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(54) Title: NOVEL THERAPEUTIC TREATMENTS USING CENTHAQUIN

(57) Abstract: Methods of treating hypertension, pain, and resuscitative hemorrhagic shock using an adrenergic agent, like centhaquin, are disclosed. The methods treat mammals, including humans.

NOVEL THERAPEUTIC TREATMENTS USING CENTHAQUIN

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of the filing date of U.S. provisional patent application No. 61/174,257, filed on April 30, 2009, incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

[0002] The present invention relates to novel therapeutic treatments using centhaquin. In one embodiment, centhaquin is used in conjunction with an endothelin antagonist in the treatment of hypertension. In a second embodiment, centhaquin is used as an analgesic in the treatment of pain. In a third embodiment, centhaquin is used in the treatment of resuscitative hemorrhagic shock.

BACKGROUND OF THE INVENTION

[0003] Hypertension is a serious disease that afflicts many people all over the world. It is estimated that one in three Americans suffer from high blood pressure, with as much as one-third of them are unaware of the problem. Beyond lifestyle changes such as exercise, losing weight, and reducing salt intake, most antihypertensive therapy involves the use of one or more antihypertensive drugs. In addition to diuretics, Ca^{++}-channel blockers, adrenergic blockers, ACE inhibitors, and angiotensin-II receptor blockers, centrally acting hypotensive drugs are available for the treatment of moderate to severe hypertension.

[0004] Clonidine, *N*-(2,6-dichlorophenyl)-4,5-dihydro-1*H*-imidazol-2-amine, is a widely used antihypertensive drug that mediates its hypotensive effects via stimulation of central α_2-adrenergic receptors (Kobinger, 1978; Guyenet and Cabot, 1981). It has an approximately 10-fold higher binding affinity for the α_2-adrenergic receptors than the α_1-adrenoreceptors (U'Prichard et al., 1977). Centrally acting antihypertensive drugs are used to treat uncontrolled or refractory hypertension. However, use is limited due to dual action. When administered, first they stimulate peripheral α_1-adrenergic receptors resulting in vasoconstriction and an increase in blood pressure, and second they act on the central α_2-adrenergic receptors to inhibit sympathetic drive resulting in vasodilatation and a decrease in

blood pressure. The central action predominates over the peripheral, and hence the overall effect of clonidine is decrease in blood pressure.

[0005] Centhaquin (2-[2-(4-(3-methyphenyl)-1-piperazinyl) ethyl-quinoline) is a centrally acting antihypertensive drug. The structure of centhaquin was determined (Bajpai et al., 2000) and the conformation of centhaquin was confirmed by X-ray diffraction (Carpy and Saxena, 1991). Although structurally different from clonidine, centhaquin produces a fall in mean arterial pressure (MAP) and heart rate (HR) similar to that seen with clonidine in anesthetized cats and rats (Srimal et al., 1990). In mice, it has LD50 of 600 mg/kg intraperitoneal and produces a dose-dependent fall in MAP in various species. Centhaquin (0.05 to 0.2 mg/kg, iv) produced a dose-dependent decrease in MAP and HR in urethane anesthetized rats. However, in cervical sectioned rats, intravenously administered centhaquin did not produce any effect on MAP or HR (Gulati et al., 1991a). Intrathecal administration of centhaquin did not produce any effect on MAP or HR (Gulati et al., 1991a). Intraduodenal administration of centhaquin (1.0 to 2.5 mg/kg) produced a 40 to 50 mmHg fall in MAP, which was not affected by pretreatment with antihistaminics and atropine (Murthi et al., 1976; Srimal et al., 1990). In spontaneously hypertensive rats, centhaquin (0.5 to 1.0 mg/kg) was effective in lowering the MAP by 50 to 60 mmHg. Repeated administration of centhaquin once a day for 15 days did not produce any potentiation or tolerance (Murthi et al., 1976).

[0006] Centhaquin (0.1, 1.0 and 10.0 μg/ml) was found to produce an initial increase followed by decrease of spontaneous release of norepinephrine (NE) and inhibited norepinephrine release evoked by potassium chloride and dimethyl phenyl piperazinium chloride indicating that centhaquin inhibits norepinephrine release (Bhatnagar et al., 1985). Upon chronic administration in rats, both centhaquin and clonidine produced hypotension and bradycardia associated with an up-regulation in α-adrenergic receptors in the hypothalamus and medulla (Gulati et al., 1991a; Gulati et al., 1991b). It is possible that a decrease in release of norepinephrine in the synapse leads to an increase in the density of α-adrenergic receptors.

[0007] The central regulation of blood pressure has been linked to an endogenous 21-residue peptide, endothelin (ET). ET was discovered two decades ago in porcine arterial epithelial cells, and has since been recognized as one of the most potent vasoconstrictors (Hickey et al., 1985; Yanagisawa et al., 1988). There are three structurally and functionally

distinct isopeptides (ET-1, ET-2, and ET-3), which in turn bind to three different receptors (ET_A, ET_{B1}, and ET_{B2}). ET_A and ET_{B2} receptors are located on the vascular smooth muscle where they produce vasoconstriction *via* the increase in intracellular Ca^{++}. On the other hand, ET_{B1} receptors are found on the vascular endothelium where they mediate vasorelaxation via the synthesis and release of nitric oxide and prostacyclin (Sakamoto et al., 1993; Shetty et al., 1993). Administration of ET-1 intravenously produces a dose-dependent, biphasic alteration in blood pressure, characterized by a brief hypotensive phase followed by a sustained hypertension along with an increase in HR (Ouchi et al., 1989; Kuwaki et al., 1990). ET is present in the brain, and central ET has been shown to regulate sympathetic nervous system (Gulati et al., 1997a; Gulati et al., 1997b).

[0008] It previously was found that ET can modify the cardiovascular effects of clonidine. Pre-treatment with ET in rats produced an antagonistic effect on the hypotension and bradycardia induced by clonidine. A postulated mechanism is that ET increased the sensitivity of peripheral α-adrenergic receptors, leading to potentiation of the peripheral hypertensive effects of clonidine (Gulati, 1992; Gulati and Srimal, 1993). Studies have shown that ET attenuates the pressor response and [^{3}H]norepinephrine release during stimulation of the rat mesenteric artery and the guinea pig femoral artery, thereby resulting in presynaptic inhibition and a subsequent increase in sympathetic tone (Wiklund et al., 1988; Tabuchi et al., 1989). It is therefore possible that the central hypotensive and bradycardic effects of clonidine could be antagonized by ET due to ET-mediated inhibition of presynaptic neuronal transmission.

[0009] It is known that there is a significant alteration of clonidine-induced cardiovascular parameters by ET and few ET antagonists already in market for the treatment of pulmonary hypertension and several are in pipeline. The effect of ET and their antagonists on adrenergic antihypertensive agent-induced changes in cardiovascular parameters therefore was studied. Structurally different compounds clonidine and centhaquin have been shown to have similar effects on blood pressure by acting on central and peripheral α-adrenergic receptors. The inventors therefore explored the involvement of ET in the modulation of peripheral adrenergic effects of clonidine and centhaquin. The study was conducted in rats using ET agonist (ET-1) and antagonists (BMS-182874 (ET_A-specific antagonist) and TAK-044 ($ET_{A/B}$ non-specific antagonist)) to investigate their effect on clonidine and centhaquin induced changes in MAP, pulse pressure (PP), and HR.

[0010] Analgesics are agents that relieve pain by acting centrally to elevate pain threshold, preferably without disturbing consciousness or altering other sensory functions. A mechanism by which analgesic drugs obtund pain (i.e., raise the pain threshold) has been formulated.

[0011] National Center for Health Statistics (2006) estimates more than one-quarter of Americans (26%) over the age of 20 years, and more than 76.5 million Americans, report that they have had a problem with pain of any sort that persisted for more than 24 hours in duration and over 191 million acute pain events occurred in the United States. Opioids are the most commonly used analgesics for the clinical management of acute and chronic pain. There are various side effects associated with the long-term use of opioids including the development of tolerance, which results in inadequate pain relief. There are several existing regimens designed to enhance analgesia and effectively manage pain, including nonsteroidal anti-inflammatory drugs (NSAIDS), additional opioids, and non-opioids in combination with opioid therapy. Although these approaches provide symptomatic relief, they have little effect on the underlying mechanisms that contribute to the development of tolerance and pose a significant risk of toxicity, dependence, and addiction.

[0012] Thus there exists a need in the art to identify agents, or combinations of agents that reduce tolerance to opioid analgesics and reduce pain symptoms, and that can act as effective non-opioid analgesics.

SUMMARY OF THE INVENTION

[0013] The present invention is directed to administration of an endothelin antagonist in combination with centhaquin or other adrenergic agents to an individual in need thereof. More particularly, administration of centhaquin or other adrenergic agents in combination with an endothelin antagonist potentiates the antihypertensive effect of the centhaquin.

[0014] Adrenergic agents useful in accordance with the present invention include, but are not limited to, centhaquin, clonidine, guanfacine, guanabenz, guanoxbenz, methyldopa, prazosin, tamsulosin, doxazosin, terazosin, phentolamine, phenoxybenzamine, mirtazapine, and mixtures thereof. The adrenergic agent is administered in conjunction with an endothelin antagonist in the treatment of hypertension. The adrenergic agents can be administered individually or in any combination, together with one or more endothelin antagonist to treat hypertension.

[0015] Another aspect of the present invention is administration of centhaquin to an individual in need thereof as an analgesic to treat pain. In another aspect of the present invention, the centhaquin is coadministered with an opiate analgesic to an individual in need thereof in a treatment for pain.

[0016] Still another aspect of the present invention is administration of centhaquin to an individual in need thereof to treat resuscitative hemorrhagic shock.

[0017] Yet another aspect of the present invention is to provide an article of manufacture for human pharmaceutical use comprising (a) a package insert, (b) a container, and either (c1) a packaged composition comprising centhaquin or (c2) a packaged composition comprising an endothelin antagonist and a packaged composition comprising centhaquin. The package insert includes instructions either for treating pain or resuscitative hemorrhagic shock (c1) or for treating hypertension (c2).

[0018] These and other aspects of the present invention will become apparent from the following detailed description of the preferred embodiments of the invention.

[0018a] The present invention as claimed herein is described in the following items 1 to 12:

1. A method of treating resuscitative hemorraghic shock or shock due to circulatory failure comprising administering to a mammal in need thereof a therapeutically effective amount of centhaquin.

2. The method of item 1 wherein the centhaquin is administered with Ringer's lactate.

3. The method of item 1 wherein the centhaquin is administered at a dose of about 0.05 to about 0.45 mg/kg.

4. The method of item 1 wherein the centhaquin is administered at a dose of about 0.05 to about 0.15 mg/kg.

5. The method of item 2 wherein Ringer's lactate is administered in a volume amount of up to 100% of a volume amount of blood loss (LR-100).

6. The method of item 2 wherein Ringer's lactate is administered in a volume amount of up to 300% of a volume amount of blood loss (LR-300).

7. Use of centhaquin in the preparation of a medicament for treating resuscitative hemorraghic shock or shock due to circulatory failure in a mammal.

8. The use of item 7 wherein the medicament is administered with Ringer's lactate.

9. The use of item 7 wherein the centhaquin is administered at a dose of about 0.05 to about 0.45 mg/kg.

10. The use of item 7 wherein the centhaquin is administered at a dose of about 0.05 to about 0.15 mg/kg.

11. The use of item 8 wherein Ringer's lactate is administered in a volume amount of up to 100% of a volume amount of blood loss (LR-100).

12. The use of item 8 wherein Ringer's lactate is administered in a volume amount of up to 300% of a volume amount of blood loss (LR-300).

BRIEF DESCRIPTION OF THE FIGURES

[0019] Fig. 1 contains graphs of Mean Blood Pressure (mmHz) vs. time (min), Pulse Pressure (mmHz) vs. time (min), and Heart Rate (beats/min) for administration of 10, 30, and 90 ug/kg of clonidine to rats;

[0020] Fig. 2 contains graphs of Mean Blood Pressure (mmHz) vs. time (min), Pulse Pressure (mmHz) vs. time (min), and Heart Rate (beats/min) for administration of clonidine (10 μg/kg) alone and with 100, 300, or 900 μg/kg of ET-1;

[0021] Fig. 3 contains graphs of Mean Blood Pressure (mmHz) vs. time (min), Pulse Pressure (mmHz) vs. time (min), and Heart Rate (beats/min) for administration of clonidine (10 μg/kg) and with TAK-044 or BMS-182874;

[0022] Fig. 4 contains graphs of Mean Blood Pressure (mmHz) vs. time (min), Pulse Pressure (mmHz) vs. time (min), and Heart Rate (beats/min) for administration of clonidine (10 μg/kg) alone and with ET-1, prazosin, and centhaquin or clonodine;

[0023] Fig. 5 contains graphs of Mean Blood Pressure (mmHz) vs. time (min), Pulse Pressure (mmHz) vs. time (min), and Heart Rate (beats/min) for administration of 0.05, 0.15, and 0.45 mg/kg of centhaquin;

[0024] Fig. 6 contains graphs of Mean Blood Pressure (mmHz) vs. time (min), Pulse Pressure (mmHz) vs. time (min), and Heart Rate (beats/min) for administration of centhaquin (0.15 mg/kg) alone and with 100, 300, and 900 mg/kg of ET-1;

[0025] Fig. 7 contains graphs of Mean Blood Pressure (mmHz) vs. time (min), Pulse Pressure (mmHz) vs. time (min), and Heart Rate (beats/min) for administration of centhaquin (0.15 mg/kg) alone and with TAK-044 or BMS182874;

[0026] Fig. 8 contains graphs of Mean Blood Pressure (mmHz) vs. time (min), Pulse Pressure (mmHz) vs. time (min), and Heart Rate (beats/min) for administration of centhaquin (0.15 mg/kg) alone or with ET-1 (300 mg/kg) and prazosin (0.1 mg/kg);

[0027] Fig 9 contains graphs of tail-flick latency (sec) vs. time (min) for vehicle and centhaquin (0.1, 0.3, or 0.9 mg/kg);

[0028] Fig. 10 contains graphs of temperature (°C) vs. time (min) for rats treated with vehicle, centhaquin, morphine, or centhaquin and morphine;

[0029] Figs. 11-13 contain graphs of tail-flick latency (sec) vs. time (min) for rats treated with vehicle, centhaquin, morphine, or centhaquin and morphine;

[0030] Fig. 14A contains an immunoblot showing ET_A receptor expression in rat brain after 1 hour of centhaquin treatment;

[0031] Fig. 14B contains bar graphs of fold change in the expression of ET_A receptor normalized to β-actin, as assessed by densitometry;

[0032] Fig. 15 contains graphs of blood lactate (mmol/L) vs. time (min) in rats resuscitated with Ringer lactate alone or with centhaquin in the hemorrhagic shock model;

[0033] Fig. 16 contains graphs of standard base deficit (mEq/L) vs. time (min) in rats resuscitated with Ringer's lactate alone or with centhaquin in the hemorrhagic shock model;

[0034] Fig. 17 contains bar graphs showing survival time (min) in rats resuscitated with Ringer's lactate alone or with centhaquin in the hemorrhagic shock model;

[0035] Figs. 18 and 19 contain pressure-volume loops for rats resuscitated with Ringer's lactate; and

[0036] Fig. 20 contains pressure-volume loops for rats resuscitated with Ringer's lactate and centhaquin.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0037] The present invention is directed to the administration of centhaquin or other adrenergic agents and an endothelin antagonist to treat hypertension. The present invention also is directed to administration of centhaquin to treat pain or resuscitative hemorrhagic shock.

[0038] The methods described herein benefit from the use of an adrenergic agent, like centhaquin, and an endothelin antagonist in the treatment of hypertension. The adrenergic agent and the endothelin antagonist can be administered simultaneously or sequentially to achieve the desired effect.

[0039] For the purposes of the invention disclosed herein, the term "treatment" includes lowering, ameliorating, or eliminating pain, hypertension, or resuscitative hemorrhagic shock, and associated symptoms of each conditions. As such, the term "treatment" includes medical therapeutic administration and, in the treatment of pain, a prophylactic administration.

[0040] The term "container" means any receptacle and closure therefore suitable for storing, shipping, dispensing, and/or handling a pharmaceutical product.

[0041] The term "insert" means information accompanying a product that provides a description of how to administer the product, along with the safety and efficacy data required to allow the physician, pharmacist, and patient to make an informed decision regarding use of the product. The package insert generally is regarded as the "label" for a pharmaceutical product.

[0042] The term "adrenergic agent" means a compound that stimulates the sympathetic nervous system, e.g., that mimic the effects of norepinephrine and epinephrine. As used herein the term "adrenergic agent" is singular or plural.

[0043] ET is an extremely potent endothelium derived vasoconstriction factor (Hickey et al., 1985) that was isolated, sequenced, and cloned (Yanagisawa et al., 1988). Endothelins

are 21 amino acid, highly potent vasoconstrictive peptides with two disulfide bonds. Endothelins are produced biologically by enzymatically cleaving preproendothelin to proendothelin, then to endothelin by endothelin-converting enzymes. ET exerts biological effects by binding to cell surface receptors, which are 7-transmembrane receptors coupled to G-proteins. There are two distinct types of endothelin receptors: (a) the ET-1 selective ET_A receptors primarily found on vascular smooth muscle and responsible for vasoconstriction, and (b) nonselective ET_B receptors primarily found in vascular endothelium and responsible for vasodilation.

[0044] The vasoconstrictive effects of ET-1 are mediated predominantly by G-protein coupled ET_A receptors. ET-1 also is made in high concentrations by prostate, metastatic cancers, and CNS. ET in the CNS is produced by endothelial cells and nonendothelial cells, such as neurons, astrocytes, and glial cells.

[0045] The global distribution of ET and its binding sites in the brain suggests that, in addition to being a vasoconstrictor, it may be acting as an important neuropeptide in the CNS (Gulati et al., 1992). Endothelin (ET) receptor antagonists, in particular selective ET_A or balanced antagonists ET_A/ET_B, represent a therapeutic area for diseases such as congestive heart failure (CHF) and pulmonary hypertension. BQ-123 and BMS-182874 are specific antagonists of ET_A receptors (Stein et al., 1994). Endothelin antagonists have profound effects on the pulmonary vasculature and the right heart, whereas ACE inhibitors primarily affect the peripheral vessel and the left heart.

[0046] Several studies indicate that the central ET receptors are predominantly of ET_B subtype. Rat cerebral astrocytes have been shown to express mainly ET_B type of receptors and glial cells also were found to intensely express ET_B receptor mRNA. However, the central administration of a highly selective ET_B receptor agonist, IRL-1620, does not produce any effect on the cardiovascular system, and the systemic and regional circulatory effects of centrally administered ET-1 have been shown to be mediated through the ET_A receptors (Gulati et al., 1995; Rebello et al., 1995).

[0047] Intracerebroventricular administration of ET-1 produces a transient rise followed by sustained fall in the mean arterial blood pressure (BP). The pressor effect was accompanied by an increase in renal sympathetic nerve activity and plasma levels of catecholamines and arginine-vasopressin.

[0048] It also has been shown that the effects of central administration of ET-1 are mediated through activation of the sympathetic nervous system because these effects were attenuated by ganglion blockers. Intracisternal administration of ET-1 elicited a transient increase in BP, renal sympathetic nerve activity, and phrenic nerve activity. A subsequent fall in BP was accompanied by a decrease in renal sympathetic nerve activity and phrenic nerve activity. The observation that central ET-1 induced increase in pressor response was suppressed by pretreatment with phenoxybenzamine (Ouchi et al., 1989) further implicates the active participation of sympathetic nervous system in the initial pressor phase.

[0049] An endothelin antagonist utilized in the present invention can be any of the endothelin receptor antagonists known in the art. As used herein, the term "endothelin receptor antagonist" and "endothelin antagonist" are synonymous and are used interchangeably, and refer to administration of one or more of the antagonists. Endothelin is a potent vasoconstrictor. Endothelin antagonists are used to treat acute heart failure, congestive/chronic heart failure, pulmonary arterial hypertension, pulmonary edema, subarachnoid hemorrhage, chronic obstructive pulmonary disease, myocardial infarction, acute cerebral ischemia, acute coronary syndromes, acute renal failure, post-operative treatment in liver operations, and prostate cancer. No adverse effects are expected when a patient is administered an endothelin antagonist.

[0050] Preferred ET antagonists are antagonists selective for endothelin A (ET_A) receptors or are balanced ET_A/endothelin B (ET_B) antagonists. Such ET antagonists are set forth in Appendices A and B herein. However, endothelin B antagonists and miscellaneous endothelin antagonists, as set forth in Appendices C and D herein, also can be used in a composition or method of the present invention. Additional useful endothelin antagonists can be found in U.S. Patent Application Publication Nos. US 2002/0082285 and US 2003/0232787, and in Wu, *Exp. Opin. Ther. Patents* (2000), *10(11)*, pages 1653-1668, each incorporated herein by reference in its entirety.

[0051] Specific examples of endothelin antagonists useful in the present invention include, but are not limited to, atrasentan, tezosentan, bosentan, sitaxsentan, enrasentan, BMS-207940 (Bristol-Myers Squibb), BMS-193884, BMS-182874, J-104132 (Banyu Pharmaceutical), VML 588/Ro 61-1790 (Vanguard Medica), T-0115 (Tanabe Seiyaku), TAK-044 (Takeda), BQ-788, BQ123, YM-598, LU 135252, PD 145065, A-127722, ABT-627, A-192621, A-182086, TBC3711, BSF208075, S-0139, TBC2576, TBC3214, PD156707, PD180988,

ABT-546, ABT-627, Z1611, RPR118031A, SB247083, SB217242, S-Lu302872, TPC10950, SB209670, and mixtures thereof.

[0052] BQ123 is a specific endothelin A antagonist, and is the sodium salt of cyclo(-D-Trp-D-Asp-Pro-D-Val-Leu-). BQ-788 is a specific endothelin B antagonist, and is the sodium salt of N-cis-2,6-dimethylpiperidinocarbonyl-L-gamma-methylleucyl-D-1-methoxycarbonyl triptophanyl-DNIe (see *Proc. Natl. Acad. Sci. USA, 91,* pp. 4892-4896 (1994)).

[0053] In addition to a conventional endothelin antagonist, a compound that inhibits the formation of endogenous endothelin also can be used as the endothelin antagonist in the present invention. Such compounds are useful because they prevent endothelin formation, and, therefore, decrease the activity of endothelin receptors. One class of such compounds is the endothelin converting enzyme (ECE) inhibitors.

[0054] Useful ECE inhibitors include, but are not limited to, CGS34225 (i.e., N-((1-((2(S)-(acetylthio)-1-oxopentyl)-amino)-1-cyclopentyl)-carbonyl-S-4-phenylphenyl-alanine methyl ester) and phosphoramidon (i.e., N-(a-rhamnopyranosyloxyhydroxyphosphinyl)-Leu-Trp).

[0055] Tests were conducted to illustrate the effects of an endothelin antagonist on an adrenergic agent, like clonidine and centhaquin, administered to a mammal, including humans. Tests also were conducted to illustrate the effects of centhaquin on analgesia and resuscitative hemorrhagic shock.

[0056] The tests and data show that a combination of an adrenergic agent, like centhaquin or clonidine, and an endothelin antagonist can be administered to mammals in methods of treating hypertension. The tests and data also show that centhaquin can be administered to mammals, alone or with an opiate analgesic, in methods of treating pain, and in methods of treating resuscitative hemorrhagic shock. The adrenergic agent and endothelin antagonist, or the centhaquin alone, can be formulated in suitable excipients for oral administration, or for parenteral administration. Such excipients are well known in the art. The active agents (e.g., centhaquin and, in some embodiments, an endothelin antagonist and adrenergic agent) typically are present in such a composition in an amount of about 0.1% to about 75% by weight, either alone or in combination.

[0057] For each of the embodiments disclosed herein, pharmaceutical compositions containing the active agents of the present invention are suitable for administration to humans

or other mammals. Typically, the pharmaceutical compositions are sterile, and contain no toxic, carcinogenic, or mutagenic compounds that would cause an adverse reaction when administered.

[0058] The method of the invention can be accomplished using the active agents as described above, or as a physiologically acceptable salt or solvate thereof. The active agents, salts, or solvates can be administered as the neat compounds, or as a pharmaceutical composition containing either or both entities.

[0059] The active agents can be administered by any suitable route, for example by oral, buccal, inhalation, sublingual, rectal, vaginal, intracisternal through lumbar puncture, transurethral, nasal, percutaneous, i.e., transdermal, or parenteral (including intravenous, intramuscular, subcutaneous, and intracoronary) administration. Parenteral administration can be accomplished using a needle and syringe, or using a high pressure technique, like POWDERJECT™. Administration of the active agents can be performed before, during, or after the onset of pain.

[0060] The pharmaceutical compositions include those wherein the active ingredients are administered in an effective amount to achieve their intended purpose. More specifically, a "therapeutically effective amount" means an amount effective to eliminate or to alleviate pain or hypertension. Determination of a therapeutically effective amount is well within the capability of those skilled in the art, especially in light of the detailed disclosure provided herein.

[0061] A "therapeutically effective dose" refers to the amount of the active agents that results in achieving the desired effect. Toxicity and therapeutic efficacy of such active agents can be determined by standard pharmaceutical procedures in cell cultures or experimental animals, e.g., determining the LD_{50} (the dose lethal to 50% of the population) and the ED_{50} (the dose therapeutically effective in 50% of the population). The dose ratio between toxic and therapeutic effects is the therapeutic index, which is expressed as the ratio between LD_{50} and ED_{50}. A high therapeutic index is preferred. The data obtained from such data can be used in formulating a range of dosage for use in humans. The dosage of the active agents preferably lies within a range of circulating concentrations that include the ED_{50} with little or no toxicity. The dosage can vary within this range depending upon the dosage form employed, and the route of administration utilized.

[0062] The exact formulation, route of administration, and dosage is determined by an individual physician in view of the patient's condition. Dosage amounts and intervals can be adjusted individually to provide levels of active agents that are sufficient to maintain therapeutic effects.

[0063] The amount of active agents administered is dependent on the subject being treated, on the subject's weight, the severity of the affliction, the manner of administration, and the judgment of the prescribing physician.

[0064] Specifically, for administration to a human in the curative treatment of hypertension, oral dosages of the adrenergic agent and the endothelin antagonist, individually generally are about 0.01 to about 200 mg daily for an average adult patient (70 kg), typically divided into two to three doses per day. Thus, for a typical adult patient, individual tablets or capsules contain about 0.1 to about 200 mg centhaquin and about 0.1 to about 50 mg endothelin antagonist, in a suitable pharmaceutically acceptable vehicle or carrier, for administration in single or multiple doses, once or several times per day. Dosages for intravenous, buccal, or sublingual administration typically are about 0.1 to about 10 mg/kg per single dose as required. In practice, the physician determines the actual dosing regimen that is most suitable for an individual patient, and the dosage varies with the age, weight, and response of the particular patient. The above dosages are exemplary of the average case, but there can be individual instances in which higher or lower dosages are merited, and such are within the scope of this invention.

