MYOCARDIAL PERFUSION IMAGING USING ADENOSINE RECEPTOR AGONISTS

BACKGROUND OF THE INVENTION

(1) Field of the Invention

This invention relates to myocardial imaging methods that are accomplished by administering doses of one or more adenosine A_{2A} adenosine receptor agonists to a mammal undergoing myocardial imaging. This invention also relates to pharmaceutical compositions useful in myocardial imaging methods.

(2) Description of the Art

Myocardial perfusion imaging (MPI) is a diagnostic technique useful for the detection and characterization of coronary artery disease. Perfusion imaging uses materials such as radionuclucides to identify areas of insufficient blood flow. In MPI, blood flow is measured at rest, and the result compared with the blood flow measured during exercise on a treadmill (cardiac stress testing), such exertion being necessary to stimulate blood flow. Unfortunately, many patients are unable to exercise at levels necessary to provide sufficient blood flow, due to medical conditions such as peripheral vascular disease, arthritis, and the like.

Therefore, a pharmacological agent that increases cardiac blood flow (CBF) for a short period of time would be of great benefit, particularly one that did not cause peripheral vasodilation. Vasodilators, for example dipyridamole, have been used for this purpose in patients prior to imaging with radionuclide. Dipyridamole is an effective vasodilator, but side effects such as pain and nausea limit the usefulness of treatment with this compound.

Adenosine, a naturally occurring nucleoside, also is useful as a vasodilator. Adenosine exerts its biological effects by interacting with a family of adenosine receptors characterized as subtypes A_1, A_{2A}, A_{2B}, and A_3. Adenoscan®(Fujisawa Healthcare Inc.) is a formulation of a naturally occurring adenosine. Adenoscan® has been marketed as an adjuvant in perfusion studies using radioactive thallium-201. However, its use is limited due to side effects such as flushing, chest discomfort, the urge to breathe deeply, headache, throat, neck, and jaw pain. These adverse effects of adenosine are due to the activation of other adenosine receptor subtypes other than A_{2A}, which mediates the vasodilatory effects of adenosine. Additionally, the short half-life of adenosine necessitates multiple treatments during the procedure, further limiting its use. Adenoscan® is contraindicated in many patients including those with second-

or third-degree block, sinus node disease, bronchoconstrictive or bronchospastic lung disease, and in patients with known hypersensitivity to the drug.

Other potent and selective agonists for the A_{2A} adenosine receptor are known. For example, MRE-0470 (Medco) is an adenosine A_{2A} receptor agonist that is a potent and selective derivative of adenosine. WRC-0470 (Medco) is an adenosine A_{2A} agonist used as an adjuvant in imaging. In general, compounds such as these have a high affinity for the A_{2A} receptor, and consequently, a long duration of action, which is undesirable in imaging.

Thus, there is still a need for a method of producing rapid and maximal coronary vasodilation in mammals without causing corresponding peripheral vasodilation, which would be useful for myocardial imaging with radionuclide agents. Preferred compounds would be selective for the A_{2A} adenosine receptor and have a short duration of action (although longer acting than compounds such as adenosine), thus obviating the need for multiple dosing.

SUMMARY OF THE INVENTION

The following are several aspects of this invention.

A method of producing coronary vasodilation without peripheral vasodilation in a human, comprising administering at least 10 μg of at least one A_{2A} receptor agonist to the human.

A method of producing coronary vasodilation without peripheral vasodilation in a human, comprising administering no more than about 1000 μg of a A_{2A} receptor agonist to the human.

A method of producing coronary vasodilation without peripheral vasodilation in a human, comprising administering a A_{2A} receptor agonist in an amount ranging from about 10 to about 600 μg to the human.

A method of producing coronary vasodilation without peripheral vasodilation in a human, comprising administering about 300 μg of a A_{2A} receptor agonist to the human.

A method of producing coronary vasodilation without peripheral vasodilation in a human, comprising administering about 400 μg of a A_{2A} receptor agonist to the human.

A method of producing coronary vasodilation without peripheral vasodilation in a human, comprising administering about 500 μg of a A_{2A} receptor agonist to the human.

A method of producing coronary vasodilation without peripheral vasodilation in a human, comprising administering about 600 μg of a A_{2A} receptor agonist to the human.

A method of producing coronary vasodilation without peripheral vasodilation in a human, comprising administering about 700 μg of a A_{2A} receptor agonist to the human.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A_{2A} receptor agonist wherein the A_{2A} receptor agonist is administered in an amount ranging from about 10 to about 600 μg and wherein the A_{2A} receptor agonist is administered in a single dose.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A_{2A} receptor agonist wherein about 300 μg of the A_{2A} receptor agonist is administered in a single dose.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A_{2A} receptor agonist wherein about 400 μg of the A_{2A} receptor agonist is administered in a single dose.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A_{2A} receptor agonist wherein about 500 μg of the A_{2A} receptor agonist is administered in a single dose.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A_{2A} receptor agonist wherein about 600 μg of the A_{2A} receptor agonist is administered in a single dose.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A_{2A} receptor agonist wherein about 700 μg of the A_{2A} receptor agonist is administered in a single dose.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A_{2A} receptor agonist wherein the A_{2A} receptor agonist is administered in an amount ranging from about 10 to about 600 μg and wherein the A_{2A} receptor agonist is administered by iv bolus.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A_{2A} receptor agonist wherein the A_{2A} receptor agonist is administered in an amount ranging from about 0.05 to about 60 μg/kg and wherein the A_{2A} receptor agonist is administered by iv bolus.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A_{2A} receptor agonist wherein the A_{2A} receptor agonist is administered in an

amount ranging from about 0.1 to about 30 μg/kg wherein the A_{2A} receptor agonist is administered by iv bolus.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A_{2A} receptor agonist wherein the A_{2A} receptor agonist is administered in an amount no greater than about 20 μg/kg to a supine patient wherein the A_{2A} receptor agonist is administered by iv bolus.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A_{2A} receptor agonist wherein the A_{2A} receptor agonist is administered in an amount no greater than about 10 μg/kg to a standing patient wherein the A_{2A} receptor agonist is administered by iv bolus.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A_{2A} receptor agonist wherein the A_{2A} receptor agonist is administered in an amount ranging from about 10 to about 600 μg wherein the wherein the A_{2A} receptor agonist is administered in about 20 seconds.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A_{2A} receptor agonist in an amount ranging from about 10 to about 600 μg wherein the A_{2A} receptor agonist is administered in less than about 10 seconds.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A_{2A} receptor agonist wherein the A_{2A} receptor agonist is administered in an amount greater than about 10 μg.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A_{2A} receptor agonist wherein the A_{2A} receptor agonist is administered in an amount greater than about 100 μg.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and an A_{2A} receptor agonist wherein the A_{2A} receptor agonist is administered in an amount no greater than 600 μ.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and an A_{2A} receptor agonist wherein the A_{2A} receptor agonist is administered in an amount no greater than 500 μg.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A_{2A} receptor agonist wherein the A_{2A} receptor agonist is administered in an amount ranging from about 100 μg to about 500 μg and preferably about 400 μg.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and an A_{2A} receptor agonist wherein the A_{2A} receptor agonist is selected from the group consisting of CVT-3033, CVT-3146 and combinations thereof.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and about 300 μg of a compound selected from the group consisting of CVT-3033, CVT-3146 to the human.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and about 400 μg of a compound selected from the group consisting of CVT-3033, CVT-3146 to the human.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and about 500 μg of a compound selected from the group consisting of CVT-3033, CVT-3146 to the human.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and about 600 μg of a compound selected from the group consisting of CVT-3033, CVT-3146 to the human.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and about 700 μg of a compound selected from the group consisting of CVT-3033, CVT-3146 to the human.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A_{2A} receptor agonist wherein the myocardium is examined for areas of insufficient blood flow following administration of the radionuclide and the A_{2A} receptor agonist.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A_{2A} receptor agonist wherein the myocardium is examined for areas of insufficient blood flow following administration of the radionuclide and the A_{2A} receptor agonist wherein the myocardium examination begins within about 1 minute from the time the A_{2A} receptor agonist is administered.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and an A_{2A} receptor agonist wherein the administration of the A_{2A} receptor agonist causes at least a 2.5 fold increase in coronary blood flow.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A_{2A} receptor agonist wherein the administration of the A_{2A} receptor agonist

causes at least a 2.5 fold increase in coronary blood flow that is achieved within about 1 minute from the administration of the A_{2A} receptor agonist.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and an A_{2A} receptor agonist wherein the radionuclide and the A_{2A} receptor agonist are administered separately.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and an A_{2A} receptor agonist wherein the radionuclide and the A_{2A} receptor agonist are administered simultaneously.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A_{2A} receptor agonist wherein the administration of the A_{2A} receptor agonist causes at least a 2.5 fold increase in coronary blood flow for less than about 5 minutes.

A method of myocardial perfusion imaging of a human, comprising administering a radionuclide and a A_{2A} receptor agonist wherein the administration of the A_{2A} receptor agonist causes at least a 2.5 fold increase in coronary blood flow for less than about 3 minutes.

A method of myocardial perfusion imaging of a human, comprising administering CVT-3146 in an amount ranging from about 10 to about 600 μg in a single iv bolus.

A method of myocardial perfusion imaging of a human, comprising administering CVT-3146 in an amount ranging from about 100 to about 500 μg and more preferably about 400 μg in a single iv bolus.

A method of myocardial perfusion imaging of a human comprising administering CVT-3146 by iv bolus in an amount ranging from 10 to about 600 μg that is independent of the weight of the human being dosed.

Pharmaceutical compositions comprising at least one A_{2a} receptor agonist, at least one liquid carrier, and at least one co-solvent.

Pharmaceutical compositions comprising at least one A_{2a} receptor agonist, at least one liquid carrier, and at least one co-solvent wherein the A_{2a} receptor agonist is selected from the group consisting of CVT-3033, CVT-3146, and combinations thereof.

Pharmaceutical compositions comprising at least one A_{2a} receptor agonist, at least one liquid carrier, and at least one co-solvent wherein the liquid carrier comprises water, distilled water, de-ionized water, saline, a buffer, or combinations thereof.

Pharmaceutical compositions comprising at least one A_{2a} receptor agonist, at least one liquid carrier, and at least one co-solvent wherein the co-solvent comprises methylboronic acid, borate buffer, propylene glycol, or polyethylene glycol.

Pharmaceutical compositions comprising at least one A_{2a} receptor agonist, at least one liquid carrier, and at least one co-solvent wherein the co-solvent is methylboronic acid.

Pharmaceutical compositions comprising at least one A_{2a} receptor agonist, at least one liquid carrier, and at least one co-solvent wherein the co-solvent is methylboronic acid and wherein the A_{2a} receptor agonist is CVT-3146.

Pharmaceutical compositions comprising CVT-3146, at least one liquid carrier, and at least one co-solvent wherein the co-solvent is methylboronic acid wherein the CVT-3146 is present in an amount ranging from about 50 micrograms/ml to about 250 micrograms/ml and the methylboronic acid is present in an amount from about 0.4% to about 0.6% (w:v).

Pharmaceutical compositions comprising CVT-3146, at least one liquid carrier, and at least one co-solvent wherein the co-solvent is methylboronic acid having a pH of from about 9.1 to about 9.4.

Pharmaceutical compositions comprising at least one A_{2a} receptor agonist, at least one liquid carrier, and at least one co-solvent wherein the co-solvent is a borate buffer and preferably about 0.5% (w:v) methylboronic acid.

Pharmaceutical compositions comprising at least one A_{2a} receptor agonist, at least one liquid carrier, and at least one co-solvent wherein a co-solvent is a borate buffer and preferably about 0.5% (w:v) methylboronic acid and wherein the composition further comprises a buffer to bring the pH of the composition to about 9.3.

Pharmaceutical compositions comprising at least one A_{2a} receptor agonist, at least one liquid carrier, and at least one co-solvent wherein the co-solvent is a borate buffer and wherein the A_{2A} receptor agonist is CVT-3146 which is preferably present in the composition in an amount from about 50 to about 150 micrograms/ml.

Pharmaceutical compositions comprising at least one A_{2a} receptor agonist, at least one liquid carrier, and at least one co-solvent wherein the co-solvent is a borate buffer, wherein the A_{2A} receptor agonist is CVT-3146 which is preferably present in the composition in an amount from about 50 to about 150 micrograms/ml and wherein said composition also comprises about 0.55% (w:v) sodium chloride and about 50 mM sodium bicarbonate.

Pharmaceutical compositions comprising at least one A_{2a} receptor agonist, at least one liquid carrier, and at least one co-solvent wherein the co-solvent is propylene glycol and the propylene glycol is present in an amount of from about 5% to about 25% (w:v) and preferably in an amount of from about 8% to about 20% (w:v).

Pharmaceutical compositions comprising at least one A_{2a} receptor agonist, at least one

liquid carrier, and at least one co-solvent wherein the co-solvent is propylene glycol and the propylene glycol is present in an amount of from about 5% to about 25% (w:v) wherein the liquid carrier includes a buffer to bring said composition to a pH of from about 6 to about 8.

Pharmaceutical compositions comprising at least one A_{2a} receptor agonist, at least one liquid carrier, and at least one co-solvent wherein the co-solvent is propylene glycol and the propylene glycol is present in an amount of from about 5% to about 25% wherein said composition further comprises EDTA.

Pharmaceutical compositions comprising at least one A_{2a} receptor agonist, at least one liquid carrier, and at least one co-solvent wherein the co-solvent is propylene glycol and the propylene glycol is present in an amount of from about 5% to about 25% (w:v) and preferably in an amount of from about 8% to about 20% (w:v) wherein the A_{2a} receptor agonist is CVT-3146 and said CVT-3146 is present in an amount from about 50 to about 150 micrograms.

A method of producing coronary vasodilation without peripheral vasodilation comprising administering to a human the pharmaceutical composition comprising at least one A_{2a} receptor agonist, at least one liquid carrier, and at least one co-solvent.

A method of producing coronary vasodilation without peripheral vasodilation comprising administering to a human the pharmaceutical composition comprising at least one A_{2a} receptor agonist, at least one liquid carrier, and at least one co-solvent wherein the A_{2a} receptor agonist is CVT-3146.

A method of producing coronary vasodilation without peripheral vasodilation comprising administering to a human the pharmaceutical composition comprising at least one A_{2a} receptor agonist, at least one liquid carrier, and at least one co-solvent wherein the A_{2a} receptor agonist is CVT-3146 and wherein said pharmaceutical composition is administered by iv bolus.

A method of producing coronary vasodilation without peripheral vasodilation comprising administering to a human the pharmaceutical composition comprising at least one A_{2a} receptor agonist, at least one liquid carrier, and at least one co-solvent wherein the A_{2a} receptor agonist is CVT-3146 and wherein said pharmaceutical composition is administered by iv bolus and wherein said pharmaceutical composition is administered in about 10 to about 20 seconds.

A method of producing coronary vasodilation without peripheral vasodilation comprising administering to a human the pharmaceutical composition comprising at least one A_{2a} receptor agonist, at least one liquid carrier, and at least one co-solvent wherein the A_{2a}

receptor agonist is CVT-3146 wherein the total amount of CVT-3146 that is administered ranges from about 100 to about 500 micrograms and is more preferably about 400 micrograms.

