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**DeLuca et al.**

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(54) **USE OF ARYL HYDROCARBON RECEPTOR LIGAND AS A THERAPEUTIC INTERVENTION IN ANGIOGENESIS-IMPLICATED DISORDERS**

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(63) Continuation-in-part of application No. 11/286,537, filed on Nov. 23, 2005, now Pat. No. 7,241,900, which is a continuation of application No. 10/364,253, filed on Feb. 11, 2003, now Pat. No. 7,002,019, and a continuation-in-part of application No. 10/074,102, filed on Feb. 12, 2002, now Pat. No. 6,916,834.

(60) Provisional application No. 60/356,585, filed on Feb. 12, 2002, provisional application No. 60/268,809, filed on Feb. 14, 2001.

(51) **Int. Cl.**

**A61K 31/427** (2006.01)

**A61K 31/405** (2006.01)

(52) **U.S. Cl.** ..... **514/365; 514/414; 514/419**

(58) **Field of Classification Search** ..... **514/365, 514/414, 419**

See application file for complete search history.

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(57) **ABSTRACT**

A method of treating angiogenesis-implicated disorders by selecting a subject predisposed to an angiogenesis-implicated disorder and then administering an effective amount of an endogenous aryl hydrocarbon receptor ligand or its analogs according to a formula as disclosed herein is disclosed.