[0065] The active agents of the present invention can be administered alone, or in admixture with a pharmaceutical carrier selected with regard to the intended route of administration and standard pharmaceutical practice. Pharmaceutical compositions for use in accordance with the present invention thus can be formulated in a conventional manner using one or more physiologically acceptable carriers comprising excipients and auxiliaries that facilitate processing of the active agents into preparations that can be used pharmaceutically.

[0066] These pharmaceutical compositions can be manufactured in a conventional manner, e.g., by conventional mixing, dissolving, granulating, dragee-making, emulsifying, encapsulating, entrapping, or lyophilizing processes. Proper formulation is dependent upon the route of administration chosen. When a therapeutically effective amount of the active agents are administered orally, the composition typically is in the form of a tablet, capsule, powder, solution, or elixir. When administered in tablet form, the composition can

additionally contain a solid carrier, such as a gelatin or an adjuvant. The tablet, capsule, and powder contain about 5% to about 95% of an active agent of the present invention, and preferably from about 25% to about 90% of an active agent of the present invention. When administered in liquid form, a liquid carrier, such as water, petroleum, or oils of animal or plant origin, can be added. The liquid form of the composition can further contain physiological saline solution, dextrose or other saccharide solutions, or glycols. When administered in liquid form, the composition contains about 0.5% to about 90% by weight of active agents, and preferably about 1% to about 50% of an active agents.

[0067] When a therapeutically effective amount of the active agents is administered by intravenous, cutaneous, or subcutaneous injection, the composition is in the form of a pyrogen-free, parenterally acceptable aqueous solution. The preparation of such parenterally acceptable solutions, having due regard to pH, isotonicity, stability, and the like, is within the skill in the art. A preferred composition for intravenous, cutaneous, or subcutaneous injection typically contains, in addition to a compound of the present invention, an isotonic vehicle.

[0068] Suitable active agents can be readily combined with pharmaceutically acceptable carriers well-known in the art. Such carriers enable the active agents to be formulated as tablets, pills, dragees, capsules, liquids, gels, syrups, slurries, suspensions and the like, for oral ingestion by a patient to be treated. Pharmaceutical preparations for oral use can be obtained by adding the active agents with a solid excipient, optionally grinding the resulting mixture, and processing the mixture of granules, after adding suitable auxiliaries, if desired, to obtain tablets or dragee cores. Suitable excipients include, for example, fillers and cellulose preparations. If desired, disintegrating agents can be added.

[0069] The active agents can be formulated for parenteral administration by injection, e.g., by bolus injection or continuous infusion. Formulations for injection can be presented in unit dosage form, e.g., in ampules or in multidose containers, with an added preservative. The compositions can take such forms as suspensions, solutions, or emulsions in oily or aqueous vehicles, and can contain formulatory agents, such as suspending, stabilizing, and/or dispersing agents.

[0070] Pharmaceutical compositions for parenteral administration include aqueous solutions of the active agent in water-soluble form. Additionally, suspensions of the active agents can be prepared as appropriate oily injection suspensions. Suitable lipophilic solvents

or vehicles include fatty oils or synthetic fatty acid esters. Aqueous injection suspensions can contain substances which increase the viscosity of the suspension. Optionally, the suspension also can contain suitable stabilizers or agents that increase the solubility of the compounds and allow for the preparation of highly concentrated solutions. Alternatively, a present composition can be in powder form for constitution with a suitable vehicle, e.g., sterile pyrogen-free water, before use.

[0071] The active agents also can be formulated in rectal compositions, such as suppositories or retention enemas, e.g., containing conventional suppository bases. In addition to the formulations described previously, the active agents also can be formulated as a depot preparation. Such long-acting formulations can be administered by implantation (for example, subcutaneously or intramuscularly) or by intramuscular injection. Thus, for example, the active agents can be formulated with suitable polymeric or hydrophobic materials (for example, as an emulsion in an acceptable oil) or ion exchange resins, or as sparingly soluble derivatives, for example, as a sparingly soluble salt.

[0072] In particular, the active agents can be administered orally, buccally, or sublingually in the form of tablets containing excipients, such as starch or lactose, or in capsules or ovules, either alone or in admixture with excipients, or in the form of elixirs or suspensions containing flavoring or coloring agents. Such liquid preparations can be prepared with pharmaceutically acceptable additives, such as suspending agents. An active agent also can be injected parenterally, for example, intravenously, intramuscularly, subcutaneously, intrathecally, intracisternally, or intracoronarily. For parenteral administration, the active agent is best used in the form of a sterile aqueous solution which can contain other substances, for example, salts, or monosaccharides, such as mannitol or glucose, to make the solution isotonic with blood.

[0073] For veterinary use, the active agents are administered as a suitably acceptable formulation in accordance with normal veterinary practice. The veterinarian can readily determine the dosing regimen and route of administration that is most appropriate for a particular animal.

Adrenergic agents as centrally acting antihypertensive agents

[0074] Clonidine is an antihypertensive agent that acts through central α_2-adrenergic receptors to lower mean arterial pressure (MAP), but it also acts on peripheral α-adrenergic

receptors (α-ARs) to produce vasoconstriction. Endothelin (ET) has been shown to modulate the action of peripheral adrenergic receptors. The present tests show the involvement of ET in the cardiovascular effects of clonidine and centhaquin. Clonidine (10, 30, and 90 μg/kg, i.v.) produced a dose-dependent fall in mean arterial pressure (MAP), pulse pressure (PP), and a decrease in heart rate (HR). Treatment with ET-1 (100, 300 and 900 ng/kg, i.v.), significantly attenuated clonidine (10 μg/kg, i.v.)-induced fall in MAP in a dose-dependent manner. In rats treated with a high dose of ET-1 (900 ng/kg, i.v.) clonidine produced 42.58% increase in MAP compared to untreated rats. Clonidine (10 μg/kg, i.v.) produced 37.42% increase in HR in rats treated with ET-1 (900 ng/kg, i.v.) compared to untreated rats. An $ET_{A/B}$ antagonist, TAK-044 (1 mg/kg, i.v.), and an ET_A antagonist, BMS-182874 (9 mg/kg, i.v.), potentiated the hypotensive effect of clonidine by 17.68% and 4.81%, respectively, compared to untreated rats.

[0075] Also studied was the interaction of ET with centhaquin which produces a fall in MAP similar to clonidine. Centhaquin (0.05, 0.15, and 0.45 mg/kg, i.v.) produced a dose-dependent fall in MAP, and a decrease in HR. It did not affect arterial blood pH, pO_2, and pCO_2. Neither plasma ET-1 levels were altered. Treatment with ET-1 (100, 300, and 900 ng/kg) significantly attenuated centhaquin (0.15 mg/kg, i.v.)-induced fall in MAP in a dose-dependent manner. In rats treated with 900 ng/kg dose of ET-1, centhaquin produced 33.48% increase in MAP compared to untreated rats. Centhaquin produced 21.44% increase in HR in rats treated with ET-1 compared to untreated rats. The hypotensive effect of centhaquin was significantly potentiated in rats treated with TAK-044 (1 mg/kg) by 16.48% or BMS-182874 (9 mg/kg) by 30.67% compared to untreated rats. Centhaquin-induced bradycardia was significantly potentiated in rats treated with TAK-044 by 12.74% or BMS-182874 by 29.00% compared to untreated rats.

[0076] Prazosin, an α-adrenergic receptor antagonist, pretreatment (0.1 mg/kg, i.v.) completely blocked ET-1 induced changes in cardiovascular effects of clonidine, as well as centhaquin. It was concluded therefore that ET modulates the vascular effects adrenergic receptors leading to alterations in the cardiovascular effects of clonidine and centhaquin. This is the first showing that ET antagonists can potentiate the antihypertensive effects of clonidine and centhaquin, i.e., an adrenergic agent, by increasing the responsiveness of vascular adrenergic receptors to the constrictor effect of centhaquin. A combination of ET

antagonist with clonidine or centhaquin, or other adrenergic agent, therefore is a useful option to treat hypertension.

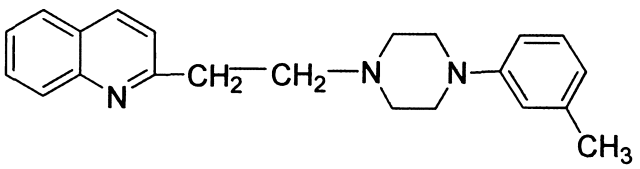
Materials and methods

Animals

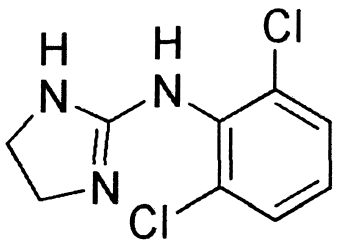
[0077] Male Sprague-Dawley rats weighing 250 to 300 g (Harlan, Indianapolis, IN) were housed for at least 4 days before being used in a room with controlled temperature (23 ± 1 °C), humidity (50 ± 10%) and light (6:00 A.M. to 6:00 P.M.). Food and water were made available continuously. Animal care and use for experimental procedures were approved by the Institutional animal care and use committee. All anesthetic and surgical procedures were in compliance with the guidelines established by the Animal Care Committee.

Drugs and chemicals

[0078] Centhaquin: 2-[2-(4-(3-methyphenyl)-1-piperazinyl) ethyl-quinoline (Central Drug Research Institute, Lucknow, India), clonidine, prazosin, urethane (Sigma-Aldrich St Louis, MO, USA), BMS-182874 hydrochloride: (5-Dimethylamino)-N-(3,4-dimethyl-5-isoxazolyl)-1-naphthalene sulfonamide hydrochloride) an ET_A-specific antagonist (Tocris Bioscience, Ellisville, MO, USA); TAK-044: cyclo [D-α-aspartyl-3-[(4-phenylpiperazin-1-yl) carbonyl]-L-alanyl-L- α-aspartyl-D-2-(2-thienyl) glycyl-L-leu-Cyl-D-tryptOphyljdisodium salt) an $ET_{A/B}$ non-specific antagonist (Takeda Chemical Industries, Osaka, Japan), Endothelin-1 (Research Biochemicals International, Natick, MA, USA), Endothelin-1 Enzyme Immunometric Assay (EIA) Kit (Catalog No. 900-020A, Assay Designs, Inc., Ann Arbor, MI, USA). Other reagents used were of the highest grade commercially available.



Centhaquin



Clonidine

Determination of cardiovascular response of drugs in anaesthetized rats

[0079] Rats were anaesthetized with urethane (1.5 g/kg i.p.) and prepared for the determination of hemodynamic parameters (Gulati and Srimal, 1993; Gulati et al., 1997b). The anesthetized rats were shaved and immobilized to prepare for cannulation. A 2-3 cm incision was made above the femoral vein and artery, and the vessels were dissected and cleaned. The left femoral vein was cannulated (PE-50 tubing, Clay Adams, Parsipanny, NJ) and secured for drug administration. An ultra-miniature Pressure transducer SPR-320 (2F Polyurethane), with a single pressure sensor side mounted at the tip (Millar Instruments, Houston, TX), was inserted in the left femoral artery to acquire the hemodynamic signals. Pressure transducer was connected to bridge amplifier (ML221 Bridge Amp; AD Instruments, Mountain View, CA, USA) with Viking connector (AEC-10C) and the signals were continuously acquired at a sampling rate of 1000 S^{-1} using Millar PowerLab 16/30 data acquisition system (AD Instruments, Mountain View, CA, USA). MAP, HR, and PP were determined and analyzed with LabChart-5.00 software program (Millar Instruments). After the experiment was completed, the animals were euthanized with higher dose of urethane (3 gm/kg).

Determination of ET-1 level in rat plasma

[0080] In order to analyze the change in ET-1 level, blood samples were withdrawn after drug treatment through right femoral artery from the anaesthetized rats before and 1 h after drug treatment and were collected into chilled EDTA tubes (1 mg/ml blood) containing aprotinin (500 KIU/mL of blood). The blood samples were centrifuged at 1,600 x g for 15 minutes at 0°C and plasma separated was stored at -70°C until analyzed. ET-1 level was estimated using Assay's Design's Endothelin-1 Enzyme Immunometric Assay Kit (Nowicki et al., 2005; Brondani et al., 2007). Briefly, plasma samples and standards were added to wells coated with a monoclonal antibody specific for ET-1. The plate then was washed after

24 hr of incubation, leaving only bound ET-1 on the plate. A solution of horseradish peroxidase (HRP) labeled monoclonal antibody to ET-1 then was added, which binds to the ET-1 captured on the plate. The plate was incubated for 30 min, then washed to remove excess HRP labeled antibody. A solution of 3,3',5,5'- tetramethylbenzidine (TMB) substrate was added which generates a blue color when catalyzed by the HRP. Hydrochloric acid (1N) was added, to stop the substrate reaction, and the resulting yellow color was read at 450 nm using DTX 800 Multimode detector. The data was analyzed with Multimode Detection Software (Beckman Coulter, Inc., Harbor Boulevard, Fullerton, CA). The measured optical density is directly proportional to the concentration of ET-1.

Blood gas analysis

[0081] Arterial blood pH, pO_2, pCO_2, Na^+, K^+, and lactate were monitored prior to and after drug administration. Blood samples were drawn from the arterial cannula using blood gas sampling syringes (Innovative Medical Technologies, Inc. Leawood, KS) and analyzed using a GEM Premier 3000 unit (Instrument Laboratory, Lexington, MA).

Determination of clonidine response on the abdominal aortic ring

[0082] The abdominal aorta was isolated and dissected out from urethane (1.5 $g.kg^{-1}$ i.p.) anesthetized rats and was transferred to Krebs bicarbonate buffer pH 7.4 (composition in mM, NaCl, 112.0; KCl, 4.7; KH_2PO_4, 1.2; $MgSO_4$, 1.2; $CaCl_2$, 2.5; $NaHCO_3$, 25.0; glucose, 11.0) with continuous supply of 95% O_2 and 5% CO_2 at 37 ± 1°C. The tissue was cut into ring segments (3 mm in length) and mounted in organ baths using 10 mm Radnoti glass ring supports. Extra care was taken while cutting and mounting the ring segment to prevent loss of endothelial layer. Tissue was equilibrated for 45 min by applying 2 g of tension with regular buffer change after every 15 min. Vessels were pre-contracted with 100 mM KCl to determine the viability. Clonidine-induced contractions of aortic ring were measured using Radnoti 8 unit tissue bath (Radnoti Glass Technology, Monrovia, CA) and the force transducer coupled with a Grass P7D polygraph. The dose response was recorded for 0.25, 0.5, 1, 2, 4, 6, 8, and 10 μM of clonidine with or without ET-1 (4 nM) treatment and ED_{50} value was calculated. Experiments were performed in Group 1: Vehicle + Clonidine (0.25 to 10 μM); and Group 2: ET-1 (4 nM) + Clonidine (0.25 to 10 μM) using (n=6) rats in each group.

Determination of ET_Ar expression in the brain and abdominal aorta

[0083] Brain and abdominal aorta isolated from vehicle and clonidine treated rats were homogenized in RIPA buffer (20 mM Tris-HCl pH 7.5, 120 mM NaCl, 1.0% Triton X100, 0.1% SDS, 1% sodium deoxycholate, 10% glycerol, 1 mM EDTA and 1X protease inhibitor, Roche). Proteins were isolated in solubilized form and concentrations were measured by Folin-Ciocalteu's phenol reagent. Solubilized protein (10 μg) was denatured in Laemmli sample buffer (Bio-Rad), resolved in 10% SDS–PAGE and transferred on nitrocellulose membrane followed by blocking of membrane with 5% BSA (w/v) in TBST (10 mM Tris, 150 mM NaCl, 0.1% Tween 20). The membranes were incubated with rabbit polyclonal anti-ETA antibodies (1:1000), followed by HRP-conjugated secondary antibodies (1:1000) and visualized by ECL Plus western blotting detection system (GE Healthcare, Buckinghamshire UK). Stripped membranes were re-probed with β-actin primary antibody (1:1000) for a protein loading control.

Study design

[0084] The animals were allowed to stabilize for at least 20 min following surgical procedures.

Studies on clonidine:

[0085] Following studies were performed to determine the involvement of ET in clonidine induced cardiovascular (MAP, HR, and PP) effects.

Study 1: Determine the cardiovascular effects of clonidine (N=4).

[0086] Group 1: Clonidine (10 μg/kg, i.v.); Group 2: Clonidine (30 μg/kg, i.v.); and Group 3: Clonidine (90 μg/kg, i.v.)

Study 2: Determine the effect of ET-1 on clonidine-induced cardiovascular effects (N=4).

[0087] Group 1: ET-1 (100 $ng.kg^{-1}$); Group 2: ET-1 (300 $ng.kg^{-1}$); Group 3: ET-1 (900 $ng.kg^{-1}$); Group 4: Vehicle (1 $ml.kg^{-1}$) + clonidine (10 $\mu g.kg^{-1}$); Group 5: ET-1 (100 $ng.kg^{-1}$) + clonidine (10 $\mu g.kg^{-1}$); Group 6: ET-1 (300 $ng.kg^{-1}$) + clonidine (10 $\mu g.kg^{-1}$); and Group 7: ET-1 (900 $ng.kg^{-1}$) + clonidine (10 $\mu g.kg^{-1}$).

Study 3: Determine the effect of TAK-044 (non selective ET_A/ET_B receptor blocker) and BMS-182874 (selective ET_B receptor) on clonidine-induced cardiovascular effects (N=4).

[0088] Group 1: TAK-044 (1 $mg.kg^{-1}$); Group 2: BMS-182874 (9 $mg.kg^{-1}$); Group 3: Vehicle (1 $ml.kg^{-1}$) + clonidine (10 $\mu g.kg^{-1}$); Group 4: TAK-044 (1 $mg.kg^{-1}$) + clonidine (10 $\mu g.kg^{-1}$); and Group 5: BMS-182874 (9 $mg.kg^{-1}$) + clonidine (10 $\mu g.kg^{-1}$).

Study 4: Determine the effect of prazosin on ET-1 induced changes in cardiovascular responses of clonidine (N=4)

[0089] Group 1: Vehicle (1 $ml.kg^{-1}$) + clonidine (10 $\mu g.kg^{-1}$); Group 2: Prazosin (0.1 $mg.kg^{-1}$) + clonidine (10 $\mu g.kg^{-1}$); and Group 3: ET-1 (300 $ng.kg^{-1}$) + prazosin (0.1 $mg.kg^{-1}$) + clonidine (10 $\mu g.kg^{-1}$).

Study 5: Determine plasma ET-1 level in clonidine treated rats (N=4)

[0090] Group 1: Vehicle (1 ml/kg, i.v.); Group 2: Clonidine (10 μg/kg, i.v.); and Group 3: Clonidine (90 μg/kg, i.v.)

Studies on centhaquin:

[0091] Following studies were performed to determine the involvement of ET in centhaquin induced cardiovascular (MAP, HR, and PP) effects.

Study 1: Determine the cardiovascular effects of clonidine (N=5).

[0092] Group 1: Centhaquin (0.05 mg/kg, i.v.); Group 2: Centhaquin (0.15 mg/kg, i.v.); and Group 3: Centhaquin (0.45 mg/kg, i.v.)

Study 2: Determine the effect of ET-1 on centhaquin-induced cardiovascular effects (N=4).

[0093] Group 1: ET-1 (100 $ng.kg^{-1}$); Group 2: ET-1 (300 $ng.kg^{-1}$); Group 3: ET-1 (900 $ng.kg^{-1}$); Group 4: Vehicle (1 $ml.kg^{-1}$) + centhaquin (0.15 $mg.kg^{-1}$); Group 5: ET-1 (100 $ng.kg^{-1}$) + centhaquin (0.15 $mg.kg^{-1}$); Group 6: ET-1 (300 $ng.kg^{-1}$) + centhaquin (0.15 $mg.kg^{-1}$); and Group 7: ET-1 (900 $ng.kg^{-1}$) + centhaquin (0.15 $mg.kg^{-1}$).

Study 3: Determine the effect of TAK-044 (non selective ETA/ETB receptor blocker) and BMS-182874 (selective ETB receptor) on centhaquin-induced cardiovascular effects (N=4).

[0094] Group 1: TAK-044 (1 $mg.kg^{-1}$) + vehicle (1 $ml.kg^{-1}$); Group 2: BMS-182874 (9 $mg.kg^{-1}$) + vehicle (1 $ml.kg^{-1}$); Group 3: Vehicle (1 $ml.kg^{-1}$) + centhaquin (0.15 $mg.kg^{-1}$); Group 4: TAK-044 (1 $mg.kg^{-1}$) + centhaquin (0.15 $mg.kg^{-1}$); and Group 5: BMS-182874 (9 $mg.kg^{-1}$) + centhaquin (0.15 $mg.kg^{-1}$).

Study 4: Determine the effect of prazosin on ET-1 induced changes in cardiovascular responses of centhaquin (N=4)

[0095] Group 1: Vehicle (1 $ml.kg^{-1}$) + centhaquin (0.15 $mg.kg^{-1}$); Group 2: Prazosin (0.1 $mg.kg^{-1}$) + centhaquin (0.15 $mg.kg^{-1}$); and Group 3: ET-1 (300 $ng.kg^{-1}$) + prazosin (0.1 $mg.kg^{-1}$) + centhaquin (0.15 $mg.kg^{-1}$).

Study 5: Determine plasma ET-1 level in centhaquin treated rats (N=4)

[0096] Group 1: Vehicle (1 ml/kg, i.v.); Group 2: centhaquin (0.15 mg/kg, i.v.); and Group 3: centhaquin (0.45 mg/kg, i.v.)

[0097] In the above studies, all drugs were injected through the left femoral vein and changes in MAP, HR, and PP after clonidine and centhaquin injection were recorded for 1 hour using Millar PowerLab 16/30 data acquisition system.

Statistical analysis of data

[0098] Data are presented as mean ± S.E.M. The significance of differences was estimated by one-way analysis of variance (intra group comparison with respect to base line data) and two-way analysis of variance (inter group comparison with respect to corresponding time points from each groups) followed by application of the Dunnett's Multiple Comparisons and Bonferroni test respectively. A *P* value of less than 0.05 was considered to be significant. The statistical analysis was processed with GraphPad Prism software Version 5.00.

Results

Effect of clonidine and centhaquin on arterial blood gases

[0099] Arterial blood pH, pO_2, pCO_2, Na^+, K^+, lactate, and hematocrit were monitored before and one hour after administration of clonidine (90 μg/kg) and centhaquin (0.45 mg/kg), and it was found that there was no significant changes in these parameters with either clonidine or centhaquin (Table 1). Blood samples were drawn from the arterial cannula using blood gas sampling syringes (Innovative Medical Technologies, Inc. Leawood, KS) and analyzed using a GEM Premier 3000 unit (Instrument Laboratory, Lexington, MA).

[00100] Table 1 summarizes arterial blood pH, pO_2, pCO_2, Na^+, K^+, lactate, and hematocrit levels before and after administration of clonidine (90 μg/kg) and centhaquin (0.45 mg/kg). It was found that there were no significant changes in these parameters with either clonidine or centhaquin

Treatment	pH	pCO_2 (mmHg)	pO_2 (mmHg)	Na^+ (mmol/L)	K^+ (mmol/L)	Lactate (mg/dL)	Hct (%)
Baseline	7.28 ± 0.02	47 ± 3	114 ± 3	140 ± 2	3.6 ± 0.2	2.42 ± 0.32	46 ± 2
Clonidine	7.28 ± 0.03	46 ± 4	100 ± 14	139 ± 2	4.3 ± 0.6	1.35 ± 0.25	50 ± 4
Baseline	7.30 ± 0.03	47 ± 4	104 ± 1	144 ± 3	3.5 ± 0.3	2.42 ± 0.17	46 ± 2
Centhaquin	7.27 ± 0.02	53 ± 2	96±9	140±1	4.0 ±0.2	1.25 ± 0.55	52 ± 1

Involvement of ET in clonidine-induced cardiovascular effects

Dose-dependent cardiovascular effects of clonidine

[0100] Clonidine administered intravenously produced a significant decrease in MAP. Lower doses of clonidine (10 μg/kg) produced a fall in MAP of 24.02% ($p<0.01$; compared to baseline), while a dose of 30 μg/kg dose produced a fall in MAP of 26.15% ($p<0.01$; compared to baseline). The fall in MAP was 19.48% ($p<0.01$; compared to baseline) with 90 μg/kg dose of clonidine. The fall in MAP induced by clonidine with 10 and 30 μg/kg dose was significantly ($p<0.01$) more than that induced by 90 μg/kg dose of clonidine (Fig. 1A).

[0101] Administration of clonidine produced a significant reduction in PP. The decrease in PP was 33.81% with 10 μg/kg, 36.39% with 30 μg/kg, and 34.27% with 90 μg/kg dose of clonidine. The decrease in PP was statistically significant ($p<0.01$) compared to respective baseline. The decrease in PP was similar with all the doses of clonidine (Fig. 1B).

[0102] Clonidine produced a decrease in HR. A dose of 10 μg/kg produced a decrease in HR of 20.84%, while 30 μg/kg produced 23.18% decrease, and 90 μg/kg produced a 23.19% decrease. Clonidine induced bradycardia was similar with all the doses (Fig. 1C).

Effect of ET-1 on clonidine induced cardiovascular effects

[0103] In these experiments, a low dose of clonidine (10 μg/kg) was used and it was found that in rats treated with ET-1 (100, 300, or 900 ng/kg), the fall in MAP normally induced by clonidine was not observed. ET-1 (100 ng/kg) treatment significantly attenuated clonidine induced fall in MAP. The maximal attenuation was 27.63% ($p<0.01$) compared to vehicle treated rats receiving clonidine. Similarly, 300 ng/kg dose of ET-1 produced an attenuation of clonidine-induced decrease in MAP by 27.41% when compared to vehicle treated rats receiving clonidine. ET-1 treatment in the dose of 900 ng/kg produced significant attenuation (42.58%; $p<0.001$) of clonidine-induced decrease in MAP, compared to vehicle treated rats

receiving clonidine. Statistical analysis showed that the attenuation of clonidine-induced decrease in MAP was similar in rats treated with different doses (100, 300, and 900 ng/kg) of ET-1 (Fig. 2A).

[0104] Clonidine-induced decrease in PP was attenuated by treatment with ET-1. The dose of 100 ng/kg of ET-1 was most effective in attenuating (33.66%) clonidine induced fall in PP and was found to be statistically significant ($p<0.01$). However, the doses of 300 and 900 ng/kg showed attenuation, but did not reach the level of statistical significance (Fig. 2B).