In all of the methods above, the dose is preferably administered in a single dose.

In all of the methods above, at least one radionuclide is administered before, with or after the administration of the A_{2A} receptor agonist to facilitate myocardial imaging.

In all of the methods above, the dose is preferably administered in 60 seconds or less, preferably 30 seconds or less, and more preferably 20 seconds or less.

DESCRIPTION OF THE FIGURES

Figure 1 are intracoronary Doppler flow profiles following administration of 18 μg adenosine IC bolus (top) and 30 μg CVT-3146 IV bolus;

Figure 2 is a plot showing the relationship of the dose of CVT-3146 on coronary peak flow rates;

Figure 3 is a Table that reports the duration of time the coronary flow velocity is greater than or equal to 2.5 times baseline coronary flow velocity for varying doses of CVT-3146 wherein "n" refers to the number of human patients dosed;

Figure 4 is a plot of the time course of the average peak velocity (APV) ratio for human patients receiving 400 μg of CVT-3146 IV bolus;

Figure 5 is a plot of the time course of heart rate for human patients receiving 400 μg of CVT-3146 IV bolus;

Figure 6 is the time course of blood pressure for human patients receiving 400 μg of CVT-3146 IV bolus; and

Figure 7 is an adverse event Table.

Figure 8 is a plot of the change over time of mean CVT-3146 plasma concentration in healthy male volunteers in a supine position. The various curves relate to different amounts of CVT-3146 administered to the patients;

Figures 9 and 10 are plots of the mean change in heart rate of healthy male volunteers either in a standing position or in a supine position over time for various bolus dosing levels of CVT-3146;

Figure 11 is a plot of the maximum change in heart rate in relationship to the total dose of CVT-3146 administered to standing or supine human male patients. In the plot, the term "DBS" refers to the observed data point while "fit" refers to a curve fitted to the

observed data points;

Figure 12 is a plot of heart rate – (area under curve) AUC(0-15min) of change from baseline in relationship to the total dose of CVT-3146 administered to standing or supine human subjects;

Figure 13 is a plot of the maximum change from baseline heart rate at maximum plasma concentration of CVT-3146 for patients in a supine position;

Figure 14 is a plot of heart rate – (area under the curve –time v. effect) AUCE (0-15 min) of change from baseline versus plasma AUC(0-15 min) for patients in a supine position;

Figure 15 is a plot of the time profiles of mean heart rate change from a baseline versus mean plasma concentration over time for a 20 μg/kg dose of CVT-3146;

Figure 16 is a plot of the average peak to blood flow velocity over time following administration of CVT-3146 measured at the pulmonary artery (PA), the four limb artery (FA), brain arterial vasculature (BA) and in the left circumflex coronary artery (LCS);

Figure 17 is a plot of the percent change in heart rate (HR) and blood pressure (BP) for various doses of CVC-3146; and

Figure 18 is a plot of the change in LBF and RBF blood flow upon administering increasing amounts of ADO or CVT-3146 to awake dogs.

DESCRIPTION OF THE INVENTION

Potent A_{2A} agonists are useful as adjuncts in cardiac imaging when added either prior to dosing with an imaging agent or simultaneously with an imaging agent. Suitable imaging agents include ^{201}Thallium or ^{99m}Technetium-Sestamibi, ^{99mTc}teboroxime, and ^{99mTc}(III).

New and potent A_{2A} agonists that increase CBF but do not significantly increase peripheral blood flow have been identified. The A_{2A} agonists, and especially CVT-3146 and CVT-3033 have a rapid onset and a short duration when administered. An unexpected and newly identified benefit of these new compounds is that they are very useful when administered in a very small quantity in a single bolus intravenous (i.v.) injection. The A_{2A} receptor agonists can be administered in amounts as little as 10 μg and as high as 600 μg or more and still be effective with few if any side-effects. An optimal dose may include as little as 10 μg and as much as about 1000 μg or more of a A_{2A} receptor agonist. More preferably, an optimal dose will range from about 100 to about 500 μg of at least one A_{2A} receptor agonist. It is preferred that the A2A receptor agonist is administered in a single bolus injection in an amount selected from about 300 μg, about 400 μg, about 500 μg, about 600

μg, and about 700 μg. These amounts are unexpectedly small when compared with adenosine which is typically administered continuously by IV infusion at a rate of about 140 μg/kg/min. Unlike adenosine, the same dosage of A_{2A} receptor agonists, and in particular, CVT-3146 and CVT-3033 can be administered to a human patient regardless of the patient's weight. Thus, the administration of a single uniform amount of a A_{2A} receptor agonists by iv bolus for myocardial imaging is dramatically simpler and less error prone than the time and weight dependent administration of adenosine. The dose of A_{2A} receptor agonist administered to a human patient can, however, be determined by weight. Typically, a weight based dose will range from about 0.05 to about 60 μg/kg and more preferably from about 0.1 to about 30 μg/kg. CVT-3146 in particular is generally well tolerated when administered in an amount up to 10 μg/kg in standing patients and up to 20 μg/kg in supine patients.

A_{2A} agonists of this invention may be administered orally, intravenously, through the epidermis or by any other means known in the art for administering therapeutic agents with bolus i.v. administration being preferred. In one embodiment, the bolus dosing occurs in 60 seconds or less. In yet other embodiments, the bolus dosing occurs in about 30 seconds or less, and more preferably in about 20 seconds or less or in about 10 seconds or less.

The A_{2A} agonists of this invention are preferably administered in a single dose. The term "single dose" refers generally to a single quickly administered dose of a therapeutic amount of at least one A_{2A} receptor agonist. The term "single dose" does not encompass a dose or doses administered over an extended period of time by, for example continuous i.v. infusion.

One aspect of this invention is directed to pharmaceutical compositions. The term "pharmaceutical composition" refers to the combination of one or more A_{2A} agonist compounds of this invention with at least one liquid carrier that together form a solution or a suspension. Lyophilized powders including compositions of this invention fall within the scope of "pharmaceutical compositions" so long as the powders are intended to be reconstituted by the addition of a suitable liquid carrier prior to use. Examples of suitable liquid carriers include, but are not limited to water, distilled water, de-ionized water, saline, buffer solutions, normal isotonic saline solution, dextrose in water, and combinations thereof. Such pharmaceutical compositions are generally suitable for injection.

The term "buffer solution" or "buffer" as used herein refers to a solution containing both a weak acid and its conjugate weak base. The buffer solutions are used in pharmaceutical compositions of this invention in order to resist pH changes. Non-limiting examples of useful

buffer solutions are solutions that comprise sodium bicarbonate and sodium phosphate.

A_{2A} receptor agonists of this invention are prepared and then administered, with or without intervening storage, as a pharmaceutical composition. Various properties considered when formulating pharmaceutical compositions of this invention include, but are not limited to product shelf life, A_{2A} receptor agonist solubility, composition pH, vein irritation, hemolysis, storage conditions (e.g., whether the pharmaceutical composition will be stored at room temperature or some other temperature) and the ability to withstand sterilization procedures.

One method to achieve the desired pharmaceutical composition properties is to include a co-solvent in the pharmaceutical composition. The co-solvent can be selected from any liquid or compound in solution that imparts the desired properties to the pharmaceutical composition. Examples of useful co-solvents include, but are not limited to methylboronic acid, borate buffer, propylene glycol, or polyethylene glycol. The amount of co-solvent in the pharmaceutical composition will depend upon properties, such as solubility and stability of the chosen A_{2A} receptor agonist.

A preferred A_{2A} receptor agonist of this invention is CVT-3146. CVT-3146 has solubility in water of about 50 micrograms/mL. Therefore, CVT-3146 can be dissolved and administered in water so long as the desired weight amount of CVT-3146 can be administered in an acceptable volume. For example, a preferred dose of about 400 micrograms can be administered in 8 mL of water. If this volume is too great for administration purposes, or if the pharmaceutical composition will be stored at other than room temperature (RT), then additional ingredients can be added to the composition to increase the solubility of CVT-3146 in the composition and/or to provide the resulting pharmaceutical composition with other improved properties such as improved stability and storage properties. Pharmaceutical compositions of this invention that include CVT-3146 may include up to about 1 milligram/mL of CVT-3146. It is preferred that pharmaceutical compositions including CVT-3146 include from about 50 to about 250 micrograms/mL, and more preferably from about 50 to 150 micrograms/mL of CVT-3146.

In order to improve their solubility and storage properties, A_{2A} receptor agonists of this invention can be administered in a pharmaceutical composition including a methylboronic acid (MBA) co-solvent. The methylboronic acid is added to the pharmaceutical composition to improve agonist solubility and shelf life. MBA increases the pH of the resulting composition. The solubility of CVT-3146 in a pharmaceutical composition including MBA

tends to decrease as the composition pH drops towards neutral. Therefore, with CVT-3146, an optimal MBA-containing composition pH is from about 8.5 to 10 with a pH of about 9.1 to about 9.4 being preferred and a pH of about 9.3 being most preferred. This corresponds to a composition including from about 50 to about 250 mg/mL of MBA. As an alternative to MBA, CVT-3146 can be combined with a borate buffer solution. Typically, a borate buffer solution will be comprised of an aqueous solution of sodium borate that is adjusted to the desired pH such as a pH of 9.3 using an acid or a base.

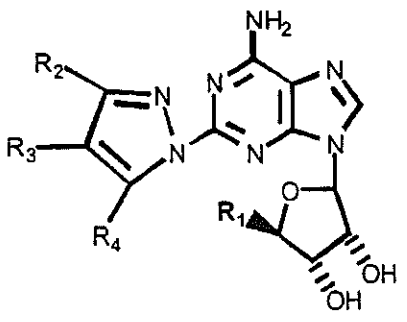
MBA containing pharmaceutical compositions can suffer from storage problems. Namely, MBA can cause delamination when packaged in certain type I glass vessels. This problem can be overcome by storing the MBA containing pharmaceutical compositions in plastic vessels or in more resistant type I glass vessels.

If A_{2A} receptor agonist containing pharmaceutical compositions having a pH closer to neutral are desired, then an alternative is to combine A_{2A} receptor agonists with a propylene glycol (PG) co-solvent. The amount of PG used in the composition may range from about 5% to up to 25% by volume with a range of about 8% to about 20% by volume being more preferred when using CVT-3146. An alternative to PG is polyethylene glycol – PEG. A preferred PEG will have an average molecular weight of from about 200 to 400.

Preferably, the CVT-3146 composition including PG or PEG will have a pH of from about 6 to about 8 with a pH of about 7 being preferred. Any physiologically acceptable buffer capable of adjusting the composition pH to the desired value can be used. Additional optional ingredients such as EDTA and dimethylacetamide could be employed in the composition as well.

The pharmaceutical compositions of this invention may include one or more anti-oxidants such as butylated hydroxyanisole (BHA).

A first class of compounds that are potent and selective agonists for the A_{2A} adenosine receptor that are useful in the methods of this invention are 2-adenosine N-pyrazole compounds having the formula:



wherein R^1 = CH_2OH, -$CONR_5R_6$;

R^3 is independently selected from the group consisting of C_{1-15} alkyl, halo, NO_2, CF_3, CN, OR^{20}, SR^{20}, $N(R^{20})_2$, $S(O)R^{22}$, SO_2R^{22}, $SO_2N(R^{20})_2$, $SO_2NR^{20}COR^{22}$, $SO_2NR^{20}CO_2R^{22}$, $SO_2NR^{20}CON(R^{20})_2$, $N(R^{20})_2$ $NR^{20}COR^{22}$, $NR^{20}CO_2R^{22}$, $NR^{20}CON(R^{20})_2$, $NR^{20}C(NR^{20})NHR^{23}$, COR^{20}, CO_2R^{20}, $CON(R^{20})_2$, $CONR^{20}SO_2R^{22}$, $NR^{20}SO_2R^{22}$, $SO_2NR^{20}CO_2R^{22}$, $OCONR^{20}SO_2R^{22}$, $OC(O)R^{20}$, $C(O)OCH_2OC(O)R^{20}$, and $OCON(R^{20})_2$,-$CONR^7R^8$, C_{2-15} alkenyl, C_{2-15} alkynyl, heterocyclyl, aryl, and heteroaryl, wherein the alkyl, alkenyl, alkynyl, aryl, heterocyclyl and heteroaryl substituents are optionally substituted with from 1 to 3 substituents independently selected from the group consisting of halo, alkyl, NO_2, heterocyclyl, aryl, heteroaryl, CF_3, CN, OR^{20}, SR^{20}, $N(R^{20})_2$, $S(O)R^{22}$, SO_2R^{22}, $SO_2N(R^{20})_2$, $SO_2NR^{20}COR^{22}$, $SO_2NR^{20}CO_2R^{22}$, $SO_2NR^{20}CON(R^{20})_2$, $N(R^{20})_2$ $NR^{20}COR^{22}$, $NR^{20}CO_2R^{22}$, $NR^{20}CON(R^{20})_2$, $NR^{20}C(NR^{20})NHR^{23}$, COR^{20}, CO_2R^{20}, $CON(R^{20})_2$, $CONR^{20}SO_2R^{22}$, $NR^{20}SO_2R^{22}$, $SO_2NR^{20}CO_2R^{22}$, $OCONR^{20}SO_2R^{22}$, $OC(O)R^{20}$, $C(O)OCH_2OC(O)R^{20}$, and $OCON(R^{20})_2$ and wherein the optional substituted heteroaryl, aryl, and heterocyclyl substituents are optionally substituted with halo, NO_2, alkyl, CF_3, amino, mono- or di- alkylamino, alkyl or aryl or heteroaryl amide, $NCOR^{22}$, $NR^{20}SO_2R^{22}$, COR^{20}, CO_2R^{20}, $CON(R^{20})_2$, $NR^{20}CON(R^{20})_2$, $OC(O)R^{20}$, $OC(O)N(R^{20})_2$, SR^{20}, $S(O)R^{22}$, SO_2R^{22}, $SO_2N(R^{20})_2$, CN, or OR^{20};

R^5 and R^6 are each individually selected from H, and C_1-C_{15} alkyl that is optionally substituted with from 1 to 2 substituents independently selected from the group of halo, NO_2, heterocyclyl, aryl, heteroaryl, CF_3, CN, OR^{20}, SR^{20}, $N(R^{20})_2$, $S(O)R^{22}$, SO_2R^{22}, $SO_2N(R^{20})_2$, $SO_2NR^{20}COR^{22}$, $SO_2NR^{20}CO_2R^{22}$, $SO_2NR^{20}CON(R^{20})_2$, $N(R^{20})_2$ $NR^{20}COR^{22}$, $NR^{20}CO_2R^{22}$, $NR^{20}CON(R^{20})_2$, $NR^{20}C(NR^{20})NHR^{23}$, COR^{20}, CO_2R^{20}, $CON(R^{20})_2$, $CONR^{20}SO_2R^{22}$, $NR^{20}SO_2R^{22}$, $SO_2NR^{20}CO_2R^{22}$, $OCONR^{20}SO_2R^{22}$, $OC(O)R^{20}$, $C(O)OCH_2OC(O)R^{20}$, and $OCON(R^{20})_2$ wherein each optional substituted heteroaryl, aryl, and heterocyclyl substituent is optionally substituted with halo, NO_2, alkyl, CF_3, amino, monoalkylamino, dialkylamino, alkylamide, arylamide, heteroarylamide, $NCOR^{22}$, $NR^{20}SO_2R^{22}$, COR^{20}, CO_2R^{20}, $CON(R^{20})_2$, $NR^{20}CON(R^{20})_2$, $OC(O)R^{20}$, $OC(O)N(R^{20})_2$, SR^{20}, $S(O)R^{22}$, SO_2R^{22}, $SO_2N(R^{20})_2$, CN, and OR^{20};