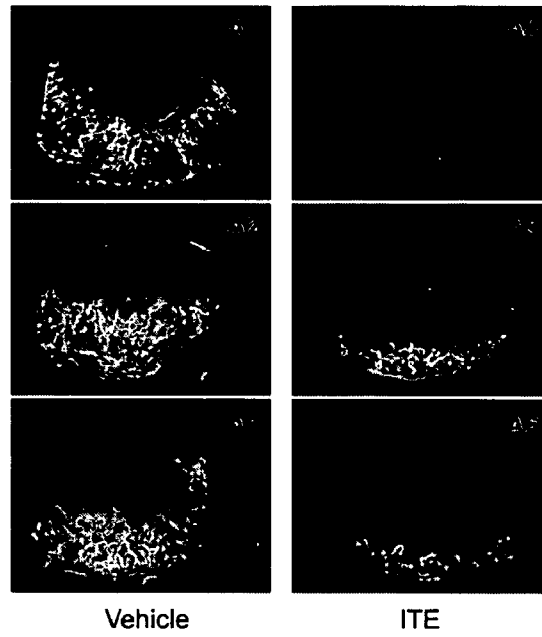


FIG.1A

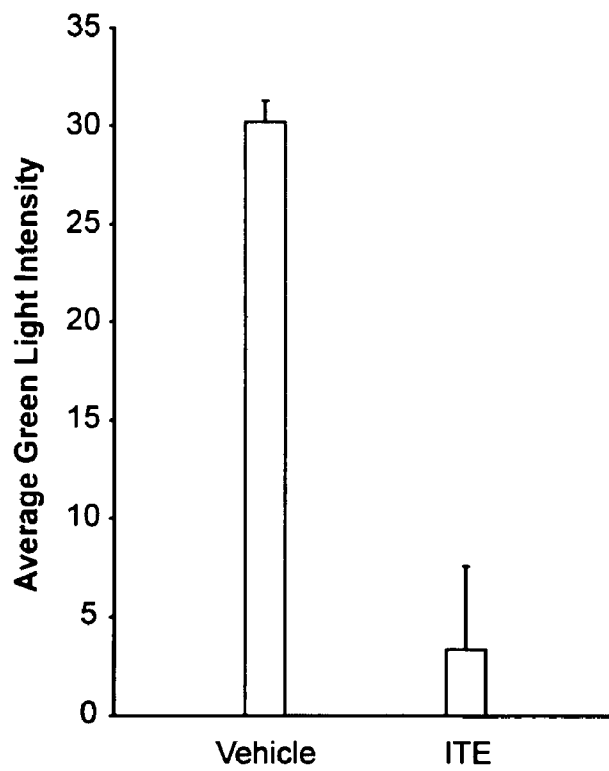


FIG.1B

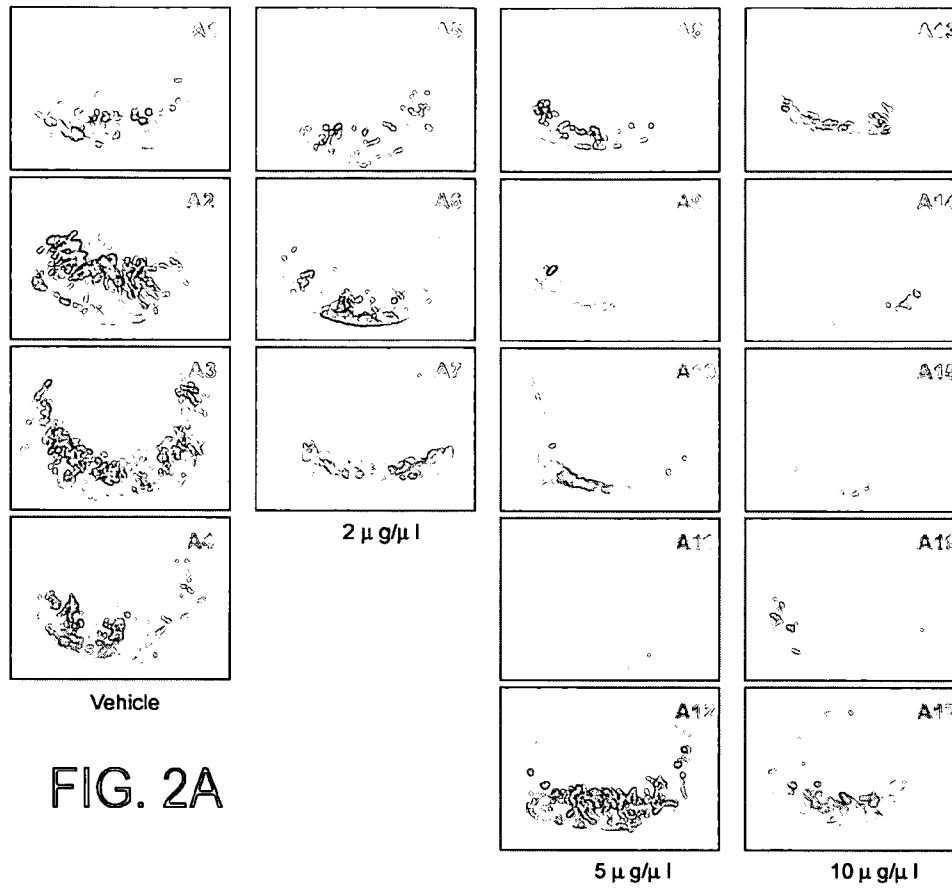


FIG. 2A

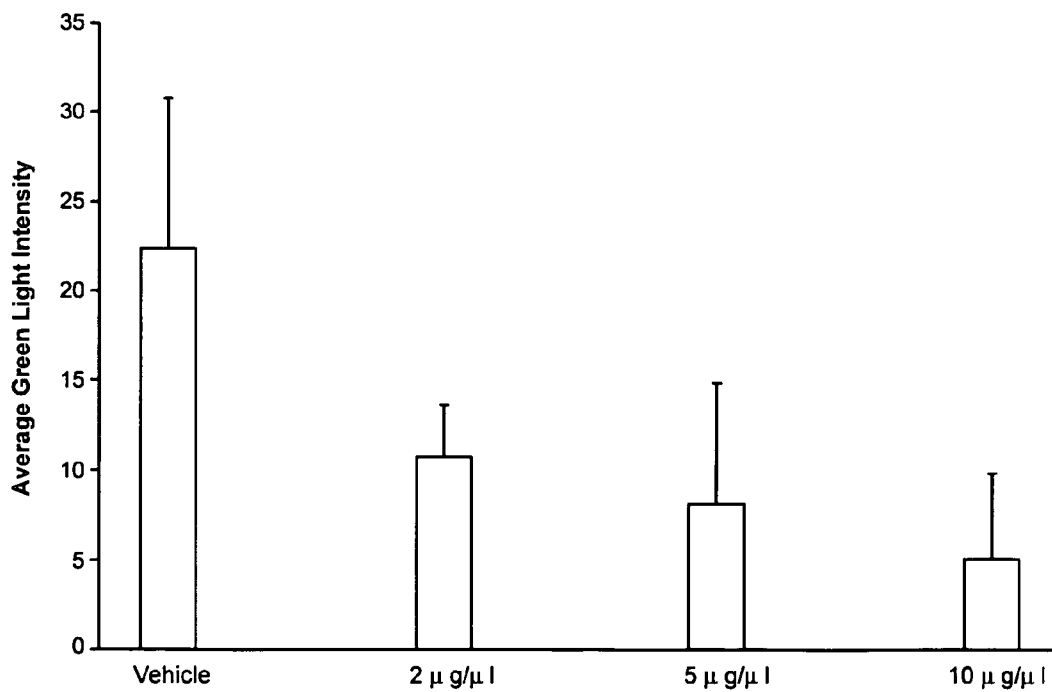


FIG. 2B

**USE OF ARYL HYDROCARBON RECEPTOR  
LIGAND AS A THERAPEUTIC  
INTERVENTION IN  
ANGIOGENESIS-IMPLICATED DISORDERS**

CROSS-REFERENCE TO RELATED  
APPLICATIONS

This application is a continuation-in-part of U.S. application Ser. No. 11/286,537, filed Nov. 23, 2005 now U.S. Pat. No. 7,241,900, which is a continuation of U.S. application Ser. No. 10/364,253, filed Feb. 11, 2003, now U.S. Pat. No. 7,002,019, which claims the benefit of U.S. Provisional Application No. 60/356,585, filed Feb. 12, 2002, and also is a continuation-in-part of U.S. application Ser. No. 10/074,102, filed Feb. 12, 2002, now U.S. Pat. No. 6,916,834, which claims the benefit of U.S. Provisional Application No. 60/268,809, filed Feb. 14, 2001.

STATEMENT REGARDING FEDERALLY  
SPONSORED RESEARCH OR DEVELOPMENT

BACKGROUND

The invention relates generally to a method of treating angiogenesis-implicated disorders, and more particularly to a method of treating angiogenesis-implicated disorders with an endogenous aryl hydrocarbon receptor ligand or one of its analogs.

Aryl Hydrocarbon Receptor. The aryl hydrocarbon receptor (AhR) is a ligand-inducible transcription factor that mediates a broad spectrum of physiological processes upon binding to its ligand. AhR was proposed and evidenced in the 1970's (Poland et al., 1976); whereas, the coding sequence for the receptor was cloned in the 1990's, revealing that the receptor is a member of an emerging basic Helix-Loop-Helix/Per-Arnt-Sim (bHLH/PAS) transcription factor super family (Burbach et al., 1992).

Upon binding to its ligand, a liganded AhR translocates from a cell's cytoplasm to its nucleus. Inside the nucleus, the liganded AhR forms a heterodimer with Ah receptor nuclear translocator (Arnt). The heterodimer then binds to a regulatory element, Ah response element (AhRE), within target genes either to enhance or to attenuate transcription of these genes. Responses mediated by AhR include expression of P450 family genes, cell proliferation or differentiation, apoptosis, immune suppression, vitamin A depletion, inhibition of adipose differentiation, waste syndrome, vascular development and remodeling, tumorigenicity or anti-tumorigenicity, and estrogenicity or anti-estrogenicity (Schmidt & Bradfield, 1996; Alexander et al., 1998; Whitlock, 1999; Poellinger, 2000; Elizondo et al. 2000; Safe, 2001; Vorderstrasse et al., 2001; Nilsson & Hakansson, 2002; Safe & Wormke, 2003; Walisser et al., 2004; Puga et al., 2005). Additionally, AhR-deficient mice show potential physiological function of AhR in liver, heart, ovary and immune system development (Fernandez-Salguero et al., 1995; Schmidt et al., 1996; Mimura et al., 1997; Benedict et al., 2000).

A Recently Identified Physiological Ligand for AhR. To date, the AhR system has been studied with artificial ligands such as polycyclic aromatic hydrocarbons including 3-methylcolanthrene (3-MC), benzo[*a*]pyrene (BP) and halogenated aromatic hydrocarbons such as 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD). While studies with these artificial ligands advance our understanding of the Ah receptor system, complete revelation of physiological roles the AhR plays and potential therapeutic benefits this system may provide necessitate the identification of its physiological ligand.

2-(1<sup>H</sup>-indole-3<sup>l</sup>-carbonyl)-thiazole-4-carboxylic acid methyl ester (ITE) is a physiological ligand for the AhR that has been purified from porcine lung and structurally identified (Song et al., 2002; U.S. Pat. No. 6,916,834). Not only has ITE been isolated from animals, but also it has been confirmed by chemical synthesis (Grzywacz et al., 2003).