[0105] Rats treated with ET-1 (100, 300, or 900 ng/kg) when injected with clonidine did not show any significant reduction in HR compared to baseline. ET-1 treatment in the dose of 100 ng/kg showed 18.01% attenuation of clonidine-induced decrease in HR, while 300 ng/kg dose of ET-1 showed 21.00% attenuation and 900 ng/kg dose of ET-1 produced 37.42% ($p<0.001$) attenuation of HR compared to vehicle treated rats receiving clonidine (Fig. 2C).

Effect of ET antagonists on clonidine induced cardiovascular effects

[0106] Rats treated with an ET_A/ET_B receptor antagonist, TAK-044 (1 mg/kg), or an ET_A receptor antagonist, BMS-182874 (9 mg/kg), when injected with clonidine (10 μg/kg) showed significant reduction in MAP by 36.59% and 29.44%, respectively when compared with the baseline. In rats treated with TAK-044, clonidine produced a maximal decrease of 17.68% ($p<0.05$) in MAP compared to vehicle treated rats receiving clonidine. However, in rats treated with BMS-182874, clonidine produced a maximal decrease of 4.81% in MAP compared to vehicle treated rats receiving clonidine (Fig. 3A).

[0107] Rats treated with TAK-044 or BMS-182874, when injected with clonidine, showed significant reduction in PP and a maximum decrease of 52.72% and 44.97%, respectively, compared to baseline. In rats treated with TAK-044, clonidine produced a maximal decrease of 31.42%, while those treated with BMS-182874 produced a 17.06% decrease in PP compared to vehicle treated rats receiving clonidine. The decrease in PP in TAK-044 treated rats was significantly more compared to those treated with BMS-182874 (Fig. 3B).

[0108] Clonidine produced a decrease in HR which was similar in rats treated with TAK-044 or BMS-182874. In rats treated with TAK-044, clonidine produced a maximal decrease of 8.83% in HR when compared to vehicle treated rats receiving clonidine. In rats treated with BMS-182874, clonidine produced a maximal decrease of 5.85% in HR when compared

to vehicle treated rats receiving clonidine (Fig. 3C). Rats treated with TAK-044 (1mg/kg) or BMS-182874 (9mg/kg) alone showed no significant change in MAP, PP, and HR (Figs. 3A, 3B, and 3C).

Effect of prazosin on ET-1 induced changes in cardiovascular responses of clonidine

[0109] In rats treated with ET-1 (300 ng/kg) and prazosin (0.1 mg/kg), clonidine produced no change in MAP compared to baseline. Prazosin completely blocked the changes produced in MAP by clonidine in ET-1 treated rats (Fig. 4A).

[0110] Similarly, in rats treated with ET-1 and prazosin, clonidine produced no change in PP compared to baseline. Prazosin significantly attenuated the decrease in PP induced by clonidine in ET-1 treated rats (Fig. 4B).

[0111] In rats treated with ET-1 and prazosin, clonidine produced no significant change in HR compared to baseline. Prazosin significantly ($p<0.05$) attenuated the decrease in HR induced by clonidine in ET-1 treated rats (Fig. 4C).

Plasma ET-1 level in rats treated with clonidine

[0112] The plasma levels of ET-1 at baseline was found to be 12.18 ± 0.42 pg/ml and after 1 hour of vehicle treatment plasma ET-1 levels were found to be 11.97 ± 1.29 pg/ml. In rats treated with clonidine 10 μg/kg, baseline line ET-1 levels were 12.39 ± 0.62 pg/ml and 1 hour of treatment did not produce any change in plasma ET-1 level (13.45 ± 0.68 pg/ml). Similarly, in rats treated with a high dose of clonidine (90 μg/kg) the baseline ET-1 levels were 12.59 ± 0.77 pg/ml and clonidine treatment did not produce any significant effect on plasma ET-1 levels (11.31 ± 0.92 pg/ml).

Effect of clonidine on abdominal aortic ring

[0113] Clonidine produced a dose-dependent (0.25-10 μM) contraction in rat abdominal aortic ring, while in ET-1 pretreated aorta the contractile response of clonidine was significantly potentiated ($p<0.001$). The percent contraction of aorta produced by clonidine (2 μM), in vehicle and ET-1 (4 nM) treated aorta, was 51.017 ± 1.70% and 75.95 ± 1.36%, respectively, while with 4 μM dose of clonidine, the percent contraction in vehicle and ET-1 treated aorta was 80.27 ± 2.48% and 96.83 ± 0.54%, respectively. The ED_{50} value of clonidine was 2.64 ± 0.02 μM in vehicle treated aorta, while in ET-1 treated aorta the ED_{50} value of clonidine was 1.81 ± 0.04 μM, indicating a significant potentiation ($p<0.001$) of clonidine response by ET-1.

Involvement of ET in centhaquin induced cardiovascular effects

Dose-dependent cardiovascular effects of centhaquin

[0114] Centhaquin administered intravenously to rats, produced significant dose-dependent decrease in MAP. The doses of 0.05 $mg.kg^{-1}$, 0.15 $mg.kg^{-1}$, and 0.45 $mg.kg^{-1}$ centhaquin produced significant decrease of 15.64, 25.15, and 28.08% ($p<0.001$), respectively, compared to baseline. The decrease in MAP produced by 0.15 or 0.45 $mg.kg^{-1}$ doses was more significant compared to 0.05 $mg.kg^{-1}$ dose (Fig. 5A).

[0115] Rats administered with 0.05 $mg.kg^{-1}$, 0.15 mg/kg, and 0.45 $mg.kg^{-1}$ doses of centhaquin showed 10.49, 12.57, and 13.34% ($p<0.01$) reduction in HR, respectively, compared to baseline (Fig. 5B).

Effect of ET-1 on centhaquin induced cardiovascular effects

[0116] Rats treated with 100, 300, and 900 $ng.kg^{-1}$ doses of ET-1 showed a fall ($p<0.001$) followed by significant rise ($p<0.001$) in MAP (Fig. 6A), while no change in HR (Fig. 6B) was observed compared to baseline. A middle dose of 0.15 $mg.kg^{-1}$ of centhaquin was used for subsequent studies. Lower doses of ET-1 (100 and 300 $ng.kg^{-1}$) showed a small statistically insignificant attenuation of centhaquin-induced decrease in MAP, while a higher dose of 900 $ng.kg^{-1}$ showed significant (33.48%; $p<0.001$) attenuation of centhaquin-induced decrease in MAP compared to vehicle treated rats receiving centhaquin (Fig. 7A).

[0117] Administration of centhaquin (0.15 $mg.kg^{-1}$) produced a decrease in HR. The decrease in HR produced by centhaquin was similar in rats treated with vehicle or 100 $ng.kg^{-1}$ dose of ET-1. However, in rats treated with higher dose (300 $ng.kg^{-1}$) of ET-1, centhaquin-induced decrease in HR was significantly attenuated. The dose of 900 ng/kg of ET-1 produced a marked attenuation of 21.44% ($p<0.001$) in centhaquin-induced decrease in HR compared to vehicle treated rats receiving centhaquin (Fig. 7B).

Effect of ET antagonists on centhaquin induced cardiovascular effects

[0118] Centhaquin (0.15 mg/kg) produced a decrease in MAP. However, in rats treated with the ET_A/ET_B receptor antagonist TAK-044 (1 mg/kg), centhaquin produced a marked decrease of 32.31% ($p<0.01$) in MAP compared to baseline. In rats treated with the ET_A receptor antagonist BMS-182874 (9 mg/kg), centhaquin produced even more significant decrease of 43.46% ($p<0.001$) in MAP compared to baseline. It was found that treatment with TAK-044 produced potentiation of centhaquin effect by 16.48% ($p>0.05$), while

treatment with BMS-182874 produced a potentiation of 30.67% ($p<0.001$) compared to vehicle treated rats (Fig. 7A).

[0119] Centhaquin produced a decrease in PP. In rats treated with TAK-044, centhaquin produced a decrease in PP by 46.49% ($p<0.001$) compared to baseline. In rats treated with BMS-182874, centhaquin produced a decrease in PP by 49.68% ($p<0.001$) compared to baseline. The decrease in PP induced by centhaquin was similar in TAK-044 and BMS-182874 treated rats (Fig. 7B).

[0120] A decrease in HR was produced by centhaquin administration. In rats treated with TAK-044, centhaquin produced a decrease in HR by 21.94%, compared to baseline. However, in rats treated with BMS-182874, centhaquin produced a decrease in HR by 35.72% ($p<0.001$), compared to baseline. It was found that TAK-044 produced potentiation of centhaquin-induced decrease in HR by 12.74%, while BMS-182874 produced potentiation by 29.00% ($p<0.001$) in HR compared to vehicle treated rats. Potentiation of centhaquin induced decrease in HR by BMS-182874 was significantly more than that produced by TAK-044 treatment by 18.63% ($p<0.05$) (Fig. 7C). Rats treated with TAK-044 (1mg/kg) or BMS-182874 (9mg/kg) alone showed no significant change in MAP and HR (Figs. 7A and 7B).

Effect of prazosin on ET-1 induced changes in cardiovascular responses of centhaquin

[0121] In rats treated with ET-1 (300 ng/kg) and prazosin (0.1 mg/kg), centhaquin produced no change in MAP compared to baseline. Prazosin completely ($p<0.01$) blocked the changes produced in MAP by centhaquin in ET-1 treated rats (Fig. 8A).

[0122] Similarly, in rats treated with ET-1 and prazosin, centhaquin produced no change in PP compared to baseline. Prazosin significantly ($p<0.001$) attenuated the decrease in PP induced by centhaquin in ET-1 treated rats (Fig. 8B).

[0123] In rats treated with ET-1 and prazosin, centhaquin produced no significant change in HR compared to baseline. Prazosin significantly ($p<0.05$) attenuated the decrease in HR induced by centhaquin in ET-1 treated rats (Fig. 8C).

[0124] Prazosin also blocked the changes in MAP and HR provided by centhaquin in vehicle treated rats (Figs. 8A and 8B).

Plasma ET-1 level in rats treated with centhaquin

[0125] The baseline plasma ET-1 levels were 12.18±0.42 pg/ml, and after 1 hour of vehicle treatment were 11.97±1.29 pg/ml. The plasma ET-1 levels did not show any change in vehicle treated rats. In rats treated with centhaquin (0.15 mg/kg), baseline ET-1 levels were 10.89 ± 1.77 pg/ml and 1 hour of treatment did not produce any change in plasma ET-1 level (10.39 ± 1.75 pg/ml). Similarly, in rats treated with a high dose of centhaquin (0.45 mg/kg), the baseline ET-1 levels were 11.83 ± 1.04 pg/ml and centhaquin treatment did not produce any significant effect on plasma ET-1 level (11.67 ± 1.41 pg/ml).

[0126] The present disclosure illustrates the interaction of ET agonists and antagonists with central acting antihypertensive drugs, clonidine and centhaquin.

[0127] Clonidine is an antihypertensive drug, which acts by stimulating α-adrenergic receptors in the brain (Schmitt, 1969; U'Prichard et al., 1977; Kobinger, 1978) leading to decrease in cardiac output, peripheral vascular resistance and blood pressure. It has specificity towards the presynaptic α_2-adrenergic receptors in the vasomotor center in the brainstem (Schmitt, 1969; Kobinger, 1978). This decreases presynaptic calcium levels, and inhibits the release of norepinephrine and the net effect is a decrease in sympathetic tone (Langer et al., 1980; van Zwieten et al., 1984; Chen et al., 1994). Clonidine also has peripheral α_1-adrenergic agonistic activity, which may produce transient vasoconstriction and hypertension when administered systemically in higher doses. It has an approximately 10-fold higher binding affinity for the α_2-adrenergic receptors than the α_1-adrenergic receptors, both in binding assays and in isolated organs (U'Prichard et al., 1977). The hypotensive effect of clonidine is mediated through the stimulation of α_2-adrenergic receptors (Kobinger, 1978; Guyenet and Cabot, 1981), while the hypertensive effect is due to the vasoconstriction caused by stimulation of peripheral α_1-adrenergic receptors (Timmermans and Van Zwieten, 1980; Bousquet and Schwartz, 1983).

[0128] Although structurally different from clonidine, centhaquin produces a fall in MAP and HR similar to that seen with clonidine in anesthetized cats and rats (Srimal et al., 1990). Centhaquin, like clonidine, is thought to act mainly on the central α_2-adrenoreceptors. Upon chronic administration in rats, both centhaquin and clonidine produced hypotension and bradycardia associated with an up-regulation in α-adrenergic receptors in the hypothalamus and medulla (Gulati et al., 1991a; Gulati et al., 1991b).

[0129] Clonidine or centhaquin administered intravenously produced a dose-dependent hypotension and bradycardia. Treatment with ET-1 completely attenuated clonidine- and centhaquin-induced hypotension and bradycardia. In rats treated with a high dose of ET-1, hypertension and tachycardia was observed when clonidine or centhaquin were administered. This attenuation of clonidine or centhaquin effect by ET-1 could be due to enhanced sensitization of peripheral adrenergic receptors resulting in functional blockage of hypotension induced by clonidine (Gulati and Srimal, 1993) or centhaquin. It can be theorized, but not relied upon, that ET-1 treatment increased the sensitivity of peripheral α-adrenergic receptors to the extent that, when clonidine or centhaquin was administered, a marked hypertensive effect was produced such that their central hypotensive effect was masked and was not observed.

[0130] In order to confirm the involvement of endogenous ET in the modulation of peripheral adrenergic receptors studies were carried out using ET antagonists. Two different ET antagonists were used: TAK-044 (non-selective ET_A/ET_B receptor blocker) (Ikeda et al., 1994)and BMS-18287 (selective ET_A receptor blocker) (Stein et al., 1994). Rats pretreated with TAK-044 and BMS-182874 showed potentiation of the hypotensive effect of clonidine or centhaquin, indicating the involvement of endogenous ET in the peripheral hypertension caused by clonidine. The potentiation was found to be more prominent with TAK-044 compared to BMS-182874, indicating the possible involvement of ET_B receptors in clonidine-induced peripheral effects (Table 2). Prazosin treatment also was used to determine whether α-adrenergic receptors are involved in ET-1 potentiation of clonidine- or centhaquin-induced cardiovascular effects. Rats treated with ET-1 and prazosin when injected with clonidine showed complete blockage of ET-1 induced attenuation of clonidine response, confirming that this effect is mediated through peripheral α-adrenergic receptors.

[0131] Table 2 summarizes the effect of non-selective ET_A/ET_B receptor antagonist TAK-044 and selective ET_A receptor antagonist BMS182874 on clonidine (10 μg/kg) and centhaquin (0.33 mg/kg) induced changes in mean arterial pressure, pulse pressure, and heart rate. A percent change is expressed compared to clonidine or centhaquin response in control rats.

	Hypotension		Decrease in pulse pressure		Bradycardia	
	Clonidine	Centhaquin	Clonidine	Centhaquin	Clonidine	Centhaquin
TAK-044	++ (17.68%)	++ (16.48%)	++++ (31.42%)	+++ (23.83%)	+ (8.83%)	++ (12.74%)
BMS-182874	+ (4.81%)	++++ (30.67%)	++ (17.06%)	+++ (28.72%)	+ (5.85%)	++++ (29.00%)

[0132] The involvement of peripheral adrenergic receptors in the modulation of clonidine effect by ET-1 has been demonstrated earlier by studies conducted in cervical sectioned rats where clonidine given intravenously did not produce any effect on blood pressure and heart rate indicating that due to cervical sectioning clonidine is not able to produce its action on CNS. However, significant hypertensive response was obtained when clonidine was administered following ET-1 treatment in cervical sectioned rats (Gulati and Srimal, 1993). These results confirmed the involvement of peripheral vascular system in the hypertensive effect of clonidine in ET-1 treated rats.

[0133] The present results are supported by studies showing that ET-1 is an important modulator of vasomotor tone and it has been demonstrated that ET-1 is capable of amplifying the contractile response of several vasoactive compounds (Consigny, 1990; Nakayama et al., 1991; Gondre and Christ, 1998). Cross-talk between ET_A receptors and α_1-adrenergic receptors has been reported. In rat fibroblasts transfected with hamster α_1-adrenergic receptors, activation of ET_A receptors resulted in α_1-adrenergic receptor phosphorylation and inhibition of α_1-adrenergic receptor activations (Vazquez-Prado et al., 1997; D'Angelo et al., 2006). The modulator role of endothelium in α-adrenergic agonist-induced vasoconstriction has been shown, because removal of endothelium enhanced the sensitivity and maximal contractile response to adrenergic agonists showing involvement of nitric oxide (Carrier and White, 1985). Results of the present study conducted *in vivo* clearly demonstrate that ET-1 alters the responses of adrenergic drugs, e.g., clonidine and centhaquin, by potentiating the peripheral vasoconstriction mediated via adrenergic receptors. Although clonidine is acting mainly on α_2-adrenergic receptors and less on α_1-adrenergic receptors, studies have shown that prazosin (an α_1-adrenergic receptor antagonist) blocks clonidine-induced contractions of the tail artery (Kennedy et al., 2006). This supports the finding that modulation of clonidine- and centhaquin-induced cardiovascular responses by ET-1 could be completely blocked by

prazosin. Involvement of α_1-adrenergic receptors is further supported by studies where it was found that these receptors mediate contractile responses to norepinephrine in femoral artery (Jarajapu et al., 2001). Vascular ring preparations of the rabbit ear artery and rat thoracic aorta showed that subtypes of α_1-adrenergic receptors are involved in the contractions (Fagura et al., 1997). A recent study shows that there is an increase in sympathetic drive and reduced parasympathetic activity followed 7 day treatment with a non-selective ET_A/ET_B receptor antagonist, bosentan, (Souza et al., 2008) indicating that endogenous ET plays an important role in autonomic control.

[0134] It is interesting to note that a non-selective ET_A/ET_B receptor antagonist, TAK-044, was significantly more effective in potentiating clonidine-induced hypotension and bradycardia compared to centhaquin. On the other hand, a selective ET_A receptor antagonist, BMS-182874 was more effective in potentiating the centhaquin-induced hypotension and bradycardia compared to clonidine. Furthermore, TAK-044 produced more or less similar potentiation of MAP, PP, and HR responses of clonidine and centhaquin, while BMS-182874 produced significantly more marked potentiation of centhaquin effect on MAP, PP and HR compared to clonidine (Table 2). These results indicate that in addition to α_1-adrenergic receptors other receptors also may be playing a role, and that the mechanism of action of clonidine and centhaquin is different. This also supports the involvement of ET_A rather than ET_B receptors in the modulation of cardiovascular effects of adrenergic drugs by ET.

[0135] Other receptors also may be involved because it has been found that repeated administration of clonidine or centhaquin produced up-regulation of 5-HT_1 receptors in the medulla (Gulati et al., 1991a; Gulati et al., 1991b) indicating that both centhaquin and clonidine also may be acting on 5-HT_1 receptors. Several reports have shown that threshold or near threshold concentrations of ET-1 potentiate contractile response to other vasoactive agents like 5-HT (Consigny, 1990; Nakayama et al., 1991). Clonidine or centhaquin treatment did not produce any change in plasma ET-1 levels, it is more likely that there is an interaction of ET receptors with adrenergic receptors.

[0136] When clonidine is administered to a patient with intact autonomic function, a transient rise in blood pressure results, followed by a sustained fall in blood pressure and, in order for clonidine to be effective in lowering blood pressure, autonomic integrity is a necessity (Naftchi and Richardson, 1997). In patients with the injury of the spinal cord, the peripherally acting effects of clonidine and centhaquin may dominate leading to

vasoconstriction and hypertension (Backo et al., 2002). In such cases, use of an ET antagonist along with an adrenergic agent, e.g., clonidine or centhaquin, may be a useful therapeutic option to prevent adverse effects.

[0137] Cases of clonidine intoxication have been reported (Pai and Lipsitz, 1976), and the symptoms of intoxication generally result from the central action of clonidine, although hypertension complicating the over dosage has also been reported (Kobinger and Walland, 1967; Hunyor et al., 1975). A case of hypertensive emergency was reported in a patient maintained with clonidine and mirtazepine prescribed concurrently (Abo-Zena et al., 2000). A possible speculative mechanism of this interaction and hypertensive urgency is that clonidine exerts its antihypertensive effect through agonist activity at central α_2-adrenergic inhibitory receptors and the antidepressant mirtazepine acts as an antagonist at the same α_2-adrenergic receptors (Troncoso and Gill, 2004). At a high dose, it displaces clonidine, leading to a possible loss of antihypertensive effect. The additional rebound hypertension of clonidine withdrawal appears to exacerbate the prior hypertensive state. It may be speculated that in such cases ET antagonists may be of use to reduce the adverse effects of clonidine.

[0138] It has been found that ET can modulate the cardiovascular effects mediated through vascular adrenergic receptors. This is the first report showing that ET antagonists can potentiate the antihypertensive effects of clonidine and centhaquin. An ET antagonist can therefore be useful in the treatment of toxic effects due to an overdose of clonidine. Since two ET antagonists already in US market for the treatment of pulmonary hypertension, and several are in pipeline, it may important to explore the interaction of these agents with other antihypertensive drugs acting on the adrenergic system. Because the use of clonidine is limited due to its adverse effects, a combination of ET antagonist with clonidine or centhaquin can be a useful option to treat hypertension.

[0139] Table 3 summarizes the proposed mechanism by which ET-1 and ET receptor antagonist modulate clonidine- and centhaquin-induced changes in mean arterial pressure. Clonidine and centhaquin act on central as well as peripheral adrenergic receptors. Stimulation of (a) peripheral receptors produces vasoconstriction, and (b) central receptors decreases the sympathetic drive producing vasodilatation, the net result is fall in blood pressure because central effect dominates over the peripheral effect. Treatment with ET-1 markedly increases the peripheral vasoconstrictor effect and now the peripheral effect dominates over the central and net result is an increase in blood pressure. However,

treatment with ET antagonist decreases the peripheral vasoconstrictor effect, therefore the central effect over dominates and the net result is a marked hypotensive effect.

	Mean Arterial Pressure		
Treatment	Central Vasodilatation	Peripheral Vasoconstriction	Change in blood pressure
None	+++	+	↓↓
ET-1	+++	++++	↑
ET antagonist	+++	-	↓↓↓↓

[0140] Figure 1 shows the cardiovascular effects of clonidine (10, 30, and 90 μg/kg) in urethane anaesthetized rats. Dose-response effect of clonidine was recorded for 60 minutes and values for MAP (Figure 1A), PP (Figure 1B), and HR (Figure 1C) are expressed as mean ± SEM with n=4 in each group. $^{*}p<0.05$ compared to baseline and #p<0.05 compared to 10 μg/kg dose of clonidine.

[0141] Figure 2 shows the effect of ET-1 (100, 300 and 900 ng/kg) treatment on clonidine-induced cardiovascular responses in urethane anaesthetized rats. The MAP (Figure 2A), PP (Figure 2B), and HR (Figure 2C) was recorded for 60 minutes after clonidine (10 μg/kg) administration, and the values are expressed as mean ± SEM with n=4 in each group. $^{*}p<0.05$ compared to baseline and #p<0.05 compared to 10 μg/kg dose of clonidine.

[0142] Figure 3 shows the effect of the non-selective ET_A/ET_B receptor antagonist TAK-044 (1 mg/kg) and the selective ET_A receptor antagonist BMS-182874 (9 mg/kg) treatment on clonidine-induced cardiovascular responses in urethane anaesthetized rats. The MAP (Figure 3A), PP (Figure 3B), and HR (Figure 3C) was recorded for 60 minutes after clonidine (10 μg/kg) administration, and the values are expressed as mean ± SEM with n=4 in each group. $^{*}p<0.05$ compared to baseline and #p<0.05 compared to 10 μg/kg dose of clonidine.

[0143] Figure 4 shows the effect of prazosin (0.1 mg/kg) on ET-1 (300 ng/kg) induced changes in cardiovascular responses of clonidine (10 μg/kg) in urethane anaesthetized rats. The MAP (Figure 4A), PP (Figure 4B), and HR (Figure 4C) was recorded for 60 minutes after clonidine (10 μg/kg) administration, and the values are expressed as mean ± SEM with n=4 in each group. $^{*}p<0.05$ compared to baseline and #p<0.05 compared to 10 μg/kg dose of clonidine.

[0144] Figure 5 shows the cardiovascular effects of centhaquin (0.05, 0.15, and 0.45 mg/kg) in urethane anaesthetized rats. Dose-response effect of centhaquin was recorded for 60 minutes, and values for MAP (Figure 5A), PP (Figure 5B) and HR (Figure 5C) are expressed as mean ± SEM with n=4 in each group. $^{*}p<0.05$ compared to baseline and #p<0.05 compared to 0.33 mg/kg dose of centhaquin.

[0145] Figure 6 shows the effect of ET-1 (100, 300, and 900 ng/kg) treatment on centhaquin-induced cardiovascular responses in urethane anaesthetized rats. The MAP (Figure 6A), PP (Figure 6B), and HR (Figure 6C) was recorded for 60 minutes after centhaquin (0.15 mg/kg) administration, and the values are expressed as mean ± SEM with n=4 in each group. $^{*}p<0.05$ compared to baseline and #p<0.05 compared to 0.15 mg/kg dose of centhaquin.

[0146] Figure 7 shows the effect of non-selective ET_A/ET_B receptor antagonist TAK-044 (1 mg/kg) and selective ET_A receptor antagonist BMS-182874 (9 mg/kg) treatment on centhaquin-induced cardiovascular responses in urethane anaesthetized rats. The MAP (Figure 7A), PP (Figure 7B), and HR (Figure 7C) was recorded for 60 minutes after centhaquin (0.15 mg/kg) administration, and the values are expressed as mean ± SEM with n=4 in each group. $^{*}p<0.05$ compared to baseline and #p<0.05 compared to 0.33 mg/kg dose of clonidine.

[0147] Figure 8 shows the effect of prazosin (0.1 mg/kg) on ET-1 (300 ng/kg) induced changes in cardiovascular responses of centhaquin (0.15 mg/kg) in urethane anaesthetized rats. The MAP (Figure 8A), PP (Figure 8B), and HR (Figure 8C) was recorded for 60 minutes after centhaquin (0.33 mg/kg) administration, and the values are expressed as mean ± SEM with n=4 in each group. $^{*}p<0.05$ compared to baseline and #p<0.05 compared to 0.15 mg/kg dose of centhaquin.

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Methods to Treat Pain

[0148] The present invention also relates to the use of centhaquin as an analgesic to treat pain in a subject.

[0149] In one aspect, the invention provides a method of treating or preventing pain comprising administering to a mammal in need thereof a therapeutically effective amount of centhaquin. In one embodiment, the centhaquin is coadministered with an opiate analgesic.

[0150] In one embodiment, the centhaquin is administered in a dose range from about 10 μg to about 300 μg.