R^7 is selected from the group consisting of hydrogen, C_{1-15} alkyl, C_{2-15} alkenyl, C_{2-15} alkynyl, heterocyclyl, aryl and heteroaryl, wherein the alkyl, alkenyl, alkynyl, aryl, heterocyclyl and heteroaryl substituents are optionally substituted with from 1 to 3 substituents independently selected from the group of halo, NO_2, heterocyclyl, aryl, heteroaryl, CF_3, CN, OR^{20}, SR^{20}, $N(R^{20})_2$, $S(O)R^{22}$, SO_2R^{22}, $SO_2N(R^{20})_2$, $SO_2NR^{20}COR^{22}$, $SO_2NR^{20}CO_2R^{22}$, $SO_2NR^{20}CON(R^{20})_2$, $N(R^{20})_2$ $NR^{20}COR^{22}$, $NR^{20}CO_2R^{22}$, $NR^{20}CON(R^{20})_2$, $NR^{20}C(NR^{20})NHR^{23}$, COR^{20}, CO_2R^{20},

$CON(R^{20})_2$, $CONR^{20}SO_2R^{22}$, $NR^{20}SO_2R^{22}$, $SO_2NR^{20}CO_2R^{22}$, $OCONR^{20}SO_2R^{22}$, $OC(O)R^{20}$, $C(O)OCH_2OC(O)R^{20}$ and $OCON(R^{20})_2$ and wherein each optional substituted heteroaryl, aryl and heterocyclyl substituent is optionally substituted with halo, NO_2, alkyl, CF_3, amino, mono- or di-alkylamino, alkyl or aryl or heteroaryl amide, $NCOR^{22}$, $NR^{20}SO_2R^{22}$, COR^{20}, CO_2R^{20}, $CON(R^{20})_2$, $NR^{20}CON(R^{20})_2$, $OC(O)R^{20}$, $OC(O)N(R^{20})_2$, SR^{20}, $S(O)R^{22}$, SO_2R^{22}, $SO_2N(R^{20})_2$, CN, and OR^{20};

R^8 is selected from the group consisting of hydrogen, C_{1-15} alkyl, C_{2-15} alkenyl, C_{2-15} alkynyl, heterocyclyl, aryl, and heteroaryl, wherein the alkyl, alkenyl, alkynyl, aryl, heterocyclyl, and heteroaryl substituents are optionally substituted with from 1 to 3 substituents independently selected from the group consisting of halo, NO_2, heterocyclyl, aryl, heteroaryl, CF_3, CN, OR^{20}, SR^{20}, $N(R^{20})_2$, $S(O)R^{22}$, SO_2R^{22}, $SO_2N(R^{20})_2$, $SO_2NR^{20}COR^{22}$, $SO_2NR^{20}CO_2R^{22}$, $SO_2NR^{20}CON(R^{20})_2$, $N(R^{20})_2$ $NR^{20}COR^{22}$, $NR^{20}CO_2R^{22}$, $NR^{20}CON(R^{20})_2$, $NR^{20}C(NR^{20})NHR^{23}$, COR^{20}, CO_2R^{20}, $CON(R^{20})_2$, $CONR^{20}SO_2R^{22}$, $NR^{20}SO_2R^{22}$, $SO_2NR^{20}CO_2R^{22}$, $OCONR^{20}SO_2R^{22}$, $OC(O)R^{20}$, $C(O)OCH_2OC(O)R^{20}$, and $OCON(R^{20})_2$ and wherein each optional substituted heteroaryl, aryl, and heterocyclyl substituent is optionally substituted with halo, NO_2, alkyl, CF_3, amino, mono- or di- alkylamino, alkyl or aryl or heteroaryl amide, $NCOR^{22}$, $NR^{20}SO_2R^{22}$, COR^{20}, CO_2R^{20}, $CON(R^{20})_2$, $NR^{20}CON(R^{20})_2$, $OC(O)R^{20}$, $OC(O)N(R^{20})_2$, SR^{20}, $S(O)R^{22}$, SO_2R^{22}, $SO_2N(R^{20})_2$, CN, and OR^{20};

R^{20} is selected from the group consisting of H, C_{1-15} alkyl, C_{2-15} alkenyl, C_{2-15} alkynyl, heterocyclyl, aryl, and heteroaryl, wherein the alkyl, alkenyl, alkynyl, heterocyclyl, aryl, and heteroaryl substituents are optionally substituted with from 1 to 3 substituents independently selected from halo, alkyl, mono- or dialkylamino, alkyl or aryl or heteroaryl amide, CN, O-C_{1-6} alkyl, CF_3, aryl, and heteroaryl;

R^{22} is selected from the group consisting of C_{1-15} alkyl, C_{2-15} alkenyl, C_{2-15} alkynyl, heterocyclyl, aryl, and heteroaryl, wherein the alkyl, alkenyl, alkynyl, heterocyclyl, aryl, and heteroaryl substituents are optionally substituted with from 1 to 3 substituents independently selected from halo, alkyl, mono- or dialkylamino, alkyl or aryl or heteroaryl amide, CN, O-C_{1-6} alkyl, CF_3, aryl, and heteroaryl; and wherein R^2 and R^4 are selected from the group consisting of H, C_{1-6} alkyl and aryl, wherein the alkyl and aryl substituents are optionally substituted with halo, CN, CF_3, OR^{20} and $N(R^{20})_2$ with the proviso that when R^2 is not hydrogen then R^4 is hydrogen, and when R^4 is not hydrogen then R^2 is hydrogen.

In an related group of compounds of this invention, R^3 is selected from the group consisting of C_{1-15} alkyl, halo,CF_3, CN, OR^{20}, SR^{20}, $S(O)R^{22}$, SO_2R^{22}, $SO_2N(R^{20})_2$, COR^{20}, CO_2R^{20}, -$CONR^7R^8$, aryl and heteroaryl wherein the alkyl, aryl and heteroaryl substituents are

optionally substituted with from 1 to 3 substituents independently selected from the group consisting of halo, aryl, heteroaryl, CF_3, CN, OR^{20}, SR^{20}, $S(O)R^{22}$, SO_2R^{22}, $SO_2N(R^{20})_2$, COR^{20}, CO_2R^{20} or $CON(R^{20})_2$, and each optional heteroaryl and aryl substituent is optionally substituted with halo, alkyl, CF_3 CN, and OR^{20}; R^5 and R^6 are independently selected from the group of H and C_1-C_{15} alkyl including one optional aryl substituent and each optional aryl substituent that is optionally substituted with halo or CF_3; R^7 is selected from the group consisting of C_{1-15} alkyl, C_{2-15} alkynyl, aryl, and heteroaryl, wherein the alkyl, alkynyl, aryl, and heteroaryl substituents are optionally substituted with from 1 to 3 substituents independently selected from the group consisting of halo, aryl, heteroaryl, CF_3, CN, OR^{20}, and each optional heteroaryl and aryl substituent is optionally substituted with halo, alkyl, CF_3 CN, or OR^{20}; R^8 is selected from the group consisting of hydrogen and C_{1-15} alkyl; R^{20} is selected from the group consisting of H, C_{1-4} alkyl and aryl, wherein alkyl and aryl substituents are optionally substituted with one alkyl substituent; and R^{22} is selected from the group consisting of C_{1-4} alkyl and aryl which are each optionally substituted with from 1 to 3 alkyl group.

In yet another related class of compounds, R^1 is CH_2OH; R^3 is selected from the group consisting of CO_2R^{20}, $-CONR^7R^8$ and aryl where the aryl substituent is optionally substituted with from 1 to 2 substituents independently selected from the group consisting of halo, C_{1-6} alkyl, CF_3 and OR^{20}; R^7 is selected from the group consisting of hydrogen, C_{1-8} alkyl and aryl, where the alkyl and aryl substituents are optionally substituted with one substituent selected from the group consisting of halo, aryl, CF_3, CN, OR^{20} and wherein each optional aryl substituent is optionally substituted with halo, alkyl, CF_3 CN, and OR^{20}; R^8 is selected from the group consisting of hydrogen and C_{1-8} alkyl; and R^{20} is selected from hydrogen and C_{1-4} alkyl.

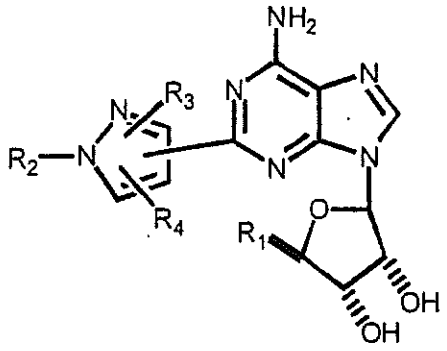
In a still another related class of compounds of this invention, $R^1 = CH_2OH$; R^3 is selected from the group consisting of CO_2R^{20}, $-CONR^7R^8$, and aryl that is optionally substituted with one substituent selected from the group consisting of halo, C_{1-3} alkyl and OR^{20}; R^7 is selected from of hydrogen, and C_{1-3} alkyl; R^8 is hydrogen; and R^{20} is selected from hydrogen and C_{1-4} alkyl. In this preferred embodiment, R^3 is most preferably selected from $-CO_2Et$ and $-CONHEt$.

In yet another related class of compounds, R^1 = -CONHEt, R^3 is selected from the group consisting of CO_2R^{20}, $-CONR^7R^8$, and aryl in that aryl is optionally substituted with from 1 to 2 substituents independently selected from the group consisting of halo, C_{1-3} alkyl, CF_3 or OR^{20}; R^7 is selected from the group consisting of hydrogen, and C_{1-8} alkyl that is optionally substituted with one substituent selected from the group consisting of halo, CF_3, CN or OR^{20}; R^8 is selected from the group consisting of hydrogen and C_{1-3} alkyl; and R^{20} is selected from the group consisting of

hydrogen and C_{1-4} alkyl. In this more preferred embodiment, R^8 is preferably hydrogen, R^7 is preferably selected from the group consisting of hydrogen, and C_{1-3}, and R^{20} is preferably selected from the group consisting of hydrogen and C_{1-4} alkyl.

Specific useful compounds are selected from ethyl 1-{9-[(4S,2R,3R,5R)-3,4-dihydroxy-5-(hydroxymethyl)oxolan-2-yl]-6-aminopurin-2-yl}pyrazole-4-carboxylate, (4S,2R,3R,5R)-2-{6-amino-2-[4-(4-chlorophenyl) pyrazolyl]purin-9-yl}-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-{6-amino-2-[4-(4-methoxyphenyl)pyrazolyl]purin-9-yl}-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-{6-amino-2-[4-(4-methylphenyl)pyrazolyl]purin-9-yl}-5-(hydroxymethyl) oxolane-3,4-diol, (1-{9-[(4S,2R,3R,5R)-3,4-dihydroxy-5-(hydroxymethyl)oxolan-2-yl]-6-aminopurin-2-yl}pyrazol-4-yl)-N-methylcarboxamide, 1-{9-[(4S,2R,3R,5R)-3,4-dihydroxy-5-(hydroxymethyl)oxolan-2-yl]-6-aminopurin-2-yl}pyrazole-4-carboxylic acid, (1-{9-[(4S,2R,3R,5R)-3,4-dihydroxy-5-(hydroxymethyl)oxolan-2-yl]-6-aminopurin-2-yl}pyrazol-4-yl)-N,N-dimethylcarboxamide, (1-{9-[(4S,2R,3R,5R)-3,4-dihydroxy-5-(hydroxymethyl)oxolan-2-yl]-6-aminopurin-2-yl}pyrazol-4-yl)-N-ethylcarboxamide, 1-{9-[(4S,2R,3R,5R)-3,4-dihydroxy-5-(hydroxymethyl)oxolan-2-yl]-6-aminopurin-2-yl}pyrazole-4-carboxamide, 1-{9-[(4S,2R,3R,5R)-3,4-dihydroxy-5-(hydroxymethyl)oxolan-2-yl]-6-aminopurin-2-yl}pyrazol-4-yl)-N-(cyclopentylmethyl)carboxamide, (1-{9-[(4S,2R, 3R,5R)-3,4-dihydroxy-5-(hydroxymethyl)oxolan-2-yl]-6-aminopurin-2-yl}pyrazol-4-yl)-N-[(4-chlorophenyl)methyl]carboxamide, Ethyl 2-[(1-{9-[(4S,2R, 3R,5R)-3,4-dihydroxy-5-(hydroxymethyl)oxolan-2-yl]-6-aminopurin-2-yl}pyrazol-4-yl)carbonylamino]acetate, and mixtures thereof.

A second class of compounds that are potent and selective agonists for the A_{2A} adenosine receptor that are useful in the methods of this invention are 2-adenosine C-pyrazole compounds having the following formula:



wherein R^1 is $-CH_2OH$, and $-C(=O)NR^5R^6$;

R^2 is selected from the group consisting of hydrogen, C_{1-15} alkyl, C_{2-15} alkenyl, C_{2-15} alkynyl, heterocyclyl, aryl, and heteroaryl, wherein the alkyl, alkenyl, alkynyl, aryl, heterocyclyl, and heteroaryl substituents are optionally substituted with from 1 to 3 substituents independently selected from the group consisting of halo, NO_2, heterocyclyl, aryl, heteroaryl, CF_3, CN, OR^{20}, SR^{20}, $N(R^{20})_2$, $S(O)R^{22}$, SO_2R^{22}, $SO_2N(R^{20})_2$, $SO_2NR^{20}COR^{22}$, $SO_2NR^{20}CO_2R^{22}$, $SO_2NR^{20}CON(R^{20})_2$, $N(R^{20})_2\,NR^{20}COR^{22}$, $NR^{20}CO_2R^{22}$, $NR^{20}CON(R^{20})_2$, $NR^{20}C(NR^{20})NHR^{23}$, COR^{20}, CO_2R^{20}, $CON(R^{20})_2$, $CONR^{20}SO_2R^{22}$, $NR^{20}SO_2R^{22}$, $SO_2NR^{20}CO_2R^{22}$, $OCONR^{20}SO_2R^{22}$, $OC(O)R^{20}$, $C(O)OCH_2OC(O)R^{20}$, and $OCON(R^{20})_2$ and wherein each optional heteroaryl, aryl, and heterocyclyl substituent is optionally substituted with halo, NO_2, alkyl, CF_3, amino, mono- or di- alkylamino, alkyl or aryl or heteroaryl amide, $NCOR^{22}$, $NR^{20}SO_2R^{22}$, COR^{20}, CO_2R^{20}, $CON(R^{20})_2$, $NR^{20}CON(R^{20})_2$, $OC(O)R^{20}$, $OC(O)N(R^{20})_2$, SR^{20}, $S(O)R^{22}$, SO_2R^{22}, $SO_2N(R^{20})_2$, CN, or OR^{20};

