unit doses.

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The specific ratios of particular active ingredients A and B in any composition according to the invention can vary over a wide range. However we prefer a composition containing from 0.4 to 400 parts by weight, and more preferably from 2 to 200 parts by weight of active ingredient A (measured as nedocromil sodium) for each part by weight of active ingredient B.

The mixtures according to the invention may be made by mixing together the various active ingredients using conventional techniques known per se.

The salts, mixtures and compositions of the invention are useful because they possess pharmacological activity in animals; in particular they are useful because they inhibit the release and/or action of pharmacological mediators which result from the in vivo combination of certain types of antibody and specific antigen, eg the combination of reaginic antibody with specific antigen

(see Example 27 of British Patent Specification No 1,292,601). The salts and compositions have also been found to inhibit the degranulation of mast cells and to interfere with reflex pathways in experimental animals and man, in particular those reflexes associated with lung function. In man, both subjective and objective changes which result from the inhalation of specific antigen by sensitised subjects are inhibited by prior administration of the new salts and compositions. Thus the new salts and compositions are useful in the treatment of reversible airway obstruction and/or to prevent the secretion of excess mucous. They are thus useful for the treatment of allergic asthma, so-called 'intrinsic' asthma (in which no sensitivity to extrinsic antigen can be demonstrated), exercise etc. induced asthma, rhinitis, farmer's lung, bird fancier's disease, bronchitis, coughs (including whooping cough) and the nasal and bronchial obstructions associated with the common cold. The new salts, mixtures and compositions are also of value in the treatment of other conditions in which antigen-antibody reactions or excess mucous secretion are responsible for, or are an adjunct to, disease.

The new salts, mixtures and compositions of the invention may be administered by a wide variety of routes and may act systemically or locally. Thus the compounds

may be administered by oral or nasal inhalation to the lung, directly to the nose or eye, to the buccal cavity, oesophageally or to other available surfaces of the body. The new salts or mixtures may be administered directly to the organ or part of the body showing symptoms or to a part remote from that showing symptoms.

The compositions of the invention may be used in a method of treatment of reversible obstructive airways disease which comprises administering a therapeutically effective amount of

a) one or more of 9-ethyl-6,9-dihydro-4,6-dioxo-10-propyl-4H-pyrano[3,2-g]quinolone-2,8-dicarboxylic acid or a pharmaceutically acceptable salt thereof as 'active ingredient A' in combination with

b) a therapeutically effective amount of one or more agents suitable for inhalation selected from B_2 selective bronchodilators, steroids and pharmaceutically acceptable derivatives thereof as 'active ingredient B', simultaneously or separated in time to a patient suffering from such a disease.

The method of treatment is preferably carried out on a regular daily basis, eg 1 - 4 times per day. The method is preferably carried out over a prolonged period, eg at least 4 weeks, more preferably at least 8 weeks. The method preferably comprises simultaneously administering

fixed doses of active ingredient A with fixed doses of active ingredient B.

The new salts, mixtures and compositions of the invention may be used in a variety of dosing schedules, either on their own or in conjunction with one or more other active compounds.

The new salts of the invention, and the active components of the mixtures and compositions, may be prepared in a wide variety of particle sizes. Thus for inhalation and other uses the compounds may have a mass median diameter of from 0.01 to 10 microns, preferably from 2 to 6, and most preferably from 2 to 4, microns.

According to our invention we also provide a pharmaceutical composition comprising (preferably less than 80%, and more preferably less than 50% by weight of) a salt or mixture according to the invention, in admixture with a pharmaceutically acceptable adjuvant, diluent or carrier.

Examples of suitable adjuvants, diluents or carriers are:

for tablets, capsules and dragees; microcrystalline cellulose, calcium phosphate, diatomaceous earth, a sugar such as lactose, dextrose or mannitol, talc, stearic acid, starch, sodium bicarbonate and/or gelatin;

for suppositories; natural or hardened oil or waxes;

and

for inhalation compositions; coarse lactose.

For administration by inhalation the new salts or mixtures may be formulated with a compressed gas, eg nitrogen, or a liquified propellant as a pressurised aerosol composition, the composition preferably containing from 1 to 20% w/v of the active agent(s).

The new salts or mixtures may also be administered as a nebulised solution.

The invention is illustrated by the following examples.

Example 1

Pressurised aerosol delivering nedocromil sodium (2mg) and salbutamol sulphate (0.1mg)

Nedocromil sodium (micronised, dried)	1.4420% w/w
Salbutamol (midronised)	0.0721
Sorbitan trioleate	0.5000
Dichlorotetrafluoroethane	39.1944
Dichlorodifluoromethane	58.7915

Cool the dichlorodifluoromethane to -55°C and disperse the sorbitan trioleate in it using a high-shearmixer. Disperse the nedocromil sodium and the butylamino)-1-4-(hydroxy-3-hydroxymethylphenyl)ethanol sulphate in the mix and add the dichlorotetrafluoroethane, previously cooled to -55°C. Fill the suspension into

cans, and crimp a metering valve of 100µl capacity onto each can.

