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**Harbeson**

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(54) **ENDOTHELIN RECEPTOR ANTAGONISTS**

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(52) **U.S. Cl.** ..... **514/247; 544/242**

(58) **Field of Classification Search** ..... **544/242;**  
**514/247**

See application file for complete search history.

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(57)

**ABSTRACT**

This invention relates to novel endothelin receptor antagonists, derivatives, acceptable acid addition salts, solvates, hydrates and polymorphs thereof. The invention also provides compositions comprising a compound of this invention and the use of such compositions in methods of treating diseases and conditions that are beneficially treated by compounds that block the endothelin signaling pathway that leads to vasoconstriction and in particular those diseases or conditions beneficially treated by endothelin receptor antagonists.

**17 Claims, No Drawings**

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## ENDOTHELIN RECEPTOR ANTAGONISTS

### RELATED APPLICATION

This application claims the benefit of U.S. Provisional Application No. 60/884,654, filed on Jan. 12, 2007. The entire teachings of the above application is incorporated herein by reference.

### BACKGROUND OF THE INVENTION

This invention relates to novel endothelin receptor antagonists, derivatives, and pharmaceutically acceptable acid addition salts thereof. The invention also provides compositions comprising a compound of this invention and the use of such compositions in methods of treating diseases and conditions that are beneficially treated by compounds that block the endothelin signaling pathway that leads to vasoconstriction and in particular those diseases or conditions beneficially treated by endothelin receptor antagonists.

Bosentan is known by the chemical names N-[6-(2-hydroxyethoxy)-5-(2-methoxyphenoxy)-2-pyrimidin-2-yl-pyrimidin-4-yl]-4-tert-butyl-benzenesulfonamide and 4-tert-butyl-N-[6-(2-hydroxy-ethoxy)-5-(2-methoxy-phenoxy)-[2, 2']-bipyrimidin-4-yl]-benzenesulfonamide.

Bosentan is a tetrasubstituted pyrimidine derivative that was reported in U.S. Pat. No. 5,292,740 to be useful for treating circulatory disorders, such as hypertension. Bosentan is now known to be a dual endothelin receptor antagonist that blocks the binding of endothelin to both the ET<sub>A</sub> and ET<sub>B</sub> receptors.

Endothelin-1 (ET-1), a 21-amino acid peptide neurohormone, was first isolated and described in 1998 and is an extremely potent and long-acting vasoconstrictor (Itoh, Y et al, FEBS Lett 1988, 231:440). ET-1 causes vasoconstriction by binding to ET<sub>A</sub> and ET<sub>B</sub>, which are receptors in the endothelium and vascular smooth muscle. ET-1 levels are elevated in the plasma and lung tissue of patients with pulmonary arterial hypertension, which suggests that ET-1 has a pathogenic role in this disease. Bosentan is believed to work by competitively and specifically binding to ET<sub>A</sub> and ET<sub>B</sub> receptor sites in the endothelium and vascular smooth muscle with a slightly higher affinity for ET<sub>A</sub> than for ET<sub>B</sub>. This binding inhibits ET-1 from binding to ET<sub>A</sub> and/or ET<sub>B</sub>, which interferes with a signaling pathway that is responsible for causing vasoconstriction.

Bosentan has been approved by the Food and Drug Administration to treat the symptoms of pulmonary arterial hypertension, high blood pressure within the main artery that carries blood from the heart's right ventricle to the lungs. Bosentan has been shown to be effective in decreasing the constriction this artery, thereby increasing the supply of blood to the lungs and reducing the workload incurred by the heart.

Bosentan has been reported to have a half-life in humans of approximately five hours and is eliminated mainly through hepatic metabolism, followed by biliary excretion of three metabolites (see Center for Drug Evaluation and Research Approval Package for Application Number 21-290; Clinical Pharmacology and Biopharmaceutics Review; Aug. 16, 2001). One of these metabolites, hydroxybosentan, is active and responsible for up to 20% of the overall pharmaceutical properties of bosentan.

Bosentan is typically administered twice per day due to its short half-life. Multiple dosing can lead to compliance problems such as missed doses and overdosing when compensating for missed doses. Moreover, bosentan may cause liver damage due to biliary excretion and birth defects if taken

during pregnancy. Thus, bosentan cannot be safely administered to patients who are pregnant or who suffer from liver impairment. Less serious side-effects of bosentan include headache, nasopharyngitis, flushing, edema of the lower limbs, hypotension, and palpitations. Bosentan may also decrease the effectiveness of hormonal contraceptives, regardless of the route of administration. Bosentan may also irreversibly lower sperm count in some men. These side effects may be attributable to one or more of the metabolites of bosentan and/or overdosing due to poor compliance.

Despite the beneficial activities of bosentan, there is a continuing need for new compounds to treat the aforementioned diseases and conditions.

### SUMMARY OF THE INVENTION

This invention relates to novel endothelin receptor antagonists, derivatives, and pharmaceutically acceptable acid addition salts thereof. The invention also provides compositions comprising a compound of this invention and the use of such compositions in methods of treating diseases and conditions that are beneficially treated by compounds that block the endothelin signaling pathway that leads to vasoconstriction and in particular those diseases or conditions beneficially treated by endothelin receptor antagonists.

### DETAILED DESCRIPTION OF THE INVENTION

#### Definitions

The terms "ameliorate" and "treat" are used interchangeably and include both therapeutic treatment and prophylactic treatment (reducing the likelihood of development). Both terms mean decrease, suppress, attenuate, diminish, arrest, or stabilize the development or progression of a disease (e.g., a disease or disorder delineated herein), lessen the severity of the disease or improve the symptoms associated with the disease.

By "disease" is meant any condition or disorder that damages or interferes with the normal function of a cell, tissue, or organ.

It will be recognized that some variation of natural isotopic abundance occurs in a synthesized compound depending upon the origin of chemical materials used in the synthesis. Thus, a preparation of bosentan will inherently contain small amounts of deuterated isotopologues. The concentration of naturally abundant stable hydrogen isotopes, notwithstanding this variation, is small and immaterial with respect to the degree of stable isotopic substitution of compounds of this invention. See for instance Wada E et al., *Seikagaku* 1994, 66:15; Ganes L Z et al., *Comp Biochem Physiol Mol Integr Physiol* 1998, 119:725. In a compound of this invention, when a particular position is designated as having deuterium, it is understood that the abundance of deuterium at that position is substantially greater than the natural abundance of deuterium, which is 0.015%. A position designated as having deuterium typically has a minimum isotopic enrichment factor of at least 3000 (45% deuterium incorporation) at each atom designated as deuterium in said compound.

The term "isotopic enrichment factor" as used herein means the ratio between the isotopic abundance and the natural abundance of a specified isotope.

In other embodiments, a compound of this invention has an isotopic enrichment factor for each deuterium present at a site designated as a potential site of deuteration on the compound of at least 1000 (15% deuterium incorporation), at least 1500 (22.5% deuterium incorporation), at least 2000 (30% deuterium incorporation), at least 2500 (37.5% deuterium incor-

poration), at least 3000 (45% deuterium incorporation), at least 3500 (52.5% deuterium incorporation), at least 4000 (60% deuterium incorporation), at least 4500 (67.5% deuterium incorporation), at least 5000 (75% deuterium), at least 5500 (82.5% deuterium incorporation), at least 6000 (90% deuterium incorporation), at least 6333.3 (95% deuterium incorporation), at least 6466.7 (97% deuterium incorporation), at least 6600 (99% deuterium incorporation), or at least 6633.3 (99.5% deuterium incorporation). It is understood that the isotopic enrichment factor of each deuterium present at a site designated as a site of deuteration is independent of other deuterated sites. For example, if there are two sites of deuteration on a compound one site could be deuterated at 22.5% while the other could be deuterated at 37.5% and still be considered a compound wherein the isotopic enrichment factor is at least 1500 (22.5%).

In some embodiment, a compound of the invention, contains less than 10%, preferably less than 6%, and more preferably less than 3% of all other isotopologues combined, including a form that lacks any deuterium. In certain aspects, the compound contains less than "X%" of all other isotopologues combined, including a form that lacks any deuterium; where X is any number between 0 and 10 (e.g., 1, 0.5, 0.001) inclusive. Compositions of matter that contain greater than 10% of all other isotopologues combined are referred to herein as "mixtures" and must meet the parameters set forth below. These limits of isotopic composition and all references to isotopic composition herein, refer solely to the relative amounts of deuterium/hydrogen present in the active, free base form of the compound of Formula 1, and neither includes the isotopic composition of counterions, or of any other atoms.

In the compounds of this invention any atom not specifically designated as a particular isotope is meant to represent any stable isotope of that atom. Unless otherwise stated, when a position is designated specifically as "H" or "hydrogen", the position is understood to have hydrogen at its natural abundance isotopic composition.

The term "isotopologue" refers to a species that differs from a specific compound of this invention only in the isotopic composition thereof or of its ions.

The term "compound," as used herein, is also intended to include solvates or hydrates thereof.

A salt of a compound of this invention is formed between an acid and a basic group of the compound, such as an amino functional group or a base and an acidic group of the compound, such as a carboxyl functional group. According to another embodiment, the compound is a pharmaceutically acceptable acid addition salt.

The term "pharmaceutically acceptable," as used herein, refers to a component that is, within the scope of sound medical judgment, suitable for use in contact with the tissues of humans and other mammals without undue toxicity, irritation, allergic response and the like, and are commensurate with a reasonable benefit/risk ratio. A "pharmaceutically acceptable salt" means any non-toxic salt that, upon administration to a recipient, is capable of providing, either directly or indirectly, a compound or a prodrug of a compound of this invention. A "pharmaceutically acceptable counterion" is an ionic portion of a salt that is not toxic when released from the salt upon administration to a recipient.

Acids commonly employed to form pharmaceutically acceptable salts include inorganic acids such as hydrogen bisulfide, hydrochloric acid, hydrobromic acid, hydroiodic acid, sulfuric acid and phosphoric acid, as well as organic acids such as para-toluenesulfonic acid, salicylic acid, tartaric acid, bitartaric acid, ascorbic acid, maleic acid, besylic acid,

fumaric acid, gluconic acid, glucuronic acid, formic acid, glutamic acid, methanesulfonic acid, ethanesulfonic acid, benzenesulfonic acid, lactic acid, oxalic acid, para-bromophenylsulfonic acid, carbonic acid, succinic acid, citric acid, benzoic acid and acetic acid, as well as related inorganic and organic acids. Such pharmaceutically acceptable salts thus include sulfate, pyrosulfate, bisulfate, sulfite, bisulfite, phosphate, monohydrogenphosphate, dihydrogenphosphate, metaphosphate, pyrophosphate, chloride, bromide, iodide, acetate, propionate, decanoate, caprylate, acrylate, formate, isobutyrate, caprate, heptanoate, propiolate, oxalate, malonate, succinate, suberate, sebacate, fumarate, maleate, butyne-1,4-dioate, hexyne-1,6-dioate, benzoate, chlorobenzoate, methylbenzoate, dinitrobenzoate, hydroxybenzoate, methoxybenzoate, phthalate, terephthalate, sulfonate, xylene-sulfonate, phenylacetate, phenylpropionate, phenylbutyrate, citrate, lactate,  $\beta$ -hydroxybutyrate, glycolate, maleate, tartrate, methanesulfonate, propanesulfonate, naphthalene-1-sulfonate, naphthalene-2-sulfonate, mandelate and other salts. In one embodiment, pharmaceutically acceptable acid addition salts include those formed with mineral acids such as hydrochloric acid and hydrobromic acid, and especially those formed with organic acids such as maleic acid.