[0151] The present method contemplates that the subject to be treated is a mammal. In one embodiment, the mammalian subject is human, or any non-human animal model for human medical research, or an animal of importance as livestock or pets, for example, companion animals. In a related embodiment, the subject is a human.

[0152] In one embodiment, the pain to be treated is chronic pain or acute pain. In a related embodiment, the pain is selected from the group consisting of causalgia, tactile allodynia,

neuropathic pain, hyperalgesia, hyperpathia, inflammatory pain, post-operative pain, chronic lower back pain, cluster headaches, postherpetic neuralgia, phantom limb and stump pain, central pain, dental pain, neuropathic pain, opioid-resistant pain, visceral pain, surgical pain, bone injury pain, diabetic neuropathy pain, post-surgery or traumatic neuropathy pain, peripheral neuropathy pain, entrapment neuropathy pain, neuropathy caused by alcohol abuse, pain from HIV infection, multiple sclerosis hypothyroidism or anticancer chemotherapy pain, pain during labor and delivery, pain resulting from burns, including sunburn, post partum pain, migraine, angina pain, and genitourinary tract-related pain including cystitis.

[0153] In a further aspect, centhaquin is useful to potentiate the analgesic effects of an opiate analgesic. As such, the invention provides a method of treating or preventing pain comprising administering to a mammal in need thereof a therapeutically effective amount of an opiate analgesic and a therapeutically effective amount of a centhaquin.

[0154] The opiate analgesic is selected from the group consisting of morphine, morphine sulfate, codeine, diacetylmorphine, dextromethorphan, hydrocodone, hydromorphone, hydromorphone, levorphanol, oxymorphone, oxycodone, levallorphan, and salts thereof.

[0155] In an embodiment, the opiate analgesic and centhaquin are administered simultaneously. In a related embodiment, the opiate analgesic and centhaquin are administered from a single composition or from separate compositions. In a further embodiment, the opiate analgesic and centhaquin are administered sequentially.

[0156] In one embodiment, the present invention relates to methods of treating pain using centhaquin which produces significant analgesia and relief from pain stimulation.

[0157] The term "treatment" as used herein, refers to preventing, reducing or otherwise ameliorating or eliminating pain. As such, the term "treatment" includes both medical therapeutic and/or prophylactic administration, as appropriate. Treatment and relief of pain symptoms may be measured using pain assessment scales known in the art. Exemplary protocols include measurement of the subjective pain threshold (visual analog scale) and the objective nociceptive flexion reflex (R III) threshold.

[0158] The term "pain" as used herein, refers to all types of pain. In one aspect, the term refers to acute and chronic pains. Exemplary types of pain include, but are not limited to, causalgia, tactile allodynia, neuropathic pain, hyperalgesia, hyperpathia, inflammatory pain,

post-operative pain, chronic lower back pain, cluster headaches, postherpetic neuralgia, phantom limb and stump pain, central pain, dental pain, neuropathic pain, opioid-resistant pain, visceral pain, surgical pain, bone injury pain, diabetic neuropathy pain, post-surgery or traumatic neuropathy pain, peripheral neuropathy pain, entrapment neuropathy pain, neuropathy caused by alcohol abuse, pain from HIV infection, multiple sclerosis hypothyroidism or anticancer chemotherapy pain, pain during labor and delivery, pain resulting from burns, including sunburn, post partum pain, migraine, angina pain, and genitourinary tract-related pain including cystitis.

[0159] The term "analgesic" as used herein refer to an active agent that relieves pain in a subject. The term "opiate analgesic" or "opioid analgesic" refers to a narcotic analgesic used, for example, as an adjunct to anesthesia, or to alleviate pain. The term "non-opiate analgesic" refers to a non-narcotic agent indicated for pain.

[0160] A "therapeutically effective dose" refers to that amount of the active agent or agents that results in achieving the desired effect. Toxicity and therapeutic efficacy of such active agents are determined by standard pharmaceutical procedures in cell cultures or experimental animals, e.g., determining the LD50 (the dose lethal to 50% of the population) and the ED50 (the dose therapeutically effective in 50% of the population). The dose ratio between toxic and therapeutic effects is the therapeutic index, which is expressed as the ratio between LD50 and ED50. A high therapeutic index is preferred. The data obtained from such data is used in formulating a range of dosage for use in humans. The dosage of the active agents, in one aspect, lies within a range of circulating concentrations that include the ED50 with little or no toxicity. The dosage varies within this range depending upon the dosage form employed, and the route of administration utilized.

[0161] "Concurrent administration," "administered in combination," "simultaneous administration" or similar phrases mean that a composition comprising two or more agents are administered concurrently to the subject being treated. By "concurrently," it is meant that each agent is administered at the same time or sequentially in any order at different points in time. However, if not administered at the same time, they are, in one aspect, administered sufficiently closely in time so as to provide the desired potentiation of treatment effect. Suitable dosing intervals and dosing order with such compounds will be readily apparent to those skilled in the art. It is also contemplated that two or more agents are administered in separate compositions, and in one aspect, one composition is administered prior to or

subsequent to administration of the first agent. Prior administration refers to administration of the agents within the range of one day (24 hours) prior to treatment up to 30 minutes before treatment. It is further contemplated that one agent is administered subsequent to administration of the other agent. Subsequent administration is meant to describe administration from 30 minutes after administration of the first agent up to one day (24 hours) after administration of the first agent. Within 30 minutes to 24 hours may includes administration at 30 minutes, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 16, 20, or 24 hours.

[0162] The term "low dose" as used herein refers to a dose of an active ingredient in a composition, wherein the amount of active ingredient in the composition is lower than that typically given in treatment of a subject. For example, the low dose of active agent may be administered in combination with a second active agent such that the active agents exhibit a synergistic effect, and the dose of each active agent in the combination treatment is lower than the dose necessary when the agent is administered not in combination with a second active ingredient.

[0163] Available opiate and opioid analgesics are derivatives of five chemical groups (i.e., phenanthrenes, phenylheptylamines, phenylpiperidines, morphinans, and benzomorphans). Pharmacologically, opiates and nonopiates differ significantly in activity. Some are strong agonists (morphine), others are moderates-to-mild agonists (codeine). In contrast, some opiate derivatives exhibit mixed agonist-antagonist activity (nalbuphine), whereas others are opiate antagonists (naloxone). Morphine is the prototype of the opiate and opioid analgesics, all of which have similar actions on the central nervous system.

[0164] Morphine is chemically derived from opium. Other drugs, such as heroin, are processed from morphine or codeine. Such opiates have been used both medically and nonmedically for centuries. By the early 19th century, morphine had been extracted in a pure form suitable for solution. With the introduction of the hypodermic needle, injection of a morphine solution became the common method of administration. Of the twenty alkaloids contained in opium, only codeine and morphine are still in widespread clinical use.

[0165] The opium group of narcotic drugs are among the most powerfully acting and clinically useful drugs producing depression of the central nervous system. Drugs of this group are used principally as analgesics, but possess numerous other useful properties. Morphine, for example, is used to relieve pain, induce sleep in the presence of pain, check diarrhea, suppress cough, ease dyspnea, and facilitate anesthesia.

[0166] When morphine and related compounds are administered over a long period of time, tolerance to the analgesic effect develops, and the dose then must be increased periodically to obtain equivalent pain relief. Eventually, tolerance and physical dependence develop, which, combined with euphoria, result in excessive use and addiction of those patients having susceptible personalities. For these reasons, morphine and its derivatives must be used only as directed by a physician (i.e., not in greater dose, more often, or longer than prescribed), and should not be used to treat pain when a different analgesic will suffice.

[0167] It is contemplated that centhaquin is useful to potentiate the analgesic effects of an opiate analgesic. Opiate analgesics include, but are not limited to, (a) opium; (b) opium alkaloids, such as morphine, morphine sulfate, codeine, codeine phosphate, codeine sulfate, diacetylmorphine, morphine hydrochloride, morphine tartrate, and diacetylmorphine hydrochloride; and (c) semisynthetic opiate analgesics, such as dextromethorphan hydrobromide, hydrocodone bitartrate, hydromorphone, hydromorphone hydrochloride, levorphanol tartrate, oxymorphone hydrochloride, and oxycodone hydrochloride.

[0168] It is contemplated that the subject treated using the methods described herein is a mammalian subject. The mammalian subject may be human, or any non-human animal model for human medical research, or an animal of importance as livestock or pets, for example, companion animals.

[0169] Administration of the pharmaceutical composition(s) can be performed before, during, or after the onset of pain.

[0170] The present invention provides methods for alleviating and treating symptoms that arise in a subject experiencing pain. In one aspect, the invention provides a method of treating or preventing pain comprising administering to a mammal a therapeutically effective amount of centhaquin.

[0171] The causes of pain include, but are not limited to inflammation, injury, disease, muscle spasm and the onset of a neuropathic event or syndrome. Acute pain is usually self-limited, whereas chronic pain generally persists for 3 months or longer and can lead to significant changes in a patient's personality, lifestyle, functional ability and overall quality of life. Ineffectively treated pain can be detrimental to the person experiencing it by limiting function, reducing mobility, complicating sleep, and interfering with general quality of life.

[0172] Inflammatory (nociceptive) pain can occur when tissue is damaged, as can result from surgery or due to an adverse physical, chemical or thermal event or to infection by a biologic agent. Neuropathic pain is a persistent or chronic pain syndrome that can result from damage to the nervous system, the peripheral nerves, the dorsal root ganglion or dorsal root, or to the central nervous system. Neuropathic pain syndromes include allodynia, various neuralgias such as post herpetic neuralgia and trigeminal neuralgia, phantom pain, and complex regional pain syndromes, such as reflex sympathetic dystrophy and causalgia. Causalgia is characterized by spontaneous burning pain combined with hyperalgesia and allodynia. Hyperalgesia is characterized by extreme sensitivity to a painful stimulus. (Meller et al., Neuropharmacol. 33:1471-8, 1994). This condition can include visceral hyperalgesia which generates the feeling of pain in internal organs. Neuropathic pain also includes hyperpathia, wherein a stimulus that is normally innocuous if given for a prolonged period of time results in severe pain.

[0173] Treatment of chronic pain in human patients is carried out generally as described in U.S. Patent No. 6,372,226. In one aspect, a patient experiencing acute inflammatory pain, neuropathic pain, spastic conditions, or other chronic pain from an injury is treated by intrathecal administration, for example by spinal tap to the lumbar region, with an appropriate dose of a composition described herein for use in a method of the invention. In an additional example, if the subject suffers from arthritis or other joint pain, compositions are administered intraarticularly. The particular dose and site of injection, as well as the frequency of administrations, depend upon a variety of factors within the skill of the treating physician.

[0174] Amelioration of pain symptoms is measured using methods known in the art, including the visual analog scale (VAS), the verbal rating scale (VRS) and the numerical rating scale (NRS) (Williamson et al., J Clin Nurs. 14:798-804, 2005; Carlsson, A., Pain. 1983 16:87-101, 1983). For the visual analog scale, the verbal rating scale, and the numeric rating scale, generally, patients are asked to rate their pain on a numeric scale before and after pain stimulus. Chronic pain is also assessed by an objective scaled test such as the Leeds Assessment of Neuropathic Symptoms and Signs (LANSS) Pain Scale (Bennett, M. Pain. 92:147-157, 2001). A decrease in hypersensitivity to pain stimulus after treatment with a composition comprising an α_2 adrenergic agonist and/or an endothelin receptor antagonist indicates that interfering with normal activity a α_2 adrenergic receptors and/or endothelin

receptors alleviates symptoms associated with chronic pain. It another aspect of the invention, the compositions described herein are administered in conjunction with another pain medications as described above, wherein the therapies provide a synergistic effect in relieving symptoms of chronic pain.

[0175] Improvement in pain is measured at varying timepoints after administration of analgesic is administered and the reduction in pain based on the measurement scale is assessed. In one embodiment, assessment of pain symptoms is carried out every 1, 2, 3, 4, 5, 6, or 8 weeks, or as determined by a treating physician. In one embodiment, the improvement in pain symptoms in a subject, when compared to assessment of pain symptoms before treatment, may be at least 10%, at least 20%, at least 25%, at least 30%, at least 35%, at least 40%, at least 45%, at least 50%, at least 55%, at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95% or 100% as measured using art-recognized pain scales.

[0176] As an additional aspect, the invention includes kits which comprise one or more compounds or compositions packaged in a manner which facilitates their use to practice methods of the invention. In a simplest embodiment, such a kit includes a compound or composition described herein as useful for practice of a method of the invention (i.e., centhaquin), packaged in a container such as a sealed bottle or vessel, with a label affixed to the container or included in the package that describes use of the compound or composition to practice the method of the invention. Preferably, the compound or composition is packaged in a unit dosage form. The kit may further include a device suitable for administering the composition according to a preferred route of administration.

[0177] The data in Figs. 9-13 show that:

(a) centhaquin (0.1, 0.3 and 0.9 mg/kg, iv) produced dose-dependent analgesia;

(b) centhaquin (0.3 and 0.9 mg/kg, iv) potentiated morphine analgesia;

(c) the analgesic effect of centhaquin (0.3 mg/kg, iv) was comparable to 4 mg/kg dose of morphine analgesia; and

(d) the analgesic effect of centhaquin (0.9 mg/kg, iv) was significantly greater than 4 mg/kg dose of morphine analgesia.

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Methods to Treat Resuscitative Hemorrhagic Shock

[0178] The present invention also is directed to methods of treating resuscitative hemorrhagic shock comprising the administration of a therapeutically effective amount of centhaquin to an individual in need thereof.

[0179] In general, hemorrhagic shock is marked by a critical reduction in tissue perfusion, leading to tissue acidosis and hypoxia, compromising the cellular metabolic activity, and cellular and organ function. Hyporesponsiveness to vasoconstrictors during hemorrhagic shock has been documented. Hemorrhagic shock states ranging from mild to severe encompass a number of pathophysiologic, immunologic, and metabolic processes. An increase in base deficit during traumatic shock correlates well with multiple organ failure and a state of decompensation followed by mortality in humans. Base deficit paralleled the hemodynamic variables including mean arterial pressure, heart rate, and cardiac output. The changes in the oxygen delivery and consumption during resuscitation that improved compensation of shock are accurately reflected in base deficit alterations. Whereas base deficit is an indicator of metabolic stress with onset and progression of shock, endothelial and smooth muscle cells in the blood vessels can release a number of vasomediators with injury and onset of blood loss.

[0180] However, limited information is available to define the role of vasomediators in the state of vascular decompensation during hemorrhagic shock. An elevation in the concentration of circulating plasma ET-1 has been observed. It is not clear whether the duration of hemorrhagic shock correlates with the systemic or regional (local) ET-1 levels during different states of hemorrhagic shock. It is possible that a need for rapid compensation for loss of blood volume during hemorrhagic shock stimulates production of ET-1, which in turn can modulate adrenergic receptors. Therefore, centhaquin was used as an adrenergic agent as a main component of a resuscitative solution for the treat of conditions

associated with compensatory and decompensatory states of hemorrhagic shock. The method is not be limited to hemorrhagic shock, but can be used to treat any shock due to circulatory failure.

[0181] Figure 14 shows the fold change in the expression of ET_A receptors normalized to β-action assessed by densitometry. The values are expressed as mean ± SEM. *$p<0.05$ compared to a vehicle control. More particularly, Figure 14 is an immunoblot showing ET_Ar expression in rat brain (Lane-2 to Lane-4) and abdominal aorta (Lane-5 to lane-7) after 1 h of clonidine treatment. Lane-1: Protein marker; Lane-2: Vehicle treatment; Lane-3: Clonidine (10 $\mu g.ml^{-1}$) treatment; Lane-4 clonidine (90 $\mu g.ml^{-1}$) treatment; Lane-5: Vehicle treatment; Lane-6: Clonidine (10 $\mu g.ml^{-1}$) treatment; Lane-7: Clonidine (90 $\mu g.ml^{-1}$) treatment. The blot is representative of four different experiments with similar results (A). Bar graph showing fold change in the expression of ET_Ar in rat brain and abdominal aorta normalized to β-actin assessed by densitometry. Values are expressed as mean ± SEM, with n=4 rats in each group. *$p<0.05$ compared with vehicle treatment.

[0182] Figure 15 shows the lactate levels in rats resuscitated with Ringer's lactate and centhaquin in a hemorrhagic shock model. Values for lactate are expressed as mean ± SEM. With n=5 rats/group. #$p<0.05$ compared to baseline and *$p<0.05$ compared to LR-100 and baseline lactate level after induction of shock. LR-100 is not effective in reversing the blood lactate levels. LR-300 is effective in reducing the blood lactate levels. The graphs show a drop in lactate (mmol/L) with administration of 0.05-0.45 mg/kg of centhaquin. The lower doses of centhaquin were more effective than the higher doses.

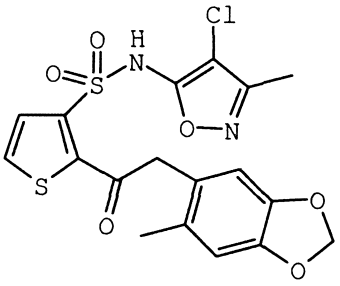
[0183] Figure 16 shows the standard base deficit (mEq/L) over time for rats resuscitated with Ringer's lactate and centhaquin in hemorrhagic shock model. Values for base deficit are expressed as mean ± SEM with n=5 rats/group. #$p<0.05$ compared to baseline. ↑, ↓ $p<0.05$ compared to baseline base after hemorrhagic shock (↑-high base deficit, ↓-low base deficit).

[0184] Figure 17 shows the improvement in survival time for rats resuscitated with Ringer lactate and centhaquin in the hemorrhagic shock model. Values are expressed as mean ± SEM with n>5 rats/group. *$p<0.05$ compared to LR-100. #$p<0.05$ compared to LR-300. The data shows an increase in survival time when centhaquin is administered with LR-100.

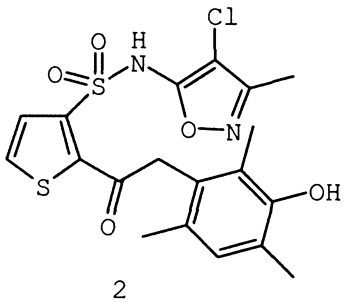
[0185] Figures 18 and 19 are pressure volume loops for resuscitation of rats with LR-100 and LR-300 over time, respectively. Figure 20 contains pressure-volume loops showing the

effect of resuscitating with LR-100 and centhaquin (0.05 mg/kg). The improvement by administering centhaquin in addition to LR-100 is observed by comparing the pressure-volume loops of Figure 20 to the loops of Figure 18.

APPENDIX A
SELECTIVE ET_A ANTAGONISTS



1
sitaxsentan



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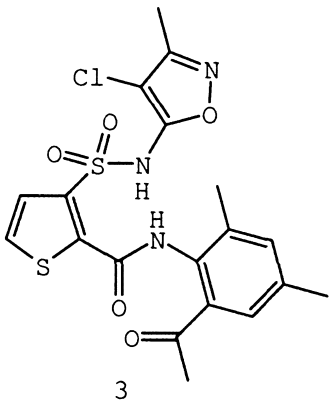

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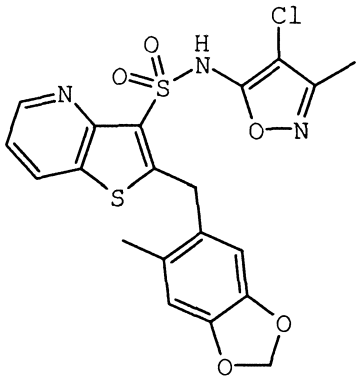
TBC3214



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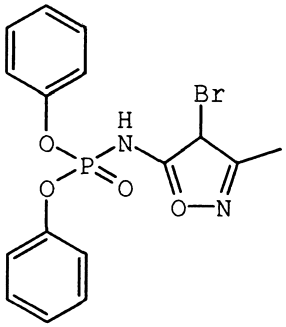

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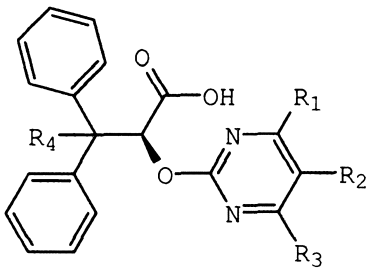
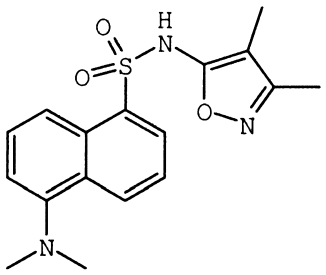


6 $R_1=R_3=R_4=CH_3$, $R_2=H$

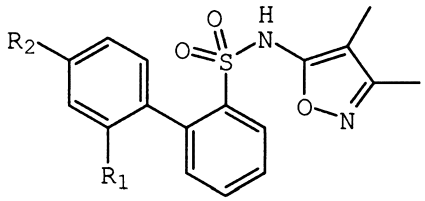
7 $R_1=R_3=R_4=OCH_3$, $R_2=F$

8 $R_1=OCH_3$, $R_2=H$, $R_3=CH_3$, $R_4=-OCH_2CON(CH_3)C_6H_5$



9

BMS 182,874



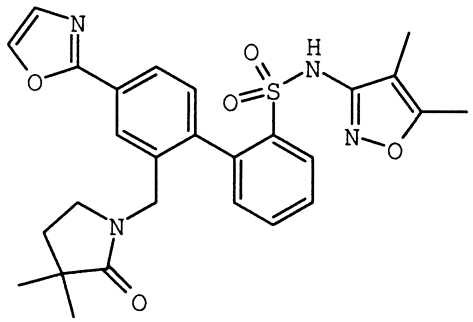
10 R_1=CH_2OH, R_2=H

11 R_1=H, R_2=2-oxazolyl

12 R_1=H, R_2=2-pyrimidinyl

13 R_1=H, R_2=4-methoxyethoxymethyl-4-oxo-1,2,4-triazol-2-yl

14 R_1=H, R_2=1,3-diazo-2-butyl-4-oxospiro(4,4)-1-nonen-3-ylmethyl



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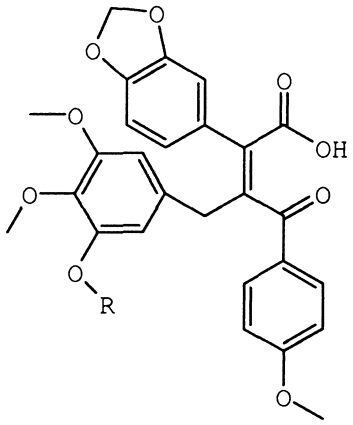
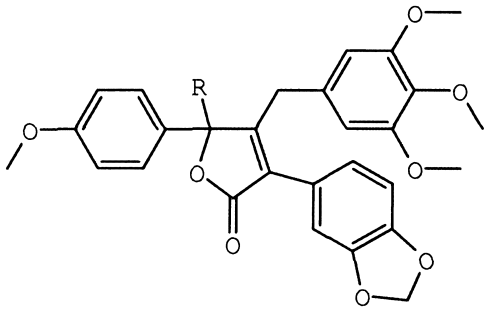


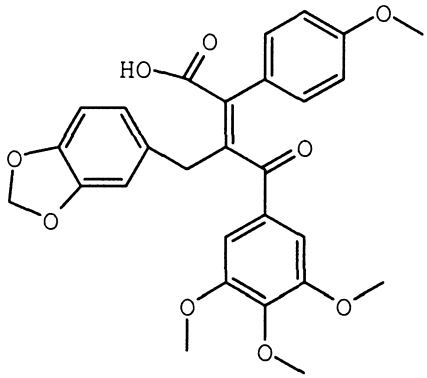
16 R=CH_3 (PD156707)

17 R=$CH_2CH_2CH_2SO_3H$



18 R=$OCH_2CH_2CH_2SO_3H$

19 R=$OCONHCH_2CO_2C_2H_5$



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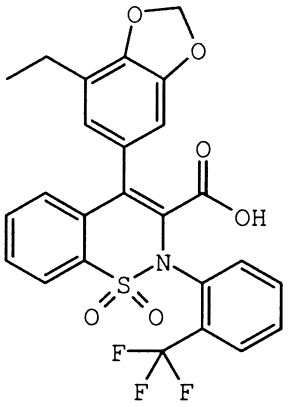

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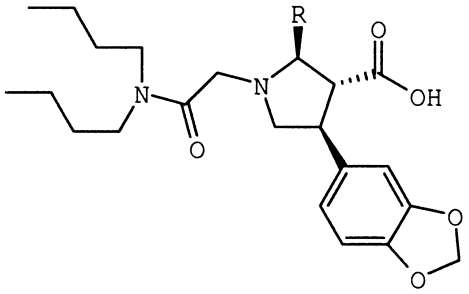
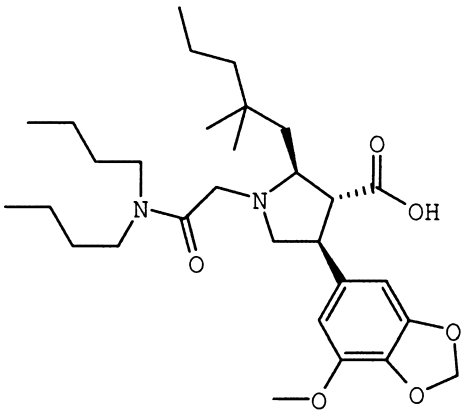
PD180988



22 R=C_6H_4-4-OCH_3 (ABT-627)

23 R=CH_2CH_2-2-pyridyl



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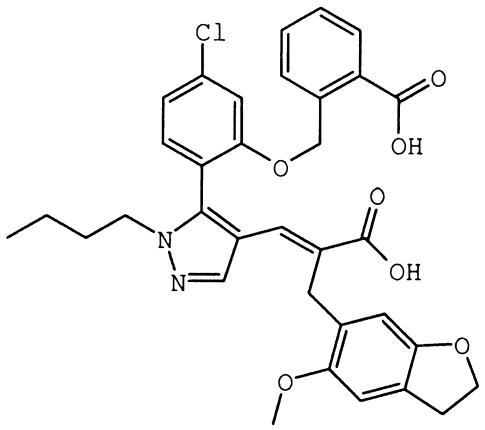

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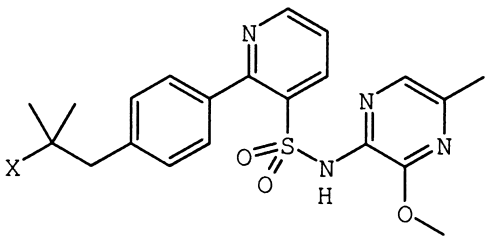
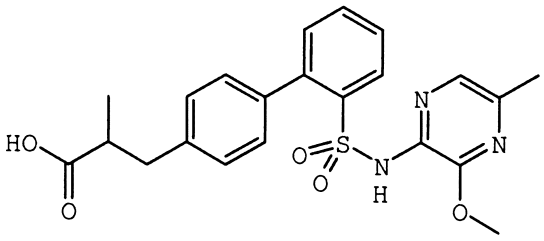
SB247083