R^3, R^4 are individually selected from the group consisting of hydrogen, C_{1-15} alkyl, C_{2-15} alkenyl, C_{2-15} alkynyl, heterocyclyl, aryl, and heteroaryl, halo, NO_2, CF_3, CN, OR^{20}, SR^{20}, $N(R^{20})_2$, $S(O)R^{22}$, SO_2R^{22}, $SO_2N(R^{20})_2$, $SO_2NR^{20}COR^{22}$, $SO_2NR^{20}CO_2R^{22}$, $SO_2NR^{20}CON(R^{20})_2$, $N(R^{20})_2\,NR^{20}COR^{22}$, $NR^{20}CO_2R^{22}$, $NR^{20}CON(R^{20})_2$, $NR^{20}C(NR^{20})NHR^{23}$, COR^{20}, CO_2R^{20}, $CON(R^{20})_2$, $CONR^{20}SO_2R^{22}$, $NR^{20}SO_2R^{22}$, $SO_2NR^{20}CO_2R^{22}$, $OCONR^{20}SO_2R^{22}$, $OC(O)R^{20}$, $C(O)OCH_2OC(O)R^{20}$, and $OCON(R^{20})_2$ wherein the alkyl, alkenyl, alkynyl, aryl, heterocyclyl, and heteroaryl substituents are optionally substituted with from 1 to 3 substituents individually selected from the group consisting of halo, NO_2, heterocyclyl, aryl, heteroaryl, CF_3, CN, OR^{20}, SR^{20}, $N(R^{20})_2$, $S(O)R^{22}$, SO_2R^{22}, $SO_2N(R^{20})_2$, $SO_2NR^{20}COR^{22}$, $SO_2NR^{20}CO_2R^{22}$, $SO_2NR^{20}CON(R^{20})_2$, $N(R^{20})_2\,NR^{20}COR^{22}$, $NR^{20}CO_2R^{22}$, $NR^{20}CON(R^{20})_2$, $NR^{20}C(NR^{20})NHR^{23}$, COR^{20}, CO_2R^{20}, $CON(R^{20})_2$, $CONR^{20}SO_2R^{22}$, $NR^{20}SO_2R^{22}$, $SO_2NR^{20}CO_2R^{22}$, $OCONR^{20}SO_2R^{22}$, $OC(O)R^{20}$, $C(O)OCH_2OC(O)R^{20}$, and $OCON(R^{20})_2$ and wherein each optional heteroaryl, aryl,

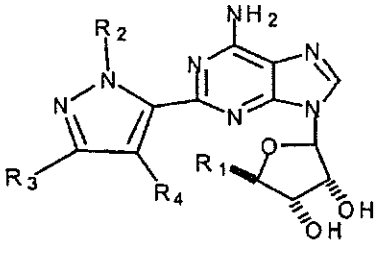
and heterocyclyl substituent is optionally substituted with halo, NO_2, alkyl, CF_3, amino, mono- or di- alkylamino, alkyl or aryl or heteroaryl amide, $NCOR^{22}$, $NR^{20}SO_2R^{22}$, COR^{20}, CO_2R^{20}, $CON(R^{20})_2$, $NR^{20}CON(R^{20})_2$, $OC(O)R^{20}$, $OC(O)N(R^{20})_2$, SR^{20}, $S(O)R^{22}$, SO_2R^{22}, $SO_2N(R^{20})_2$, CN, or OR^{20};

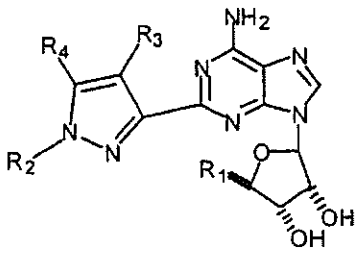
R^5 and R^6 are each individually H, C1-15 alkyl with from 1 to 2 substituents independently selected from the group consisting of halo, NO_2, heterocyclyl, aryl, heteroaryl, CF_3, CN, OR^{20}, SR^{20}, $N(R^{20})_2$, $S(O)R^{22}$, SO_2R^{22}, $SO_2N(R^{20})_2$, $SO_2NR^{20}COR^{22}$, $SO_2NR^{20}CO_2R^{22}$, $SO_2NR^{20}CON(R^{20})_2$, $N(R^{20})_2$ $NR^{20}COR^{22}$, $NR^{20}CO_2R^{22}$, $NR^{20}CON(R^{20})_2$, $NR^{20}C(NR^{20})NHR^{23}$, COR^{20}, CO_2R^{20}, $CON(R^{20})_2$, $CONR^{20}SO_2R^{22}$, $NR^{20}SO_2R^{22}$, $SO_2NR^{20}CO_2R^{22}$, $OCONR^{20}SO_2R^{22}$, $OC(O)R^{20}$, $C(O)OCH_2OC(O)R^{20}$, and $OCON(R^{20})_2$ and wherein each optional heteroaryl, aryl, and heterocyclyl substituent is optionally substituted with halo, NO_2, alkyl, CF_3, amino, mono- or di- alkylamino, alkyl or aryl or heteroaryl amide, $NCOR^{22}$, $NR^{20}SO_2R^{22}$, COR^{20}, CO_2R^{20}, $CON(R^{20})_2$, $NR^{20}CON(R^{20})_2$, $OC(O)R^{20}$, $OC(O)N(R^{20})_2$, SR^{20}, $S(O)R^{22}$, SO_2R^{22}, $SO_2N(R^{20})_2$, CN, or OR^{20};

R^{20} is selected from the group consisting of H, C_{1-15} alkyl, C_{2-15} alkenyl, C_{2-15} alkynyl, heterocyclyl, aryl, and heteroaryl, wherein the alkyl, alkenyl, alkynyl, heterocyclyl, aryl, and heteroaryl substituents are optionally substituted with from 1 to 3 substituents independently selected from halo, alkyl, mono- or dialkylamino, alkyl or aryl or heteroaryl amide, CN, O-C_{1-6} alkyl, CF_3, aryl, and heteroaryl; and

R^{22} is a member selected from the group consisting of C_{1-15} alkyl,C_{2-15} alkenyl, C_{2-15} alkynyl, heterocyclyl, aryl, and heteroaryl, wherein the alkyl, alkenyl, alkynyl, heterocyclyl, aryl, and heteroaryl substituents are optionally substituted with from 1 to 3 substituents independently selected from halo, alkyl, mono- or dialkylamino, alkyl or aryl or heteroaryl amide, CN, O-C_{1-6} alkyl, CF_3, and heteroaryl wherein, when $R^1 = CH_2OH$, R^3 is H, R^4 is H, the pyrazole ring is attached through C^4, and R^2 is not H.

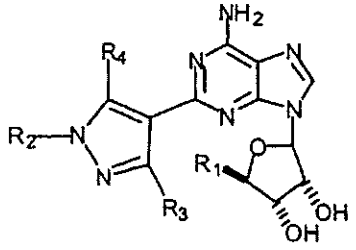
When the compound is selected has one of the following formulas:





then it is preferred that R^1 is $-CH_2OH$; R^2 is selected from the group consisting of hydrogen, C_{1-8} alkyl wherein the alkyl is optionally substituted with one substituent independently selected from the group consisting of aryl, CF_3, CN, and wherein each optional aryl substituent is optionally substituted with halo, alkyl, CF_3 or CN; and R^3 and R^4 are each independently selected from the group consisting of hydrogen, methyl and more preferably, R^3 and R^4 are each hydrogen.

When the compound of this invention has the following formulas:

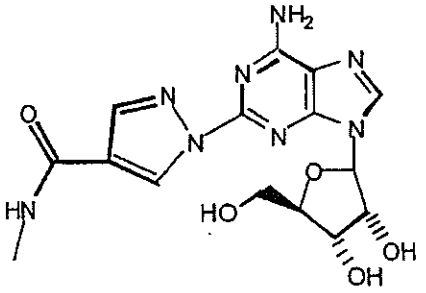


then it is preferred that R^1 is $-CH_2OH$; R^2 is selected from the group consisting of hydrogen, and C_{1-6} alkyl optionally substituted by phenyl. More preferably, R^2 is selected from benzyl and pentyl; R^3 is selected from the group consisting of hydrogen, C_{1-6} alkyl, aryl, wherein the alkyl, and aryl substituents are optionally substituted with from 1 to 2 substituents independently selected from the group consisting of halo, aryl, CF_3, CN, and wherein each optional aryl substituent is optionally substituted with halo, alkyl, CF_3 or CN; and R^4 is selected from the group consisting of hydrogen and C_{1-6} alkyl, and more preferably, R^4 is selected from hydrogen and methyl.

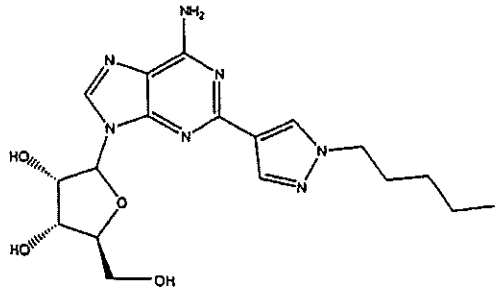
A more specific class of compounds is selected from the group consisting of (4S,2R,3R,5R)-2-{6-amino-2-[1-benzylpyrazol-4-yl]purin-9-yl}-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-[6-amino-2-(1-pentylpyrazol-4-yl)purin-9yl]-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-[6-amino-2-(1-methylpyrazol-4-yl)purin-

9-yl]-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-{6-amino-2-[1-(methylethyl)pyrazol-4-yl]purin-9-yl}-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-{6-amino-2-[1-(3-phenylpropyl)pyrazol-4-yl]purin-9-yl}-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-{6-amino-2-[1-(4-t-butylbenzyl)pyrazol-4-yl]purin-9-yl}-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-(6-amino-2-pyrazol-4-ylpurin-9-yl)-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-{6-amino-2-[1-pent-4-enylpyrazol-4-yl]purin-9-yl}-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-{6-amino-2-[1-decylpyrazol-4-yl]purin-9-yl}-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-{6-amino-2-[1-(cyclohexylmethyl)pyrazol-4-yl]purin-9-yl}-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-{6-amino-2-[1-(2-phenylethyl)pyrazol-4-yl]purin-9-yl}-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-{6-amino-2-[1-(3-cyclohexylpropyl)pyrazol-4-yl]purin-9-yl}-5-(hydroxymethyl)oxolane-3,4-diol, (4S,2R,3R,5R)-2-{6-amino-2-[1-(2-cyclohexylethyl)pyrazol-4-yl]purin-9-yl}-5-(hydroxymethyl)oxolane-3,4-diol, and combinations thereof.

A very useful and potent and selective agonists for the A_{2A} adenosine receptor is CVT-3146 or (1-{9-[(4S,2R,3R,5R)-3,4-dihydroxy-5-(hydroxymethyl)oxolan-2-yl]-6-aminopurin-2-yl}pyrazol-4-yl)-N-methylcarboxamide which has the formula:



Another preferred compound that is useful as a selective A_{2A}-adenosine receptor agonist with a short duration of action is a compound of the formula:



CVT-3033

CVT-3033 is particularly useful as an adjuvant in cardiological imaging.

The first and second classes of compounds identified above are described in more detail in U.S. Patent Nos. 6,403,567 and 6,214,807, the specification of each of which is incorporated herein by reference.

The following definitions apply to terms as used herein.

"Halo" or "Halogen" - alone or in combination means all halogens, that is, chloro (Cl), fluoro (F), bromo (Br), iodo (I).

"Hydroxyl" refers to the group -OH.

"Thiol" or "mercapto" refers to the group -SH.

"Alkyl" - alone or in combination means an alkane-derived radical containing from 1 to 20, preferably 1 to 15, carbon atoms (unless specifically defined). It is a straight chain alkyl, branched alkyl or cycloalkyl. Preferably, straight or branched alkyl groups containing from 1-15, more preferably 1 to 8, even more preferably 1-6, yet more preferably 1-4 and most preferably 1-2, carbon atoms, such as methyl, ethyl, propyl, isopropyl, butyl, t-butyl and the like. The term "lower alkyl" is used herein to describe the straight chain alkyl groups described immediately above. Preferably, cycloalkyl groups are monocyclic, bicyclic or tricyclic ring systems of 3-8, more preferably 3-6, ring members per ring, such as cyclopropyl, cyclopentyl, cyclohexyl, adamantyl and the like. Alkyl also includes a straight chain or branched alkyl group that contains or is interrupted by a cycloalkyl portion. The straight chain or branched alkyl group is attached at any available point to produce a stable compound. Examples of this include, but are not limited to, 4-(isopropyl)-cyclohexylethyl or 2-methyl-cyclopropylpentyl. A substituted alkyl is a straight chain alkyl, branched alkyl, or cycloalkyl group defined previously, independently substituted with 1 to 3 groups or substituents of halo, hydroxy, alkoxy, alkylthio, alkylsulfinyl, alkylsulfonyl, acyloxy, aryloxy, heteroaryloxy, amino optionally mono- or di-substituted with alkyl, aryl or heteroaryl groups, amidino, urea optionally substituted with alkyl, aryl, heteroaryl or heterocyclyl groups, aminosulfonyl optionally N-mono- or N,N-di-substituted with alkyl, aryl or heteroaryl groups, alkylsulfonylamino, arylsulfonylamino, heteroarylsulfonylamino, alkylcarbonylamino, arylcarbonylamino, heteroarylcarbonylamino, or the like.

"Alkenyl" - alone or in combination means a straight, branched, or cyclic hydrocarbon containing 2-20, preferably 2-17, more preferably 2-10, even more preferably 2-8, most preferably 2-4, carbon atoms and at least one, preferably 1-3, more preferably 1-2, most preferably one, carbon to carbon double bond. In the case of a cycloalkyl group, conjugation of more than one

carbon to carbon double bond is not such as to confer aromaticity to the ring. Carbon to carbon double bonds may be either contained within a cycloalkyl portion, with the exception of cyclopropyl, or within a straight chain or branched portion. Examples of alkenyl groups include ethenyl, propenyl, isopropenyl, butenyl, cyclohexenyl, cyclohexenylalkyl and the like. A substituted alkenyl is the straight chain alkenyl, branched alkenyl or cycloalkenyl group defined previously, independently substituted with 1 to 3 groups or substituents of halo, hydroxy, alkoxy, alkylthio, alkylsulfinyl, alkylsulfonyl, acyloxy, aryloxy, heteroaryloxy, amino optionally mono- or di-substituted with alkyl, aryl or heteroaryl groups, amidino, urea optionally substituted with alkyl, aryl, heteroaryl or heterocyclyl groups, aminosulfonyl optionally N-mono- or N,N-di-substituted with alkyl, aryl or heteroaryl groups, alkylsulfonylamino, arylsulfonylamino, heteroarylsulfonylamino, alkylcarbonylamino, arylcarbonylamino, heteroarylcarbonylamino, carboxy, alkoxycarbonyl, aryloxycarbonyl, heteroaryloxycarbonyl, or the like attached at any available point to produce a stable compound.