As used herein, the term "hydrate" means a compound which further includes a stoichiometric or non-stoichiometric amount of water bound by non-covalent intermolecular forces.

As used herein, the term "solvate" means a compound which further includes a stoichiometric or non-stoichiometric amount of solvent such as water, acetone, ethanol, methanol, dichloromethane, 2-propanol, or the like, bound by non-covalent intermolecular forces.

The compounds of the present invention may contain one or more asymmetric carbon atoms. As such, a compound of this invention can exist as the individual stereoisomers (enantiomers or diastereomers) as well a mixture of any possible stereoisomers. Accordingly, a compound of the present invention will include not only a stereoisomeric mixture, but also individual respective stereoisomers that are substantially free from other stereoisomers. The term "substantially free from other stereoisomers" as used herein means less than 25% of other stereoisomers, preferably less than 10% of other stereoisomers, more preferably less than 5% of other stereoisomers and most preferably less than 2% of other stereoisomers, or less than "X%" of other stereoisomers (wherein X is a number between 0 and 100, inclusive) are present. Methods of obtaining or synthesizing diastereomers are well known in the art and may be applied as practicable to final compounds or to starting material or intermediates. Other embodiments are those wherein the compound is an isolated compound. The term "at least X % enantiomerically enriched" as used herein means that at least X % of the compound is a single enantiomeric form, wherein X is a number between 0 and 100, inclusive.

The term "stable compounds", as used herein, refers to compounds which possess stability sufficient to allow for their manufacture and which maintain the integrity of the compound for a sufficient period of time to be useful for the purposes detailed herein (e.g., formulation into therapeutic products, intermediates for use in production of therapeutic compounds, isolatable or storable intermediate compounds, treating a disease or condition responsive to therapeutic agents).

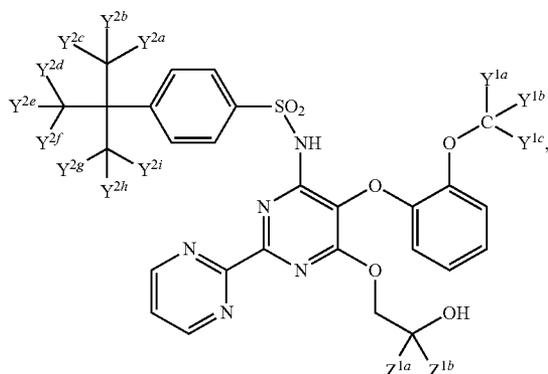
"D" refers to deuterium. "Stereoisomer" refers to both enantiomers and diastereomers. "tert" refers to tertiary. "Bu" refers to t-butyl.

## 5

Throughout this specification, a variable may be referred to generally (e.g., "each Y") or may be referred to specifically (e.g., Y<sup>1a</sup>, Y<sup>1b</sup>, Y<sup>1c</sup>, Y<sup>2a</sup>, Y<sup>2b</sup>, Y<sup>2c</sup>, Y<sup>2d</sup>, etc.). Unless otherwise indicated, when a variable is referred to generally, it is meant to include all specific embodiments of that particular variable.

## Therapeutic Compounds

The present invention provides a compound of Formula I:



or a pharmaceutically acceptable salt thereof, wherein:

each Y is independently selected from hydrogen or deuterium, and Y<sup>2a</sup> is additionally selected from OH;

each Z is independently selected from hydrogen, deuterium, or fluorine; and

at least one Y or Z is deuterium.

In one embodiment, each Y is the same. In a more specific embodiment, Y<sup>1a</sup>, Y<sup>1b</sup> and Y<sup>1c</sup> are simultaneously deuterium.

In another embodiment, Y<sup>2b</sup>, Y<sup>2c</sup>, Y<sup>2d</sup>, Y<sup>2e</sup>, Y<sup>2f</sup>, Y<sup>2g</sup>, Y<sup>2h</sup>, Y<sup>2i</sup> are the same. In still another embodiment, Y<sup>2a</sup>, Y<sup>2b</sup>, Y<sup>2c</sup>, Y<sup>2d</sup>, Y<sup>2e</sup>, Y<sup>2f</sup>, Y<sup>2g</sup>, Y<sup>2h</sup>, Y<sup>2i</sup> are the same.

In another embodiment, Y<sup>1a</sup>, Y<sup>1b</sup> and Y<sup>1c</sup> are simultaneously deuterium and Y<sup>2a</sup>, Y<sup>2b</sup>, Y<sup>2c</sup>, Y<sup>2d</sup>, Y<sup>2e</sup>, Y<sup>2f</sup>, Y<sup>2g</sup>, Y<sup>2h</sup>, Y<sup>2i</sup> are simultaneously hydrogen.

In another embodiment, Y<sup>1a</sup>, Y<sup>1b</sup> and Y<sup>1c</sup> are simultaneously deuterium; Y<sup>2a</sup> is OH; and Y<sup>2b</sup>, Y<sup>2c</sup>, Y<sup>2d</sup>, Y<sup>2e</sup>, Y<sup>2f</sup>, Y<sup>2g</sup>, Y<sup>2h</sup>, Y<sup>2i</sup> are simultaneously hydrogen.

In another embodiment, Y<sup>2a</sup>, Y<sup>2b</sup> and Y<sup>2c</sup> are simultaneously deuterium.

In another embodiment, Y<sup>2b</sup> and Y<sup>2c</sup> are simultaneously deuterium; and Y<sup>2a</sup> is OH.

In another embodiment, Y<sup>2a</sup>, Y<sup>2b</sup>, Y<sup>2c</sup>, Y<sup>2d</sup>, Y<sup>2e</sup> and Y<sup>2f</sup> are simultaneously deuterium.

In another embodiment, Y<sup>2b</sup>, Y<sup>2c</sup>, Y<sup>2d</sup>, Y<sup>2e</sup> and Y<sup>2f</sup> are simultaneously deuterium; and Y<sup>2a</sup> is OH.

In another embodiment, Y<sup>2a</sup>, Y<sup>2b</sup>, Y<sup>2c</sup>, Y<sup>2d</sup>, Y<sup>2e</sup>, Y<sup>2f</sup>, Y<sup>2g</sup>, Y<sup>2h</sup>, Y<sup>2i</sup> are simultaneously deuterium.

In another embodiment, Y<sup>2b</sup>, Y<sup>2c</sup>, Y<sup>2d</sup>, Y<sup>2e</sup>, Y<sup>2f</sup>, Y<sup>2g</sup>, Y<sup>2h</sup>, Y<sup>2i</sup> are simultaneously deuterium; and Y<sup>2a</sup> is OH.

In another embodiment, each Z is the same.

In another embodiment each of Z<sup>1a</sup> and Z<sup>1b</sup> are independently selected from fluorine or deuterium. In a more specific embodiment, Z<sup>1a</sup> and Z<sup>1b</sup> are simultaneously deuterium.

In another embodiment, each Y<sup>1</sup> is the same, each of Y<sup>2b</sup>, Y<sup>2c</sup>, Y<sup>2d</sup>, Y<sup>2e</sup>, Y<sup>2f</sup>, Y<sup>2g</sup>, Y<sup>2h</sup>, Y<sup>2i</sup> is the same; each Z is the same, and the compound (Cmpd) is selected from any one of the compounds described in Table 1 (below).

## 6

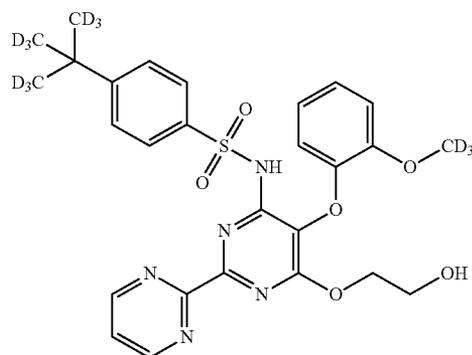
TABLE 1

Description of Exemplary Compounds of This Invention				
Cmpd	Each Y <sup>1</sup>	Y <sup>2a</sup>	Y <sup>2b</sup> -Y <sup>2i</sup>	Each Z
100	D	H	H	D
101	D	D	D	H
102	D	H	H	H
103	H	D	D	H
104	H	H	H	D
105	H	D	D	D
106	D	D	D	D
107	D	OH	H	D
108	D	OH	D	H
109	D	OH	H	H
110	H	OH	D	H
111	H	OH	H	D
112	H	OH	D	D
113	D	OH	D	D
114	D	H	H	F
115	D	D	D	F
116	H	D	D	F
117	D	OH	H	F
118	D	OH	D	F
119	H	OH	D	F

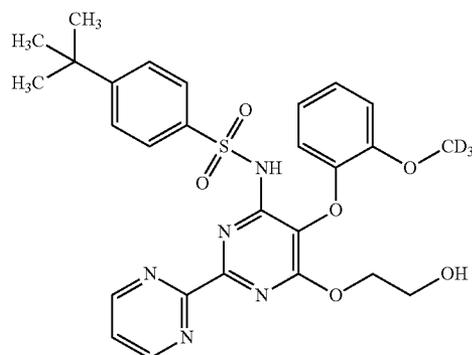
In another set of embodiments, any atom not designated as deuterium in any of the embodiments set forth above is present at its natural isotopic abundance.

In an even more specific embodiment, the compound of Formula I is selected from:

Compound 101

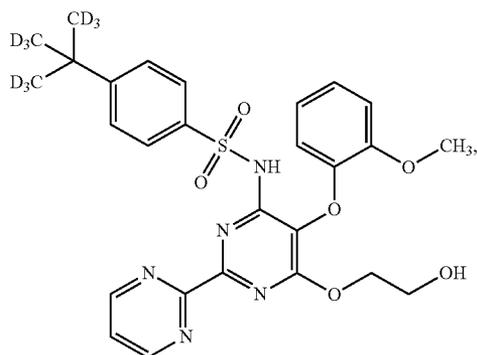


Compound 102

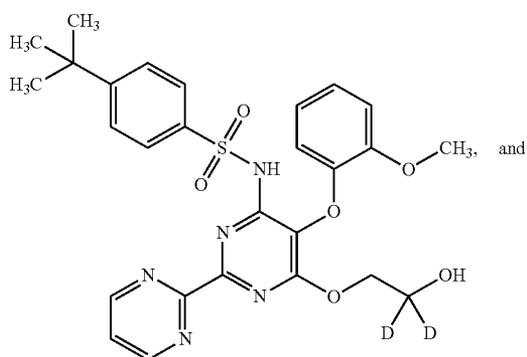


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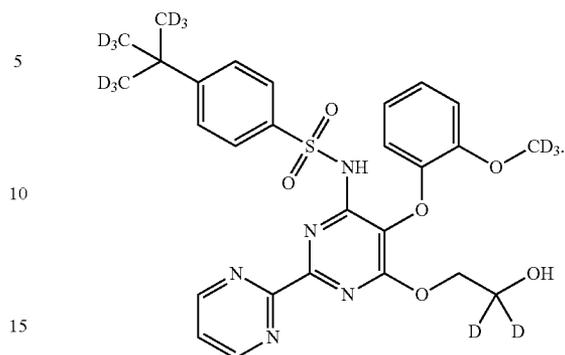
Compound 103