26 X=CO_2H (Z1611)
27 X=H



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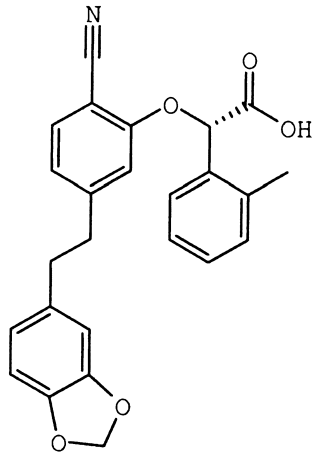

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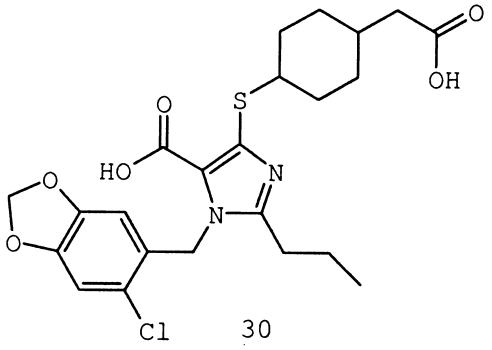

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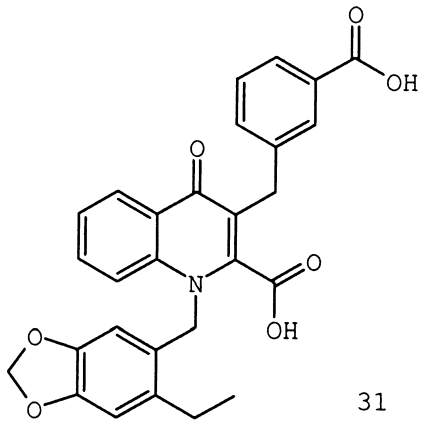

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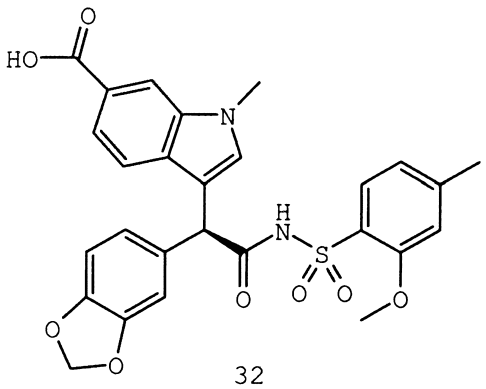

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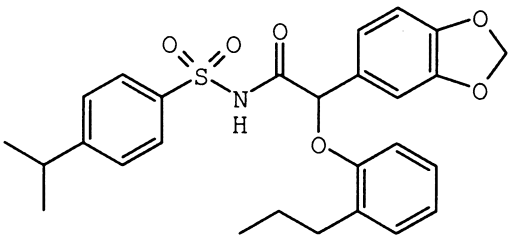

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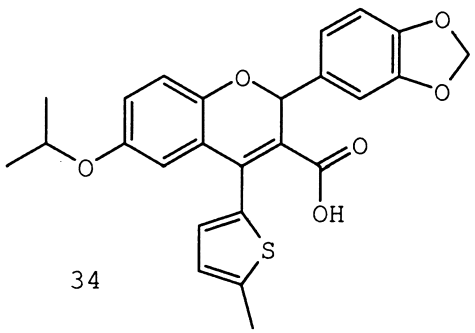

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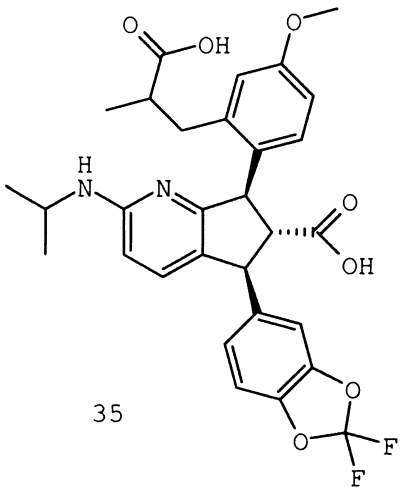
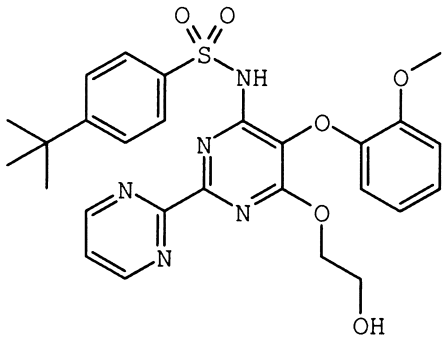


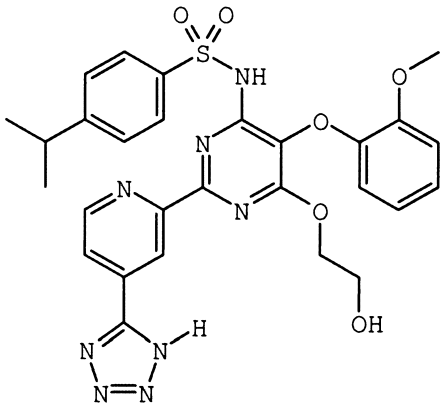
35

APPENDIX B
BALANCED ET_A/ET_B ANTAGONISTS



bosentan

46



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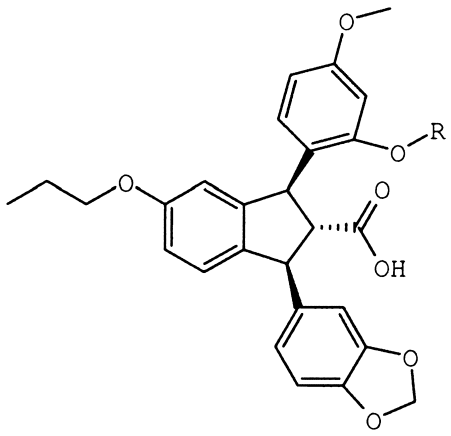
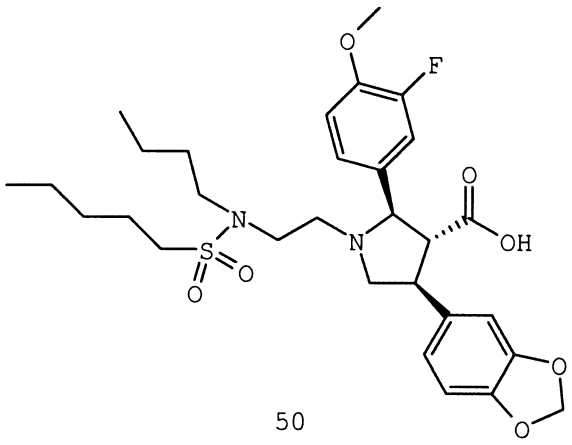


48 R=CH_2CO_2H SB209670

49 R=CH_2CH_2OH SB217242



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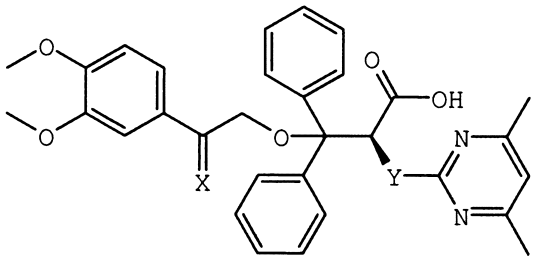
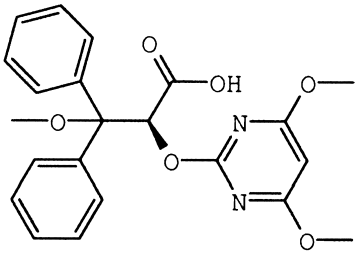


51 X=H_2, Y=CH_2 S-LU 302872

52 X=O, Y=O



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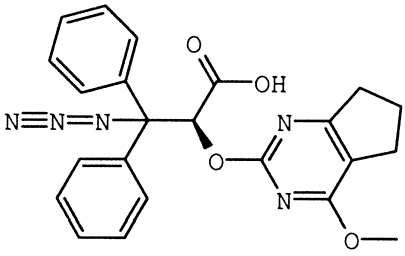

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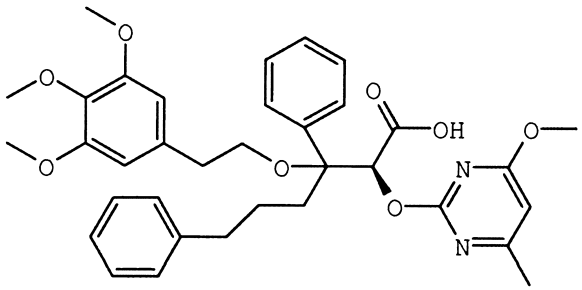

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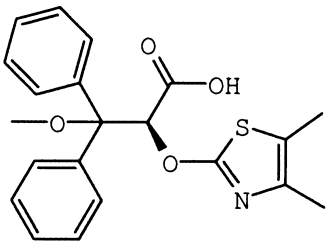

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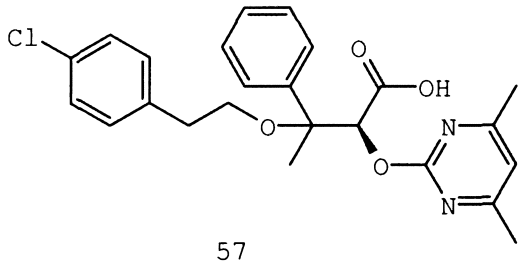

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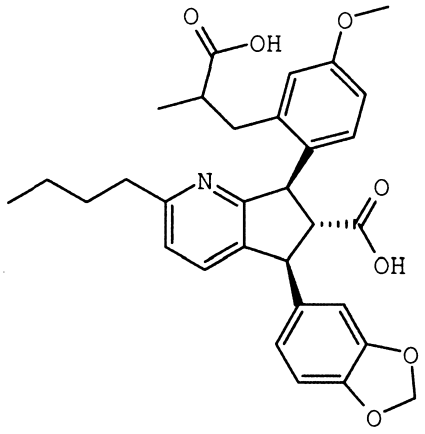
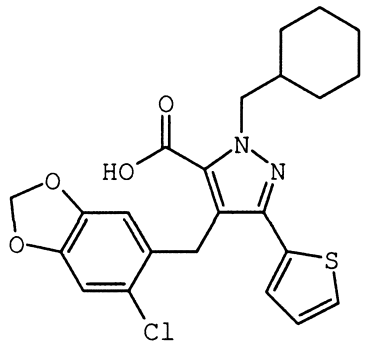


J-104132

58



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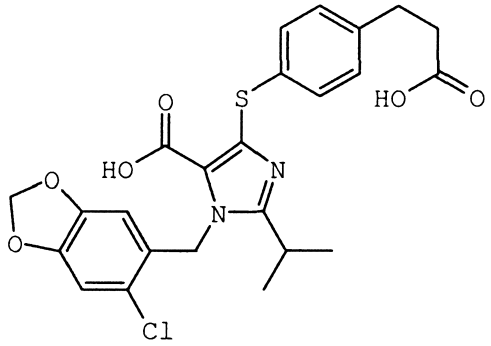

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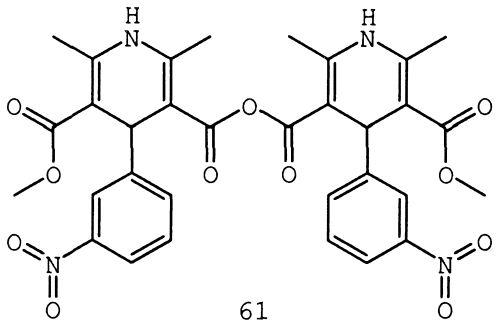

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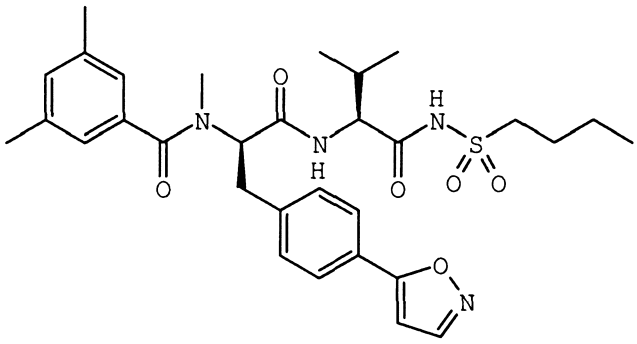

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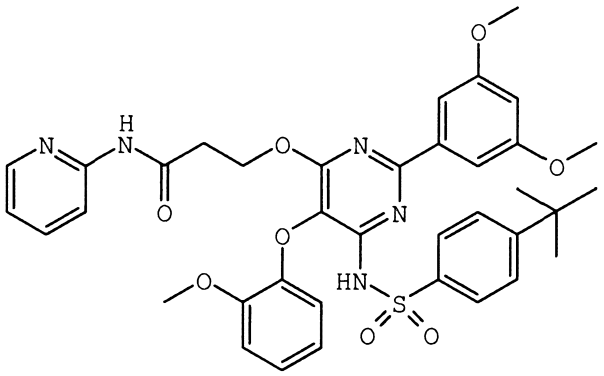

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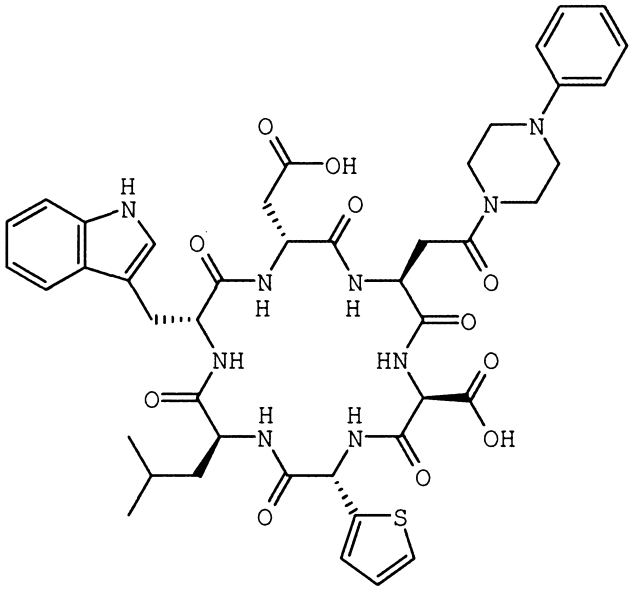
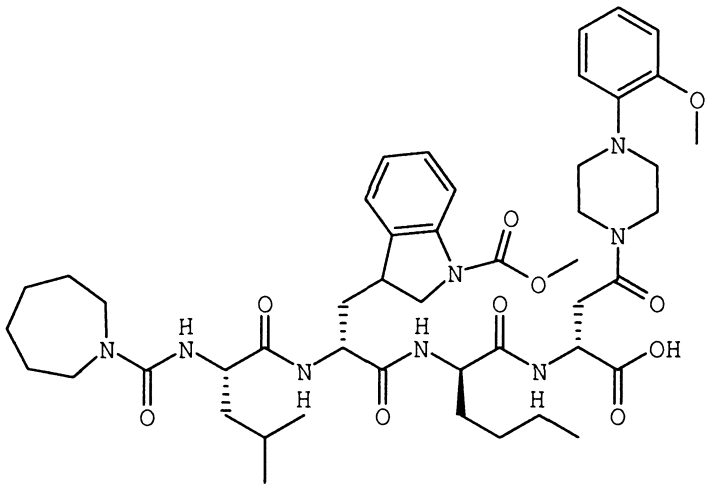


TAK-044

64



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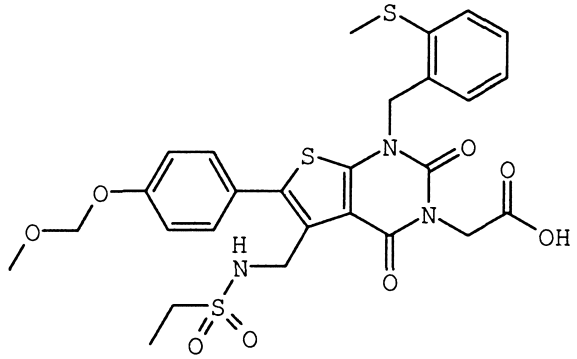

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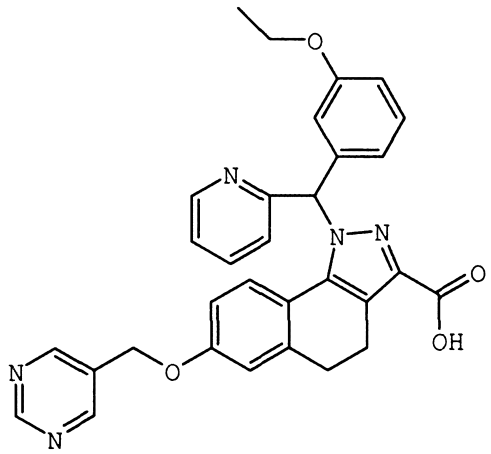

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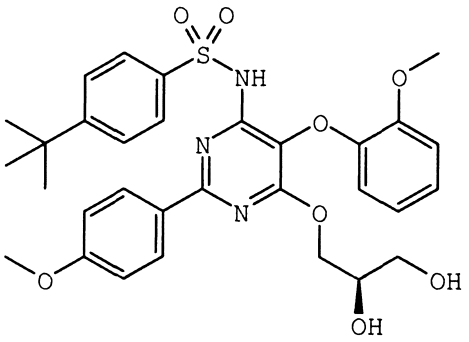
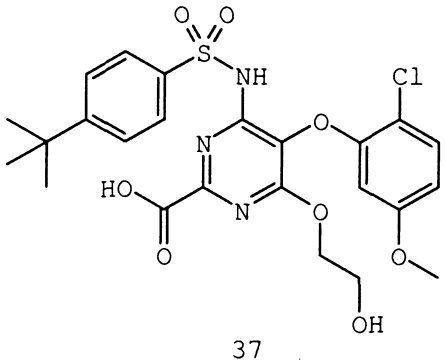
APPENDIX C
SELECTIVE ET_B ANTAGONISTS



Ro 46-8443

36



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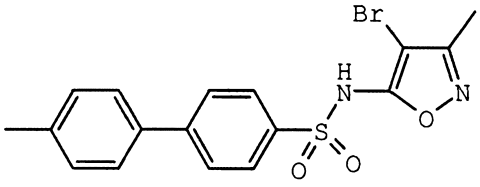
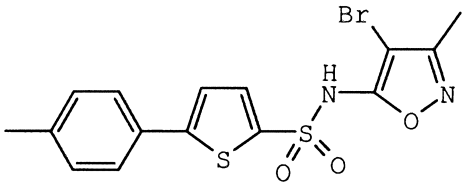


TBC10950

38



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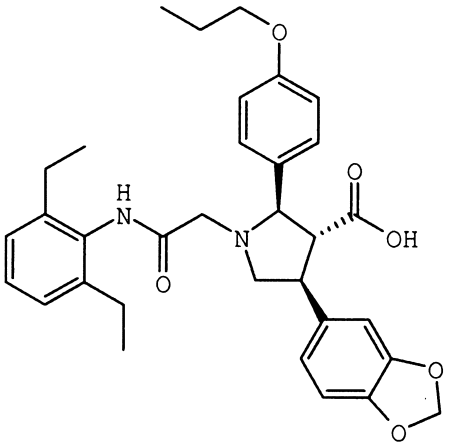

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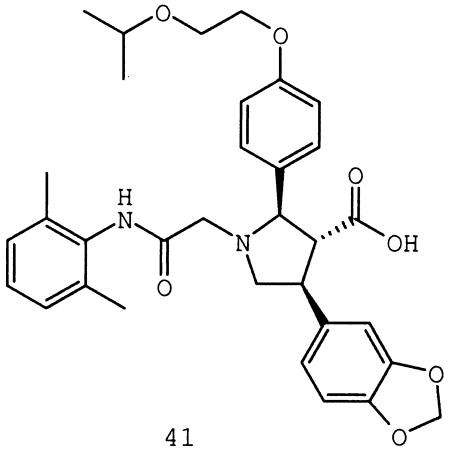

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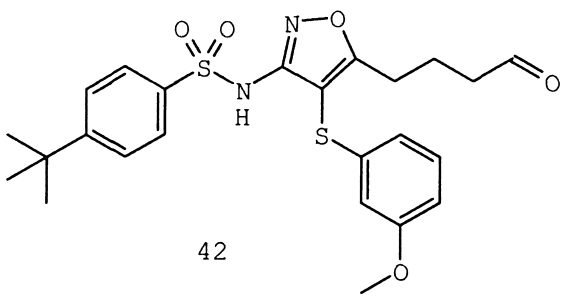

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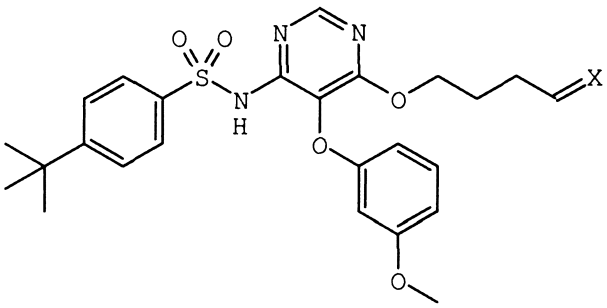
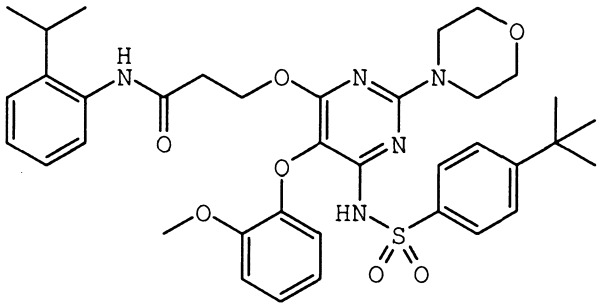


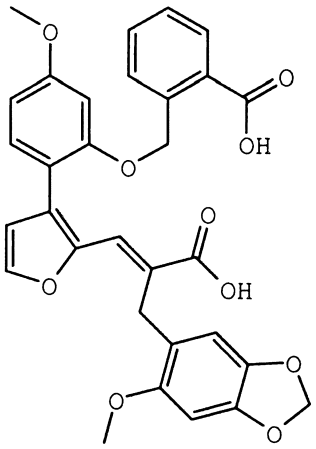
43 X=O

44 X=NNHCO-3-pyridyl



45

APPENDIX D
MISCELLANEOUS ET ANTAGONISTS



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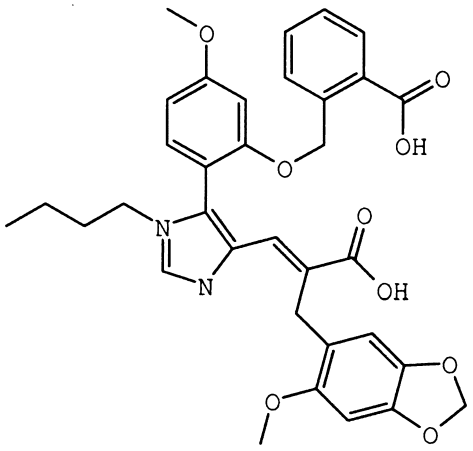

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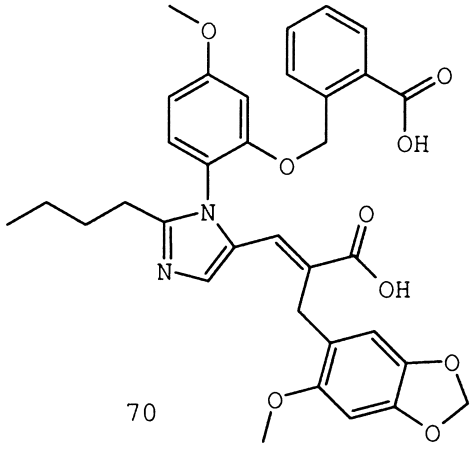

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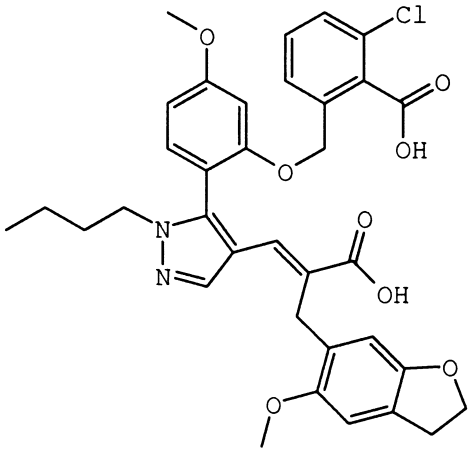

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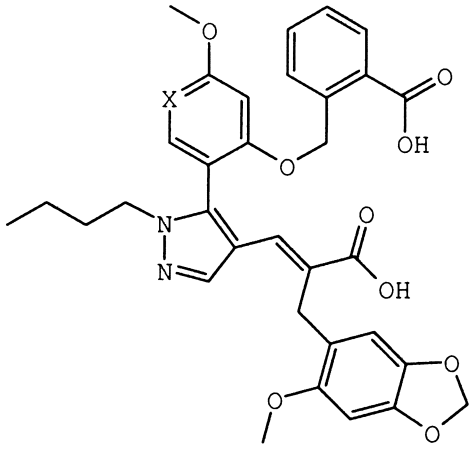
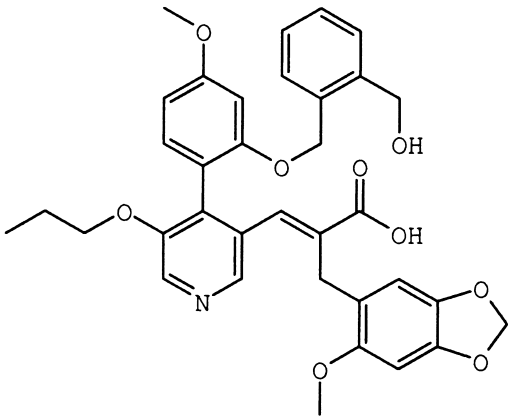


72 X=C
73 X=N



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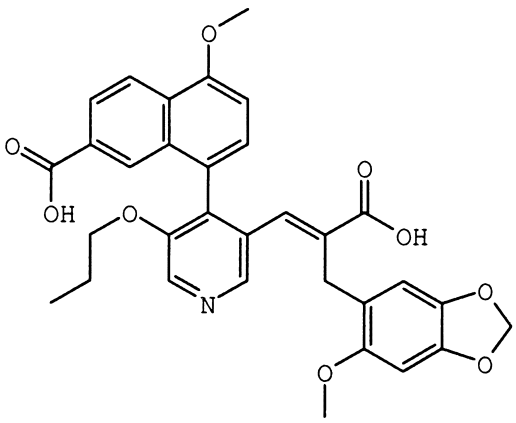