"Alkynyl" - alone or in combination means a straight or branched hydrocarbon containing 2-20, preferably 2-17, more preferably 2-10, even more preferably 2-8, most preferably 2-4, carbon atoms containing at least one, preferably one, carbon to carbon triple bond. Examples of alkynyl groups include ethynyl, propynyl, butynyl and the like. A substituted alkynyl refers to the straight chain alkynyl or branched alkenyl defined previously, independently substituted with 1 to 3 groups or substituents of halo, hydroxy, alkoxy, alkylthio, alkylsulfinyl, alkylsulfonyl, acyloxy, aryloxy, heteroaryloxy, amino optionally mono- or di-substituted with alkyl, aryl or heteroaryl groups, amidino, urea optionally substituted with alkyl, aryl, heteroaryl or heterocyclyl groups, aminosulfonyl optionally N-mono- or N,N-di-substituted with alkyl, aryl or heteroaryl groups, alkylsulfonylamino, arylsulfonylamino, heteroarylsulfonylamino, alkylcarbonylamino, arylcarbonylamino, heteroarylcarbonylamino, or the like attached at any available point to produce a stable compound.

"Alkyl alkenyl" refers to a group -R-CR'=CR''' R'''', where R is lower alkyl, or substituted lower alkyl, R', R''', R'''' may independently be hydrogen, halogen, lower alkyl, substituted lower alkyl, acyl, aryl, substituted aryl, hetaryl, or substituted hetaryl as defined below.

"Alkyl alkynyl" refers to a groups -RC□CR' where R is lower alkyl or substituted lower alkyl, R' is hydrogen, lower alkyl, substituted lower alkyl, acyl, aryl, substituted aryl, hetaryl, or substituted hetaryl as defined below.

"Alkoxy" denotes the group -OR, where R is lower alkyl, substituted lower alkyl, acyl, aryl, substituted aryl, aralkyl, substituted aralkyl, heteroalkyl, heteroarylalkyl, cycloalkyl,

substituted cycloalkyl, cycloheteroalkyl, or substituted cycloheteroalkyl as defined.

"Alkylthio" denotes the group -SR, -$S(O)_{n=1-2}$-R, where R is lower alkyl, substituted lower alkyl, aryl, substituted aryl, aralkyl or substituted aralkyl as defined herein.

"Acyl" denotes groups -C(O)R, where R is hydrogen, lower alkyl substituted lower alkyl, aryl, substituted aryl and the like as defined herein.

"Aryloxy" denotes groups -OAr, where Ar is an aryl, substituted aryl, heteroaryl, or substituted heteroaryl group as defined herein.

"Amino" denotes the group NRR', where R and R' may independently by hydrogen, lower alkyl, substituted lower alkyl, aryl, substituted aryl, hetaryl, or substituted hetaryl as defined herein or acyl.

"Amido" denotes the group -C(O)NRR', where R and R' may independently by hydrogen, lower alkyl, substituted lower alkyl, aryl, substituted aryl, hetaryl, substituted hetaryl as defined herein.

"Carboxyl" denotes the group -C(O)OR, where R is hydrogen, lower alkyl, substituted lower alkyl, aryl, substituted aryl, hetaryl, and substituted hetaryl as defined herein.

"Aryl" - alone or in combination means phenyl or naphthyl optionally carbocyclic fused with a cycloalkyl of preferably 5-7, more preferably 5-6, ring members and/or optionally substituted with 1 to 3 groups or substituents of halo, hydroxy, alkoxy, alkylthio, alkylsulfinyl, alkylsulfonyl, acyloxy, aryloxy, heteroaryloxy, amino optionally mono- or di-substituted with alkyl, aryl or heteroaryl groups, amidino, urea optionally substituted with alkyl, aryl, heteroaryl or heterocyclyl groups, aminosulfonyl optionally N-mono- or N,N-di-substituted with alkyl, aryl or heteroaryl groups, alkylsulfonylamino, arylsulfonylamino, heteroarylsulfonylamino, alkylcarbonylamino, arylcarbonylamino, heteroarylcarbonylamino, or the like.

"Substituted aryl" refers to aryl optionally substituted with one or more functional groups, *e.g.*, halogen, lower alkyl, lower alkoxy, alkylthio, acetylene, amino, amido, carboxyl, hydroxyl, aryl, aryloxy, heterocycle, hetaryl, substituted hetaryl, nitro, cyano, thiol, sulfamido and the like.

"Heterocycle" refers to a saturated, unsaturated, or aromatic carbocyclic group having a single ring (*e.g.*, morpholino, pyridyl or furyl) or multiple condensed rings (*e.g.*, naphthpyridyl, quinoxalyl, quinolinyl, indolizinyl or benzo[b]thienyl) and having at least one hetero atom, such as N, O or S, within the ring, which can optionally be unsubstituted or substituted with, *e.g.*, halogen, lower alkyl, lower alkoxy, alkylthio, acetylene, amino, amido, carboxyl, hydroxyl, aryl, aryloxy, heterocycle, hetaryl, substituted hetaryl, nitro, cyano, thiol, sulfamido and the like.

"Heteroaryl" - alone or in combination means a monocyclic aromatic ring structure

containing 5 or 6 ring atoms, or a bicyclic aromatic group having 8 to 10 atoms, containing one or more, preferably 1-4, more preferably 1-3, even more preferably 1-2, heteroatoms independently selected from the group O, S, and N, and optionally substituted with 1 to 3 groups or substituents of halo, hydroxy, alkoxy, alkylthio, alkylsulfinyl, alkylsulfonyl, acyloxy, aryloxy, heteroaryloxy, amino optionally mono- or di-substituted with alkyl, aryl or heteroaryl groups, amidino, urea optionally substituted with alkyl, aryl, heteroaryl or heterocyclyl groups, aminosulfonyl optionally N-mono- or N,N-di-substituted with alkyl, aryl or heteroaryl groups, alkylsulfonylamino, arylsulfonylamino, heteroarylsulfonylamino, alkylcarbonylamino, arylcarbonylamino, heteroarylcarbonylamino, or the like. Heteroaryl is also intended to include oxidized S or N, such as sulfinyl, sulfonyl and N-oxide of a tertiary ring nitrogen. A carbon or nitrogen atom is the point of attachment of the heteroaryl ring structure such that a stable aromatic ring is retained. Examples of heteroaryl groups are pyridinyl, pyridazinyl, pyrazinyl, quinazolinyl, purinyl, indolyl, quinolinyl, pyrimidinyl, pyrrolyl, oxazolyl, thiazolyl, thienyl, isoxazolyl, oxathiadiazolyl, isothiazolyl, tetrazolyl, imidazolyl, triazinyl, furanyl, benzofuryl, indolyl and the like. A substituted heteroaryl contains a substituent attached at an available carbon or nitrogen to produce a stable compound.

"Heterocyclyl" - alone or in combination means a non-aromatic cycloalkyl group having from 5 to 10 atoms in which from 1 to 3 carbon atoms in the ring are replaced by heteroatoms of O, S or N, and are optionally benzo fused or fused heteroaryl of 5-6 ring members and/or are optionally substituted as in the case of cycloalkyl. Heterocycyl is also intended to include oxidized S or N, such as sulfinyl, sulfonyl and N-oxide of a tertiary ring nitrogen. The point of attachment is at a carbon or nitrogen atom. Examples of heterocyclyl groups are tetrahydrofuranyl, dihydropyridinyl, piperidinyl, pyrrolidinyl, piperazinyl, dihydrobenzofuryl, dihydroindolyl, and the like. A substituted hetercyclyl contains a substituent nitrogen attached at an available carbon or nitrogen to produce a stable compound.

"Substituted heteroaryl" refers to a heterocycle optionally mono or poly substituted with one or more functional groups, *e.g.*, halogen, lower alkyl, lower alkoxy, alkylthio, acetylene, amino, amido, carboxyl, hydroxyl, aryl, aryloxy, heterocycle, substituted heterocycle, hetaryl, substituted hetaryl, nitro, cyano, thiol, sulfamido and the like.

"Aralkyl" refers to the group -R-Ar where Ar is an aryl group and R is lower alkyl or substituted lower alkyl group. Aryl groups can optionally be unsubstituted or substituted with, *e.g.*, halogen, lower alkyl, alkoxy, alkylthio, acetylene, amino, amido, carboxyl, hydroxyl, aryl, aryloxy, heterocycle, substituted heterocycle, hetaryl, substituted hetaryl, nitro, cyano, thiol,

sulfamido and the like.

"Heteroalkyl" refers to the group -R-Het where Het is a heterocycle group and R is a lower alkyl group. Heteroalkyl groups can optionally be unsubstituted or substituted with *e.g.*, halogen, lower alkyl, lower alkoxy, alkylthio, acetylene, amino, amido, carboxyl, aryl, aryloxy, heterocycle, substituted heterocycle, hetaryl, substituted hetaryl, nitro, cyano, thiol, sulfamido and the like.

"Heteroarylalkyl" refers to the group -R-HetAr where HetAr is an heteroaryl group and R lower alkyl or substituted lower alkyl. Heteroarylalkyl groups can optionally be unsubstituted or substituted with, *e.g.*, halogen, lower alkyl, substituted lower alkyl, alkoxy, alkylthio, acetylene, aryl, aryloxy, heterocycle, substituted heterocycle, hetaryl, substituted hetaryl, nitro, cyano, thiol, sulfamido and the like.

"Cycloalkyl" refers to a divalent cyclic or polycyclic alkyl group containing 3 to 15 carbon atoms.

"Substituted cycloalkyl" refers to a cycloalkyl group comprising one or more substituents with, *e.g.*, halogen, lower alkyl, substituted lower alkyl, alkoxy, alkylthio, acetylene, aryl, aryloxy, heterocycle, substituted heterocycle, hetaryl, substituted hetaryl, nitro, cyano, thiol, sulfamido and the like.

"Cycloheteroalkyl" refers to a cycloalkyl group wherein one or more of the ring carbon atoms is replaced with a heteroatom (*e.g.*, N, O, S or P).

Substituted cycloheteroalkyl" refers to a cycloheteroalkyl group as herein defined which contains one or more substituents, such as halogen, lower alkyl, lower alkoxy, alkylthio, acetylene, amino, amido, carboxyl, hydroxyl, aryl, aryloxy, heterocycle, substituted heterocycle, hetaryl, substituted hetaryl, nitro, cyano, thiol, sulfamido and the like.

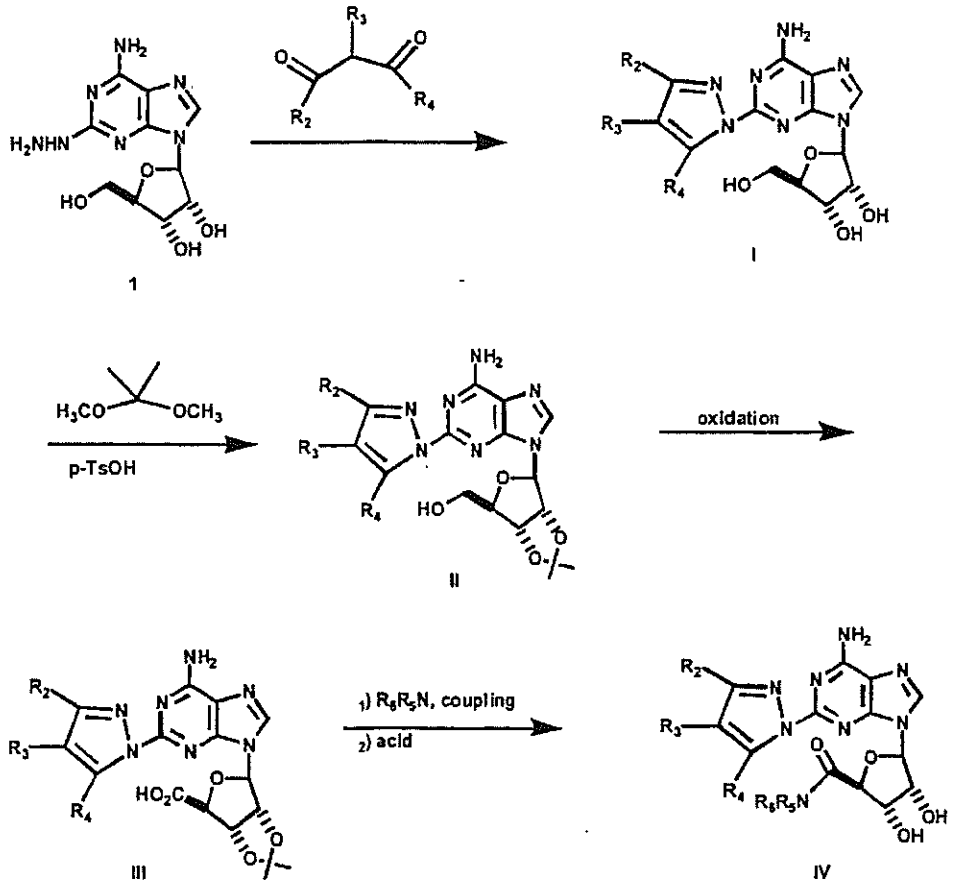
"Alkyl cycloalkyl" denotes the group -R-cycloalkyl where cycloalkyl is a cycloalkyl group and R is a lower alkyl or substituted lower alkyl. Cycloalkyl groups can optionally be unsubstituted or substituted with *e.g.* halogen, lower alkyl, lower alkoxy, alkylthio, acetylene, amino, amido, carboxyl, hydroxyl, aryl, aryloxy, heterocycle, substituted heterocycle, hetaryl, substituted hetaryl, nitro, cyano, thiol, sulfamido and the like.

"Alkyl cycloheteroalkyl" denotes the group -R-cycloheteroalkyl where R is a lower alkyl or substituted lower alkyl. Cycloheteroalkyl groups can optionally be unsubstituted or substituted with *e.g.* halogen, lower alkyl, lower alkoxy, alkylthio, amino, amido, carboxyl, acetylene, hydroxyl, aryl, aryloxy, heterocycle, substituted heterocycle, hetaryl, substituted hetaryl, nitro, cyano, thiol, sulfamido and the like.

The first class of compounds identified above can be prepared as outlined in Schemes 1-4.

Compounds having the general formula IV can be prepared as shown in Scheme 1.

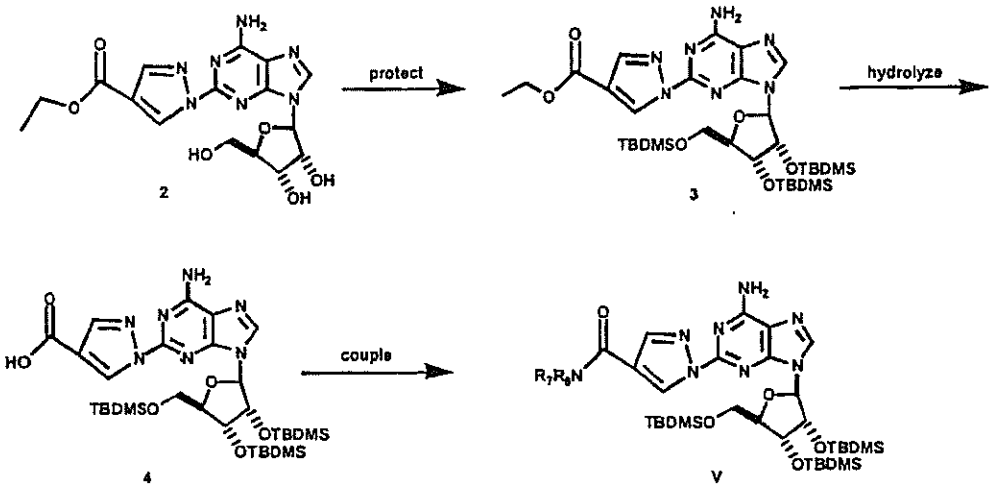
Scheme 1.