Compound 104

8  
-continued

Compound 106

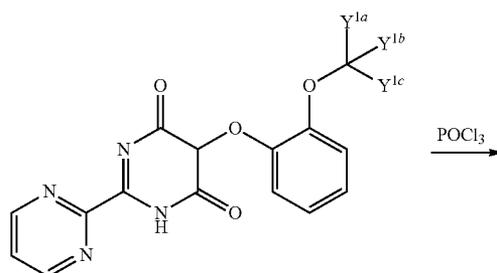
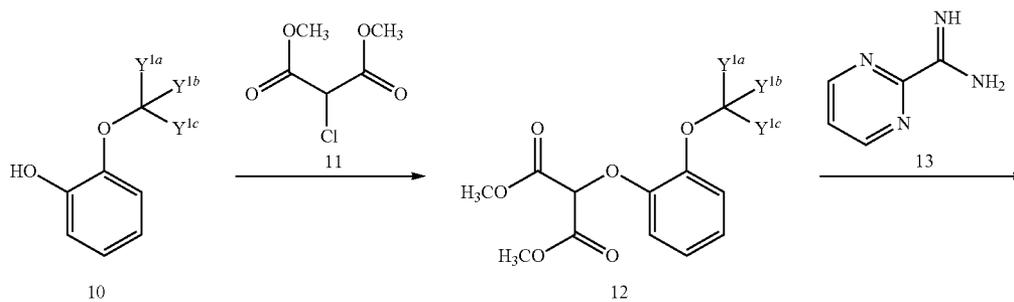


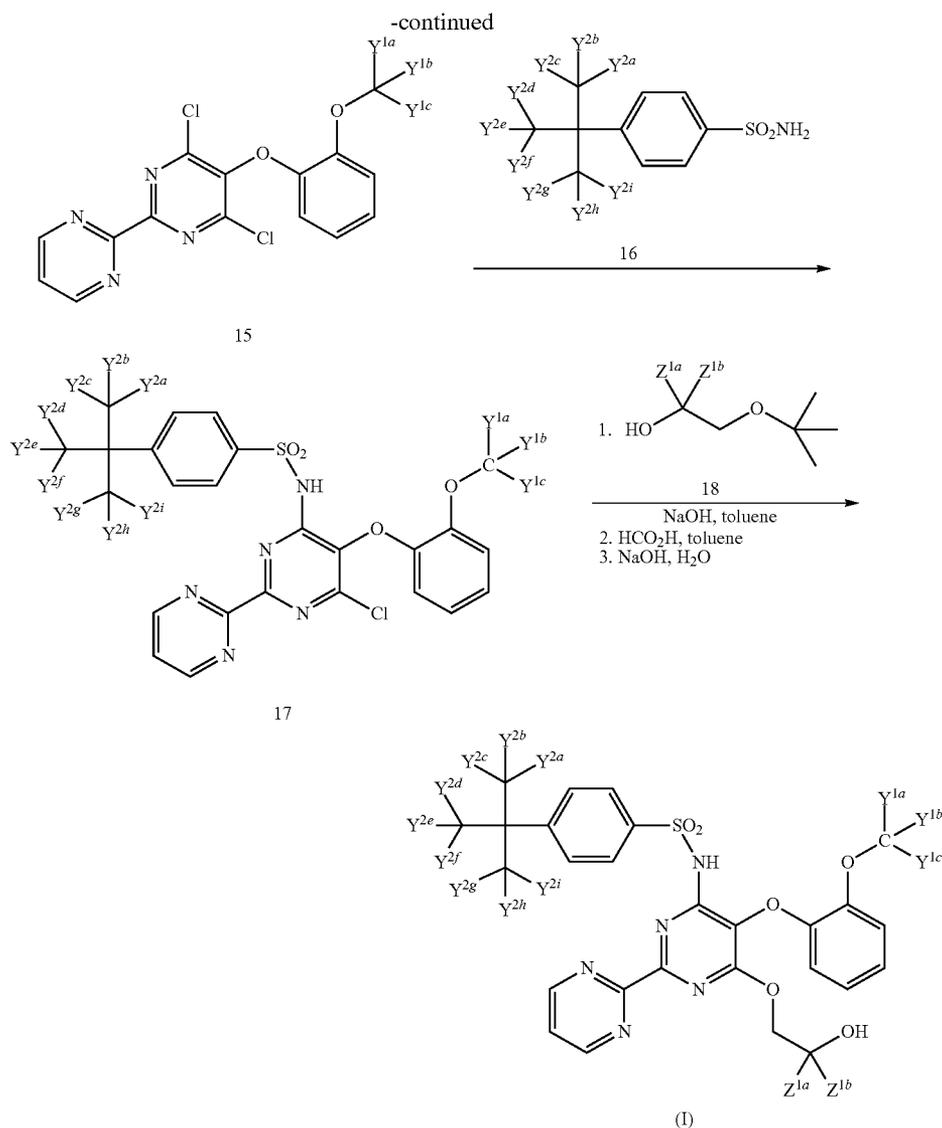
The synthesis of compounds of the formulae herein (e.g.,  
 20 Formula 1) can be readily achieved by synthetic chemists of  
 ordinary skill. Relevant procedures and intermediates are dis-  
 closed, for instance, in U.S. Pat. Nos. 5,292,740 and 6,139,  
 971; PCT patent publication WO2001005120; and Har-  
 rington, P J et al, Org Process Res Dev, 6(2): 120. Such  
 25 methods can be carried out utilizing corresponding deuter-  
 ated reagents to synthesize the compounds delineated herein,  
 or invoking standard synthetic protocols known in the art for  
 introducing isotopic atoms to a chemical structure.

## 30 Exemplary Synthesis

A convenient method for producing compounds of the  
 formulae herein (e.g., Formula 1) is illustrated in Scheme 1.

## Scheme 1

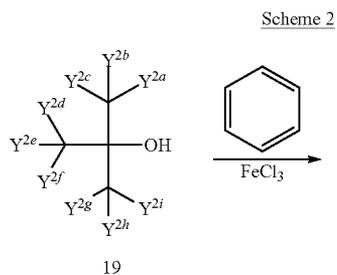




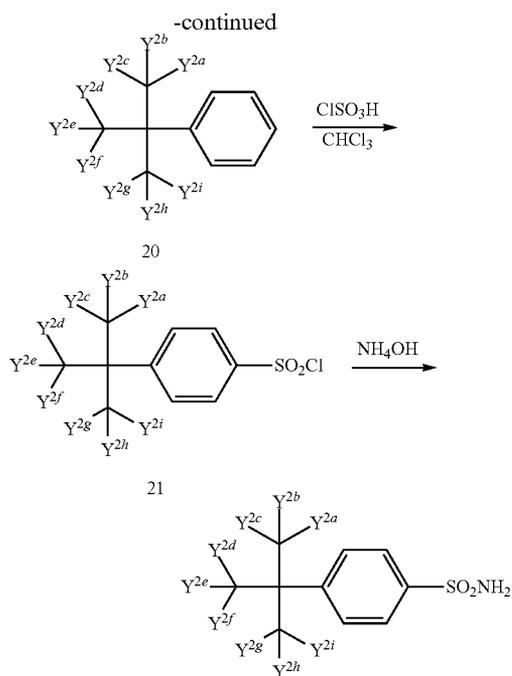
The exemplary synthesis depicted in Scheme 1 involves condensation of 2-chloromalic acid dimethyl ester 11 with an appropriately deuterated guaiacol 10 to afford the 2-(2-methoxyphenoxy)malonic acid dimethyl ester 12, followed by cyclization of 12 with 13 to afford the corresponding bipyrimidinedione 14. This compound 14 is treated with refluxing  $\text{POCl}_3$  to afford the dichlorobipyrimidine 15, which is subsequently treated with an appropriately deuterated 4-tert-butylphenylsulfonamide 16,  $\text{K}_2\text{CO}_3$  and tetrabutylammonium bromide (TBAB) in toluene to provide the mono-substituted sulfonamide 17. Compound 17 is thereafter treated with an appropriately deuterated or fluorinated ethylene glycol mono-tert-butyl ether 18 and NaOH in hot toluene to afford the tert-butyl ether protected intermediate, which is thereafter deprotected by reaction with formic acid to afford the formate ester. This ester is then hydrolyzed with NaOH in a mixture of water and ethanol, to afford the target compounds of Formula 1. Such compounds of Formula 1 are readily purified by crystallization, comprising heating the crude product into a mixture of ethanol and water to afford a solution and thereafter allowing the solution to cool. Other

approaches to synthesizing compounds of the formulae herein (e.g., Formula 1) can readily be adapted from references cited herein. Variations of these procedures and their optimization are within the skill of the ordinary practitioner.

An appropriately deuterated 4-tert-butylphenylsulfonamide 16 can be synthesized as in Scheme 2.



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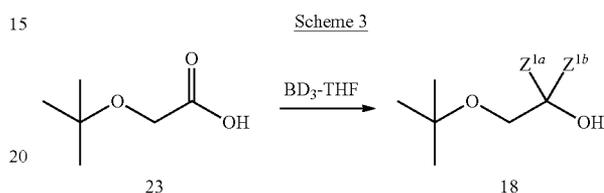


An appropriately deuterated tert-butanol, such as commercially available d9-tert-butanol, is reacted with benzene in the presence of ferric chloride (see Potts, W M et al, J Am Chem

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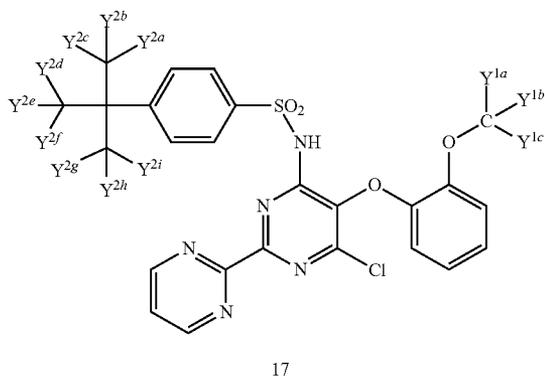
Soc 1939, 61:2553) to provide 20, which is then reacted with chlorosulfonic acid to provide the sulfonyl chloride 21 (Gayen, S et al, Internet Electronic J Mol Design 2005, 4:556). The sulfonyl chloride is converted to the sulfonamide 5 16 according to the method of Morimoto, H et al, J Med Chem, 2001, 44:3355. Although not shown in Scheme 2, the sulfonic acid analog of compound 21 (compound 23) is readily available via hydrolysis of 21 in aqueous dioxane according to the method of Tonnet, M L et al, Aus J Chem 10 1971, 24:703.

An appropriately deuterated ethyleneglycol mono-tert-butyl ether 18 may be prepared as shown in Scheme 3.

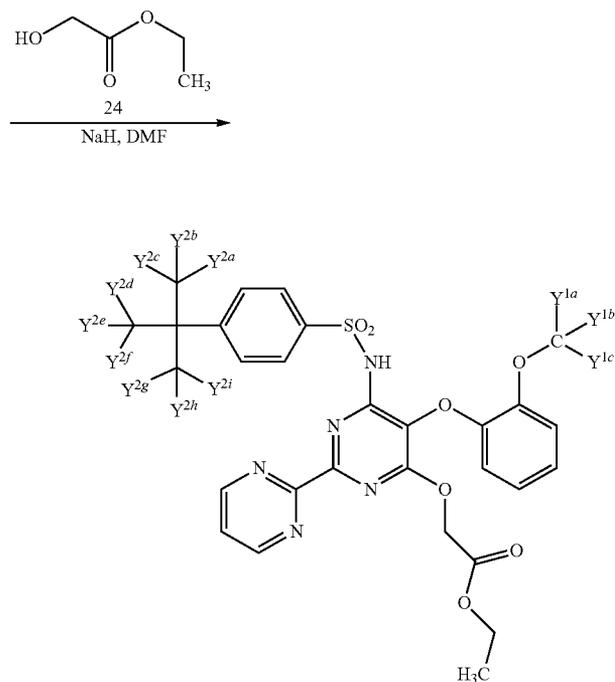


Commercially available 2-tert-butoxyacetic acid (22) is reduced with d3-borane according to the method of Yoon, N M et al., J Org Chem 1973, 38:2786 to produce the corresponding deuterated ethyleneglycol mono-tert-butyl ether 18.