Hypoxia-Inducible Factors and Arnt-Mediated Gene Expression. Hypoxia-inducible factor-1 $\alpha$  (HIF-1 $\alpha$ ) and hypoxia-inducible factor-2 $\alpha$  (HIF-2 $\alpha$ ) are also members of the bHLH/PAS transcription factor super family. Like AhR, HIF-1 $\alpha$  and HIF-2 $\alpha$  require Arnt to form a heterodimer to regulate transcription of their target genes. Under hypoxic conditions, both HIF-1 $\alpha$  and HIF-2 $\alpha$  are stabilized and their capability for transactivation are increased. Once activated, HIF-1 $\alpha$  heterodimers and HIF-2 $\alpha$  heterodimers affect transcription of over sixty genes involved in increasing oxygen delivery and activating alternative metabolic pathways (Tian et al., 1997; Giatromanolaki & Harris, 2001; Bracken et al., 2003; Quintero et al., 2004). One mechanism of increasing oxygen delivery through HIF-1 $\alpha$ - and HIF-2 $\alpha$ -mediated transcription is angiogenesis.

Angiogenesis. Angiogenesis is the generation of new blood vessels from existing ones and is a complex biological process involving a delicate balance of pro-angiogenic factors and anti-angiogenic factors. Pro-angiogenic factors include, but are not limited to, vascular endothelial growth factor (VEGF), basic fibroblast growth factor (bFGF), platelet-derived growth factor (PDGF), placental growth factor (PIGF), epidermal growth factor (EGF), angiopoietins, angiogenin and angiotropin. Whereas, anti-angiogenic factors include, but are not limited to, pigment epithelium-derived factor (PEGF), angiostatin, endostatin and thrombospondin.

Under physiological conditions, such as in wound healing, in female reproduction and in cancer growth and metastasis, the pro-angiogenic factors dominate and lead to angiogenesis. The initial steps of angiogenesis include vasodilation and enhanced permeability and destabilization of a blood vessel wall. Endothelial cells, also present in blood vessels, then proliferate, migrate and form tubes. The tubes are stabilized by pericytes and vascular smooth muscle cells (Distler et al., 2003; Carmeliet, 2004).

AhR and Angiogenesis. Since AhR, HIF-1 $\alpha$  and HIF-2 $\alpha$  share a common dimerization partner, Arnt, and are members of the same transcription factor super family, an extensive cross-talk between them is expected. In relation to angiogenesis, AhR may compete for Arnt binding with HIF-1 $\alpha$  and HIF-2 $\alpha$  to modulate angiogenesis (Gradin et al., 1996; Chan et al., 1999; Giatromanolaki & Harris, 2001). However, AhR interacts with other systems, such as transforming growth factor  $\alpha$  and  $\beta$  (TGF $\alpha$  and TGF $\beta$ , respectively), epidermal growth factor receptor (EGFR), growth hormone receptor (GHR) and estrogen receptor (ER) (Hudson et al., 1986; Choi et al., 1991; Lin et al., 1991; Bryant et al., 1997; Enan et al., 1998; Zaher et al., 1998; Carlson & Perdew, 2002; Davis et al., 2003; Safe & Wormke, 2003; Nukaya et al., 2004). Therefore, AhR may modulate angiogenesis through other unknown pathways.

AhR and Vascular Development and Remodeling. Studies with TCDD, an artificial ligand of AhR, showed reduced growth of common cardinal veins (CCV) in zebrafish during a period of forty-four to sixty-two hours post fertilization (Bello et al., 2004). TCDD also blocked the regression of CCV between eighty and ninety-six hours post fertilization (Ld.). Likewise, in chick embryos, TCDD inhibited VEGF-directed vasculogenesis using coronary endothelial tube formation and outgrowth as endpoints (Ivnitski-Steele & Walker, 2003). Furthermore, AhR-deficient mice have a patent ductus venosus in their livers (Lahvis et al., 2000).

Even mice expressing low levels of AhR (hypomorphs) had phenotypes similar to AhR-deficient mice (Walisser et al., 2004).

Angiogenesis-Implicated Disorders. Under physiological conditions, regulated angiogenesis occurs in wound healing, female reproductive cycles and embryonic development. Conversely, in pathophysiological conditions, unregulated angiogenesis occurs in disorders such as purpura, angioma, pallor and bone loss. Additionally, unregulated angiogenesis occurs in disorders such as growth and metastasis of cancers, eye diseases including blinding retinopathies, and chronic diseases such as psoriasis and rheumatoid arthritis.

Angiogenesis is also involved in many other disorders. For one, anti-angiogenic factors reduced adipose tissue in obese mice (Li et al., 2002; Ruppnick et al., 2002). Additionally, bacterial and viral pathogens induced angiogenic genes to advance pathological processes (Meyer et al., 1999; Harada et al., 2000). Furthermore, angiogenesis occurs in atherosclerosis, restenosis, transplant arteriopathy, warts, allergic dermatitis, keloids, peritoneal adhesions, synovitis, osteomyelitis, asthma, nasal polyps, chorioidal and intraocular disorders, acquired immune deficiency, endometriosis, uterine bleeding and ovarian cysts (Carmeliet, 2004).

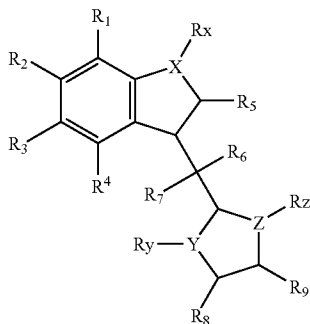
Therapeutic Inhibition of Angiogenesis. Endothelial cells (EC) are an attractive target for anti-angiogenesis therapy in angiogenesis-implicated disorders. For one, EC are involved in the early stages of angiogenesis. Additionally, EC are in direct contact with the blood and are therefore easily accessible. Furthermore, EC are genetically stable and are a homogenous diploid cell. As such, EC are less likely to develop acquired drug resistance to anti-angiogenic therapy (Folkman, 1995; Boehm et al., 1997).

Many anti-angiogenic agents are known. These agents are generally proteins, peptides or small molecules. Examples of these agents include, but are not limited to, anti-VEGF antibodies, anti-VEGFR antibodies, inhibitors of receptor tyrosine kinases such as VEGFR1, VEGFR2, PDGFR, bFGFR and EGFR, angiostatin, endostatin, fumagilin or its derivatives, and integrin inhibitors (Eskens, 2004). Despite the existence of these anti-angiogenic agents, there is a continued demand for new anti-angiogenic agents that are safe and effective.