Compound I can be prepared by reacting compound 1 with appropriately substituted 1,3-dicarbonyl in a mixture of AcOH and MeOH at 80^0C (Holzer et al., J. Heterocycl. Chem. (1993) 30, 865). Compound II, which can be obtained by reacting compound I with 2,2-dimethoxypropane in the presence of an acid, can be oxidized to the carboxylic acid III, based on structurally similar compounds using potassium permanganate or pyridinium chlorochromate (M. Hudlicky, (1990) Oxidations in Organic Chemistry, ACS Monographs, American Chemical Society, Washington D. C.). Reaction of a primary or secondary amine having the formula HNR^6R^7, and compound III using DCC (M. Fujino et al., Chem. Pharm. Bull. (1974), 22, 1857), PyBOP (J. Martinez et al., J. Med. Chem. (1988) 28, 1874) or PyBrop

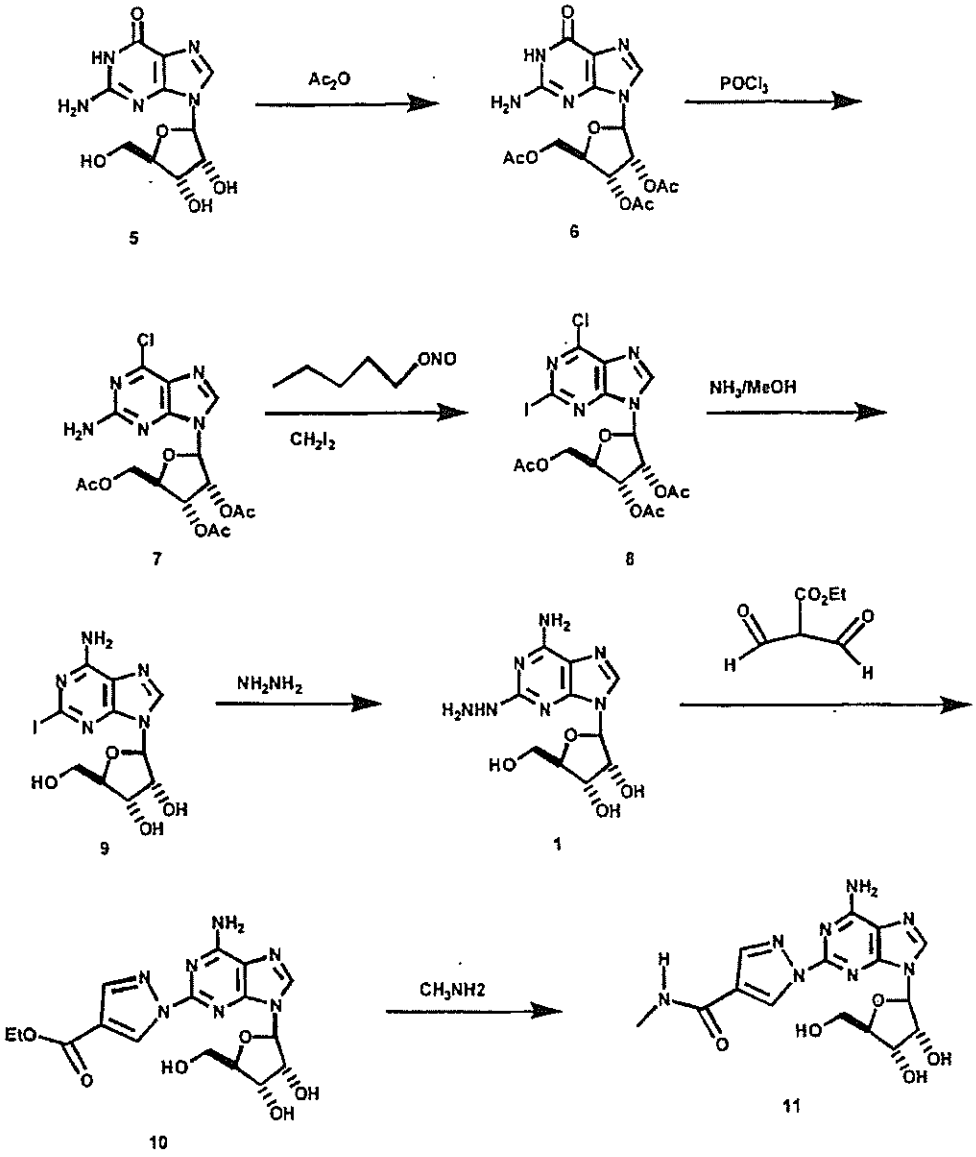
(J. Caste et al. Tetrahedron, (1991), 32, 1967) coupling conditions can afford compound IV.

Scheme 2.



Compound V can be prepared as shown in Scheme 2. The Tri TBDMS derivative 4 can be obtained by treating compound 2 with TBDMSCl and imidazole in DMF followed by hydrolysis of the ethyl ester using NaOH. Reaction of a primary or secondary amine with the formula HNR^6R^7, and compound 4 using DCC (M. Fujino et al., Chem. Pharm. Bull. (1974), 22, 1857), PyBOP (J. Martinez et al., J. Med. Chem. (1988) 28, 1874) or PyBrop (J. Caste et al. Tetrahedron, (1991), 32, 1967) coupling conditions can afford compound V.

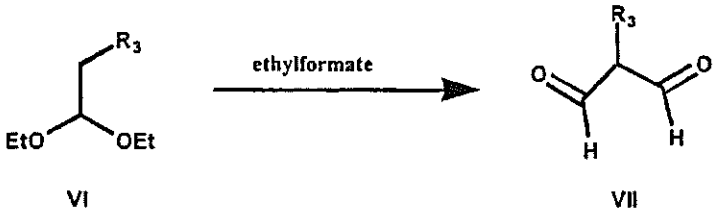
Scheme 3



A specific synthesis of Compound 11 is illustrated in Scheme 3. Commercially available guanosine 5 was converted to the triacetate 6 as previously described (M. J. Robins and B. Uznanski, Can. J. Chem. (1981), 59, 2601-2607). Compound 7, prepared by following the literature procedure of Cerster et al. (J. F. Cerster, A. F. Lewis, and R.K. Robins, Org. Synthesis, 242-243), was converted to compound 9 in two steps as previously described (V. Nair et al., J. Org. Chem., (1988), 53, 3051-3057). Compound 1 was obtained by reacting hydrazine hydrate with compound 9 in ethanol at 80^0C. Condensation of compound 1 with ethoxycarbonylmalondialdehyde in a mixture of AcOH and MeOH at 80^0C produced

compound 10. Heating compound 10 in excess methylamine afforded compound 11.

Scheme 4

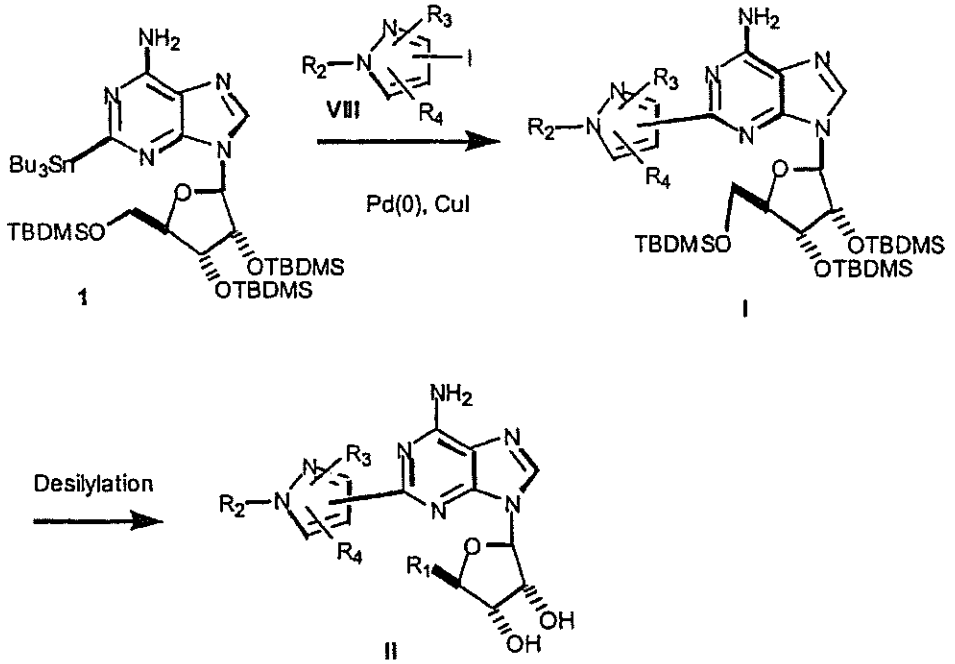


VI VII

The synthesis of 1,3-dialdehyde VII is described in Scheme 4. Reaction of 3,3-diethoxypropionate or 3,3-diethoxypropionitrile or 1,1-diethoxy-2-nitroethane VI ($R_3 = CO_2R$, CN or NO_2) with ethyl or methyl formate in the presence of NaH can afford the dialdehyde VII (Y. Yamamoto et al., J. Org. Chem. (1989) 54, 4734).

The second class of compound described above may be prepared by as outlined in schemes 1-5. Compounds having the general formula II:

Scheme 1

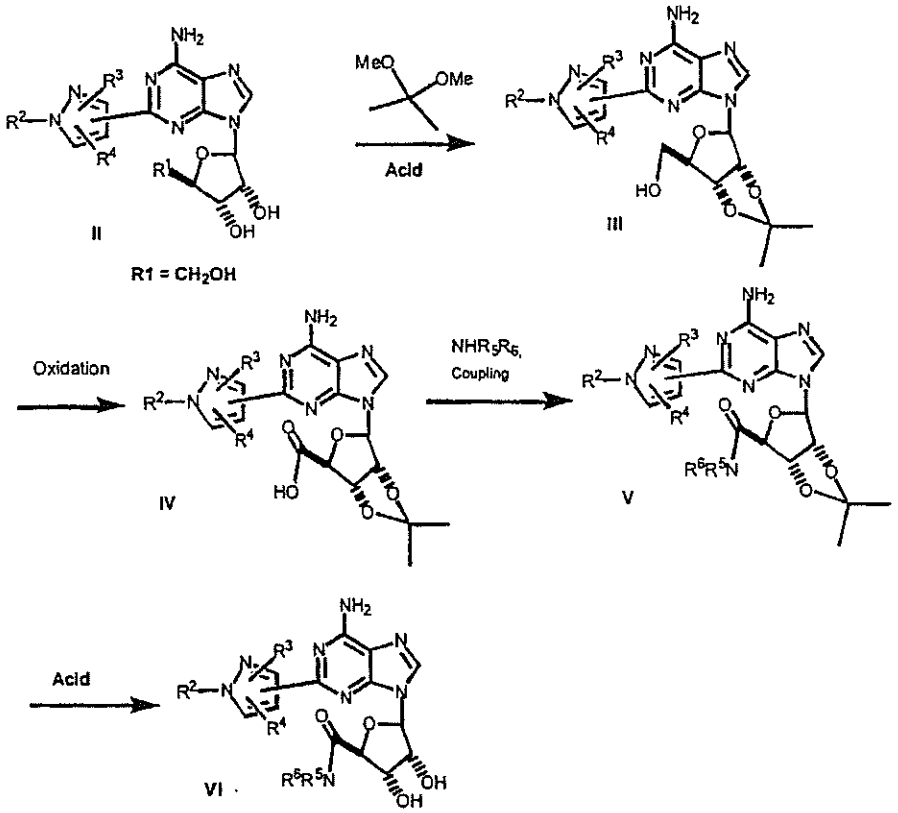


were prepared by the palladium mediated coupling of compound 1 with halo-pyrazoles represented by the formula VIII (scheme 4) in the presence or absence of copper salts (K. Kato et. al. J. Org. Chem. 1997, 62, 6833-6841; Palladium Reagents and Catalysts-Innovations in Organic Synthesis, Tsuji, John Wiley and Sons, 1995) followed by de-protection with either TBAF or

NH_4F (Markiewicz et. al Tetrahedron Lett.(1988), 29, 1561). The preparation of compound 1 has been previously described (K. Kato et. al. J. Org. Chem. 1997, 62, 6833-6841) and is outlined in scheme 5.

Compounds with general formula VI can be prepared as shown in Scheme 2. Compound III, which can be obtained by reacting II with 2,2-dimethoxypropane in presence of an

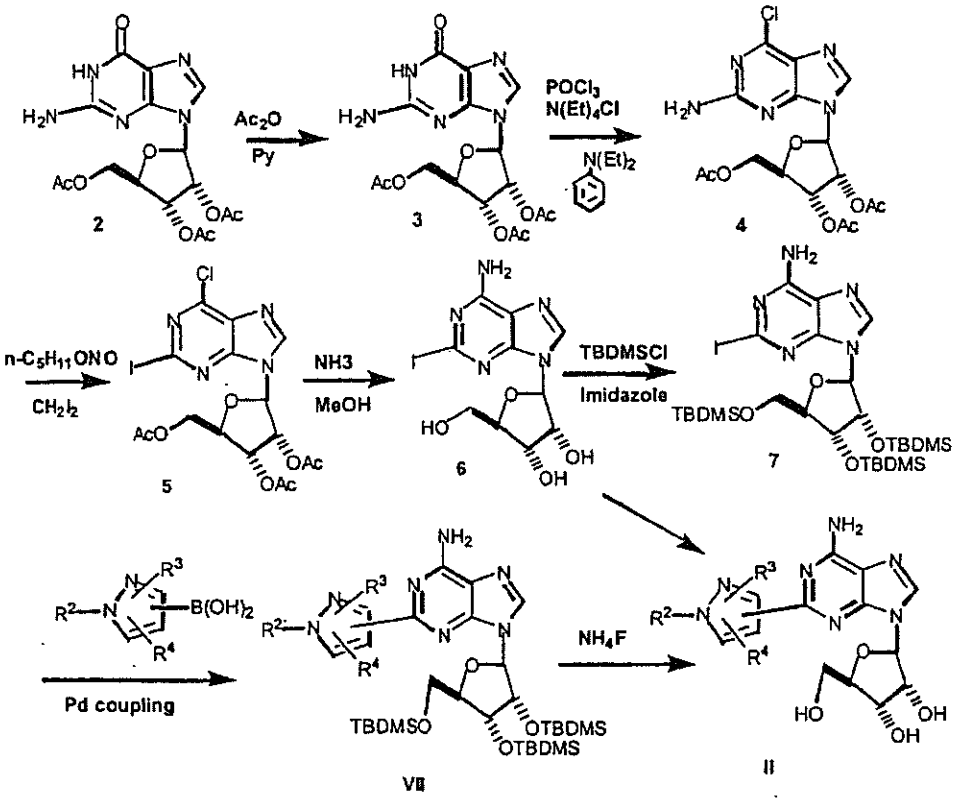
Scheme 2



acid, can be oxidized to the carboxylic acid IV, based on structurally similar compounds, using potassium permanganate or pyridinium chlorochromate etc. (Jones et.al., J. Am.Chem. Soc.(1949), 71, 3994.; Hudlicky, Oxidations in organic chemistry, American Chemical Society, Washington D. C., 1990) to compound IV. Reaction of primary or secondary amine of the formula NHR^5R^6, and compound IV using DCC (Fujino et.al., Chem. Pharm. Bull. (1974), 22, 1857), PyBOP (J. Martinez et. al., J. Med. Chem. (1988), 28, 1967) or PyBrop (J. Caste et.al. Tetrahedron, (1991), 32, 1967) coupling conditions can afford compound V. Deprotection of compound V can be performed by heating with 80% aq. acetic acid (T. W. Green and P. G. M. Wuts, (1991), Protective Groups in Organic Synthesis, A, Wiley-Interscience publication) or with anhydrous HCl (4N) to obtain compound of the general formula VI.