Example 2

Pressurised aerosol delivering nedocromil sodium (2mg) and terbutaline (0.25mg).

Nedocromil sodium, dried, micronised	1.4286% w/w
Terbutaline (micronised)	0.1786
Sorbitan trioleate	0.5000
Trichlorofluoromethane	24.4732
Dichlorotetrafluoroethane	24.4732
Dichlorodifluoromethane	48.9464

Dissolve the sorbitan trioleate in the trichlorofluoromethane and disperse the nedocromil sodium and terbutaline sulphate in the solution. Cool the solution to -55°C and add the dichlorotetrafluoroethane and dichlorodifluoromethane, cooled to -55°C. Fill the suspension into cans and crimp a metering valve of 100µl capacity onto each can.

Example 3

Pressurised aerosol delivering nedocromil sodium (2mg) and reproterol (0.5mg).

Nedocromil sodium, dried, micronised	1.4663% w/w
Reproterol hydrochloride (micronised)	0.3666
Sorbitan trioleate	1.0000
Trichlorofluoromethane	50.0000

Dichlorotetrafluoroethane	13.0751
Dichlorodifluoromethane	74.0920

Prepare as Example 2.

Example 4

Pressurised aerosol delivering nedocromil sodium (2mg) and beclomethasone diproprionate (0.05mg).

Nedocromil sodium, dried, micronised	1.4420% w/w
Reproterol hydrochloride (micronised)	0.0361% w/w
Sorbitan trioleate	0.5000
Dichlorotetrafluoroethane	39.2088
Dichlorodifluoromethane	58.8131

Prepare as Example 1.

The effects of mixtures, salts and compositions according to the invention were investigated in the following systems:

Example A

Rat Passive Lung Anaphylaxis Test

Female rats (Charles River) weighing 250g were passively sensitised by injecting intravenously 0.5ml of potentiated rat IgE antiserum raised against egg albumen.

The rats were anaesthetised with sodium pentobarbitone (70mg.kg) intravenously. Tne trachea was cannulated and the rat ventilated with a Palmer Miniature Ideal respiratory pump in a closed system. Tracheal pressure was recorded through a side arm of the cannula

connected to a differential air pressure transducer (UPI, Pye Ether Ltd). The respiratory rate was set at 99 strokes per minute with a tracheal pressure of 6 cm water.

The rats were challenged, 48 hours after sensitisation, with egg albumen (25mg.kg, intravenously) and the subsequent increase in tracheal pressure expressed as a percentage of maximum possible degree of bronchconstriction (Δ PCB max), measured by clamping the trachea.

Active ingredient A and/or active ingredient B either alone or in combination, were administered intravenously in saline over the period 1 to 5 minutes before antigen challenge.

The results of giving the two compounds in combination were analysed using an analysis of variance for a factorial design with repeated measures in each cell. A square root transformation was carried out prior to the analysis.

Any antagonistic or synergistic effect of the two compounds was further examined using the method described by Berenbaum, Clin. Exp. Immunol., 28, 1 (1977). This consists of calculating the value:-

$$Z = \frac{\text{dose of A}}{Ae} + \frac{\text{dose of B}}{Be}$$

Where: (A,B) is the combination of giving an effect X.

Ae is the dose of A alone having an effect X.

Be is the dose of B alone having an effect X.

If: $Z < 1$, A and B are synergistic.

$Z = 1$, A and B are additive.

$Z > 1$, A and B are antagonistic.

Example B

Inhibition of mediator release from bronchoalveolar cells

Materials and methods

Materials

[^{3}H]-S-Adenosyl-L-Methionine (500mCi/mmol) and [^{32}P]-orthophosphate (carrier free) weere obtained from Amersham International (Amersham, Buckinghamshire, UK), sheep antiserum to rat IgE, goat antiserum to human IgE and normal goat serum from Miles Laboratories (Slough, Buckinghamshire, UK). The goat anti-human IgE and control serum were precipitated with 40% saturated ammonium sulphate (Largman et al, Methods Enzymol (1981) 74:22) and, after dialysis, the globul fraction adjusted to the original serum volume. The ascaris antigen was prepared from adult Ascaris suum pseudocoelomic fluid by

chromatography on Sephadex (registered Trade Mark) G200 (Pharmacia, Milton Keynes, Buckinghamshire, UK), using the method of Ambler et al, J. Immunol. Meth. (1972), 1317.

Infection and bronchoalveolar lavage of macaques

A group of 20 Macaca arctoides monkeys, weight 8-18kg, was used in these studies. The animals were infected with A. suum and lavaged as described in Pritchard et al, Clin. Exp. Immunol., (1983), 54:469. The lavage fluid was recovered into heparinised tubes and placed on ice.