### SUMMARY

We disclose herein a method for therapeutic application of an AhR ligand for treatment of angiogenesis-implicated disorders.

In a first aspect the invention is a method for treating angiogenesis-implicated disorders. The method comprises the first step of selecting a subject predisposed to an angiogenesis-implicated disorder. The method comprises the second step of administering an effective amount of an AhR ligand having a formula of:



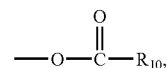
wherein:

$R_1$ ,  $R_2$ ,  $R_3$  and  $R_4$  can be independently selected from the group consisting of hydrogen, halo, hydroxy ( $-\text{OH}$ ), thiol ( $-\text{SH}$ ), cyano ( $-\text{CN}$ ), formyl ( $-\text{CHO}$ ), alkyl, haloalkyl, alkenyl, alkynyl, amino, nitro ( $-\text{NO}_2$ ), alkoxy, haloalkoxy, thioalkoxy, alkanoyl, haloalkanoyl and carbonyloxy.

$R_5$  can be selected from the group consisting of hydrogen, halo, hydroxy, thiol, cyano, formyl,  $=\text{O}$ , alkyl, haloalkyl, alkenyl, alkynyl, amino, nitro, alkoxy, haloalkoxy, thioalkoxy, alkanoyl, haloalkanoyl and carbonyloxy.

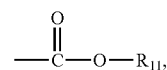
$R_6$  and  $R_7$  together can be  $=\text{O}$ . Alternatively,  $R_6$  can be selected from the group consisting of hydrogen, halo, cyano, formyl, alkyl, haloalkyl, alkenyl, alkynyl, alkanoyl and haloalkanoyl, and  $R_7$  is independently selected from the group consisting of hydrogen, halo, hydroxy, thiol, cyano, formyl, alkyl, haloalkyl, alkenyl, alkynyl, amino, nitro, alkoxy, haloalkoxy, thioalkoxy, alkanoyl and haloalkanoyl and carbonyloxy. Alternatively,  $R_7$  can be selected from the group consisting of hydrogen, halo, cyano, formyl, alkyl, haloalkyl, alkenyl, alkynyl, alkanoyl and haloalkanoyl, and  $R_6$  is independently selected from the group consisting of hydrogen, halo, hydroxy, thiol, cyano, formyl, alkyl, haloalkyl, alkenyl, alkynyl, amino, nitro, alkoxy, haloalkoxy, thioalkoxy, alkanoyl, haloalkanoyl and carbonyloxy.

$R_8$  and  $R_9$ , independently, can be



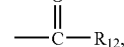
and  $R_{10}$  is selected from the group consisting of hydrogen, halo, cyano, alkyl, haloalkyl, alkenyl and alkynyl.

Alternatively,  $R_8$  and  $R_9$ , independently, can be



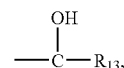
and  $R_{11}$  is selected from the group consisting of hydrogen, halo, alkyl, haloalkyl, alkenyl and alkynyl.

Alternatively,  $R_8$  and  $R_9$ , independently, can be



and  $R_{12}$  is selected from the group consisting of hydrogen, halo, hydroxy, thiol, cyano, alkyl, haloalkyl, alkenyl, alkynyl, amino and nitro.

Alternatively,  $R_8$  and  $R_9$ , independently, can be



and  $R_{13}$  is selected from the group consisting of hydrogen, halo, alkyl, haloalkyl, alkenyl and alkynyl.

Alternatively,  $R_8$  and  $R_9$ , independently, can be selected from the group consisting of hydrogen, halo, hydroxy, thiol, cyano, formyl,  $=\text{O}$ , alkyl, haloalkyl, alkenyl, alkynyl, amino, nitro, alkoxy, haloalkoxy, thioalkoxy, alkanoyl, haloalkanoyl and carbonyloxy.

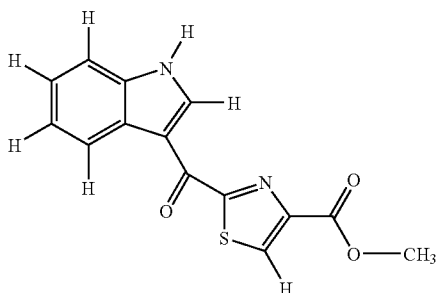
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X can be oxygen or sulfur, and  $R_x$  is nothing. Alternatively, X can be nitrogen, and  $R_x$  is selected from the group consisting of hydrogen, halo, formyl, alkyl, haloalkyl, alkenyl, alkynyl, alkanoyl, haloalkanoyl and a nitrogen protective group. Alternatively, X can be carbon, and  $R_x$  is selected from the group consisting of hydrogen, halo, hydroxy, thiol, cyano, formyl, =O, alkyl, haloalkyl, alkenyl, alkynyl, amino, nitro, alkoxy, haloalkoxy, thioalkoxy, alkanoyl, haloalkanoyl and carbonyloxy.

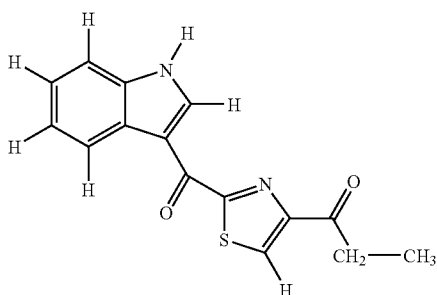
Y can be oxygen or sulfur, and  $R_y$  is nothing. Alternatively, Y can be nitrogen, and  $R_y$  is selected from the group consisting of hydrogen, halo, formyl, alkyl, haloalkyl, alkenyl, alkynyl, alkanoyl, haloalkanoyl and a nitrogen protective group. Alternatively, Y can be carbon, and  $R_y$  is selected from the group consisting of hydrogen, halo, hydroxy, thiol, cyano, formyl, =O, alkyl, haloalkyl, alkenyl, alkynyl, amino, nitro, alkoxy, haloalkoxy, thioalkoxy, alkanoyl, haloalkanoyl and carbonyloxy.

Z can be oxygen or sulfur, and  $R_z$  is nothing. Alternatively, Z is nitrogen, and  $R_z$  is selected from the group consisting of hydrogen, halo, formyl, alkyl, haloalkyl, alkenyl, alkynyl, alkanoyl, haloalkanoyl and a nitrogen protective group. Alternatively, Z can be carbon, and  $R_z$  is selected from hydrogen, halo, hydroxy, thiol, cyano, formyl, =O, alkyl, haloalkyl, alkenyl, alkynyl, amino, nitro, alkoxy, haloalkoxy, thioalkoxy, alkanoyl, haloalkanoyl and carbonyloxy.