Alternatively, compounds with the general formula II can also be prepared by Suzuki type coupling as shown in scheme 3.

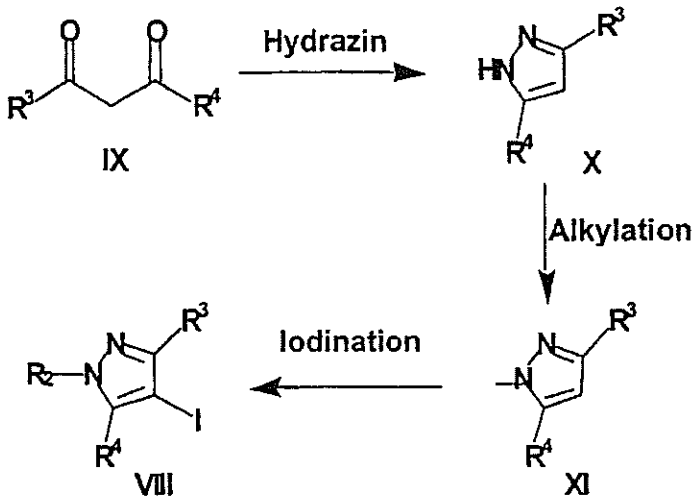
Scheme 3



2-Iodoadenosine 6 can be prepared in four steps from guanosine 2 following literature procedures (M. J. Robins et.al. Can. J. Chem. (1981), 59, 2601-2607; J. F. Cerster et.al. Org. Synthesis, ---242-243; V. Nair at. al., J. Org. Chem., (1988), 53, 3051-3057). Palladium mediated Suzuki coupling of 6 with appropriately substituted pyrazole-boronic acids XVII in presence of a base can provide final compounds with general formula II (A.Suzuki, Acc.Chem.Res) (1982), 15, 178). If necessary, 2', 3', 5' hydroxyls on 6 can be protected as TBDMS ethers prior to Suzuki coupling.

Compounds with the general formula VIII can be either commercially available or prepared following the steps shown in scheme 4.

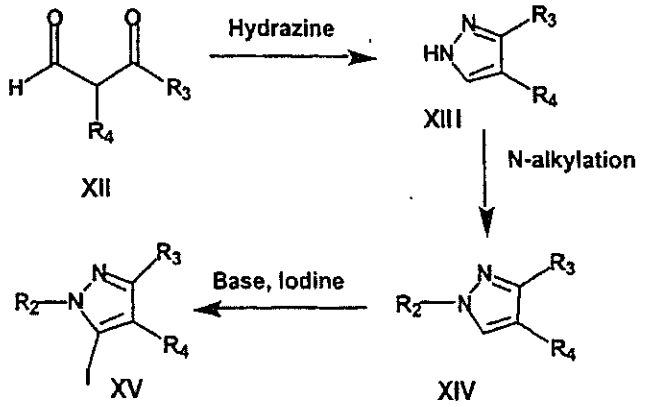
Scheme 4



Condensation of 1,3-diketo compounds of the formula IX with hydrazine in an appropriate solvent can give pyrazoles with the general formula X (R.H.Wiley et. al.Org.Synthsis, Coll.Vol IV (1963), 351. These pyrazoles can be N-alkylated with various alkyl halides to give compounds of the formula XI which on iodination give 4-iodo derivatives with the general formula VIII (R. Huttel et.al. Justus Liebigs Ann.Chem.(1955), 593, 200).

5-iodopyrazoles with the general formula XV can be prepared following the steps outlined in the scheme 5.

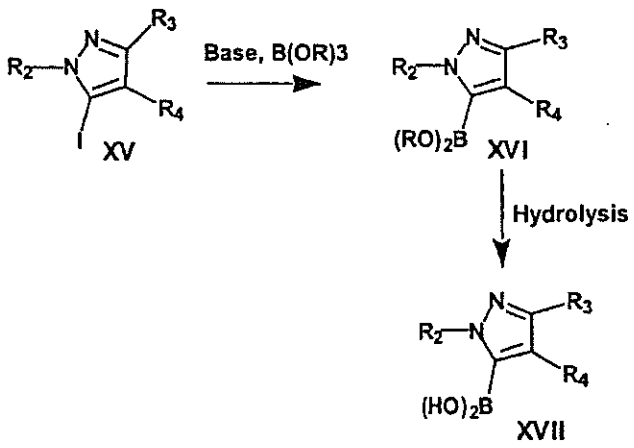
Scheme 5



Condensation of 1,3-diketo compounds of the formula XII with hydrazine in an appropriate solvent can give pyrazoles with the general formula XIII. These pyrazoles can be N-alkylated with various alkyl halides to give compounds of the formula XIV. Abstraction of 5-H with a strong base followed by quenching with iodine can provide 5-iodo derivatives with general formula XV (F. Effenberger et. al. J. Org. Chem. (1984), 49, 4687).

4- or 5- iodopyrazoles can be transformed into corresponding boronic acids as shown in the scheme 6. Transmetallation with n-buLi followed by treatment with trimethylborate can

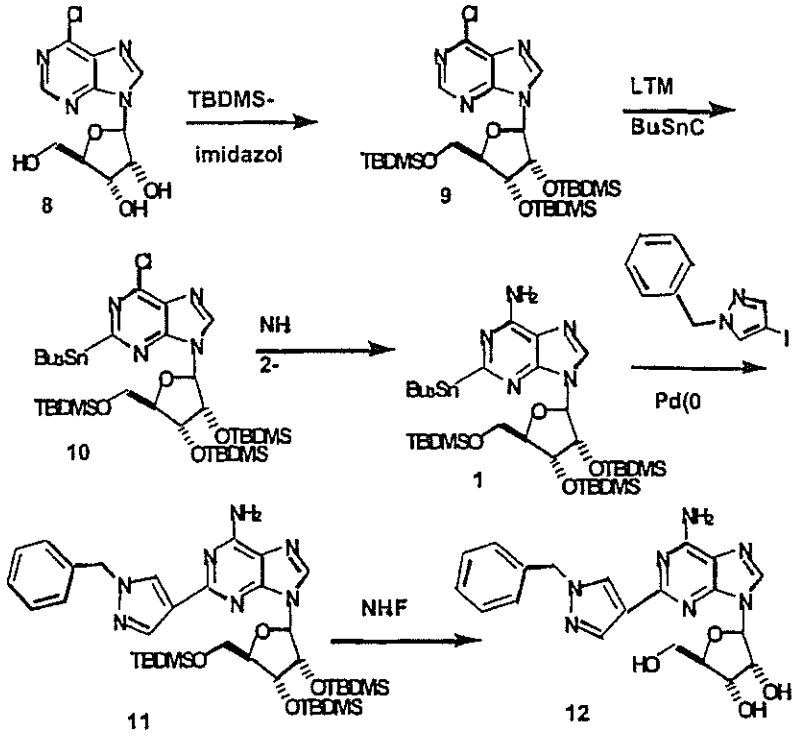
Scheme 6



give compounds with the general formula XVI which on hydrolysis can provide boronic acids with the general formula XVII (F. C. Fischer et.al. RECUEIL (1965), 84, 439).

2-Stannyladenosine 1 was prepared in three steps from the commercially available 6-chloropurine riboside following literature procedure (K. Kato et.al., J. Org. Chem. (1997), 62, 6833-6841). Tri TBDMS derivative was obtained by treating 8 with TBDMSCl and imidazole in DMF. Lithiation with LTMP followed by quenching with tri n-butyltin chloride gave exclusively 2-stannyl derivative 10. Ammonolysis in 2-propanol gave 2-stannyladenosine 1. Stille coupling of 1 with 1-benzyl-4-iodopyrazole in presence of Pd(PPh3)4 and CuI resulted in 11 (K. Kato et.al., J. Org. Chem. (1997), 62, 6833-6841). Deprotection of silyl groups on 2',3' and 5'

Scheme 7



hydroxyls with 0.5 M ammonium fluoride in methanol gave 12 in good yield (Scheme 7). The methods used to prepare the compounds of this invention are not limited to those described above. Additional methods can be found in the following sources and are included by reference (J. March, Advanced Organic Chemistry; Reaction Mechanisms and Studies (1992), A Wiley Interscience Publications; and J. Tsuji, Palladium reagents and catalysts-Innovations in organic synthesis, John Wiley and Sons, 1995).

If the final compound of this invention contains a basic group, an acid addition salt may be prepared. Acid addition salts of the compounds are prepared in a standard manner in a suitable solvent from the parent compound and an excess of acid, such as hydrochloric, hydrobromic, sulfuric, phosphoric, acetic, maleic, succinic, or methane sulfonic. The hydrochloric salt form is especially useful. If the final compound contains an acidic group, cationic salts may be prepared. Typically the parent compound is treated with an excess of an alkaline reagent, such as hydroxide, carbonate or alkoxide, containing the appropriate cation. Cations such as Na^+, K^+, Ca^{+2} and NH_4^+ are examples of cations present in pharmaceutically acceptable salts. Certain of the compounds form inner salts or zwitterions which may also be acceptable.

EXAMPLES

Three different aqueous pharmaceutical CVT-3146 formulations were used in the Examples below.

Examples 1-7 employed aqueous pharmaceutical compositions (a) and (b) below. Pharmaceutical compositions (a) and (b) were aseptically filled into 10 mL type I glass vials.

(a) An aqueous pharmaceutical composition consisting of 200 micrograms/mL of CVT-3146 in 0.5 (w:v) methylboronic acid buffered with sodium bicarbonate to a pH of 9.3.

(b) An aqueous pharmaceutical composition including 200 micrograms/mL of CVT-3146, 0.1% (w:v) methylboronic acid, 50 mM sodium bicarbonate buffer adjusted to pH 9.3 with the addition of 0.55 % (w:v) NaCl to make an isotonic pharmaceutical composition.

Example 8 employed a pharmaceutical composition consisting of an aqueous composition of 100 micrograms/mL CVT-3146 in 15% (w:v) propylene glycol and 100 mM phosphate buffer at pH 7 with 0.1% EDTA. The formulation was stored in type I glass vials at 5 mL per vial.

EXAMPLE 1

BACKGROUND: CVT-3146 (CVT), with an initial half-life of 3 minutes with a rapid onset and offset of action, is > 100 –fold more potent than adenosine (Ado) in increasing coronary blood flow velocity (CBFv) in awake dogs. The purpose of this open label study was to determine the magnitude and duration of effect of CVT-3146 (10-500 μg) on CBFv in humans.

METHODS: Patients undergoing a clinically indicated coronary catheterization with no more than a 70% stenosis in any coronary artery and no more than a 50% stenosis of the study vessel had CBFv determined by Doppler flow wire. Study subject were selected after measuring baseline and peak CBFv after an intracoronary (IC) injection of 18 μg of Ado. Twenty-three patients, who were identified as meeting the study criteria of having a peak to baseline CBFv ratio of $\geq$ 2.5 in response to Adenosine, received a rapid ($\leq$ 10 sec) peripheral IV bolus of CVT-3146; Doppler signals were stable and interpretable over the time-course of the increase in CBFv in 17 patients.

RESULTS CVT-3146 caused a rapid increase in CBFv that was near peak by 30 to 40 seconds post onset of bolus. CVT-3146 at doses of 100 μg (n=3), 300 μg (n=4), and 500 μg (n=2) induced a peak to baseline ratio of 3.2 $\pm$ 0.6 (mean $\pm$ SD), similar to that obtained by IC Ado (3.2 $\pm$ 0.5). The duration of CBFv augmentation ($\geq$ 2-fold increase in CBFv) was dose

dependent; at 300 μg the duration was 4.0 ± 4.9 minutes and at 500 μg was 6.9 ± 7.6 minutes. At 500 μg (n=3) the maximal increase in heart rate (HR) was 18.7 ± 4.0 and the maximal decrease in systolic blood pressure (BP) was 8.7 ± 7.6. Adverse events (AEs) were infrequent and included nausea, flushing, and headache; these were mild and self-limited. No AEs were noted in the 3 patients receiving the 500 μg dose.

CONCLUSION: In humans peak CBFv following CVT-3146 (IV bolus) is comparable to CBFv following IC Ado without major changes in either HR or BP. This agent's magnitude and duration of effect, adverse event profile and bolus administration make CVT-3146 a useful pharmacological stress agent for myocardial perfusion imaging.

EXAMPLE 2

This example is a study performed to determine the range of dosages over which the selective A_{2A} receptor agonist, CVT-3146 can be administered and be effective as a coronary vasodilator.

The study included patients undergoing a clinically indicated coronary catheterization with no more than a 70% stenosis in any coronary artery and no more than a 50% stenosis of the study vessel had CBFv determined by Doppler flow wire. Study subject were selected after measuring baseline and peak CBFv after an intracoronary (IC) injection of 18 μg of Ado. 36 subjects were identified as meeting the study criteria of having a peak to baseline CBFv ration of ≥ 2.5 in response to Adenosine,

CVT-3146 was administered to the study subjects by IV bolus in less that 10 seconds in amounts ranging from 10 μg to 500 μg.

The effectiveness of both compounds was measured by monitoring coronary flow velocity. Other coronary parameters that were monitored included heart rate and blood pressure. These parameters were measured in order to evaluate the time to peak dose response, the magnitude of the dose response and the duration of the dose response. Adverse events were also monitored. Coronary blood flow velocity was measured at the left anterior descending coronary artery (LAD) or left circumflex coronary artery (LCx). The velocity measurements were taken by following standard heart catheterization techniques and inserting a 0.014 inch Doppler-tipped Flowire into the LAD or LCx vessel and thereafter monitoring blood flow velocity. In addition, hemodynamic and electrocardiographic measurements were recorded continuously.

Overall, 36 human subjects (n=36) were evaluated. Of the 36, 18 were female and 18

were male. Their mean age was 53.4 and they ranged from 24-72 years in age. Of the 36 subjects evaluated, the LAD vessel of 31 subjects was monitored, and the LCx vessel of 5 subjects was monitored. The following doses (μg) of CVT-3146 were given to the subjects in a single iv bolus: 10 (n=4); 30 (n=6); 100 (n=4); 300 (n=7); 400 (n=9); 500 (n=6).