An alternate route to a compound of formula 1, wherein each Z is deuterium is shown in Scheme 4.



Scheme 4

LiAlD<sub>4</sub>NaOH  
H<sub>2</sub>O, THF



ing Oral and Parenteral Drug Delivery: Basic Principles and Biological Examples," Kishor M. Wasan, ed. Wiley-Interscience, 2006.

Another known method of enhancing bioavailability is the use of an amorphous form of a compound of this invention optionally formulated with a poloxamer, such as LUTROL™ and PLURONIC™ (BASF Corporation), or block copolymers of ethylene oxide and propylene oxide. See U.S. Pat. No. 7,014,866; and United States patent publications 20060094744 and 20060079502.

The pharmaceutical compositions of the invention include those suitable for oral, rectal, nasal, topical (including buccal and sublingual), vaginal or parenteral (including subcutaneous, intramuscular, intravenous and intradermal) administration. In certain embodiments, the compound of the formulae herein is administered transdermally (e.g., using a transdermal patch or iontophoretic techniques). Other formulations may conveniently be presented in unit dosage form, e.g., tablets, sustained release capsules, and in liposomes, and may be prepared by any methods well known in the art of pharmacy. See, for example, Remington's Pharmaceutical Sciences, Mack Publishing Company, Philadelphia, Pa. (17th ed. 1985).

Such preparative methods include the step of bringing into association with the molecule to be administered ingredients such as the carrier that constitutes one or more accessory ingredients. In general, the compositions are prepared by uniformly and intimately bringing into association the active ingredients with liquid carriers, liposomes or finely divided solid carriers, or both, and then, if necessary, shaping the product.

In certain embodiments, the compound is administered orally. Compositions of the present invention suitable for oral administration may be presented as discrete units such as capsules, sachets, or tablets each containing a predetermined amount of the active ingredient; a powder or granules; a solution or a suspension in an aqueous liquid or a non-aqueous liquid; an oil-in-water liquid emulsion; a water-in-oil liquid emulsion; packed in liposomes; or as a bolus, etc. Soft gelatin capsules can be useful for containing such suspensions, which may beneficially increase the rate of compound absorption.

In the case of tablets for oral use, carriers that are commonly used include lactose and corn starch. Lubricating agents, such as magnesium stearate, are also typically added. For oral administration in a capsule form, useful diluents include lactose and dried cornstarch. When aqueous suspensions are administered orally, the active ingredient is combined with emulsifying and suspending agents. If desired, certain sweetening and/or flavoring and/or coloring agents may be added.

Compositions suitable for oral administration include lozenges comprising the ingredients in a flavored basis, usually sucrose and acacia or tragacanth; and pastilles comprising the active ingredient in an inert basis such as gelatin and glycerin, or sucrose and acacia.

Compositions suitable for parenteral administration include aqueous and non-aqueous sterile injection solutions which may contain anti-oxidants, buffers, bacteriostats and solutes which render the formulation isotonic with the blood of the intended recipient; and aqueous and non-aqueous sterile suspensions which may include suspending agents and thickening agents. The formulations may be presented in unit-dose or multi-dose containers, for example, sealed ampules and vials, and may be stored in a freeze dried (lyophilized) condition requiring only the addition of the sterile liquid carrier, for example water for injections, immediately

prior to use. Extemporaneous injection solutions and suspensions may be prepared from sterile powders, granules and tablets.

Such injection solutions may be in the form, for example, of a sterile injectable aqueous or oleaginous suspension. This suspension may be formulated according to techniques known in the art using suitable dispersing or wetting agents (such as, for example, Tween 80) and suspending agents. The sterile injectable preparation may also be a sterile injectable solution or suspension in a non-toxic parenterally-acceptable diluent or solvent, for example, as a solution in 1,3-butenediol. Among the acceptable vehicles and solvents that may be employed are mannitol, water, Ringer's solution and isotonic sodium chloride solution. In addition, sterile, fixed oils are conventionally employed as a solvent or suspending medium. For this purpose, any bland fixed oil may be employed including synthetic mono- or diglycerides. Fatty acids, such as oleic acid and its glyceride derivatives are useful in the preparation of injectables, as are natural pharmaceutically-acceptable oils, such as olive oil or castor oil, especially in their polyoxyethylated versions. These oil solutions or suspensions may also contain a long-chain alcohol diluent or dispersant.

The pharmaceutical compositions of this invention may be administered in the form of suppositories for rectal administration. These compositions can be prepared by mixing a compound of this invention with a suitable non-irritating excipient which is solid at room temperature but liquid at the rectal temperature and therefore will melt in the rectum to release the active components. Such materials include, but are not limited to, cocoa butter, beeswax and polyethylene glycols.

The pharmaceutical compositions of this invention may be administered by nasal aerosol or inhalation. Such compositions are prepared according to techniques well-known in the art of pharmaceutical formulation and may be prepared as solutions in saline, employing benzyl alcohol or other suitable preservatives, absorption promoters to enhance bioavailability, fluorocarbons, and/or other solubilizing or dispersing agents known in the art. See, e.g.: Rabinowitz J D and Zafaroni A C, U.S. Pat. No. 6,803,031, assigned to Alexza Molecular Delivery Corporation.

Topical administration of the pharmaceutical compositions of this invention is especially useful when the desired treatment involves areas or organs readily accessible by topical application. For topical application to the skin, the pharmaceutical composition should be formulated with a suitable ointment containing the active components suspended or dissolved in a carrier. Carriers for topical administration of the compounds of this invention include, but are not limited to, mineral oil, liquid petroleum, white petroleum, propylene glycol, polyoxyethylene polyoxypropylene compound, emulsifying wax, and water. Alternatively, the pharmaceutical composition can be formulated with a suitable lotion or cream containing the active compound suspended or dissolved in a carrier. Suitable carriers include, but are not limited to, mineral oil, sorbitan monostearate, polysorbate 60, cetyl esters wax, cetaryl alcohol, 2-octyldodecanol, benzyl alcohol, and water. The pharmaceutical compositions of this invention may also be topically applied to the lower intestinal tract by rectal suppository formulation or in a suitable enema formulation. Topically-transdermal patches and iontophoretic administration are also included in this invention.

Application of the subject therapeutics may be local, so as to be administered at the site of interest. Various techniques can be used for providing the subject compositions at the site of interest, such as injection, use of catheters, trocars, projec-

tiles, pluronic gel, stents, sustained drug release polymers or other device which provides for internal access.

Thus, according to yet another embodiment, the compounds of this invention may be incorporated into compositions for coating an implantable medical device, such as prostheses, artificial valves, vascular grafts, stents, or catheters. Suitable coatings and the general preparation of coated implantable devices are known in the art and are exemplified in U.S. Pat. Nos. 6,099,562; 5,886,026; and 5,304,121. The coatings are typically biocompatible polymeric materials such as a hydrogel polymer, polymethylsiloxane, polycaprolactone, polyethylene glycol, polylactic acid, ethylene vinyl acetate, and mixtures thereof. The coatings may optionally be further covered by a suitable topcoat of fluorosilicone, polysaccharides, polyethylene glycol, phospholipids or combinations thereof to impart controlled release characteristics in the composition. Coatings for invasive devices are to be included within the definition of pharmaceutically acceptable carrier, adjuvant or vehicle, as those terms are used herein.

According to another embodiment, the invention provides a method of coating an implantable medical device comprising the step of contacting said device with the coating composition described above. It will be obvious to those skilled in the art that the coating of the device will occur prior to implantation into a mammal.

According to another embodiment, the invention provides a method of impregnating an implantable drug release device comprising the step of contacting said drug release device with a compound or composition of this invention. Implantable drug release devices include, but are not limited to, biodegradable polymer capsules or bullets, non-degradable, diffusible polymer capsules and biodegradable polymer wafers.

According to another embodiment, the invention provides an implantable medical device coated with a compound or a composition comprising a compound of this invention, such that said compound is therapeutically active.

According to another embodiment, the invention provides an implantable drug release device impregnated with or containing a compound or a composition comprising a compound of this invention, such that said compound is released from said device and is therapeutically active.

Where an organ or tissue is accessible because of removal from the patient, such organ or tissue may be bathed in a medium containing a composition of this invention, a composition of this invention may be painted onto the organ, or a composition of this invention may be applied in any other convenient way.

In another embodiment, a composition of the present invention further comprises a second therapeutic agent. The second therapeutic agent includes any compound or therapeutic agent known to have or that demonstrates advantageous properties when administered with an endothelin antagonist. Such agents are the same as those indicated as useful in combination with bosentan, including, but not limited to those described in U.S. Pat. Nos. 6,635,648; 6,586,391; 6,869,970; 5,945,448; and 5,696,116; and in PCT patent publications WO 2005101608; WO 2004082637; WO 2004017993; and WO 2002074034. Preferably, the second therapeutic agent is an agent useful in the treatment or prevention of a disease or condition selected from pulmonary arterial hypertension, erectile dysfunction, chronic obstructive pulmonary disease, chronic pelvic pain syndrome type III, primary dysmenorrhea, pre-eclampsia, thalassemia, skin fibrosis, hypertension, hypoxia-induced pulmonary artery hypertension, interstitial lung disease, scleroderma, idiopathic pulmonary fibrosis, pulmonary hypertension, chronic

thromboembolic pulmonary hypertension, Eisenmenger's syndrome, benign prostatic hyperplasia, high blood pressure, coronary disorders, cardiac insufficiency, renal cerebral ischemia, cardiac infarct, migraine, subarachnoid haemorrhage, Raynaud syndrome, skin cancer, atherosclerosis, sickle cell disease, digital ulcers, and others, including, but not limited to those disclosed in U.S. Pat. No. 6,635,648; U.S. Pat. No. 5,292,740; U.S. Pat. No. 6,586,391; U.S. Pat. No. 6,869,970; U.S. Pat. No. 5,945,448; U.S. Pat. No. 5,696,116; WO 2005101608; WO 2004082637; WO 2004017993; WO 2002074034; and WO 9638173A1.

In one embodiment, the second therapeutic agent is selected from a prostacyclin, a prostacyclin derivative, a second endothelin antagonist, a dopaminergic agonist, a phosphodiesterase inhibitor, a sympathetic nervous system antagonist, an inhibitor of endothelin converting enzyme, an antihypertensive, an alpha-adrenergic blocker, or an angiotensin II receptor antagonist.

In another embodiment, the second therapeutic agent is selected from a phosphodiesterase inhibitor, such as sildenafil.

In another embodiment, the second therapeutic agent is selected from a prostacyclin or prostacyclin derivative, such as epoprostenol, treprostinil, iloprost, or beraprost.

In another embodiment, the invention provides separate dosage forms of a compound of this invention and a second therapeutic agent that are associated with one another. The term "associated with one another" as used herein means that the separate dosage forms are packaged together or otherwise attached to one another such that it is readily apparent that the separate dosage forms are intended to be sold and administered together (within less than 24 hours of one another, consecutively or simultaneously).