In a preferred embodiment of the first aspect, the aryl hydrocarbon receptor ligand has a formula of:



In another preferred embodiment of the first aspect, the aryl hydrocarbon receptor ligand has a formula of:



In an additional preferred embodiment of the first aspect, the angiogenesis-implicated disorder is either a retinopathy, psoriasis, rheumatoid arthritis, obesity or cancer.

In a further preferred embodiment of the first aspect, the step of administering the aryl hydrocarbon receptor ligand is selected from the group consisting of capsules, creams, lozenges, tablets and injection.

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The previously described embodiments of the present invention have many advantages, including a first advantage that a patient is less prone to induce acquired drug resistance.

A second advantage of the present invention is that it eliminates the side-effects of dioxins.

These and other features, aspects and advantages of the present invention will become better understood from the description that follows. In the description, reference is made to the accompanying drawings, which form a part hereof and in which there is shown by way of illustration, not limitation, embodiments of the invention. The description of preferred embodiments is not intended to limit the invention to cover all modifications, equivalents and alternatives. Reference should therefore be made to the claims herein for interpreting the scope of the invention.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be better understood and features, aspects and advantages other than those set forth above will become apparent when consideration is given to the following detailed description thereof. Such detailed description makes reference to the following drawings, wherein:

FIG. 1 shows angiogenesis in mouse corneas in response to bFGF stimulation and intra-peritoneal (i.p.) injection of either vehicle (DMSO:propylene glycol, 1:1, v/v) or 10  $\mu\text{g}/\mu\text{l}$  of ITE in vehicle, wherein FIG. 1A1 through FIG. 1A3 show corneas from three mice injected with vehicle, wherein FIG. 1A4 through FIG. 1A6 show corneas from three mice injected with 10  $\mu\text{g}/\mu\text{l}$  of ITE in vehicle, and wherein FIG. 1B shows a quantification of newly formed blood vessels in the vehicle-treated mice and the ITE-treated mice; and

FIG. 2 shows dose-response effects of different concentrations of ITE on angiogenesis in mouse corneas in response to bFGF stimulation with i.p. injection of either vehicle or different concentrations of ITE in vehicle, wherein FIG. 2A1 through 2A4 show corneas from four mice injected with vehicle, wherein FIG. 2A5 through FIG. 2A7 show corneas from three mice injected with 2  $\mu\text{g}/\mu\text{l}$  of ITE in vehicle, wherein FIG. 2A8 through 2A12 show corneas from five mice injected with 5  $\mu\text{g}/\mu\text{l}$  of ITE in vehicle, wherein FIG. 2A13 through FIG. 2A17 show corneas from five mice injected with 10  $\mu\text{g}/\mu\text{l}$  of ITE in vehicle, and wherein FIG. 2B shows a quantification of newly formed blood vessels in the vehicle-treated mice and the ITE-treated mice.

#### DESCRIPTION OF PREFERRED EMBODIMENTS

Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the invention pertains. Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, the preferred methods and materials are described below.

As used herein, "angiogenesis-implicated disorder" refers to any disorder associated with the concurrent process of angiogenesis or depending on angiogenesis for its occurrence and progression.

As used herein, "an effective amount" is defined as that concentration of ligand, such as ITE, to attenuate angiogenesis by at least 50% as measured by the procedure described in Examples.

As used herein, "analog" is defined as a compound with structural similarity to ITE that is within the general formula.

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As used herein, "alkyl" refers to a group of hydrogen saturated one to six carbons connected in either straight or branched fashion.

As used herein, "haloalkyl" refers to an alkyl substituted by one or more halogen atoms.

As used herein, "alkenyl" refers to a group of hydrocarbons containing two to six carbons connected in either straight or branched fashion with at least one carbon-to-carbon double bond.

As used herein, "alkynyl" refers to a group of hydrocarbons containing two to six carbons connected in either straight or branched fashion with at least one carbon-to-carbon triple bond.

As used herein, "amino" refers to  $\text{—NRaRb}$  where Ra and Rb can be independently selected from the group consisting of hydrogen, halo, formyl ( $\text{—CHO}$ ), alkyl, haloalkyl, alkenyl, alkynyl, alkanoyl, haloalkanoyl and a nitrogen protective group.

As used herein, "halo" refers to any halogen atom (F, Cl, Br, or I).

As used herein, "alkanoyl" refers to an alkyl connected to the parent moiety through a carbonyl group, such as [ $\text{—C(O)—alkyl}$ ].

As used herein, "haloalkanoyl" refers to a haloalkyl connected to the parent moiety through a carbonyl group, such as [ $\text{—C(O)—haloalkyl}$ ].

As used herein, "carbonyl" refers to  $\text{—C(O)—}$ .

As used herein, "nitrogen protective group" refers to groups commonly used to protect nitrogen from undesired chemical reactions during synthesis procedures, such as  $\text{—CH}_3$ ,  $\text{—C(CHC}_3)_3$ ,  $\text{—CH}_2\text{CN}$ , and  $\text{—CH}_2\text{C}_6\text{H}_4\text{OCH}_3$ , etc.

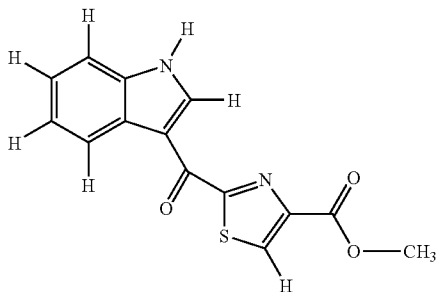
As used herein, "alkoxy" refers to an alkyl connected to the parent structure through an oxygen atom, such as [ $\text{—O—alkyl}$ ].

As used herein, "haloalkoxy" refers to a haloalkyl connected to the parent moiety through an oxygen atom, such as [ $\text{—O—haloalkyl}$ ].

As used herein, "thioalkoxy" refers to an alkyl connected to the parent structure through a sulfur atom, such as [ $\text{—S—alkyl}$ ].

As used herein, "carbonyloxy" refers to an alkanoyl connected to the parent moiety through an oxygen atom [ $\text{—O—C(O)—alkyl}$ ].