The study results are reported in Figures 1-6. The plot of Figure 1 shows that CVT-3146 increases peak flow velocity in amounts as low as 10 μg and reaches plateau peak velocity upon administration of less than about 100 μg of CVT-3146. Other test results and conclusions include:

- The peak flow was reached by about 30 seconds with all doses;
- At does above about 100 μg, peak effects were equivalent to 18 μg adenosine administered IC;
- CVT-3146 was generally well tolerated with adverse events being reported in The table attached as Figure 7;
- At 400 μg:
    - Coronary blood flow velocity ≥ 2.5-fold above baseline was maintained for 2.8 minutes.
    - Maximum increase in heart rate (18 ± 8 bpm) occurs about 1 minute after dosing.
    - Maximum decrease in systolic BP (20 ± 8 mmHg) occurs about 1 minute after dosing.
    - Maximum decrease in diastolic BP (10 ± 5 mmHg) occurs about 1 minute after dosing.

Example 3

This Example is a study performed to evaluate (1) the maximum tolerated dose of CVT-3146 and (2) the pharmacokinetic profile of CVT-3146 in healthy volunteers, after a single IV bolus dose.

Methods

The study was performed using thirty-six healthy, non-smoking male subjects between the ages of 18 and 59 and within 15% of ideal body weight.

Study design

The study was performed in phase 1, single center, double-blind, randomized, placebo-

controlled, crossover, ascending dose study. Randomization was to CVT-3146 or placebo, in both supine and standing positions.

CVT-3146 was administered as an IV bolus (20 seconds) in ascending doses of 0.1, 0.3, 1.3, 10, 20 and 30 μg/kg.

Subjects received either CVT-3146 of placebo on Day 1 supine, then crossover treatment on Day 2 supine. On Day 3, subjects received CVT-3146 or placebo standing, then crossover treatment on Day 4 standing.

Assessments

Patient safety was monitored by ECG, laboratory assessments, and collection of vital signs and adverse events.

Pharmacokinetics:

Plasma samples were drawn during supine phase (Days 1 and 2) at 0, 1, 2, 3, 4, 5, 7, 10, 15, 20, 30, 45 minutes after dosing and at 1, 1.5., 2, 4, 6, 8, 12 and 24 hours after dosing. Urine was collected for 24 hours for CVT-3146 excretion.

Pharmacodynamics:

- The study evaluated the relationship of changes in heart rate to dose in both standing and supine positions and plasma concentration in the supine position. Some of the study results are reported in Figures 8-14.

Results

Safety

In general, adverse events reflected the pharmacologic effect of CVT-3146 and were related to vasodilation or an increase in heart rate (HR). Overall, adverse events were short-lived and mild to moderate in severity. There were no serious adverse events. Three events were assessed as severe in intensity. (Table 1).

Table 1. Adverse Events labeled as severe in intensity

	Number of Subjects with AE	
Event	20 μg/kg Standing	30 μg/kg Supine
No subjects per group	4	4
Palpitation	0	2
Dizziness	1	0
Syncope	1	0

A three-compartment open model was fit to the data using observed Tmax (1-4 minutes) as the

duration of a zero-order infusion. Reliable parameter estimates were obtained for dose of 1-30 μg/kg. Parameters are summarized in the following (Table 2):

Table 2

Mean (SD) CVT-3146 Pharmacokinetic Parameters Estimated Using a Three – Compartment Model

Dose (μg/kg)	1	3	10	20	30	Total
N	3	4	4	8	3	22
CL (mL/min)	737 (106)	668 (167)	841 (120)	743 (123)	1021 (92.7)	768 (168)
Vc (L)	9.84 (4.12)	13.7 (6.06)	17.9 (6.11)	12.5 (5.83)	15.7 (4.59)	13.8 (5.67)
Vss (L)	69.0 (28.2)	90.0 (29.6)	101 (11.3)	75.2 (10.6)	89.6 (10.9)	75.5 (24.4)
α Half-life (min)	2.14 (1.38)	3.11 (2.14)	4.15 (2.75)	4.69 (4.01)	3.00 (1.05)	3.73 (2.88)
β Half-life (min)	8.93 (4.10)	17.2 (11.4)	50.2 (52.1)	32.6 (32.4)	14.0 (4.98)	27.2 (31.0)
λ Half-life (min)	99.0 (28.6)	130 (23.1)	132 (20.5)	117 (36.0)	99.4 (8.10)	86.4 (57.5)
K21 (1/min)	0.246 (0.255)	0.203 (0.272)	0.187 (0.305)	0.387 (0.615)	0.0948 (0.0443)	0.258 (0.410)
K31 (1/min)	0.01808 (0.00548)	0.0152 (0.00490)	0.0108 (0.00592)	0.0141 (0.00728)	0.0148 (0.000900)	0.0143 (0.00580)

CL = clearance
Vc = central volume of distribution
V_{ss} = volume of distribution at steady state
K_{21} = the rate constant for transfer from first peripheral to central compartment
K_{31} = rate constant for transfer from second peripheral to central compartment

Results

- CVT-3146 was well-tolerated, with AE's mainly representing its pharmacological effects as an adenosine A_{2A} receptor agonist.
- Mean tolerable dose for CVT-3146 was 10 μg/kg standing and 20 μg/kg supine.
- CVT-3146 does not require weight-adjusted dosing.
- There was no time lag between plasma concentration changes and changes in heart rate.
- The relationship between HR increase and dose or concentration was adequately described with a sigmoidal Emax model.

Example 4

CVT -3146 is a novel selective A_{2A} adenosine receptor agonist being developed as a pharmacologic stressor for radionuclide myocardial perfusion imaging. Previously it has been shown that CVT -3146 causes coronary vasodilation without significantly affecting either

total peripheral resistance or renal blood flow in awake dogs. The goal of this study was to determine the differential effects of CVT -3146 on blood flow velocity in various vascular beds.

The effect of CVT - 3146 was studied on the blood flow velocity in left circumflex coronary artery (LCX), brain arterial vasculature (BA), forelimb artery (FA) and pulmonary artery (PA) of comparable diameter in the anesthetized dog. CVT3146 (1.0 μg/kg) was administered as an intravenous bolus, transiently enhanced blood flow which was site specific. The effects of CVT -3146 were quantified as the average peak blood flow velocity (APV) using intravascular Doppler transducer tipped catheter. Heart rate (HR) and systemic arterial blood pressure (BP) were also monitored.

APV increased 3.1 ± 0.2, 1.4 ± 0.1, 1.2 ± 0.1, and 1.1 ± 0.01 fold in the LCX, BA, FA and PA, respectively manifesting a site-potency rank order of LCX>>BA>FA>PA (figure 16). The effect of CVT -3146 on blood flow velocity was short lasting; reaching a peak in less than 30 sec and dissipating in less than ten minutes. Increased blood flow velocity was associated with a small transient increase in HR (16 bpm) and decrease in BP (12 mmHg). In conclusion, this study demonstrated that CVT -3146 is a potent, short lasting vasodilator that is highly selective for the coronary vasculature.

Example 5

The present study was carried out to determine whether CVT-3146, a selective A_{2A} adenosine receptor agonist, causes sympathoexcitation.

CVT (0.31μg/kg-50 μg/kg) was given as a rapid i.v. bolus to awake rats and heart rate (HR) and blood pressure (BP) were monitored. CVT-3146 caused an increase in BP and systolic pressure (SP) at lower doses while at higher doses there was a decrease in BP and SP. CVT-3146 caused a dose-dependent increase in HR (Figure 17). The increase in HR was evident at the lowest dose of CVT at which there was no appreciable decrease in BP. ZM241385 (30 μg/kg , N=5), an A_{2A} receptor antagonist, attenuated the decrease in BP (CVT-3146: 14±3%, ZM: 1±1 %) and the increase in HR (CVT: 27±3%, ZM: 18±3%) caused by CVT-3146. Pretreatment with metoprolol (MET, 1 mg/kg, n=5), a beta-blocker, attenuated the increase in HR (CVT: 27±3%, MET: 15±2%), but had no effect on hypotension caused by CVT-3146. In the presence of hexamethonium (HEX, 10 mg/kg, n=5), a ganglionic blocker, the tachycardia was prevented (CVT: 27±3%, HEX: -1±2%), but BP was further reduced (CVT: -11±2%, HEX: -49±5%). CVT-3146 (10 μg/kg, n=6) also

significantly ($p<0.05$) increased plasma norepinephrine (control: 146±11, CVT-3146 269±22 ng/ml) and epinephrine (control:25:f:5, CVT:I00:f:20 ng/ml) levels. The separation of HR and BP effects by dose, time and pharmacological interventions provides evidence that tachycardia caused by CVT-3146 is independent of the decrease in BP, suggesting that CVT-3146, via activation of A_{2A} receptors may cause a direct stimulation of the sympathetic nervous system.

Example 6

Pharmacologic stress SPECT myocardial perfusion imaging (MPI) with adenosine (A) is a well-accepted technique, with excellent diagnostic and prognostic value and proven safety. However, side effects are common and AV nodal block and severe flushing are poorly tolerated. Agents such as CVT-3146 selectively act upon the A2A adenosine receptor and avoid stimulation of other receptor subtypes which may prevent such adverse reactions.

To determine the ability of CVT-3146 to produce coronary hyperemia and accurately detect CAD, 35 subjects (26 men, 9 women; 67±10 years) underwent both A and CVT-3146 stress/rest MPI, with 10.0±9.1 days between studies. Prior MI was noted in 12 patients, and many had prior revascularization [CABG (n=19),PCI (n=22)]. CVT-3146 [400 mcg (n=18), 500 mcg (n=17)] was administered as an IV bolus immediately followed by a saline flush, and then a Tc-99m radiopharmaceutical [sestamibi (n=34), tetrofosmin (n=1)]. SPECT images were uniformly processed, intermixed with control studies (normal and fixed-only defects), and interpreted by three observers in a blinded fashion using a 17-segment model. Quantitative analysis was also performed using 4D MSPECT. In addition to three separate readings, a consensus interpretation was performed and then a direct, same-screen comparison of A and CVT-3146 images undertaken to determine relative differences, using 5 regions per study.

The summed scores following stress were similar, both with visual (A=13.9±1.5, CVT-3146=13.2±1.3; p=n.s.) and quantitative methods of analysis (A=13.7±1.5, CVT - 3146=13.6±1.6; p=n.s.). Similarly, comparisons between the summed rest and summed difference scores were identical. The direct comparison also revealed no differences in ischemia detection, with a regional concordance for ischemia extent and severity of 86.3% and 83.4%, respectively. No dose-dependent effect of CVT-3146 on ischemia detection was noted. A conclusion of the study is that CVT-3146, administered by a logistically simple bolus injection, provides a similar ability to detect and quantify myocardial ischemia with SPECT

MPI as noted with an A infusion.

Example 7

CVT-3146 is a selective A2A adenosine receptor agonist that produces coronary hyperemia and potentially less adverse effects due to its limited stimulation of receptor subtypes not involved with coronary vasodilation. This study evaluated the effectiveness of CVT-3146 as a pharmacologic stress agent.

36 subjects (27 men, 9 women; 67±10 years) were studied with two doses of CVT-3146 [400 mcg (n=18), 500 mcg (n=18)], administered as an IV bolus, as part of a pharmacologic stress myocardial perfusion imaging protocol.

Adverse effects (AE) occurred in 26 pts (72%), including chest discomfort (33%), headache (25%), and abdominal pain (11%), with a similar incidence for both doses. Flushing, dyspnea, and dizziness were more frequent in the 500-mcg group (44%, 44%, and 28%, respectively) than in the 400-mcg group (17%, 17%, and 11%, respectively). Most AEs were mild to moderate (96%) and resolved within 15 min without treatment (91%). One serious AE occurred, with exacerbation of a migraine headache, which required hospitalization. ST and T wave abnormalities developed with CVT-3146 in 7 and 5 pts, respectively. No 2nd or 3rd degree AV block was noted and there were no serious arrhythmias. Peak hemodynamic effects are shown in Table 3 and were noted at 4 min for systolic blood pressure (BP), 8 min for diastolic BP, and within 2 min for heart rate (HR). The effect on BP was minimal and systolic BP did not fall below 90 mmHg with either dose. The mean change in HR response was higher for the 500 mcg dose (44.2%) than for 400 mcg (34.8%; p=n.s.). Thirty min after CVT-3146, BP changes deviated <2% from baseline but HR remained above baseline by 8.6%.

The results of this study indicate that CVT-3146 is well-tolerated and has acceptable hemodynamic effects. Minimal differences were noted in BP and HR responses between the 400 mcg and 500 mcg doses, but AEs were more frequently at the higher dose. CVT-3146 appears safe and well-tolerated for bolus-mediated pharmacologic stress perfusion imaging.

Hemodynamic Changes (mean±S.D.)

Table 3

	Absolute Change	Relative Change
Heart Rate	+21.9±10.4 beats per min	+36.7%+21.0%
Systolic BP	-5.9±10.7 mmHg	-4.1%±7.6%
Diastolic BP	-5.4±7.2 mmHg	-7.9%±10.5%

Example 8

In this study the vasodilator effects of CVT-3146 were compared to those of ADO in different vascular beds in awake dogs. Dogs were chronically instrumented for measurements of the blood flow in coronary (CBF), mesenteric (MBF), hind limb (LBF), and renal (RBF) vascular beds, and hemodynamics. Bolus injections (iv) to CVT-3146 (0.1 to 2.5 μg/kg) and ADO (10 to 250 μg/kg) caused significant increases in CBF (35±6 to 205±23% and 58±13 to 163±16%) and MBF (18±4 to 88±14% and 36±8 to 84±5%).

The results of the study demonstrate that CVT-3146 is a more potent and longer lasting coronary vasodilator compared to ADO (the duration for CBF above 2-fold of the baseline; CVT-3146 (2.5 μg/kg): 130±19s; ADO (250 μg/kg): 16±3s, $P<0.5$). As shown in Figure 18 (mean ± SE, n=6), CVT-3146 caused a smaller increase in LBF than ADO. ADO caused a dose-dependent renal vasoconstriction (RBF –46±7 to – 85±4%), whereas CVT-3146 has no or a little effect on RBF (-5±2 to –11±4%, $P<0.05$, compared to ADO). In conclusion, CVT-3146 is a more selective and potent coronary vasodilator than ADO. CVT-3146 has no the significant effect on renal blood flow in awake dogs. These features of CVT-3146 make it an ideal candidate for radionuclide myocardial perfusion imaging.

The invention now having been fully described, it will be apparent to one of ordinary skill in the art that many changes and modifications can be made thereto without departing from the spirit or scope of the invention.

What is claimed is:

1. A pharmaceutical composition having a pH from about 6 to about 8 comprising: CVT-3146,

a.) a buffer, and

b.) a propylene glycol co-solvent present in an amount from about 8% to about 20% (w:v),

wherein the pharmaceutical composition does not include a methylboronic acid or a borate buffer co-solvent.

2. The pharmaceutical composition of claim 1 wherein the ~~said~~ pharmaceutical composition further comprises EDTA.

3. The pharmaceutical composition of claim 1 wherein the CVT-3146 is present in an amount from about 50 to about 150 micrograms.

4. Use of a composition comprising CVT-3146,

a.) a buffer, and

b.) a propylene glycol co-solvent present in an amount from about 8% to about 20% (w:v),

wherein the composition does not include a methylboronic acid or a borate buffer co-solvent,

in the preparation of a medicament for producing coronary vasodilation without peripheral vasodilation.

5. The use of claim 4 wherein said medicament is suitable for iv bolus administration.

6. The use of claim 5 wherein said medicament is suitable for administration in about 10 to about 20 seconds.