Treatment of BAL cells

The lavage fluid was filtered through a 175um nylon mesh and the cells recovered by centrifugation (450g for 5 minutes at 4°C). The cells were washed and resuspended to the required working dilution in buffer (10mm HEPES-buffered Tyrode, pH 7.4 containing 1mg/ml gelatin and 5 units/ml heparin). Differential cell counts were carried out in wet preparations in Kimura's stain (20). When only histamine release was to be measured, the cells were challenged in triplicate by adding 0.05ml cells, at a density of 10^5 mast cells/ml, ingredient A, eg to 0.05ml buffer containing releasing agent and ingredient B, eg ($3x10^{-8}$-10^{-6}M) and nedocromil sodium ($3x10^{-6}$-10^{-4}V) alone and in combination at 37°C. After incubating for 20 minutes at 37°C, the release

process was quenched by the addition of 0.25ml ice cold Ca^{2+}-,Mg^{2+}-free buffer containing 2mM EDTA. After centrifugation (450g for 5 minutes at 4°C), 0.2ml supernatant was sampled for histamine analysis. In all inhibiting experiments a submaximal level of challenge was chosen which, from the experience of previous lavages of that animal, released 15-25% of the total histamine, but not more than half the maximum release attainable.

Measurement of Histamine

Histamine was measured by the double isotope method of Beaven et al, Clin. Chim. Acta, (1972), 37,97 modified as described in Pritchard et al.

Example C

Non-specific Bronchial Hyperactivity in Adult Asthmatics

Adult asthmatics gave informed consent and entered the study.

Histamine challenge was performed by the method of Cockcroft, Clin. Allergy, (1977), 7, 235. Doubling concentrations of histamine acid phosphate (0.03 - 8mg/ml) were inhaled for two minutes at five minute intervals. FEV_1 was measured on a Vitalograph dry wedge spirometerm before and at 0.5 minutes and 1.5 minutes after each inhalation. The challenge was discontinued when FEV_1 had fallen by 20% or more from the baseline measure.

Log-dose response curves wree constructed and the PC_{20} measured by interpolation of the last two points.

Example D

Human volunteers suffering from specific allergic asthma were selected for the study. In these human volunteers an asthma attack normally follows the inhalation of an antigen to which he is specifically sensitive. The degree of asthma provoked by this method can be measured by repeated examination of the airway resistance.

A suitable designated spirometer is used to measure the forced expirataory volume at one second (FEV_1) hence the changes in airway resistance.

Drug induced changes in FEV_1 are measured at 5 minutes after administration of the drug.

Six hours after drug administration a standard antigen challenge is administered to the human volunteer and the fall in FEV_1 measured at 5 minutes after the antigen administration.

We claim:

1. A pharmaceutical mixture comprising

(a) one or more of 9-ethyl-6,9-dihydro-4,6-dioxo-10-propyl-4H-pyrano[3,2-g]quinoline-2,8-dicarboxylic acid or a pharmaceutically acceptable salt thereof as 'active ingredient A' in combination with

(b) one or more agents suitable for inhalation selected from bronchodilators, steroids and pharmaceutically acceptable derivatives thereof as 'active ingredient B'.

2. A mixture according to Claim 1, wherein active ingredient A is nedocromil sodium.

3. A mixture according to Claim 1, comprising from 0.4 to 400 parts by weight of active ingredient A, measured as nedocromil sodium, for each part by weight of active ingredient B.

4. A mixture according to any one of the preceding Claims, wherein active ingredient B is a bronchodilator or a pharmaceutically acceptable derivative thereof.

5. A mixture according to any one of the preceding Claims, wherein active ingredient B is a B-2 selective bronchodilator or a pharmaceutically acceptable derivative thereof.

6. A mixture according to any one of the preceding Claims, wherein active ingredient B is salbutamol or a pharmaceutically acceptable salt thereof.

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7. A mixture according to any one of claims 1 to 4, wherein active ingredient B is terbutaline, fenoterol, reproterol, pirbuterol, rimiterol or a pharmaceutically acceptable salt thereof.

8. A mixture according to any one of claims 1 to 3, wherein active ingredient B is a steroid or a pharmaceutically acceptable derivative thereof.

9. A mixture according to claim 8, wherein active ingredient B is beclomethasone or a pharmaceutically acceptable derivative thereof.

10. A mixture according to claim 8, wherein active ingredient B is hydrocortisone, betamethasone valerate, clobetasone butyrate, fluocinolone acetonide, fluocortolone hexanoate, hydrocortisone butyrate, diflucortolone valerate, triamcinolone acetonide, flucinonide, desonide, flurandrenalone, flumethasone pivalate, methylprednisolone, clobetasol propionate, halcinonide tixocortol, prednisolone or fluprednylidene-21-acetate.

11. A salt of 9-ethyl-6,9-dihydro-4,6-dioxo-10-propyl-4H-pyrano[3,2-g]quinoline-2,8-dicarboxylic acid with a basic agent suitable for inhalation selected from β-2 selective bronchodilators and steroids.

12. A pharmaceutical composition comprising a mixture according to any one of claims 1 to 10 or a salt according to claim 9 in admixture with a pharmaceutically acceptable

adjuvant, diluent or carrier and in a form suitable for inhalation.

13. A composition according to claim 12 in the form of a pressurised aerosol composition containing from 1 to 20% w/w of the active ingredient(s).