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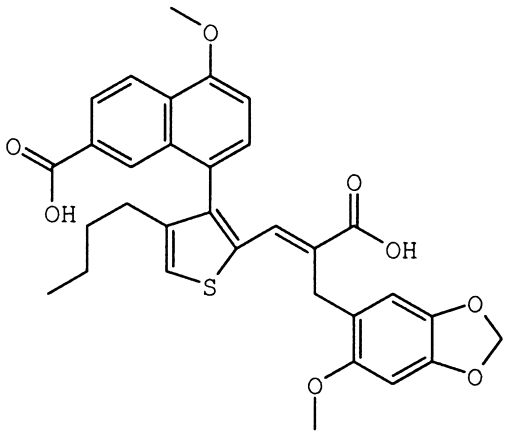

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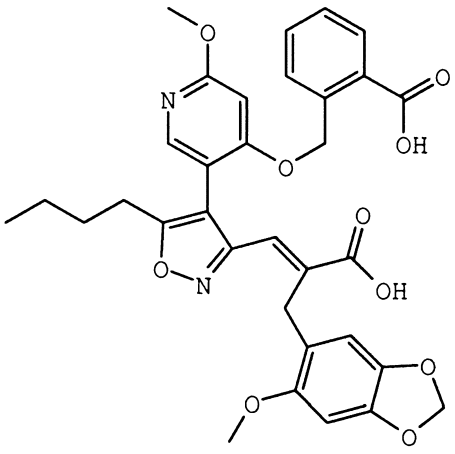

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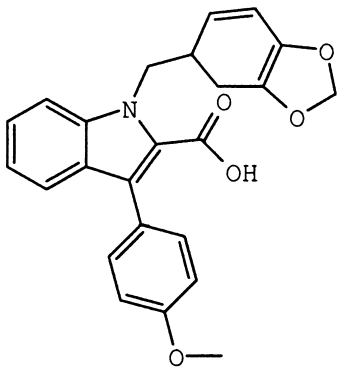

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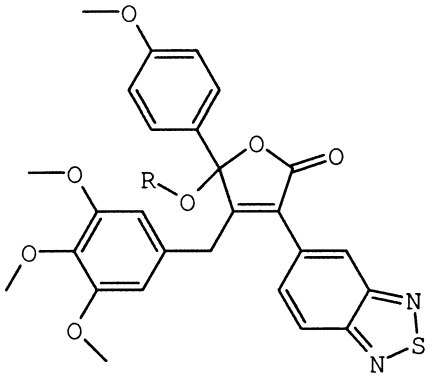
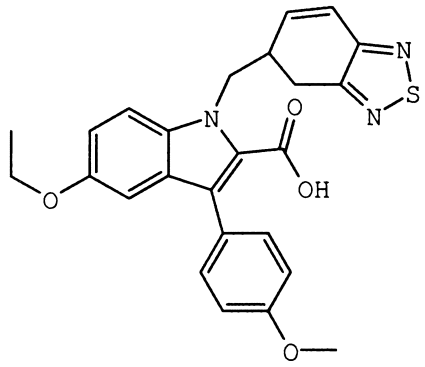


79 R=H

80 R=CONHCH$_2$CO$_2$C$_2$H$_5$



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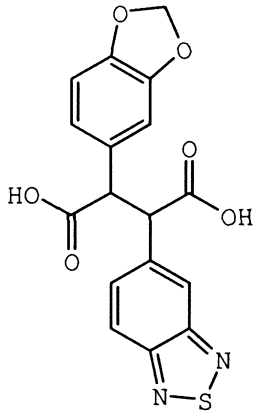

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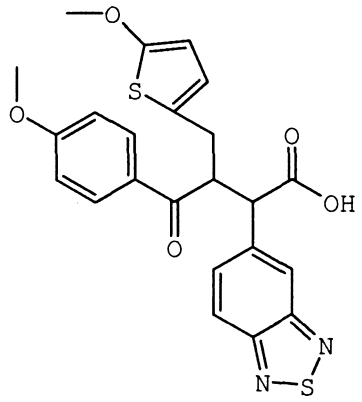

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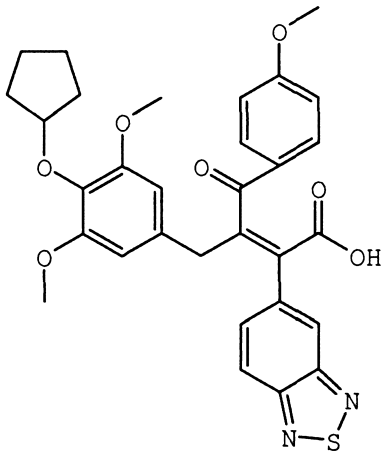

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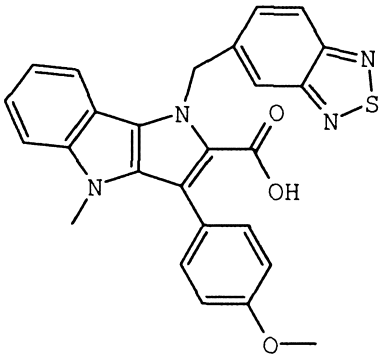

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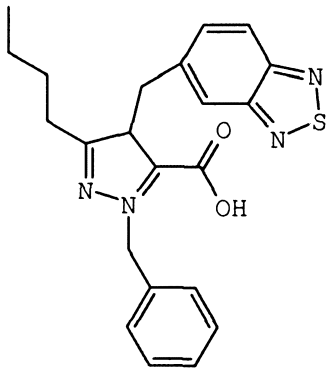

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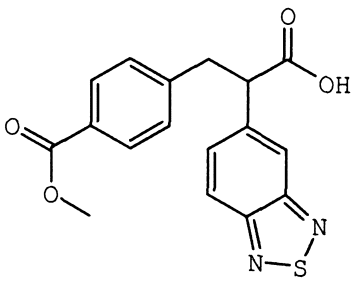

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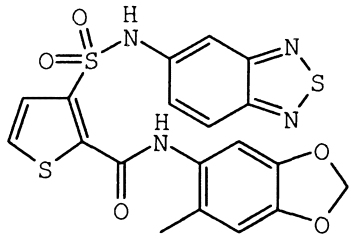

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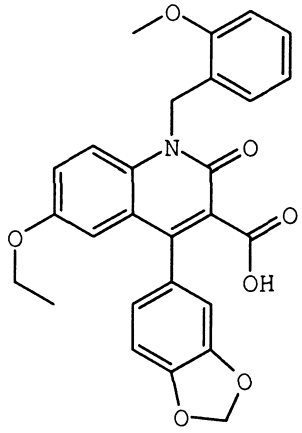

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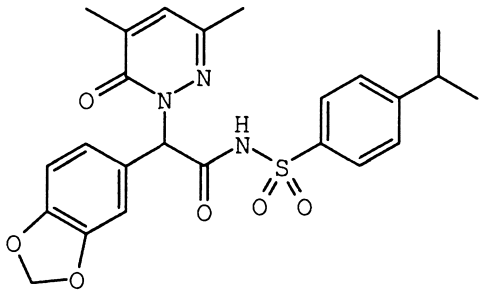

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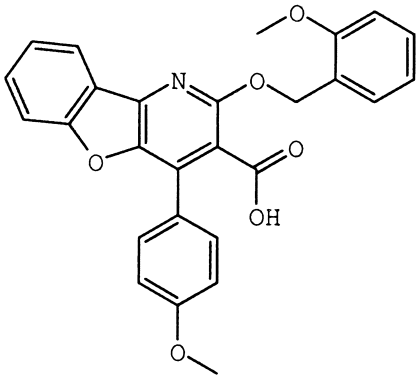

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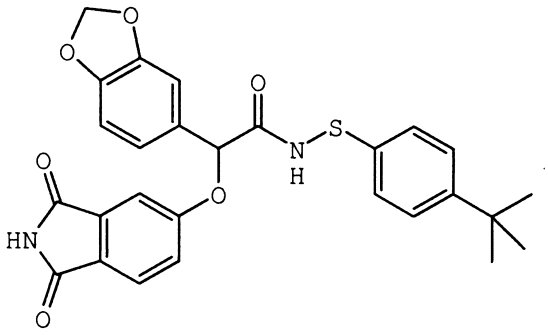

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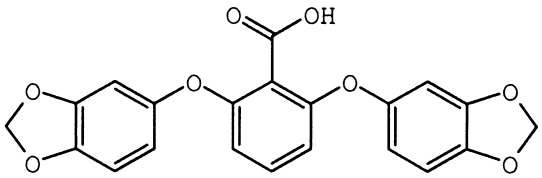

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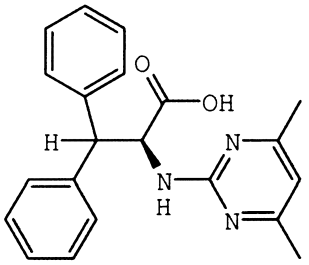

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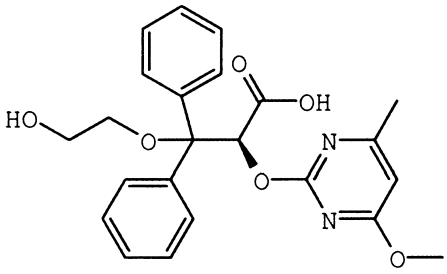

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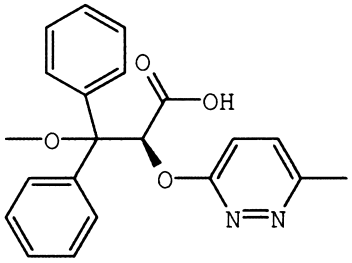

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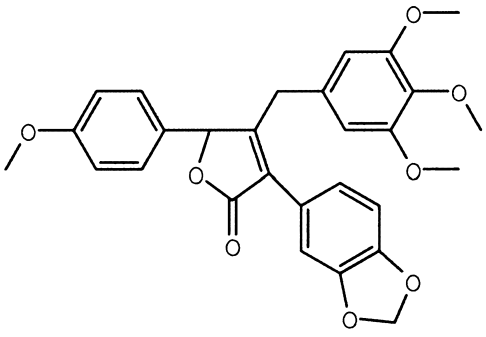

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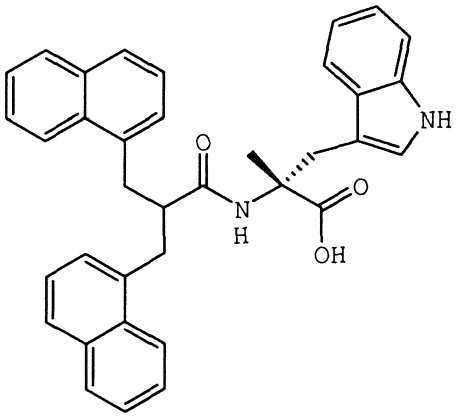
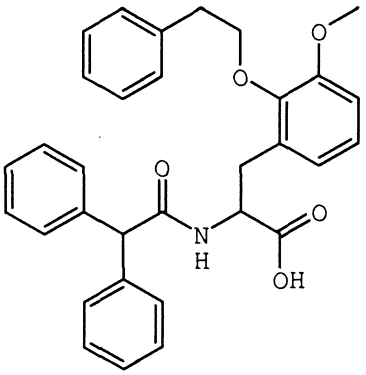


98



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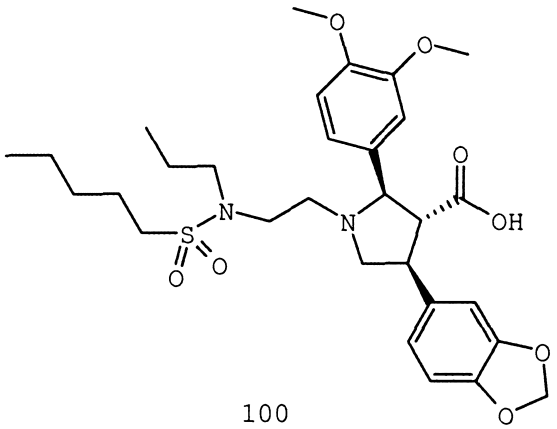

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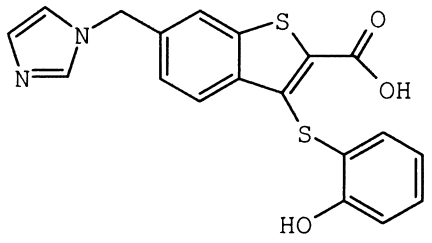

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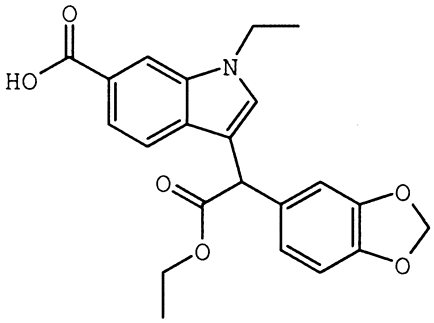

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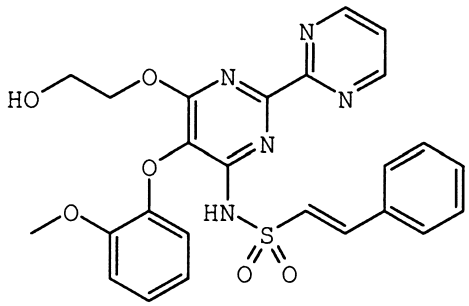

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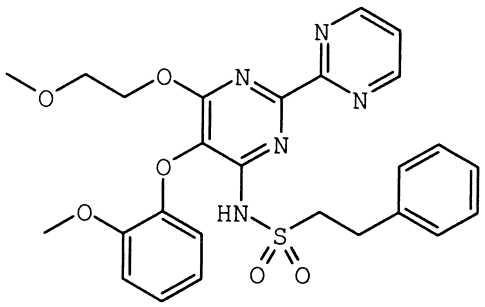

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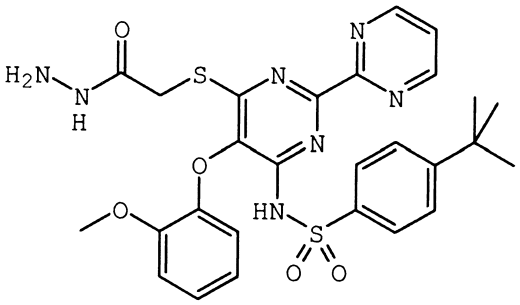

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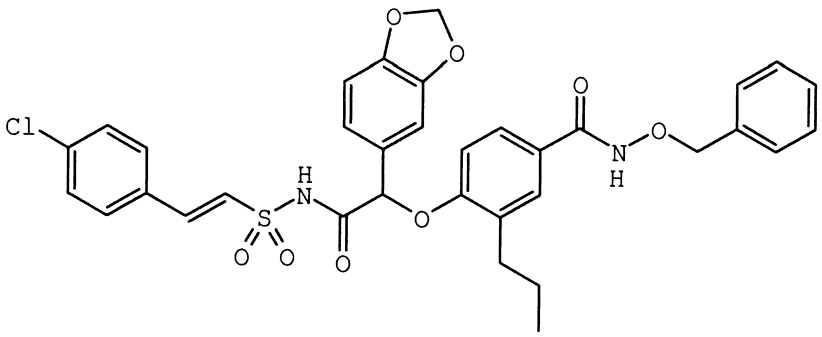

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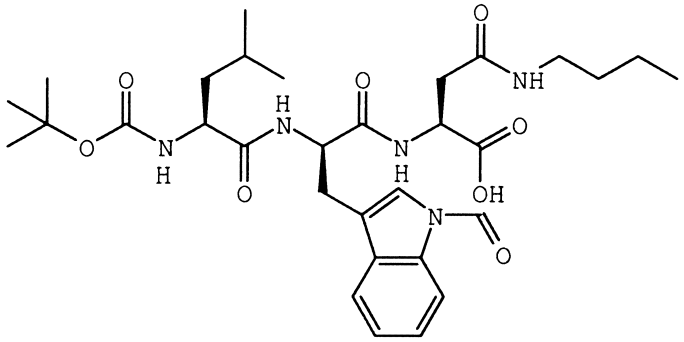

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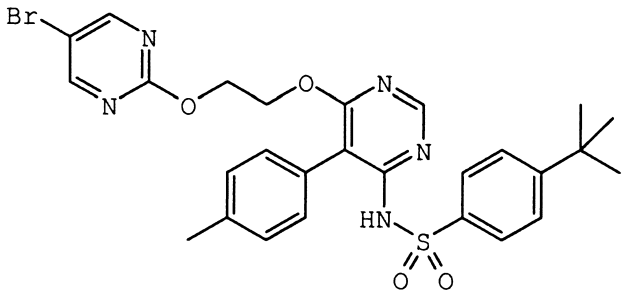

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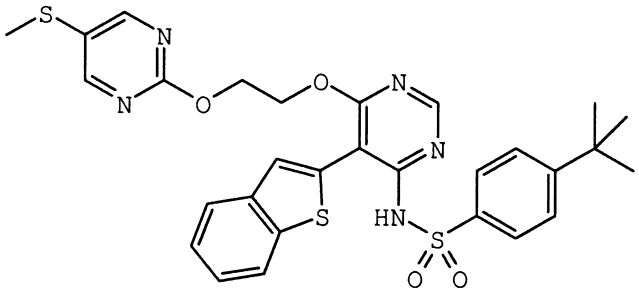

109

[0186] Modifications and variations of the invention as hereinbefore set forth can be made without departing from the spirit and scope thereof, and, therefore, only such limitations should be imposed as are indicated by the appended claims.

[0187] It is to be understood that, if any prior art publication is referred to herein, such reference does not constitute an admission that the publication forms a part of the common general knowledge in the art, in Australia or any other country.

[0188] In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary implication, the word "comprise" or variations such as "comprises" or "comprising" is used in an inclusive sense, i.e. to specify the presence of the stated features but not to preclude the presence or addition of further features in various embodiments of the invention.

CLAIMS:

1. A method of treating resuscitative hemorraghic shock or shock due to circulatory failure comprising administering to a mammal in need thereof a therapeutically effective amount of centhaquin.

2. The method of claim 1 wherein the centhaquin is administered with Ringer's lactate.

3. The method of claim 1 wherein the centhaquin is administered at a dose of about 0.05 to about 0.45 mg/kg.

4. The method of claim 1 wherein the centhaquin is administered at a dose of about 0.05 to about 0.15 mg/kg.

5. The method of claim 2 wherein Ringer's lactate is administered in a volume amount of up to 100% of a volume amount of blood loss (LR-100).

6. The method of claim 2 wherein Ringer's lactate is administered in a volume amount of up to 300% of a volume amount of blood loss (LR-300).

7. Use of centhaquin in the preparation of a medicament for treating resuscitative hemorraghic shock or shock due to circulatory failure in a mammal.

8. The use of claim 7 wherein the medicament is administered with Ringer's lactate.

9. The use of claim 7 wherein the centhaquin is administered at a dose of about 0.05 to about 0.45 mg/kg.

10. The use of claim 7 wherein the centhaquin is administered at a dose of about 0.05 to about 0.15 mg/kg.

11. The use of claim 8 wherein Ringer's lactate is administered in a volume amount of up to 100% of a volume amount of blood loss (LR-100).

12. The use of claim 8 wherein Ringer's lactate is administered in a volume amount of up to 300% of a volume amount of blood loss (LR-300).

13. The method of any one of claims 1 to 6, or the use of any one of claims 7 to 12, substantially as herein described with reference to any one of the Examples.