In the pharmaceutical compositions of the invention, the compound of the present invention is present in an effective amount. As used herein, the term "effective amount" refers to an amount which, when administered in a proper dosing regimen, is sufficient to treat (therapeutically or prophylactically) the target disorder. For example, an effective amount is sufficient to reduce or ameliorate the severity, duration or progression of the disorder being treated, prevent the advancement of the disorder being treated, cause the regression of the disorder being treated, or enhance or improve the prophylactic or therapeutic effect(s) of another therapy.

The interrelationship of dosages for animals and humans (based on milligrams per meter squared of body surface) is described in Freireich et al., (1966) Cancer Chemother. Rep 50: 219. Body surface area may be approximately determined from height and weight of the patient. See, e.g., Scientific Tables, Geigy Pharmaceuticals, Ardsley, N.Y., 1970, 537. An effective amount of a compound of this invention to be administered to a normal adult human can range from about 1 mg to about 1000 mg/day, more preferably from about 5 mg to about 500 mg/day, more preferably from about 25 mg/ to about 250 mg/day. Daily amounts of a compound of this invention will be administered in from one to about nine unit dosages per day. Effective doses will also vary, as recognized by those skilled in the art, depending on the diseases treated, the severity of the disease, the route of administration, the sex, age and general health condition of the patient, excipient usage, the possibility of co-usage with other therapeutic treatments such as use of other agents and the judgment of the treating physician.

For pharmaceutical compositions that comprise a second therapeutic agent, an effective amount of the second therapeutic agent is between about 20% and 100% of the dosage normally utilized in a monotherapy regime using just that

agent. Preferably, an effective amount is between about 70% and 100% of the normal monotherapeutic dose. The normal monotherapeutic dosages of these second therapeutic agents are well known in the art. See, e.g., Wells et al., eds., *Pharmacotherapy Handbook*, 2nd Edition, Appleton and Lange, Stamford, Conn. (2000); PDR *Pharmacopoeia*, Tarascon Pocket *Pharmacopoeia 2000*, Deluxe Edition, Tarascon Publishing, Loma Linda, Calif. (2000), each of which references are incorporated herein by reference in their entirety.

It is expected that some of the second therapeutic agents referenced above will act synergistically with the compounds of this invention. When this occurs, it will allow the effective dosage of the second therapeutic agent and/or the compound of this invention to be reduced from that required in a monotherapy. This has the advantage of minimizing toxic side effects of either the second therapeutic agent of a compound of this invention, synergistic improvements in efficacy, improved ease of administration or use and/or reduced overall expense of compound preparation or formulation.

#### Methods of Treatment

According to another embodiment, the invention provides a method of treating a disease that is beneficially treated by bosentan comprising the step of administering to a subject in need thereof an effective amount of a compound or a composition of this invention. Such conditions and diseases are well known in the art and include but are not limited to pulmonary arterial hypertension, erectile dysfunction, chronic obstructive pulmonary disease, chronic pelvic pain syndrome type III, primary dysmenorrhea, pre-eclampsia, thalassemia, skin fibrosis, hypertension, hypoxia-induced pulmonary artery hypertension, interstitial lung disease, scleroderma, idiopathic pulmonary fibrosis, pulmonary hypertension, chronic thromboembolic pulmonary hypertension, Eisenmenger's syndrome, benign prostatic hyperplasia, high blood pressure, coronary disorders, cardiac insufficiency, renal cerebral ischemia, cardiac infarct, migraine, subarachnoid haemorrhage, Raynaud syndrome, skin cancer, atherosclerosis, sickle cell disease, and digital ulcers.

In a more specific embodiment, the method of this invention is used to treat a disease or condition selected from pulmonary arterial hypertension, erectile dysfunction, skin fibrosis, interstitial lung disease, scleroderma, chronic thromboembolic pulmonary hypertension, Eisenmenger's syndrome, skin cancer, sickle cell disease, digital ulcers.

In an even more specific embodiment, the method of this invention is used to treat a disease or condition selected from pulmonary hypertension (including pediatric subjects, subjects with class II disease who are mildly symptomatic, patients with sickle cell anemia, and patients with chronic thromboembolic pulmonary hypertension), idiopathic pulmonary fibrosis, digital ulcerations in patients with scleroderma, and interstitial lung disease in patients with scleroderma.

Methods delineated herein include those wherein the subject is identified as in need of a particular stated treatment. Identifying a subject in need of such treatment can be in the judgment of a subject or a health care professional and can be subjective (e.g. opinion) or objective (e.g. measurable by a test or diagnostic method).

In another embodiment, the invention provides a method of modulating the interaction between ET-1 and its receptors in a cell, said modulation comprising contacting a cell with one or more compounds of any of the formulae herein.

In another embodiment, the above method of treatment comprises the further step of co-administering to the patient one or more second therapeutic agents. The choice of second therapeutic agent may be made from any second therapeutic

agent known to be useful for co-administration with bosentan. Examples of such agents and the conditions and diseases for which each may be used in conjunction with a compound of this invention are described in PCT publications WO 04017993A1 and WO 9638173A1. Preferably, the second therapeutic agent is an agent useful in the treatment or prevention of a disease or condition selected from pulmonary arterial hypertension, brain edema or Eisenmenger's syndrome.

In one embodiment, the second therapeutic agent is selected from a prostacyclin or a prostacyclin analogue and the condition treated is pulmonary arterial hypertension. In a more specific embodiment, the prostacyclin or prostacyclin analogue is selected from epoprostenol, treprostinil, iloprost, or beraprost.

In another embodiment, the second therapeutic agent is a phosphodiesterase V inhibitor and the condition treated is selected from pulmonary arterial hypertension and Eisenmenger's syndrome. In a more specific embodiment, the phosphodiesterase V inhibitor is sildenafil.

The term "co-administered" as used herein means that the second therapeutic agent may be administered together with a compound of this invention as part of a single dosage form (such as a composition of this invention comprising a compound of the invention and an second therapeutic agent as described above) or as separate, multiple dosage forms. Alternatively, the additional agent may be administered prior to, consecutively with, or following the administration of a compound of this invention. In such combination therapy treatment, both the compounds of this invention and the second therapeutic agent(s) are administered by conventional methods. The administration of a composition of this invention comprising both a compound of the invention and a second therapeutic agent to a subject does not preclude the separate administration of that same therapeutic agent, any other second therapeutic agent or any compound of this invention to said subject at another time during a course of treatment.

Effective amounts of these second therapeutic agents are well known to those skilled in the art and guidance for dosing may be found in patents and published patent applications referenced herein, as well as in Wells et al., eds., *Pharmacotherapy Handbook*, 2nd Edition, Appleton and Lange, Stamford, Conn. (2000); PDR *Pharmacopoeia*, Tarascon Pocket *Pharmacopoeia 2000*, Deluxe Edition, Tarascon Publishing, Loma Linda, Calif. (2000), and other medical texts. However, it is well within the skilled artisan's purview to determine the second therapeutic agent's optimal effective-amount range.

In one embodiment of the invention where a second therapeutic agent is administered to a subject, the effective amount of the compound of this invention is less than its effective amount would be where the second therapeutic agent is not administered. In another embodiment, the effective amount of the second therapeutic agent is less than its effective amount would be where the compound of this invention is not administered. In this way, undesired side effects associated with high doses of either agent may be minimized. Other potential advantages (including without limitation improved dosing regimens and/or reduced drug cost) will be apparent to those of skill in the art.

In yet another aspect, the invention provides the use of a compound of formula I alone or together with one or more of the above-described second therapeutic agents in the manufacture of a medicament, either as a single composition or as separate dosage forms, for treatment or prevention in a subject of a disease, disorder or symptom set forth above.

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Another aspect of the invention is a compound of the formulae herein for use in the treatment or prevention in a subject of a disease, disorder or symptom thereof delineated herein. Diagnostic Methods and Kits

The compounds and compositions of this invention are also useful as reagents in methods for determining the concentration of bosentan in solution or biological sample such as plasma, examining the metabolism of bosentan and other analytical studies.

According to one embodiment, the invention provides a method of determining the concentration, in a solution or a biological sample, of bosentan, comprising the steps of:

- adding a known concentration of a compound of Formula I to the solution of biological sample;
- subjecting the solution or biological sample to a measuring device that distinguishes bosentan from a compound of Formula I;
- calibrating the measuring device to correlate the detected quantity of the compound of Formula I with the known concentration of the compound of Formula I added to the biological sample or solution; and
- measuring the quantity of bosentan in the biological sample with said calibrated measuring device; and
- determining the concentration of bosentan in the solution of sample using the correlation between detected quantity and concentration obtained for a compound of Formula I.

Measuring devices that can distinguish bosentan from the corresponding compound of Formula I include any measuring device that can distinguish between two compounds that differ from one another only in isotopic abundance. Exemplary measuring devices include a mass spectrometer, NMR spectrometer, or IR spectrometer.

In another embodiment, the invention provides a method of evaluating the metabolic stability of a compound of Formula I comprising the steps of contacting the compound of Formula I with a metabolizing enzyme source for a period of time and comparing the amount of the compound of Formula I with the metabolic products of the compound of Formula I after the period of time.

In a related embodiment, the invention provides a method of evaluating the metabolic stability of a compound of Formula I in a patient following administration of the compound of Formula I. This method comprises the steps of obtaining a serum, urine or feces sample from the patient at a period of time following the administration of the compound of Formula I to the subject; and comparing the amount of the compound of Formula I with the metabolic products of the compound of Formula I in the serum, urine or feces sample.

The present invention also provides kits for use to treat a condition or disease selected from pulmonary arterial hypertension, scleroderma, chronic thromboembolic pulmonary hypertension, and idiopathic pulmonary fibrosis. These kits comprise (a) a pharmaceutical composition comprising a compound of Formula I or a salt thereof; or a prodrug, or a salt of a prodrug thereof; or a hydrate, solvate, or polymorph thereof, wherein said pharmaceutical composition is in a container; and (b) instructions describing a method of using the pharmaceutical composition to treat a condition or disease selected from pulmonary arterial hypertension, scleroderma, chronic thromboembolic pulmonary hypertension, and idiopathic pulmonary fibrosis.

The container may be any vessel or other sealed or sealable apparatus that can hold said pharmaceutical composition. Examples include bottles, divided or multi-chambered holders bottles, wherein each division or chamber comprises a single dose of said composition, a divided foil packet wherein

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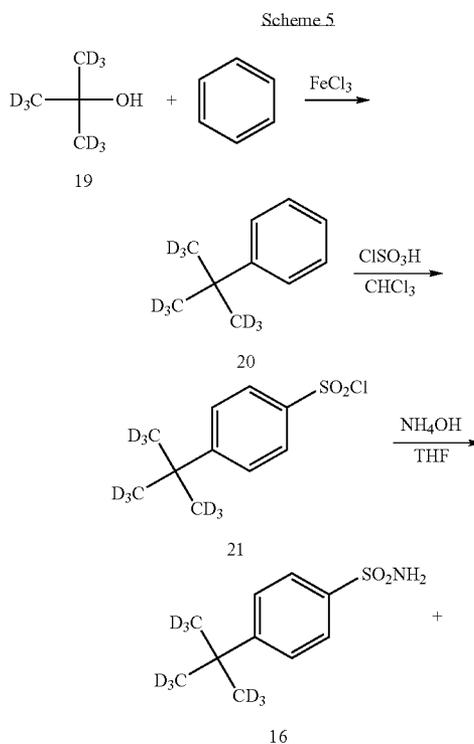
each division comprises a single dose of said composition, or a dispenser that dispenses single doses of said composition. The container can be in any conventional shape or form as known in the art which is made of a pharmaceutically acceptable material, for example a paper or cardboard box, a glass or plastic bottle or jar, a re-sealable bag (for example, to hold a "refill" of tablets for placement into a different container), or a blister pack with individual doses for pressing out of the pack according to a therapeutic schedule. The container employed can depend on the exact dosage form involved, for example a conventional cardboard box would not generally be used to hold a liquid suspension. It is feasible that more than one container can be used together in a single package to market a single dosage form. For example, tablets may be contained in a bottle, which is in turn contained within a box. Preferably, the container is a blister pack.