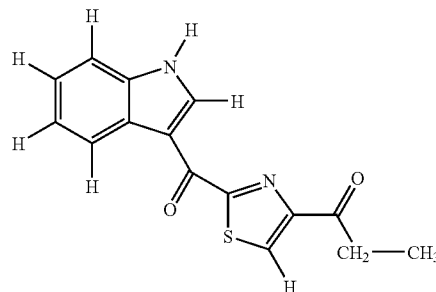
The present invention is a method of therapeutic treatment of angiogenesis-implicated disorders including, but not limited to, retinopathies, psoriasis, rheumatoid arthritis, obesity, and growth and metastasis of cancers with AhR ligand and its analogs including, but not limited to, ITE and its analogs. The formula of ITE is as follows:



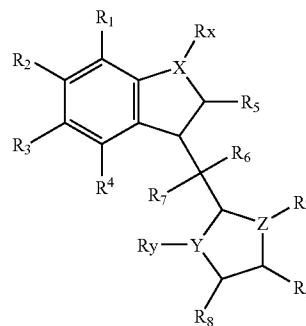
We envision that an especially useful analog of ITE will increase its stability and extend its half-life in animals, such

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as mammals, because a ketone has replaced the ester, an easy target for numerous esterases, on the original ITE structure. The extended half-life will certainly translate into higher potency in treatment of angiogenesis-implicated disorders. A specific preferable ITE analog is of the following formula:



However, other analogs of ITE useful in therapeutic applications in treating angiogenesis-implicated disorders are ones corresponding to the following formula:



wherein:

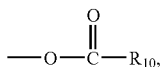
$R_1$ ,  $R_2$ ,  $R_3$  and  $R_4$  can be independently selected from the group consisting of hydrogen, halo, hydroxy ( $\text{—OH}$ ), thiol ( $\text{—SH}$ ), cyano ( $\text{—CN}$ ), formyl ( $\text{—CHO}$ ), alkyl, haloalkyl, alkenyl, alkynyl, amino, nitro ( $\text{—NO}_2$ ), alkoxy, haloalkoxy, thioalkoxy, alkanoyl, haloalkanoyl and carbonyloxy.

$R_5$  can be selected from the group consisting of hydrogen, halo, hydroxy, thiol, cyano, formyl,  $\text{=O}$ , alkyl, haloalkyl, alkenyl, alkynyl, amino, nitro, alkoxy, haloalkoxy, thioalkoxy, alkanoyl, haloalkanoyl and carbonyloxy.

$R_6$  and  $R_7$  together can be  $\text{=O}$ . Alternatively, if  $R_6$  is selected from the group consisting of hydrogen, halo, cyano, formyl, alkyl, haloalkyl, alkenyl, alkynyl, alkanoyl and haloalkanoyl, then  $R_7$  is independently selected from the group consisting of hydrogen, halo, hydroxy, thiol, cyano, formyl, alkyl, haloalkyl, alkenyl, alkynyl, amino, nitro, alkoxy, haloalkoxy, thioalkoxy, alkanoyl, haloalkanoyl and carbonyloxy. Alternatively, if  $R_7$  is selected from the group consisting of hydrogen, halo, cyano, formyl, alkyl, haloalkyl, alkenyl, alkynyl, alkanoyl and haloalkanoyl, then  $R_6$  is independently selected from the group consisting of hydrogen, halo, hydroxy, thiol, cyano, formyl, alkyl, haloalkyl, alkenyl, alkynyl, amino, nitro, alkoxy, haloalkoxy, thioalkoxy, alkanoyl, haloalkanoyl and carbonyloxy.

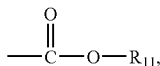
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$R_8$  and  $R_9$ , independently, can be



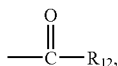
and  $R_{10}$  is selected from the group consisting of hydrogen, halo, cyano, alkyl, haloalkyl, alkenyl and alkynyl.

Alternatively,  $R_8$  and  $R_9$ , independently, can be



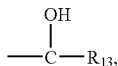
and  $R_{11}$  is selected from the group consisting of hydrogen, halo, alkyl, haloalkyl, alkenyl and alkynyl.

Alternatively,  $R_8$  and  $R_9$ , independently, can be



and  $R_{12}$  is selected from the group consisting of hydrogen, halo, hydroxy, thiol, cyano, alkyl, haloalkyl, alkenyl, alkynyl, amino and nitro.

Alternatively,  $R_8$  and  $R_9$ , independently, can be



and  $R_{13}$  is selected from the group consisting of hydrogen, halo, alkyl, haloalkyl, alkenyl and alkynyl.

Alternatively,  $R_8$  and  $R_9$ , independently, can be selected from the group consisting of hydrogen, halo, hydroxy, thiol, cyano, formyl, =O, alkyl, haloalkyl, alkenyl, alkynyl, amino, nitro, alkoxy, haloalkoxy, thioalkoxy, alkanoyl, haloalkanoyl and carbonyloxy.

X can be oxygen or sulfur, and  $R_x$  is nothing. Alternatively X can be nitrogen, and  $R_x$  is selected from the group consisting of hydrogen, halo, formyl, alkyl, haloalkyl, alkenyl, alkynyl, alkanoyl, haloalkanoyl and a nitrogen protective group. Alternatively, X can be carbon, and  $R_x$  is selected from the group consisting of hydrogen, halo, hydroxy, thiol, cyano, formyl, =O, alkyl, haloalkyl, alkenyl, alkynyl, amino, nitro, alkoxy, haloalkoxy, thioalkoxy, alkanoyl, haloalkanoyl and carbonyloxy.

Y can be oxygen or sulfur, and  $R_y$  is nothing. Alternatively, Y can be nitrogen, and  $R_y$  is selected from the group consisting of hydrogen, halo, formyl, alkyl, haloalkyl, alkenyl, alkynyl, alkanoyl, haloalkanoyl and a nitrogen protective group. Alternatively, Y can be carbon, and  $R_y$  is selected from the group consisting of hydrogen, halo, hydroxy, thiol, cyano, formyl, =O, alkyl, haloalkyl, alkenyl, alkynyl, amino, nitro, alkoxy, haloalkoxy, thioalkoxy, alkanoyl, haloalkanoyl and carbonyloxy.

Z can be oxygen or sulfur, and  $R_z$  is nothing. Alternatively, Z is nitrogen, and  $R_z$  is selected from the group consisting of hydrogen, halo, formyl, alkyl, haloalkyl, alkenyl, alkynyl, alkanoyl, haloalkanoyl and a nitrogen protective group. Alternatively, Z can be carbon, and  $R_z$  is selected from hydrogen, halo, hydroxy, thiol, cyano, formyl, =O, alkyl, haloalkyl,

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alkenyl, alkynyl, amino, nitro, alkoxy, haloalkoxy, thioalkoxy, alkanoyl, haloalkanoyl and carbonyloxy.