Figure 1

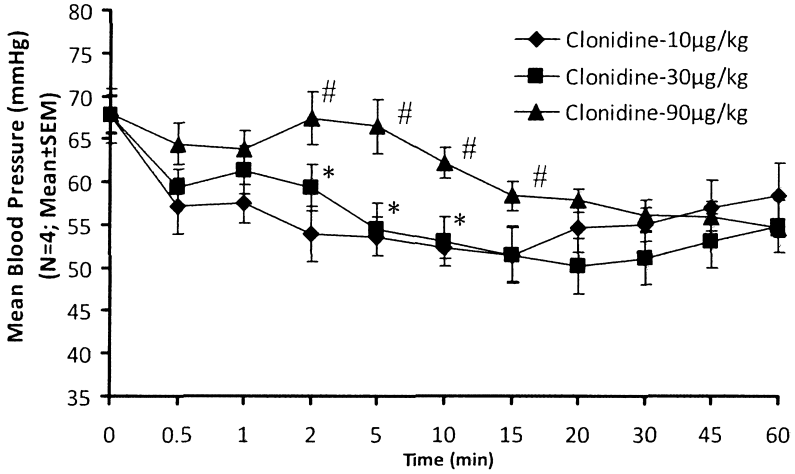

Figure 1A

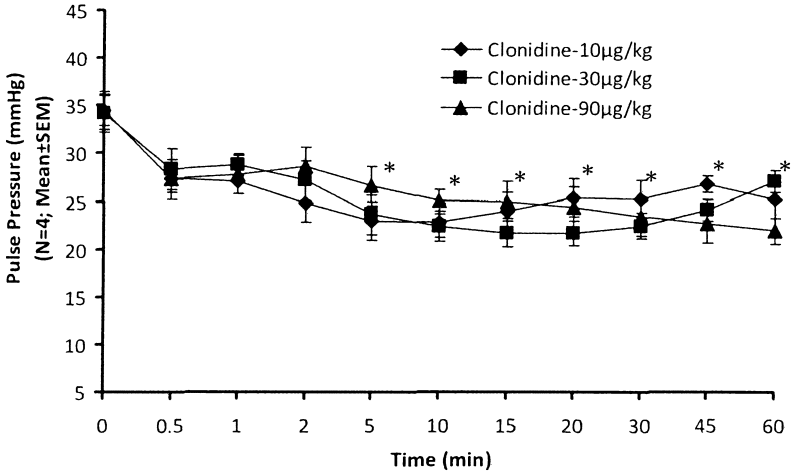

Figure 1B

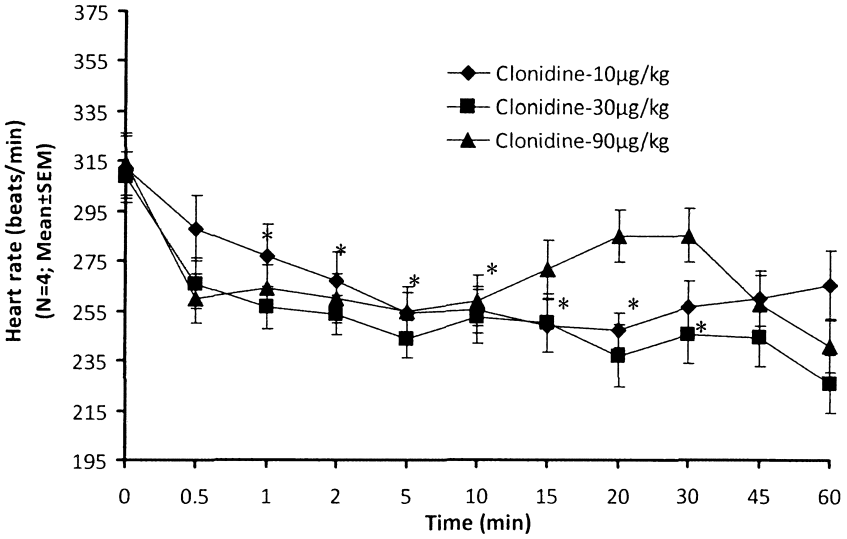

Figure 1C

Figure 2

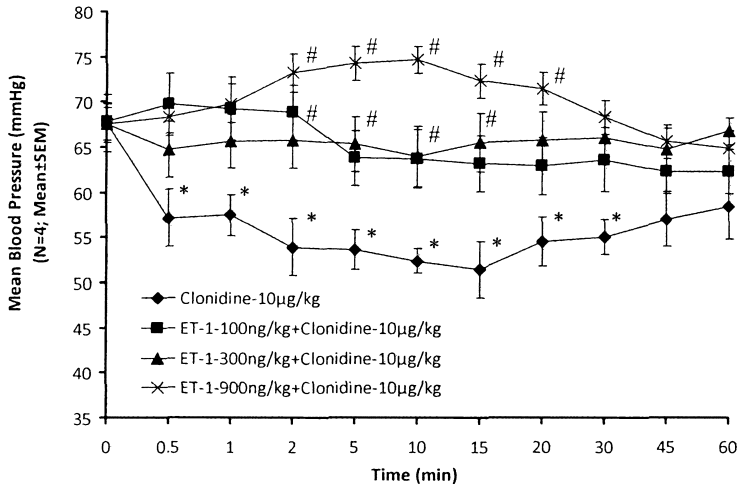

Figure 2A

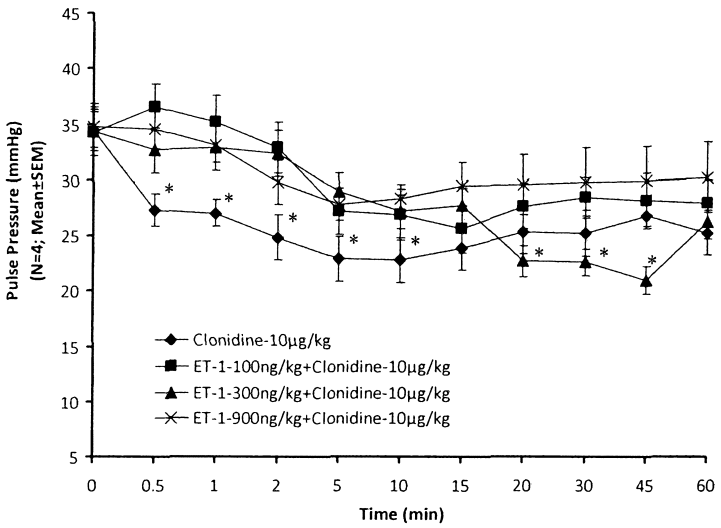

Figure 2B

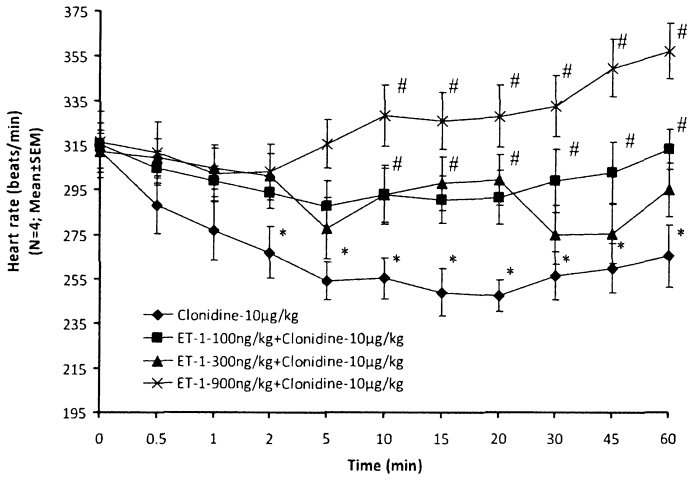

Figure 2C

Figure 3

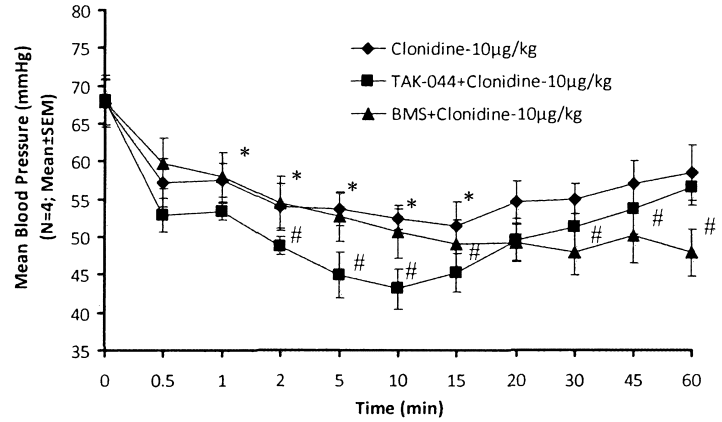

Figure 3A

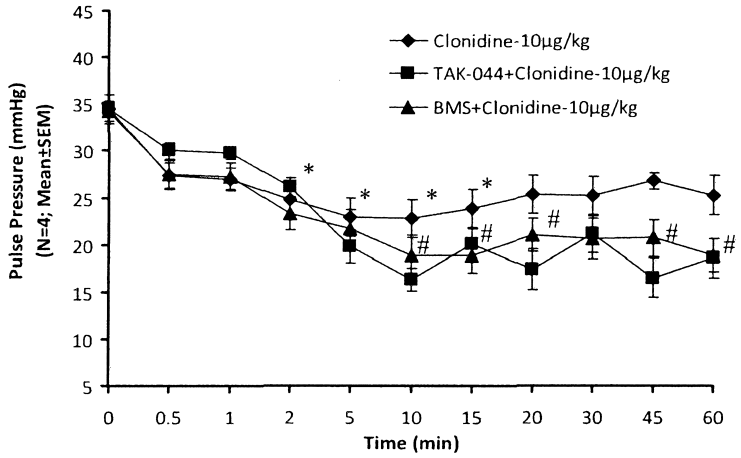

Figure 3B

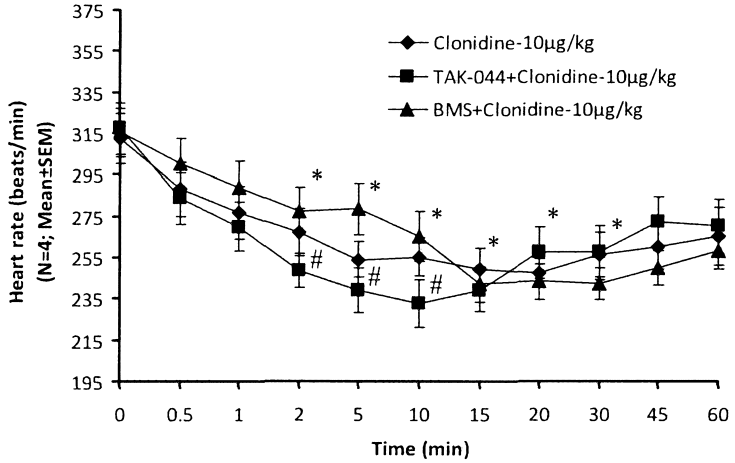

Figure 3C

Figure 4

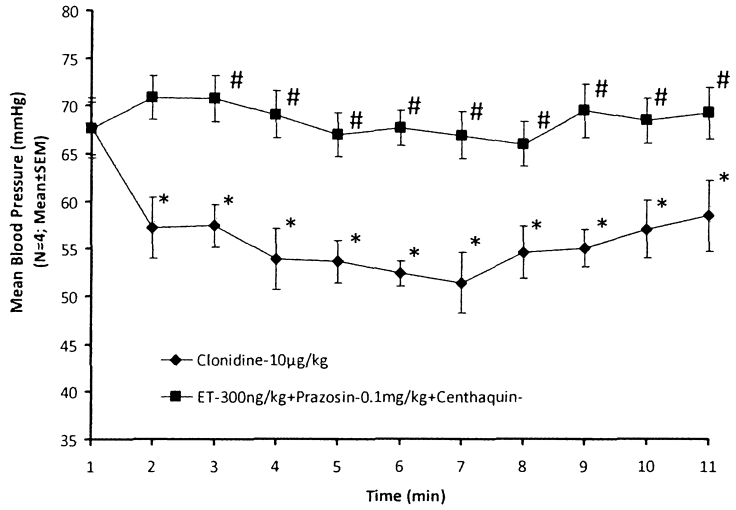

Figure 4A

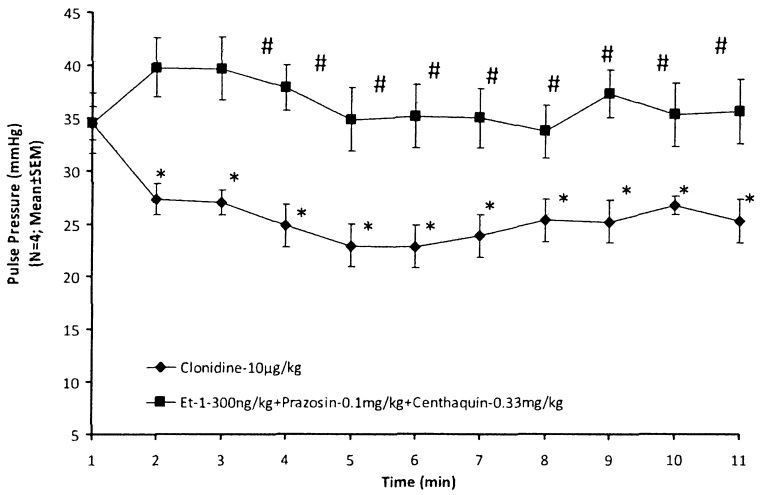

Figure 4B

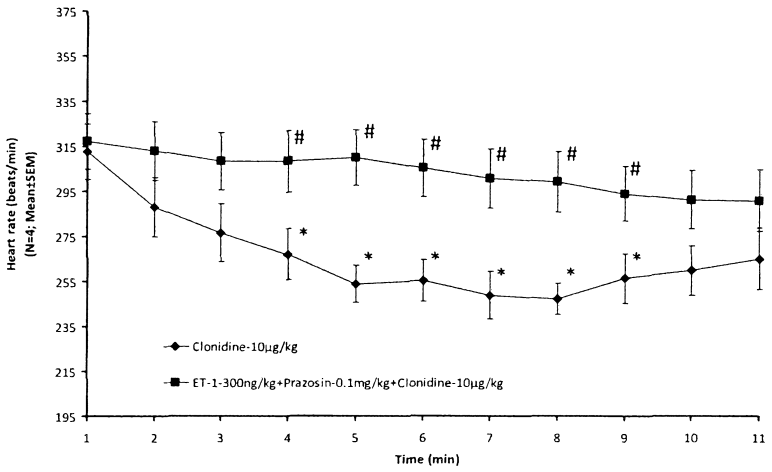

Figure 4C

Figure 5

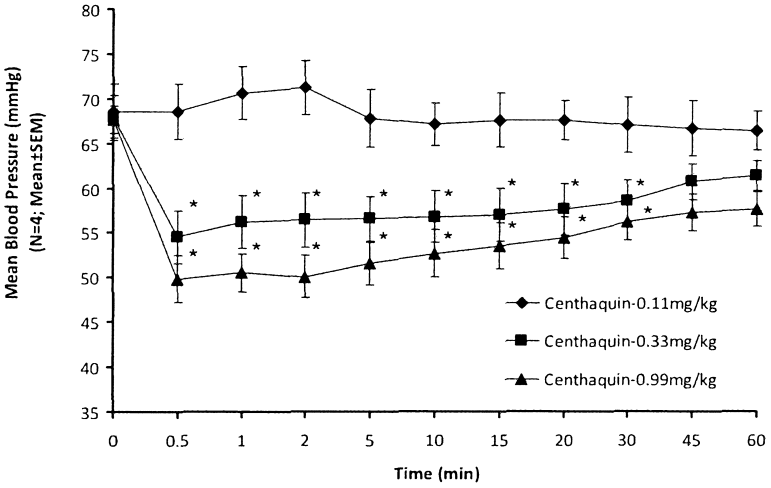

Figure 5A

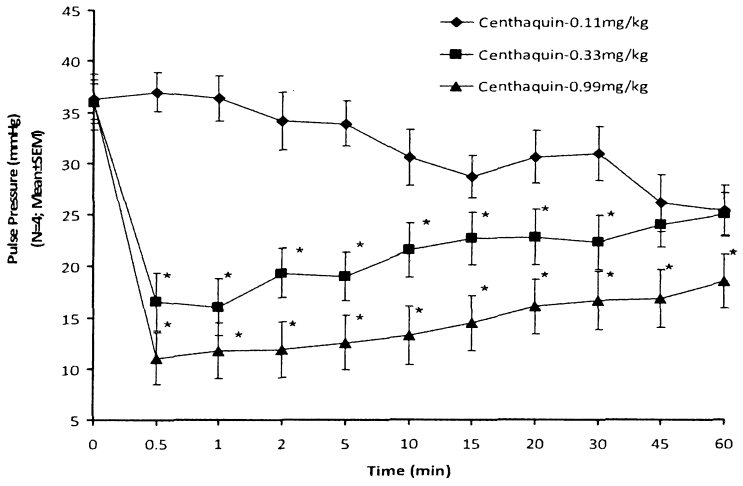

Figure 5B

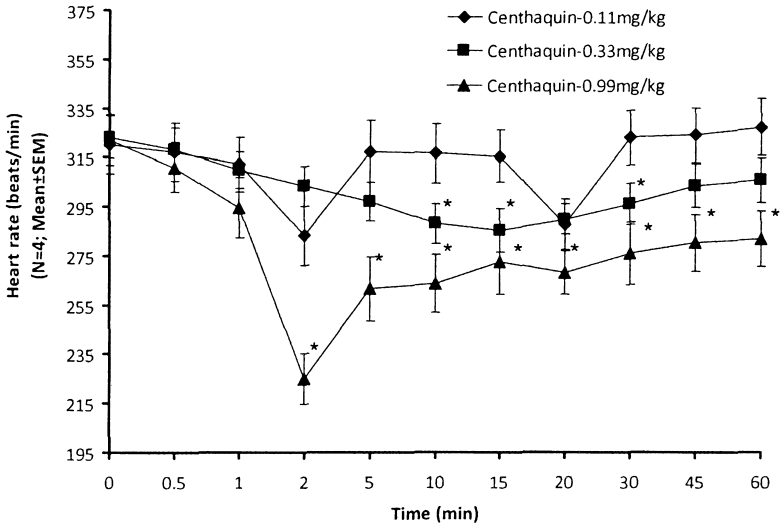

Figure 5C

Figure 6

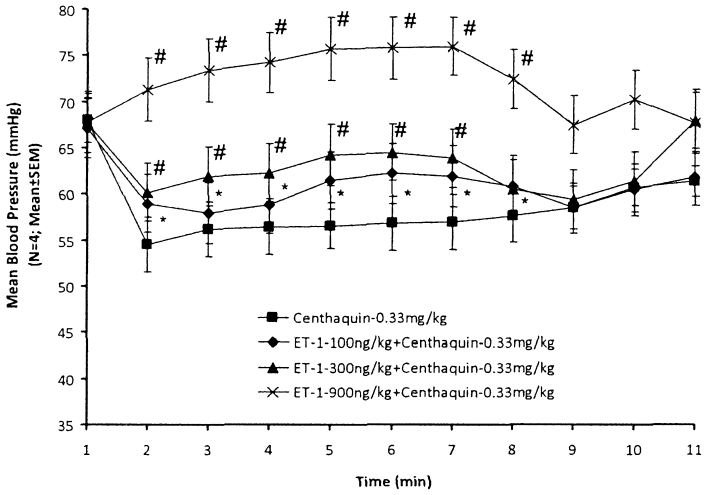

Figure 6A

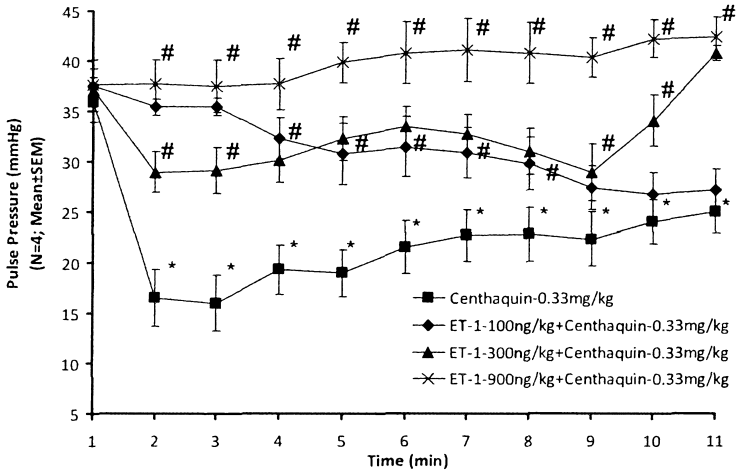

Figure 6B

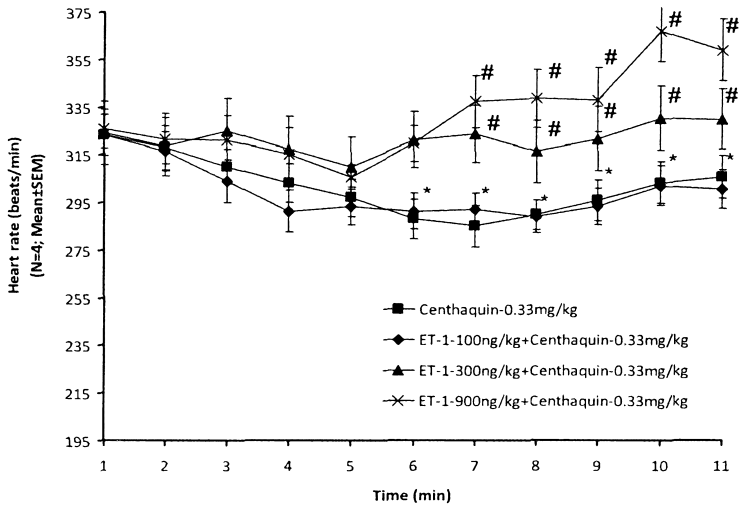

Figure 6C

Figure 7

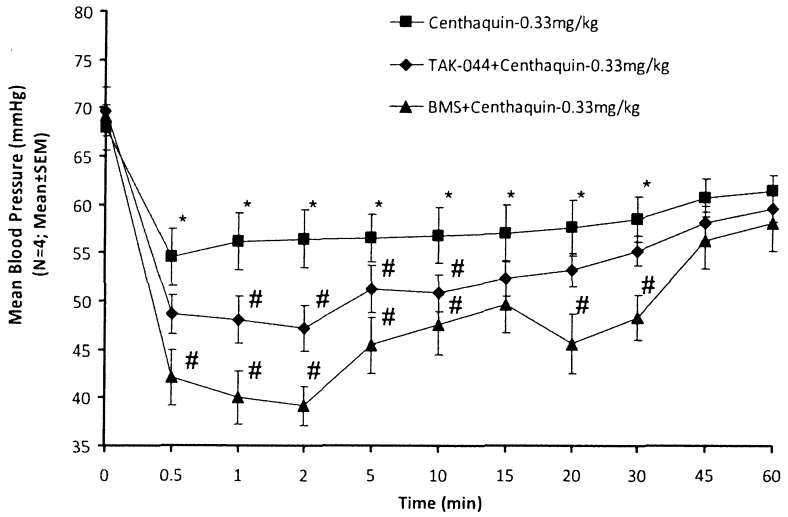

Figure 7A

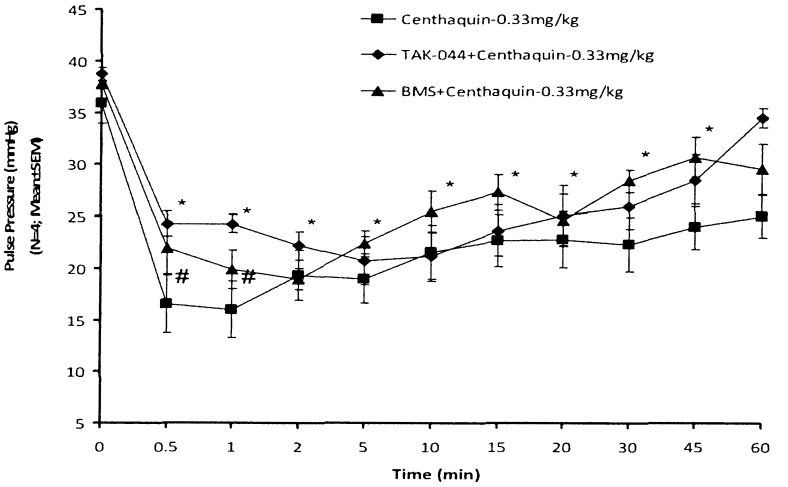

Figure 7B

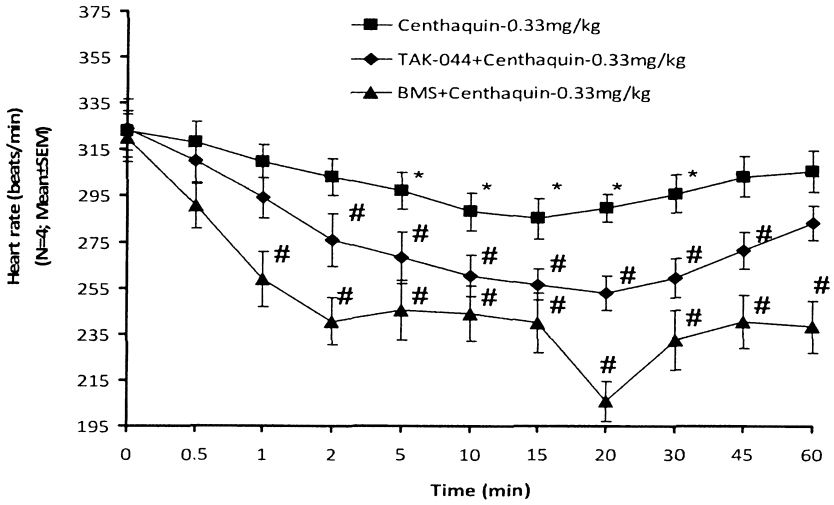

Figure 7C

Figure 8

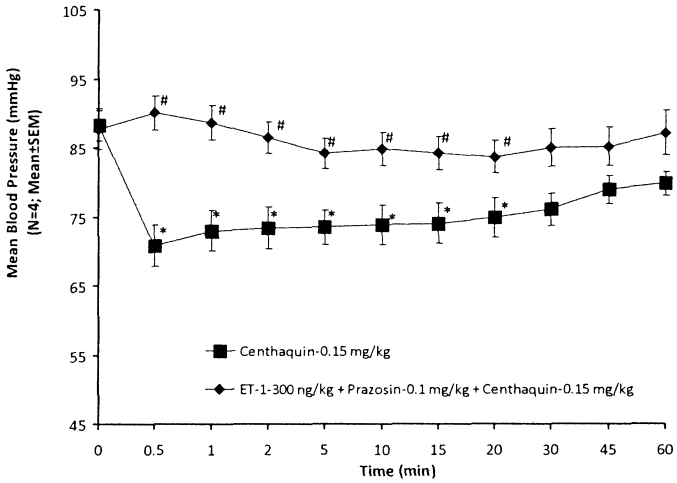

Figure 8A

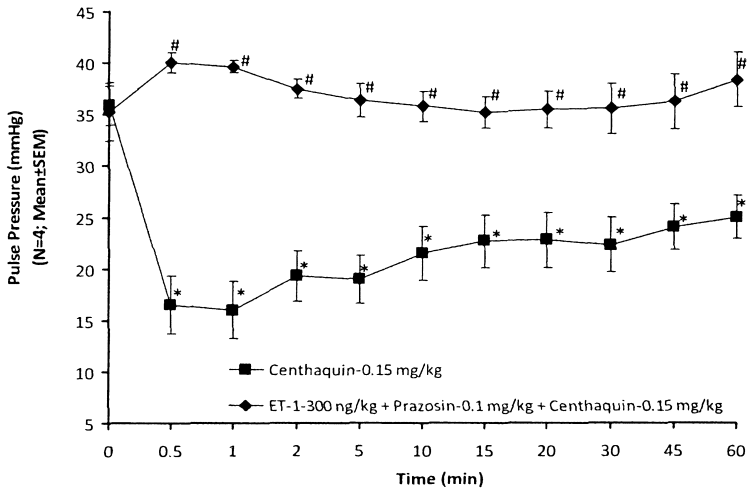

Figure 8B

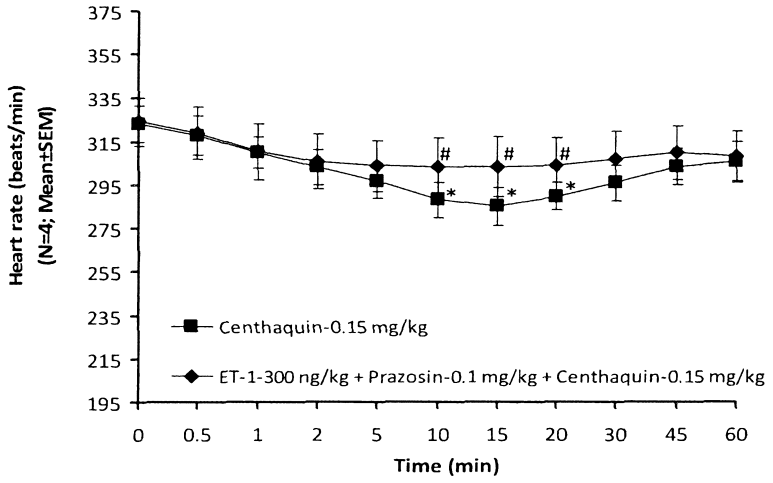

Figure 8C

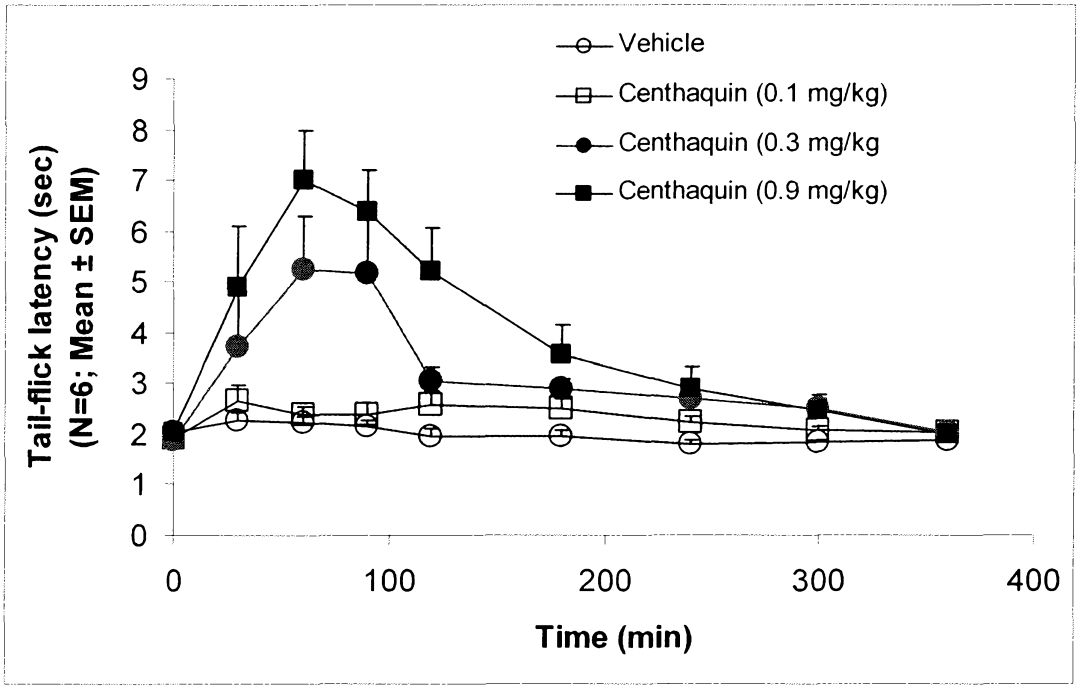

Figure 9

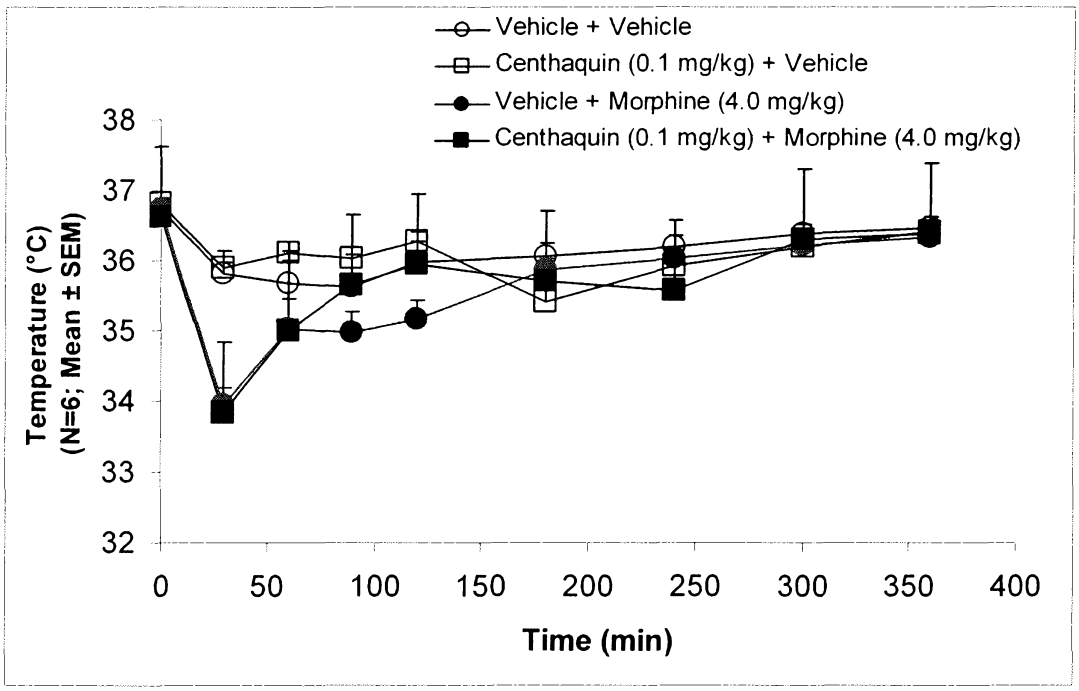

Figure 10