The kits of this invention may also comprise a device to administer or to measure out a unit dose of the pharmaceutical composition. Such device may include an inhaler if said composition is an inhalable composition; a syringe and needle if said composition is an injectable composition; a syringe, spoon, pump, or a vessel with or without volume markings if said composition is an oral liquid composition; or any other measuring or delivery device appropriate to the dosage formulation of the composition present in the kit.

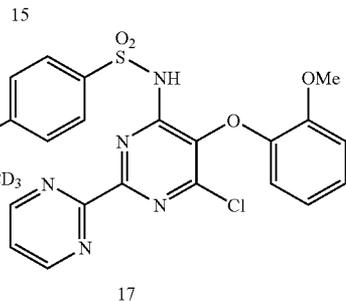
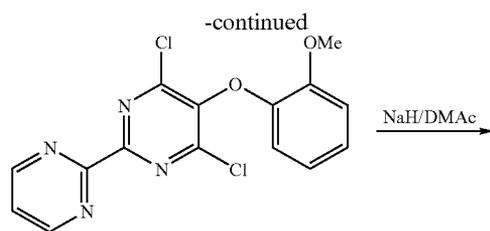
In certain embodiment, the kits of this invention may comprise in a separate vessel of container a pharmaceutical composition comprising a second therapeutic agent, such as one of those listed above for use for co-administration with a compound of this invention.

## SYNTHETIC EXAMPLES

The synthesis described below and illustrated in Scheme 5 provided key intermediates for the preparation of compounds of this invention.



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Example 1

Synthesis of 4- $d_9$ -tert-butyl-N-(6-chloro-5-(2-methoxyphenoxy)-2,2'-bipyrimidin-4-yl)benzenesulfonamide (Compound 17)

Step 1. Synthesis of  $d_9$ -tert-Butyl-benzene (Compound 20) A solution of  $d_9$ -tert-butanol, 19 (25.0 g, 0.3012 mol, 1.0 equiv) in benzene (20 mL) was added over 0.25 hr to a suspension of iron(III) chloride (48.8 g, 0.3012 mol, 1.0 equiv) in benzene (175 mL, 1.9615 mol, 6.5 equiv). Mild cooling was used to maintain the reaction temperature at 22-27° C. during the addition (benzene (5 mL) was used to rinse the addition funnel). The suspension was stirred at room temperature for 7.5 hr then diluted with hexanes (200 mL). The mixture was filtered through a pad of silica gel (0.5 in) topped with Celite (0.5 in), washing the pad with hexanes (700 mL). The filtrate was concentrated under reduced pressure (bath temperature about 20° C.) to give a yellow liquid. The crude product was distilled to give 19.8 g (46%) of  $d_9$ -tert-butyl-benzene, 20 as a colorless liquid, bp 55-60° C., 35-37 Torr).

Step 2. Synthesis of 4- $d_9$ -tert-Butyl-benzene-1-sulfonyl chloride (Compound 21) A solution of  $d_9$ -tert-butyl-benzene, 20 (19.3 g, 0.135 mol, 1.0 equiv) in chloroform (250 mL) was cooled to -5° C. in an ice/brine bath. Chlorosulfonic acid (44.1 g, 25 mL, 0.377 mol, 2.8 equiv) was added dropwise over 0.75 hr, maintaining the reaction temperature at -5° C. ± 1° C. The ice/brine bath was replaced with an ice/water bath and the mixture was stirred at 0-2° C. for 1 hr, then allowed to warm to room temperature and stirred 1 hr. The turbid mixture was poured cautiously onto ice (600 mL). The biphasic mixture was diluted with dichloromethane (200 mL). The organic phase was washed with water (500 mL), brine (2x500 mL), dried (Na<sub>2</sub>SO<sub>4</sub>), filtered and the filtrate concentrated under reduced pressure to give an oily solid. The oily solid was placed under high vacuum for 1 hr to give 26.1 g (80%) of crude 4- $d_9$ -tert-butyl-benzene-1-sulfonyl chloride, 21. The crude product was used without further purification.

Step 3. Synthesis of 4- $d_9$ -tert-Butyl-benzenesulfonamide (Compound 16) A mixture of about 15N ammonium hydroxide (24.6 mL, 0.3703 mol, 3.5 equiv) and tetrahydrofuran

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(200 mL) was cooled to about 2° C. and a solution of crude 4- $d_9$ -tert-butyl-benzene-1-sulfonyl chloride, 21 (25.5 g, 0.1058 mol, 1.0 equiv) in tetrahydrofuran (200 mL) was added dropwise over 0.75 hr at 2-5° C. The mixture (some solids coating sides of flask) was allowed to warm to room temperature and stirred 0.5 hr. Water (about 50 mL) was added to dissolve solids and the mixture was concentrated under reduced pressure to remove the bulk of the tetrahydrofuran. The residual oily mixture was partitioned between ethyl acetate (500 mL) and 1N hydrochloric acid (100 mL). The organic phase was washed with brine (100 mL), dried (Na<sub>2</sub>SO<sub>4</sub>), filtered and the filtrate concentrated under reduced pressure to give a white solid, crude weight—25.9 g. TLC (30% ethyl acetate/heptanes)—product (R<sub>f</sub>=0.47) and 3 minor impurities (R<sub>f</sub>=0.73, R<sub>f</sub>=0.66, R<sub>f</sub>=0.54). The crude product was absorbed onto silica gel using dichloromethane and dry-loaded on a column of silica gel (250 g) packed in toluene. The column was eluted with toluene (1.5 L), 10% ethyl acetate/toluene (2 L) and 25% ethyl acetate/toluene (1 L). The one mixed fraction was purified a second time by silica gel chromatography (150 g), eluting with a gradient of 0-30% ethyl acetate/heptanes. Product fractions from both columns were concentrated under reduced pressure to give a white solid that was triturated with heptanes (150 mL), filtered and dried to give 21.9 g (93%) of 4- $d_9$ -tert-Butyl-benzenesulfonamide, 16. <sup>1</sup>H-NMR (300 MHz, CDCl<sub>3</sub>): δ 4.93 (s, 2H), 7.52 (d, J=8.2, 2H), 7.86 (d, J=8.7, 2H). HPLC (method: 20 mm C18-RP column-gradient method 2-95% ACN+0.1% formic acid in 3.3 min with 1.7 min hold at 95% ACN; Wavelength: 254 nm): retention time=3.10 min. LCMS (M+H<sup>+</sup>): 223.2, 206.1.

Step 4. Synthesis of 4- $d_9$ -tert-Butyl-N-(6-chloro-5-(2-methoxyphenoxy)-2,2'-bipyrimidin-4-yl)benzenesulfonamide (Compound 17) 60% Sodium hydride (0.97 g, 24.2 mmol, 2.2 equiv) was suspended in N,N'-dimethylacetamide (50 mL) and the mixture was cooled in an ice-bath. 4- $d_9$ -tert-Butyl-benzenesulfonamide, 16 (2.44 g, 11 mmol, 1.1 equiv) was added portionwise as a solid, maintaining the reaction temperature at >3° C. The white suspension was allowed to warm to room temperature over 0.75 hr, then cooled to ~-5° C. 4,6-dichloro-5-(2-methoxyphenoxy)-2,2'-bipyrimidine, 15 [prepared by the method described in Bioorg. & Med. Chem. Letters, 2001, 9, 2955] (3.49 g, 10 mmol, 1.0 equiv) was added as a solid. The reaction mixture developed a yellow color but no exotherm was observed. The mixture was stirred at 2-5° C. for 0.25 hr (slow H<sub>2</sub> evolution), then was allowed to warm to room temperature and was stirred 3.5 hr (the rate of H<sub>2</sub> evolution increased as the mixture warmed, and the color of the mixture deepened to yellow-orange). The suspension was poured slowly into ice-water (200 mL) and the yellow suspension was adjusted to pH 1-2 with 1N hydrochloric acid. The yellow solid was filtered, washed with water (300 mL), dried on the filter for 1.5 hr, then dried overnight in a vacuum oven at 40-50° C. The crude product was dissolved in a minimum amount of dichloromethane containing a few mL of methanol and was absorbed onto silica gel. The absorbed material was dry-loaded onto a column of silica gel (65 g) packed in dichloromethane. The column was eluted with a gradient of 0-5% methanol/dichloromethane (slow elution). Clean product fractions were concentrated under reduced pressure to give a yellow foamy solid. The foamy solid was triturated with ethyl acetate (about 50 mL) to give a suspension. The suspension was concentrated to near dryness and diluted with 1:1 ethyl acetate/heptanes (150 mL). The solid was filtered, washed with 1:1 ethyl acetate/heptanes (25 mL) and dried to give 3.51 g (66%) of 4- $d_9$ -tert-butyl-N-(6-chloro-5-(2-methoxyphenoxy)-2,2'-bipyrimidin-4-yl)benzene-

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sulfonamide, 17 as a light-yellow solid. <sup>1</sup>H-NMR (300 MHz, DMSO-d<sub>6</sub>): δ 3.78 (s, 3H), 6.59 (bs, 1H), 6.81 (t, J=7.6, 1H), 7.02 (t, J=7.6, 1H), 7.09 (d, J=7.6, 1H), 7.42 (bs, 2H), 7.66 (t, J=4.7, 1H), 8.02 (bs, 2H), 9.05 (d, J=4.1, 2H). HPLC (method: 150 mm C18-RP column-gradient method 5-95% ACN; Wavelength: 254 nm): retention time=3.85 min. LCMS (M+H<sup>+</sup>): 535.1.

#### Evaluation of Metabolic Stability

Certain *in vitro* liver metabolism studies have been described previously in the following references, each of which is incorporated herein in their entirety: Obach, R S, Drug Metab Disp, 1999, 27:1350; Houston, J B et al., Drug Metab Rev, 1997, 29:891; Houston, J B, Biochem Pharmacol, 1994, 47:1469; Iwatsubo, T et al., Pharmacol Ther, 1997, 73:147; and Lave, T, et al., Pharm Res, 1997, 14:152.

**Microsomal Assay:** The metabolic stability of compounds of Formula 1 is tested using pooled liver microsomal incubations. Full scan LC-MS analysis is then performed to detect major metabolites. Samples of the test compounds, exposed to pooled human liver microsomes, are analyzed using HPLC-MS (or MS/MS) detection. For determining metabolic stability, multiple reaction monitoring (MRM) is used to measure the disappearance of the test compounds. For metabolite detection, Q1 full scans are used as survey scans to detect the major metabolites.