As angiogenesis inhibitors, endogenous AhR ligands, including ITE and its analogs, are useful in the treatment of primary and metastatic cancers. Cancers cannot grow beyond the size of one to two cubic millimeters or cannot migrate from a primary site to other locations without an adequate supply of oxygen and nutrients and removal of metabolic wastes. Intuitively, that seems to be true only for those "solid" tumors. Some studies, however, revealed that advancement of leukemia and other "liquid" tumors may also rely on angiogenic processes, at least before they spread into the general circulation (Perez-Atayde et al., 1997). Thus, the applicability of anti-angiogenic therapy extends virtually to all types of cancer.

By targeting genetically stable endothelial cells responsible for the initial process of neovascularization, anti-angiogenesis therapy is less prone to induce acquired drug resistance, which is a challenge in conventional chemotherapy targeting genetically heterogeneous cancer cells. It is also advantageous for the anti-angiogenic therapy to target endothelial cells, which are in constant contact with the blood and thus are readily accessible to anti-angiogenic agents in general circulation.

ITE and its analogs may also possess anti-tumorigenic capability. Studies revealed that some AhR ligands with phytochemical origin, including some with an indole moiety, are anti-estrogenic and anti-tumorigenic (McDougal et al., 2001; Bradshaw et al., 2002; Safe & McDougal, 2002). Additionally, liganded AhR arrested cell cycle, promoted apoptosis and antagonized estrogen actions (Heimler et al., 1998; Elizondo et al., 2000; Puga et al., 2000; Safe & Wormke, 2003). Furthermore, AhR agonists inhibited pancreatic cancer cell lines with high AhR expression (Koliopoulos et al., 2002). We believe that ITE and its analogs will be effective therapeutic agents in treating cancers through multiple mechanisms.

Like cancer, adipose tissue expansion also depends on angiogenesis. As reported, pro-angiogenic factors are stimulated by the growth of adipose tissue and inhibition of angiogenesis in mouse models resulted in body weight loss and in adipose tissue reduction (Li et al., 2002; Rupnick et al., 2002). Through inhibition of angiogenesis, we envision that ITE and its analogs will be useful in controlling body weight.

As noted previously, in vitro systems confirmed the inhibitory effects of TCDD/AhR on adipose differentiation (Alexander et al., 1998; Shimba et al., 2001). Recently, AhR was shown to affect feeding behavior of animals through regulation of SIM1, which is believed to be involved in hypothalamus functioning (Yang et al., 2004). Thus, it is advantageous to use AhR ligands and their analogs, including ITE and its analogs, in body weight control since they will work through more than one mechanism.

Retinopathies, such as diabetic retinopathy and retinopathy of prematurity, are major causes of blindness. Estimates show that nearly three-fourths of diabetic patients within fifteen years of onset of disease develop diabetic retinopathy (Klein et al., 1984; Sjolje et al., 1997). Similarly, retinopathy of prematurity is an ischemic proliferative retinopathy that leads to irreversible childhood blindness.

Current therapies to treat retinopathies include invasive procedures such as laser photocoagulation and cryotherapy. Unfortunately, these therapies cause side-effects including decreased peripheral vision, impaired night vision and changed color perception. In some cases, the disease continues to advance despite surgical intervention (Caldwell et al., 2003; Stout & Stout, 2003). As an effective angiogenesis inhibitor, endogenous AhR ligands, including ITE and its analogs, will be useful in medical intervention of blinding retinopathies.

Psoriasis and rheumatoid arthritis represent chronic, inflammatory, hyperproliferative diseases affecting approximately 2% of U.S. and world populations (Elder et al., 2001; Louie et al., 2003). Both are autoimmune disorders whose pathological advancements are aided by angiogenesis. Immune suppressants, such as cyclosporin, and anti-angiogenic agents are effective in therapeutic intervention in disease models (Oliver et al., 1995; Lebowitz et al., 1998; Powell et al., 1999; Sone et al., 2001). We envision that endogenous AhR ligands, including ITE and its analogs, will be effective therapy for these diseases not only because ITE is anti-angiogenic in vivo, but also because it may well be an effective immune suppressant (Vorderstrasse et al., 2001; Kerkvliet, 2002).

From implantation of a fertilized egg to further development of an embryo in a reproductive period of an adult mammal, a finely coordinated process including angiogenesis is a prerequisite for successful reproduction. Inhibition of angiogenesis at this critical moment would be a huge challenge to this process. It has been hypothesized, not surprisingly, that inhibition of angiogenesis may even provide a novel alternative for birth control (Zhang & Bicknell, 2001). Therefore, as anti-angiogenesis agents, AhR ligands, including ITE and its analogs, may be useful in contraception for humans and animals.

Dosing regimes for ITE and its analogs can be routinely determined in accordance with pharmacological activity data from in vivo experimental models. A pharmaceutical composition will be composed of ITE or its analogs (the active ingredients), pharmaceutically acceptable carrier(s), other compatible ingredients such as preservatives, and even other compatible therapeutic agents. Pharmaceutically acceptable carriers are inert materials useful for administering the active ingredients, preferably sterile and nontoxic, and compatible with the active ingredients and can be solid, liquid, or gas in nature. The pharmaceutical compositions can be administered orally and parenterally. The preparation can be provided in capsules, creams, lozenges, tablets or intravenously. Initial screening will be conducted by the procedure described below. Further screening procedures will be devised accordingly once a disease target is identified.

In an ideal treatment plan, the formulated ITE or its analogs will be administered either orally (capsules or tablets, for example) or parentally (topical application or injection, for example) by a human patient with a disorder mentioned above. The effective dosing range will be determined by the blood concentrations of ITE or its analogs achievable by a specific dosing regimen. The said concentrations in blood should be equivalent to those achieved in mice when dosed i.p. at 2 to 10 mg/kg body weight. The frequency of dosing will be decided by the kinetics of ITE and its analogs in the system. Currently, twice a day is proposed as preferable with ITE. The dosing will be continued until the patient is free from the disorder. It may be preferable to provide a maintenance dosing.

## EXAMPLES

### Example 1

#### Inhibition of Angiogenesis With Aryl Hydrocarbon Receptor Ligand: Mouse Corneal Grafting Assay

Methods: Polyvinyl sponges (Rippey, Eldorado Hills, Calif.) pre-irradiated with 2,000 Gy from a cesium source are cut into 0.4x0.4x0.2 mm pieces and 100 ng of a bFGF (Sigma-Aldrich, St. Louis, Mo.) dissolved in Dulbecco's

phosphate buffered saline without calcium or magnesium (DPBS; Cambrex, Walkersville, Md.) are introduced into each sponge using a syringe. The loaded sponges are then air-dried.