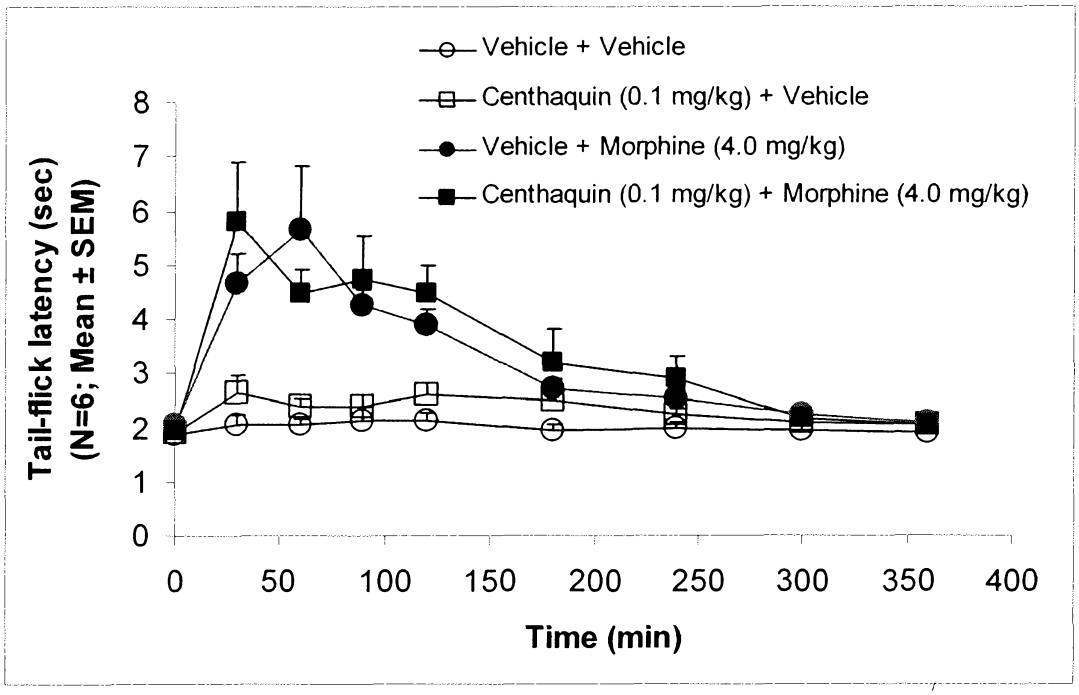

Figure 11

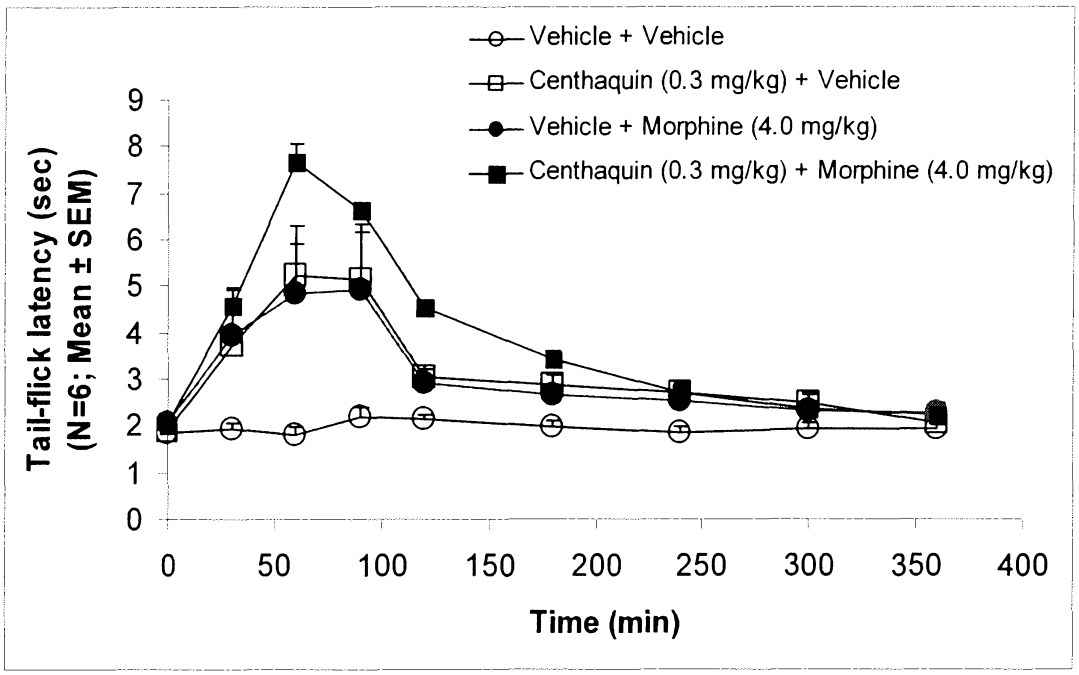

Figure 12

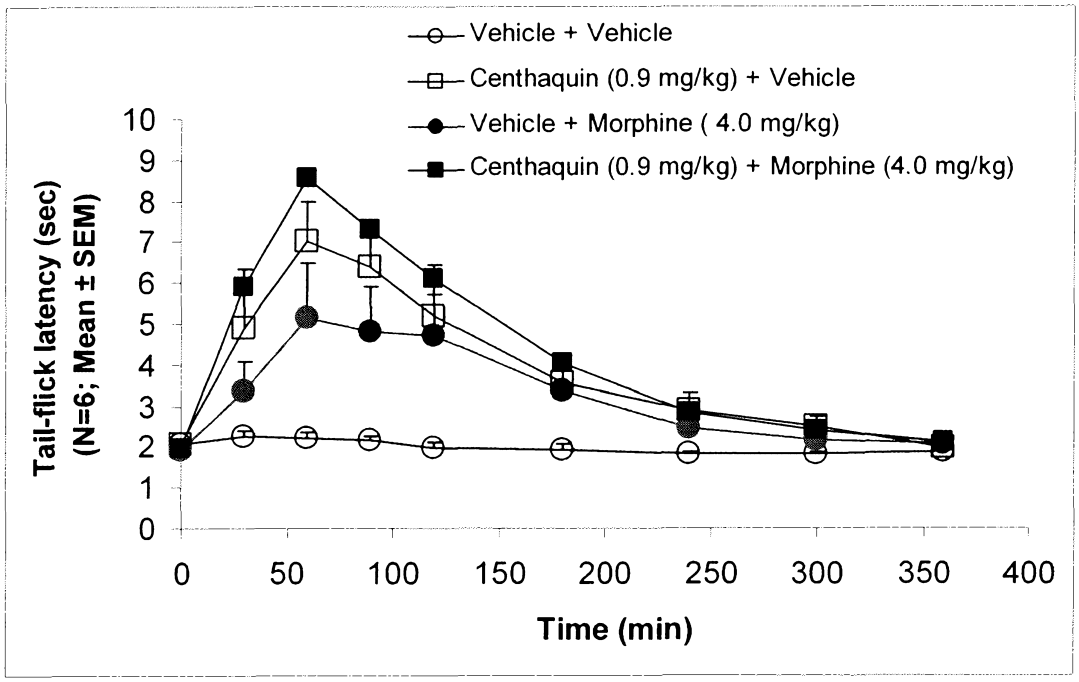
Vehicle + Vehicle
Centhaquin (0.9 mg/kg) + Vehicle
Vehicle + Morphine (4.0 mg/kg)
Centhaquin (0.9 mg/kg) + Morphine (4.0 mg/kg)
Tail-flick latency (sec)
(N=6; Mean ± SEM)
10
9
8
7
6
5
4
3
2
1
0
0
50
100
150
200
250
300
350
400
Time (min)

Figure 13

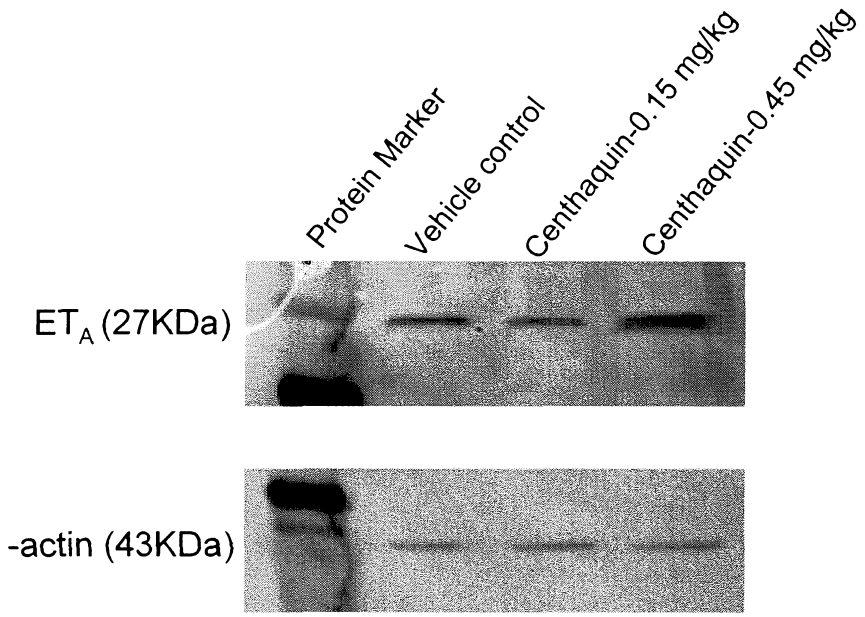

Figure 14A

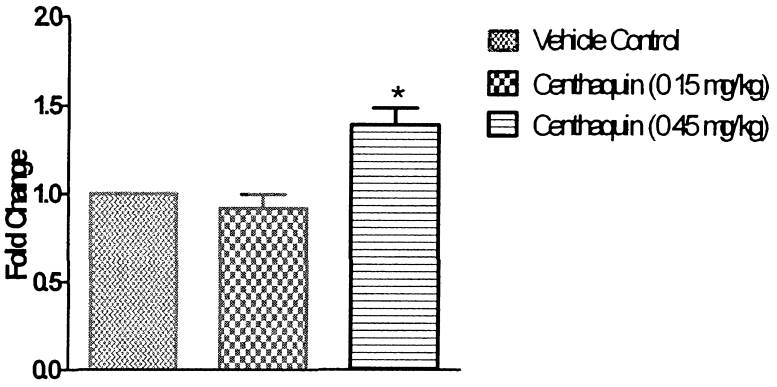

Figure 14B

Blood Lactate Level

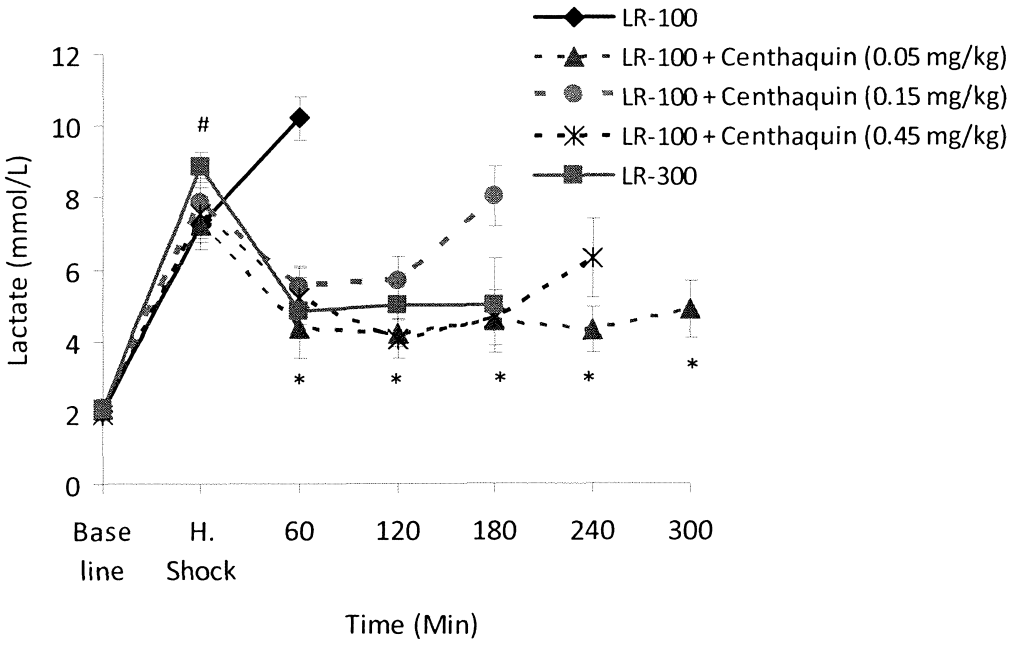

Figure 15

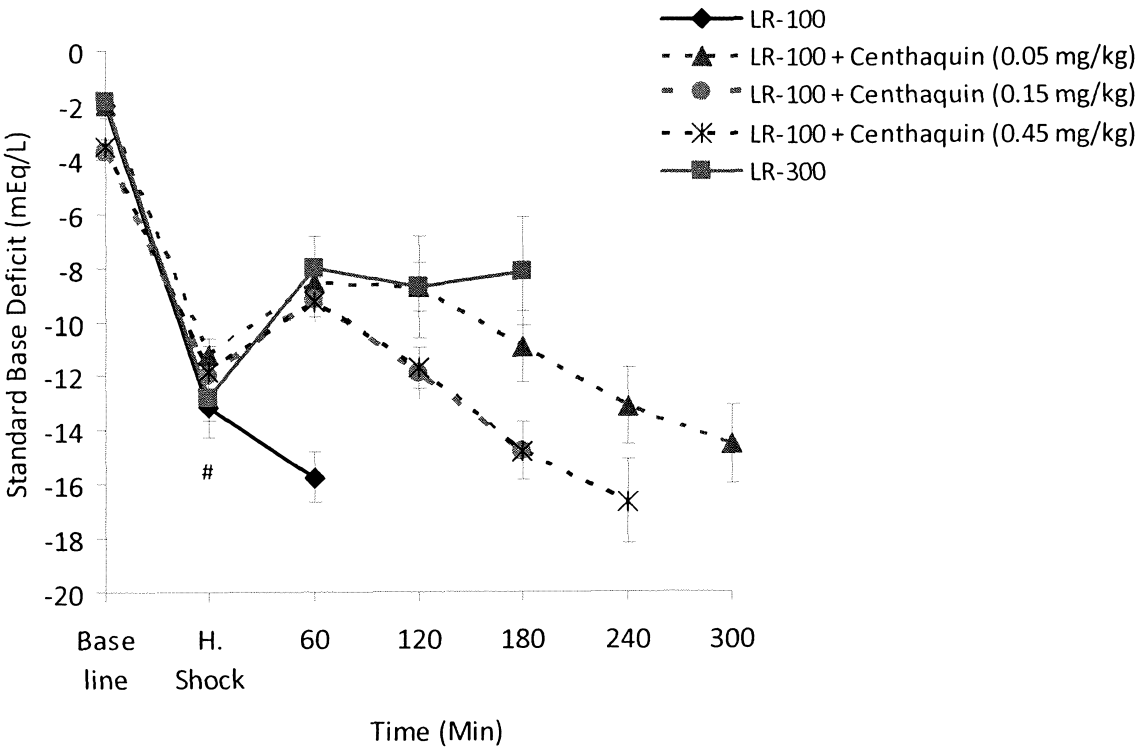

Figure 16

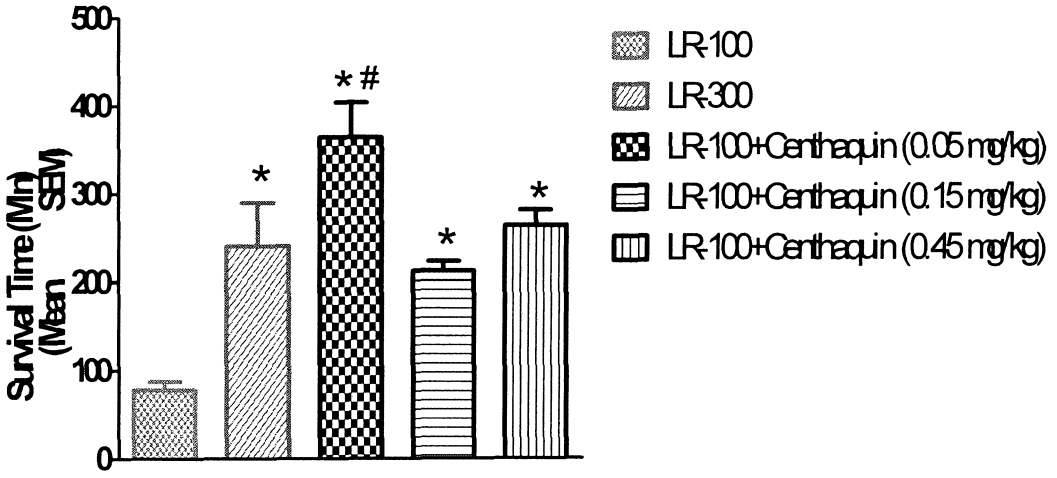

Figure 17

Base line

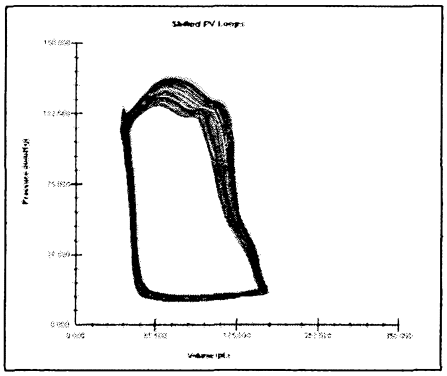

Fig. 18A

Hemorrhagic Shock

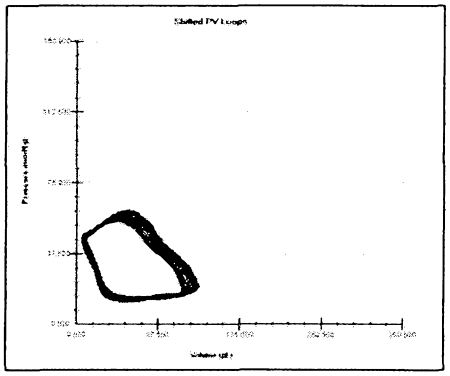

Fig. 18B

30 min after Resuscitation

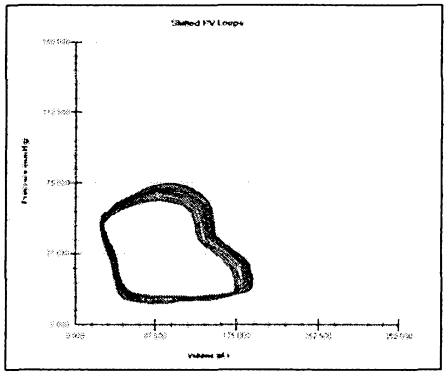

Fig. 18C

60 min after Resuscitation

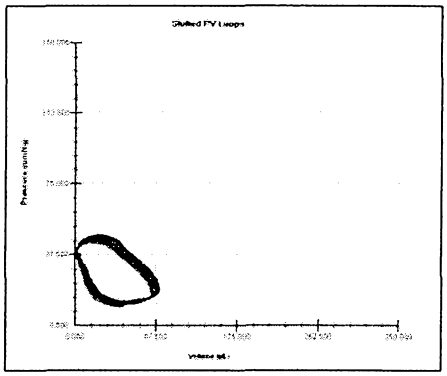

Fig. 18D

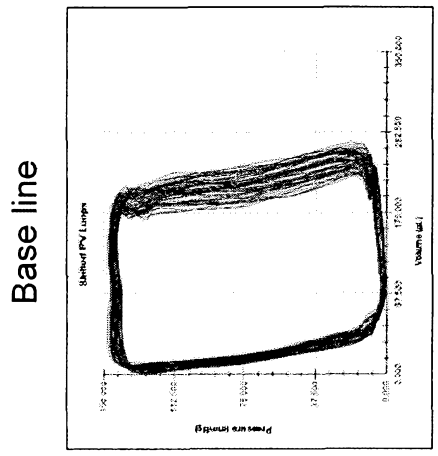

Fig. 19A

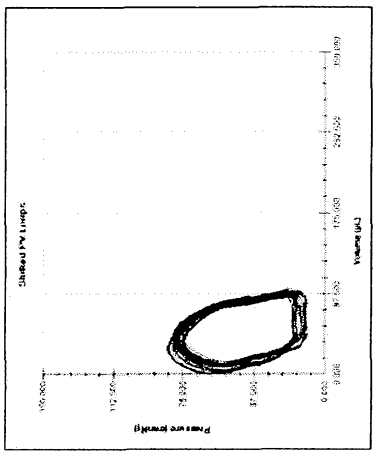

Fig. 19B

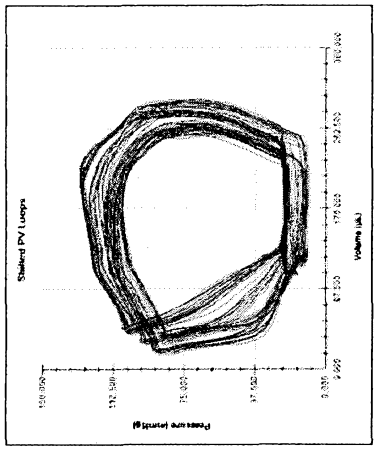

Fig. 19C

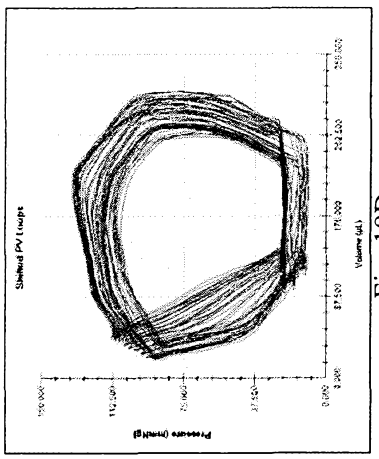

Fig. 19D

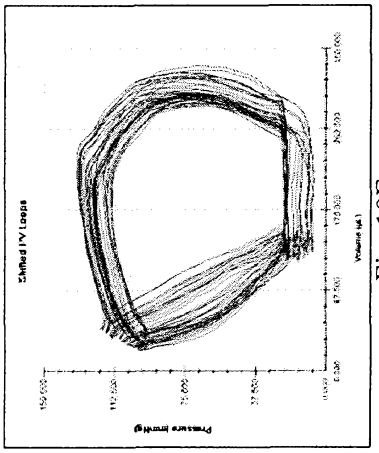

Fig. 19E

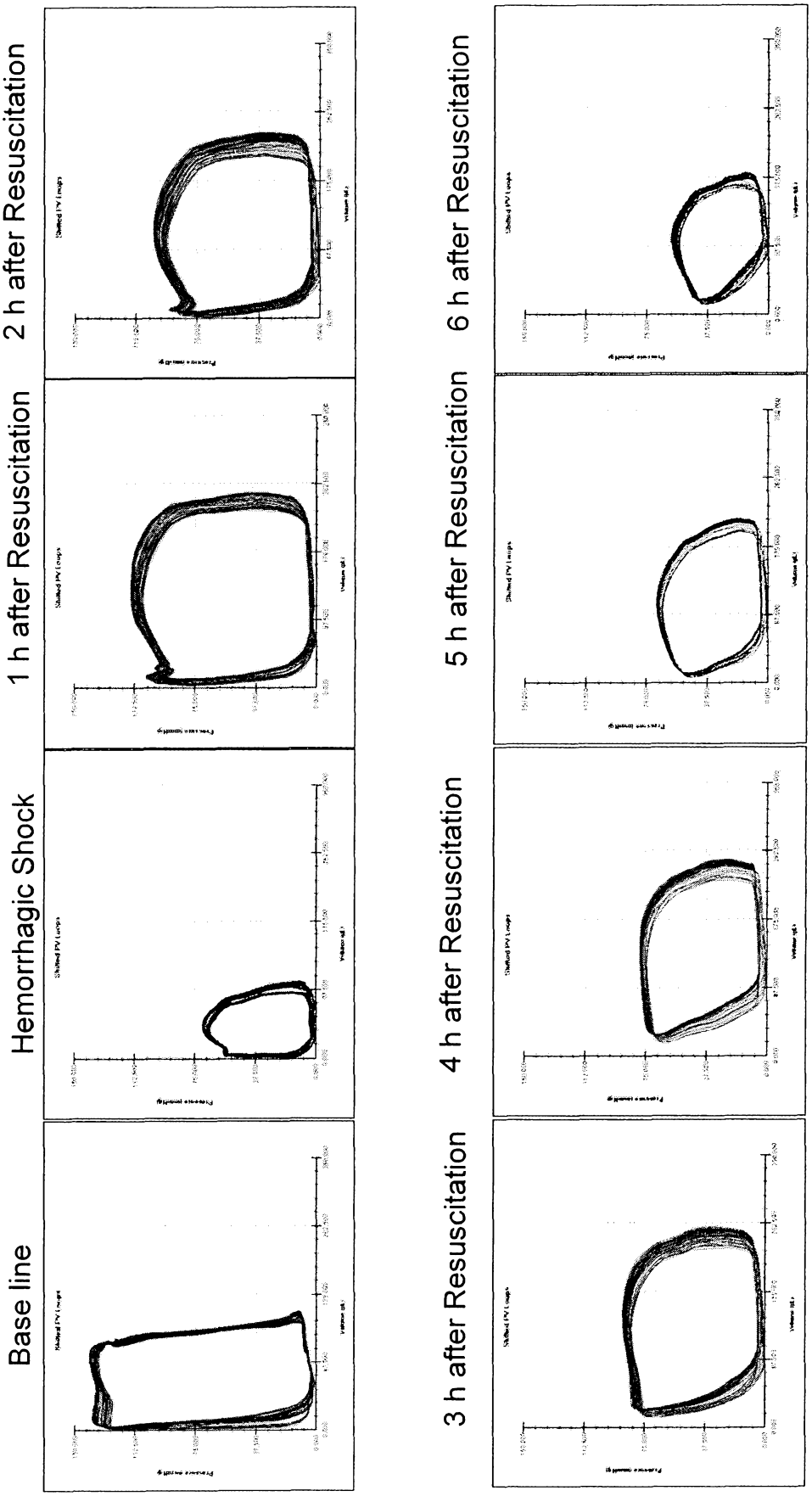
Base line
Hemorrhagic Shock
1 h after Resuscitation
2 h after Resuscitation
3 h after Resuscitation
4 h after Resuscitation
5 h after Resuscitation
6 h after Resuscitation

Figure 20