**Experimental Procedures:** Human liver microsomes are obtained from a commercial source (e.g., XenoTech, LLC (Lenexa, Kans.)). The incubation mixtures are prepared as follows:

#### Reaction Mixture Composition

Liver Microsomes	0.5-2.0 mg/mL
NADPH	1 mM
Potassium Phosphate, pH 7.4	100 mM
Magnesium Chloride	10 mM
Test Compound	0.1-1 μM.

#### Incubation of Test Compounds with Liver Microsomes:

The reaction mixture, minus cofactors, is prepared. An aliquot of the reaction mixture (without cofactors) is incubated in a shaking water bath at 37° C. for 3 minutes. Another aliquot of the reaction mixture is prepared as the negative control. The test compound is added into both the reaction mixture and the negative control at a final concentration of 1 μM. An aliquot of the reaction mixture is prepared as a blank control, by the addition of plain organic solvent (not the test compound). The reaction is initiated by the addition of cofactors (not into the negative controls), and then incubated in a shaking water bath at 37° C. Aliquots (200 μL) are withdrawn in triplicate at multiple time points (e.g., 0, 15, 30, 60, and 120 minutes) and combined with 800 μL of ice-cold 50/50 acetonitrile/dH<sub>2</sub>O to terminate the reaction. The positive controls, testosterone and propranolol, as well as Compound 1, are each run simultaneously with the test compounds in separate reactions.

All samples are analyzed using LC-MS (or MS/MS). An LC-MRM-MS/MS method is used for metabolic stability. Also, Q1 full scan LC-MS methods are performed on the blank matrix and the test compound incubation samples. The Q1 scans serve as survey scans to identify any sample unique peaks that might represent the possible metabolites. The masses of these potential metabolites can be determined from the Q1 scans.

**SUPERSOMES™ Assay.** Various human cytochrome P450-specific SUPERSOMES™ are purchased from Gentest

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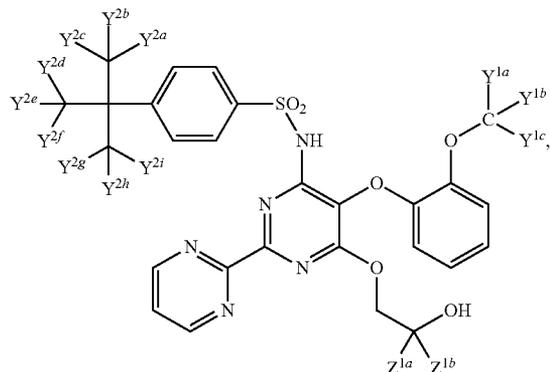
(Woburn, Mass., USA). A 1.0 mL reaction mixture containing 25 pmole of SUPERSOMES™, 2.0 mM NADPH, 3.0 mM MgCl<sub>2</sub>, and 1 μM of a test compound in 100 mM potassium phosphate buffer (pH 7.4) was incubated at 37° C. in triplicate. Positive controls contain 1 μM of bosentan instead of a test compound. Negative controls used Control Insect Cell Cytosol (insect cell microsomes that lacked any human metabolic enzyme) purchased from GenTest (Woburn, Mass., USA). Aliquots (50 μL) are removed from each sample and placed in wells of a multi-well plate at various time points (e.g., 0, 2, 5, 7, 12, 20, and 30 minutes) and to each aliquot is added 50 μL of ice cold acetonitrile with 3 μM haloperidol as an internal standard to stop the reaction.

Plates containing the removed aliquots are placed in -20° C. freezer for 15 minutes to cool. After cooling, 100 μL of deionized water is added to all wells in the plate. Plates are then spun in the centrifuge for 10 minutes at 3000 rpm. A portion of the supernatant (100 μL) is then removed, placed in a new plate and analyzed using Mass Spectrometry.

Without further description, it is believed that one of ordinary skill in the art can, using the preceding description and the illustrative examples, make and utilize the compounds of the present invention and practice the claimed methods. It should be understood that the foregoing discussion and examples merely present a detailed description of certain preferred embodiments. It will be apparent to those of ordinary skill in the art that various modifications and equivalents can be made without departing from the spirit and scope of the invention.

#### What is claimed is:

1. A method of treating a subject suffering from disease or condition selected from pulmonary arterial hypertension, interstitial lung disease, pulmonary hypertension, chronic thromboembolic pulmonary hypertension, and Eisenmenger's syndrome, comprising the step of administering to said patient an effective amount of a compound of the formula (1):



or a pharmaceutically acceptable salt thereof,

wherein:

each Y is independently selected from hydrogen or deuterium, and Y<sup>2a</sup> is additionally selected from OH;

each Z is independently selected from hydrogen, deuterium, and fluorine; and

at least one Y or Z is deuterium.

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2. The method of claim 1, wherein the disease or condition is pulmonary arterial hypertension.

3. The method of claim 2, comprising the additional step of co-administering to the patient a second therapeutic agent selected from epoprostenol, treprostinil, iloprost, and beraprost.

4. The method of claim 1, comprising the additional step of co-administering to the patient a second therapeutic agent, wherein the second therapeutic agent is sildenafil and the disease or condition is pulmonary arterial hypertension or Eisenmenger's syndrome.

5. The method of claim 1, wherein each  $Y^1$  of formula (I) is simultaneously deuterium.

6. The method of claim 1, wherein each  $Y^1$  of formula (I) is simultaneously hydrogen.

7. The method according to claim 1, wherein  $Y^{2b}$ ,  $Y^{2c}$ ,  $Y^{2d}$ ,  $Y^{2e}$ ,  $Y^{2f}$ ,  $Y^{2g}$ ,  $Y^{2h}$ , and  $Y^{2i}$  of formula (I) are the same.

8. The method of claim 7, wherein  $Y^{2a}$ ,  $Y^{2b}$ ,  $Y^{2c}$ ,  $Y^{2d}$ ,  $Y^{2e}$ ,  $Y^{2f}$ ,  $Y^{2g}$ ,  $Y^{2h}$ , and  $Y^{2i}$  of formula (I) are the same.

9. The method of claim 7, wherein  $Y^{2a}$  of formula (I) is OH.

10. The method of claim 7, wherein  $Y^{2b}$ ,  $Y^{2c}$ ,  $Y^{2d}$ ,  $Y^{2e}$ ,  $Y^{2f}$ ,  $Y^{2g}$ ,  $Y^{2h}$ , and  $Y^{2i}$  of formula (I) are simultaneously deuterium.

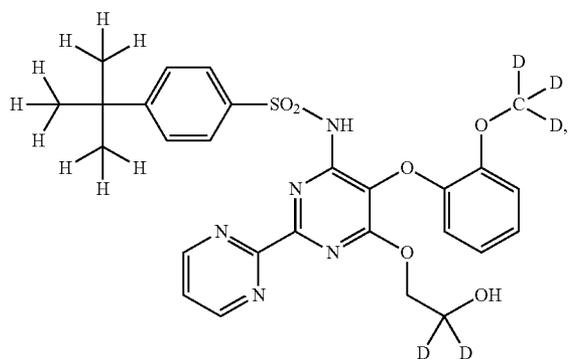
11. The method of claim 7, wherein  $Y^{2b}$ ,  $Y^{2c}$ ,  $Y^{2d}$ ,  $Y^{2e}$ ,  $Y^{2f}$ ,  $Y^{2g}$ ,  $Y^{2h}$ , and  $Y^{2i}$  of formula (I) are simultaneously hydrogen.

12. The method according to any one of claims 1 or 5 to 11, wherein  $Z^{1a}$  and  $Z^{1b}$  of formula (I) are simultaneously deuterium.

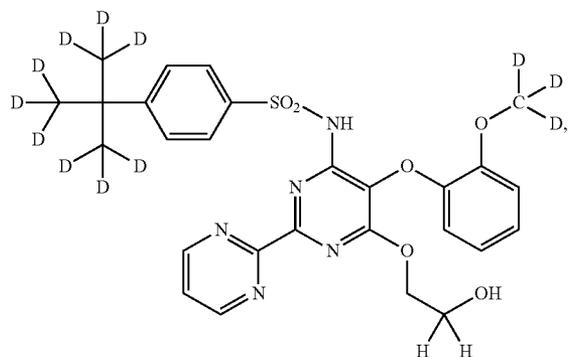
13. The method according to any one of claims 1 or 5 to 11, wherein  $Z^{1a}$  and  $Z^{1b}$  of formula (I) are simultaneously hydrogen.

14. The method according to any one of claims 1 or 5 to 11, wherein  $Z^{1a}$  and  $Z^{1b}$  of formula (I) are simultaneously fluorine.

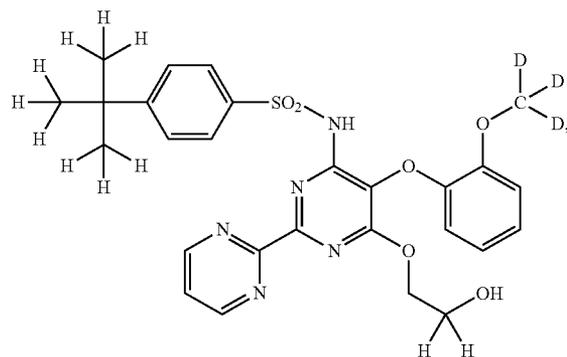
15. The method of claim 1, wherein the compound is selected from any one of the compounds below:



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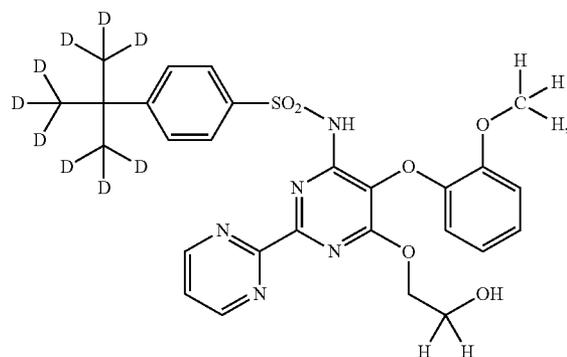
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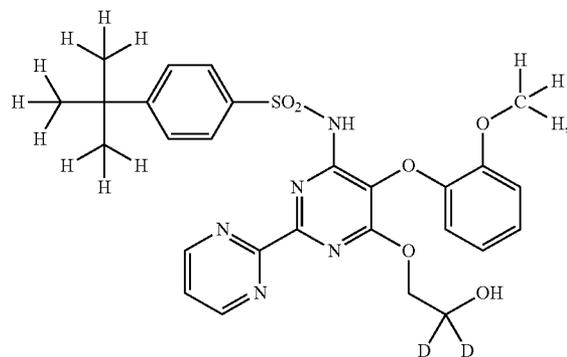