A female adult BALB/c mouse (~20 g in body weight; Harlan, Indianapolis, Ind.) is anesthetized with Avertin composed of tribromoethanol (Aldrich, Milwaukee, Wis.), tertiary amyl alcohol (Aldrich), ethanol, and distilled water in a ratio of 1:1:9.8:88.2 (w/v/v/v). One of the sponges are introduced into a surgically created micro-pocket in an avascular area of one cornea. Mice are put under a 75 W incandescent light bulb to recover from the effect of anesthesia.

The vehicle for delivering ITE is a 1:1 (v/v) mixture of dimethyl sulphoxide (DMSO; Sigma-Aldrich) and propylene glycol (Gallipot, St. Paul, Minn.). Intra-peritoneal injection of 20  $\mu$ l of the vehicle or ITE in the vehicle is started at the same day. The injections are done twice a day for six consecutive days. On day 6, 200  $\mu$ l of fluorescein 5(6)-isothiocyanate (FITC) conjugated with high molecular weight dextran (2,000,000 MW; Sigma-Aldrich) are injected into the tail vein. Mice are euthanized three to five minutes after the injection. Sponge-containing eyes are enucleated and fixed for 5 minutes with 4% paraformaldehyde. The cornea with the adjacent limbus are dissected, rinsed in DPBS, and mounted with 10% glycerol onto a glass slide.

A stereomicroscope with an epifluorescence attachment (Stemi SV11, Zeiss, Thornwood, N.Y.) is used to visualize the overall appearance of a cornea and the presence of the perfused blood vessels (appearing green). Images are digitally recorded with a Hitachi HV-C20U-S4 camera and saved as JPEG files. The saved images are analyzed with Adobe Photoshop 6.0 (Adobe Systems Inc., San Jose, Calif.). Intensities of green light of each pixel in an image is integrated and an average is taken as total average intensity. The background intensity of green light is estimated by cropping the background area of several images, integrating the intensities, and taking the average. The net average green light intensity of each image is then obtained by subtracting the background from the total average green light intensity and reported.

Results of the In Vivo Angiogenesis Inhibition Assay: Under the stimulation of bFGF, numerous neovessels grew toward the stimulant in sponges for mice injected with 20  $\mu$ l of the vehicle (DMSO:propylene glycol, 1:1, v/v) each time (FIG. 1A1 to 1A3) while the growth is considerably inhibited for mice injected with 20  $\mu$ l of ITE in the vehicle at a concentration of 10  $\mu$ g/ $\mu$ l (FIG. 1A4 to 1A6). Quantification of the data presented in FIG. 1B confirms the results of visual impression.

The effective dose of about 10 mg/kg of body weight is in accord with our unpublished in vivo observations on induction of mRNA transcription of CYP1A1, an extensively characterized AhR target gene, suggesting the specificity of ITE action in angiogenesis inhibition.

In another independent experiment, ITE (10  $\mu$ g/ $\mu$ l) inhibited angiogenesis (FIG. 2A13 to FIG. 2A17) compared to vehicle-treated mice (FIG. 2A1 to FIG. 2A4). The ability of ITE to inhibit angiogenesis was also present at a concentration of 5  $\mu$ g/ $\mu$ l (FIG. 2A8 to FIG. 2A12) and at a concentration 2  $\mu$ g/ $\mu$ l (FIG. 2A5 to FIG. 2A7). FIG. 2B represents the quantified data from that experiment.

The invention has been described in connection with what are presently considered to be the most practical and preferred embodiments. However, the present invention has been presented by way of illustration and is not intended to be limited to the disclosed embodiments. Accordingly, those skilled in the art will realize that the invention is intended to

encompass all modifications and alternative arrangements within the spirit and scope of the invention as set for by the appended claims.

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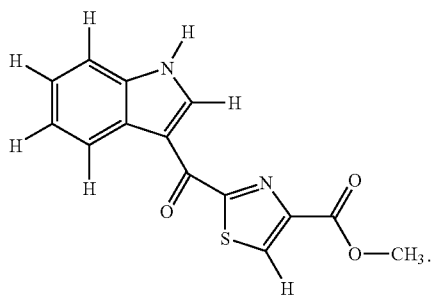
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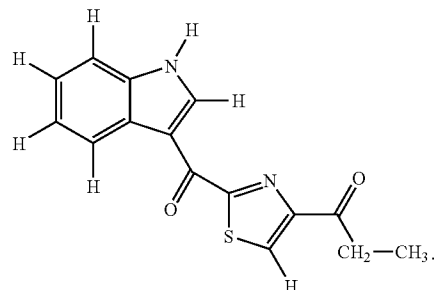
The invention claimed is:

1. A method for treating an angiogenesis-implicated disorder, wherein the disorder is selected from the group consisting of retinopathies, psoriasis, rheumatoid arthritis, and obesity comprising the steps of:
- selecting a subject predisposed to the angiogenesis-implicated disorder; and
- administering an amount of an aryl hydrocarbon receptor ligand effective to inhibit angiogenesis, the ligand having a formula of:



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2. The method of claim 1, wherein the step of administering the aryl hydrocarbon receptor ligand is selected from the group consisting of capsules, creams, lozenges, tablets and injection.
3. The method of claim 1, wherein the ligand is combined with a pharmaceutically acceptable carrier.
4. The method of claim 1, wherein the patient is dosed twice a day.
5. The method of claim 1, additionally comprising the step of supplying a maintenance dose of the ligand.
6. The method of claim 1, wherein the concentration of the ligand within the patient's blood is determined after administration.
7. A method for treating an angiogenesis-implicated disorder, wherein the disorder is selected from the group consisting of retinopathies, psoriasis, rheumatoid arthritis, and obesity, comprising the steps of:
- selecting a subject predisposed to the angiogenesis-implicated disorder; and
- administering an amount of an aryl hydrocarbon receptor ligand effective to inhibit angiogenesis, the ligand having a formula of:



8. The method of claim 7, wherein the step of administering the aryl hydrocarbon receptor ligand is selected from the group consisting of capsules, creams, lozenges, tablets and injection.
9. The method of claim 7, wherein the ligand is combined with a pharmaceutically acceptable carrier.
10. The method of claim 7, wherein the patient is dosed twice a day.
11. The method of claim 7, additionally comprising the step of supplying a maintenance dose of the ligand.
12. The method of claim 7, wherein the concentration of the ligand within the patient's blood is determined after administration.

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