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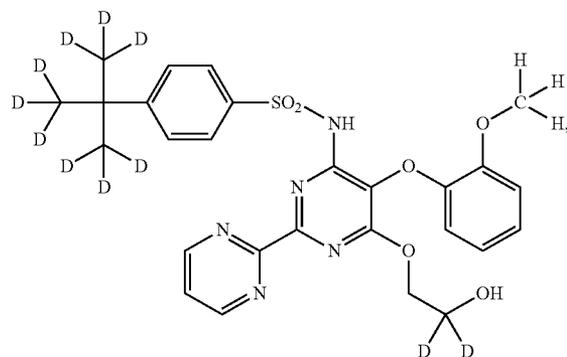
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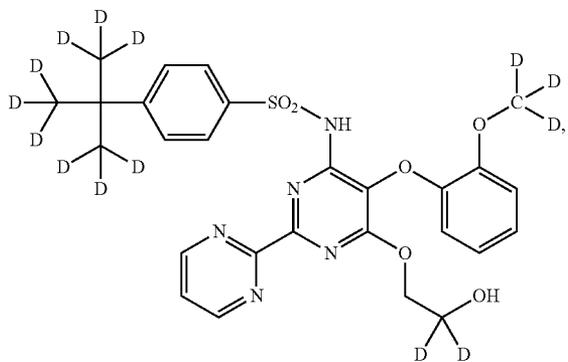
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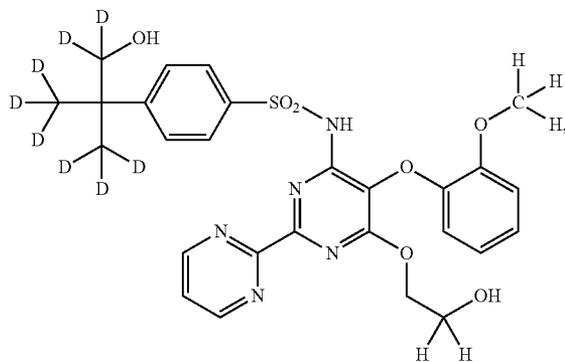
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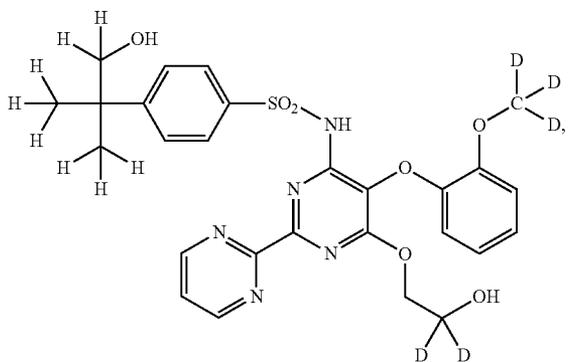
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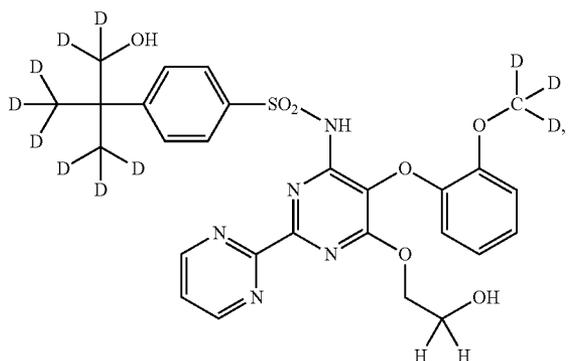
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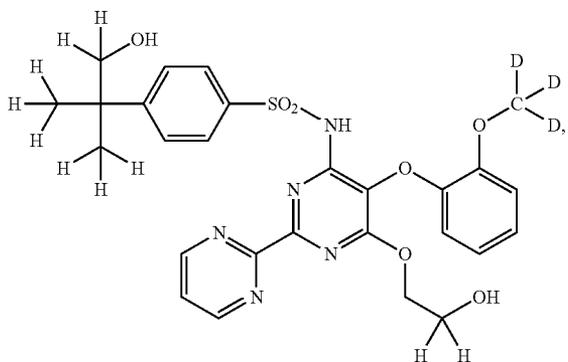
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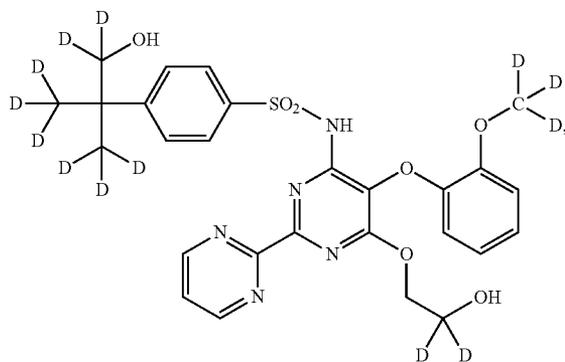


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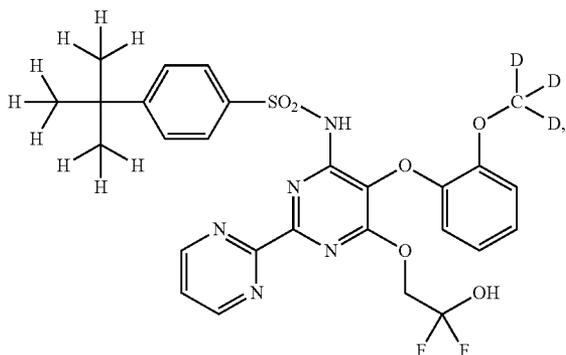


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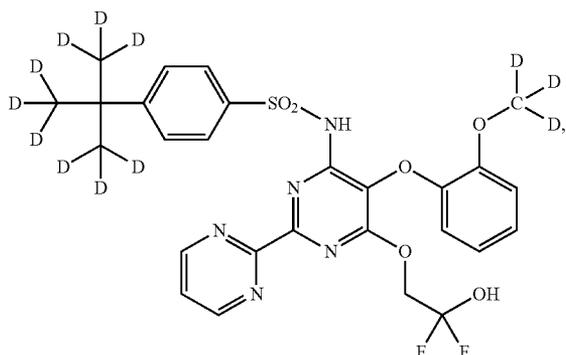
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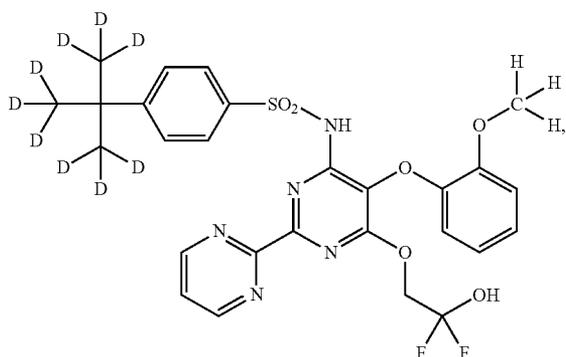


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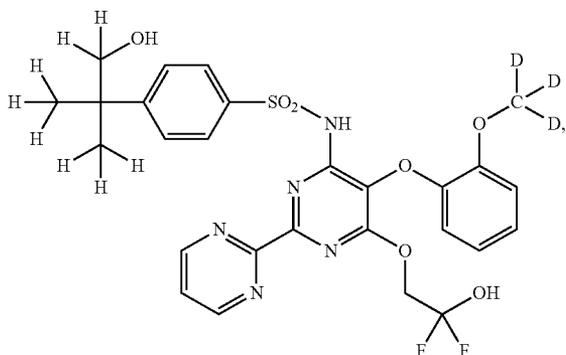


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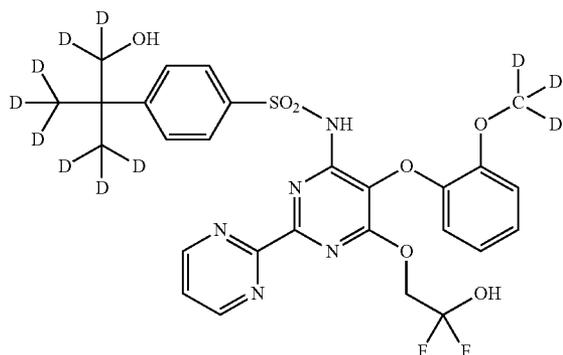
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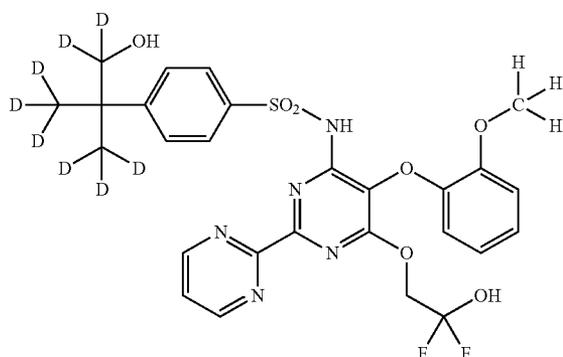
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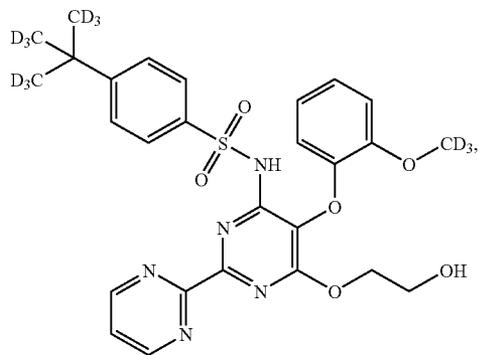
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or a pharmaceutically acceptable salt thereof.

**16.** The method according to claim 1, wherein for compounds of formula (I) any atom not specified as deuterium is present in its natural isotopic abundance.

**17.** The method according to claim 1, wherein the compound of formula (I) is selected from:

Compound 101



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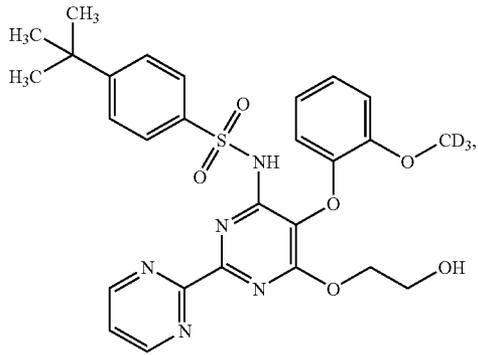
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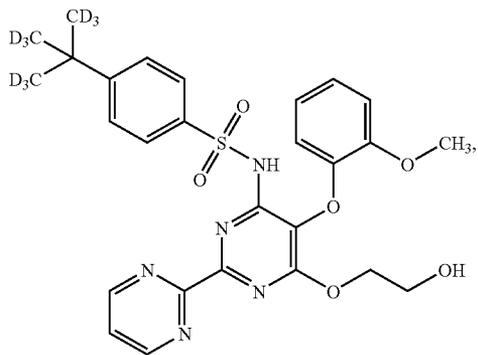
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Compound 102



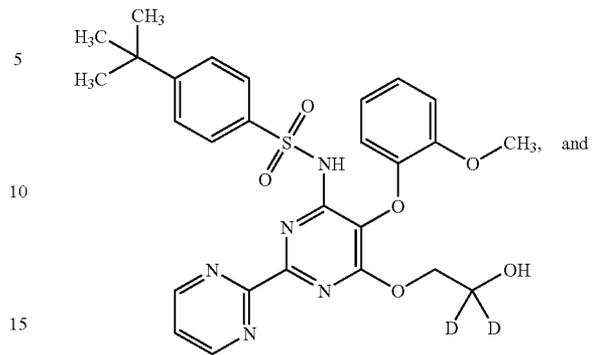
Compound 103



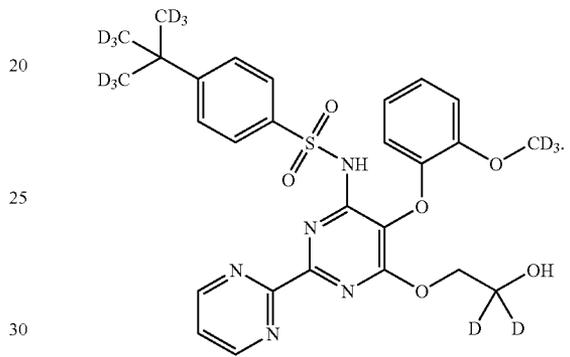
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Compound 104



Compound 106



or a pharmaceutically acceptable salt of any of the foregoing.

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