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Title	Use of Acacetin and Related Compounds as Potassium Channel Inhibitors
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(54) **USE OF ACACETIN AND RELATED COMPOUNDS AS POTASSIUM CHANNEL INHIBITORS**

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(60) Provisional application No. 60/892,556, filed on Mar. 2, 2007.

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(52) **U.S. Cl.** **514/27**; 514/456

(57) **ABSTRACT**

This invention provides a method for treating or preventing human atrial arrhythmia (fibrillation) using the leading flavone compound acacetin, and its derivatives and analogues that inhibit the ultra-rapidly-activating delayed rectifier potassium current (I_{Kur} or I_{Ksus}), transient outward potassium (I_{to}), and acetylcholine-activated potassium current ($I_{K.ACh}$).
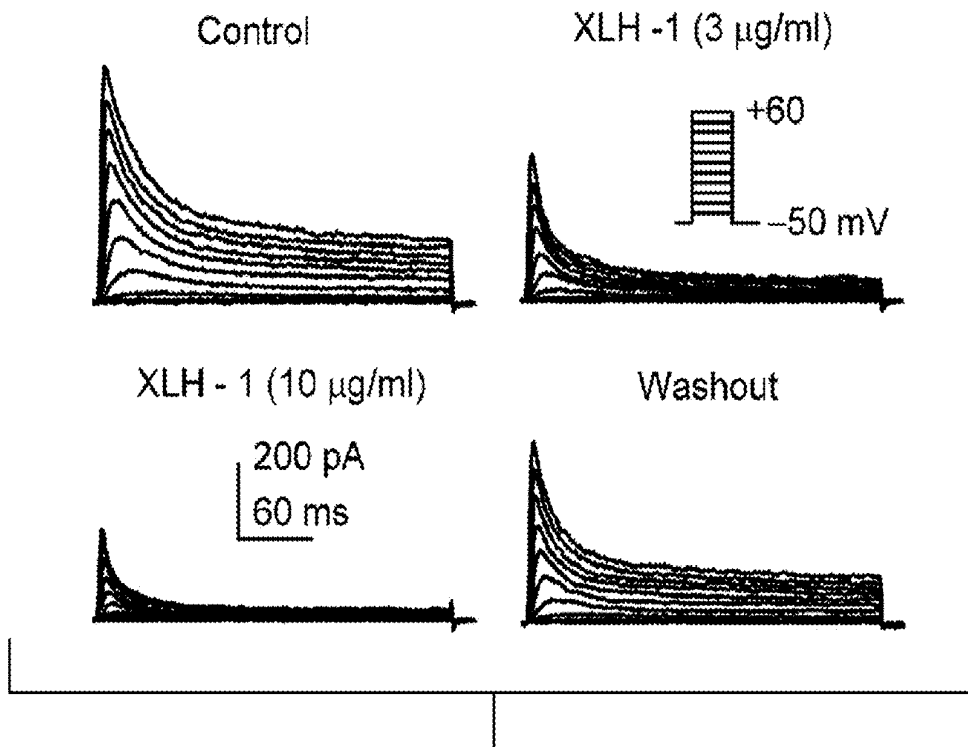
Control

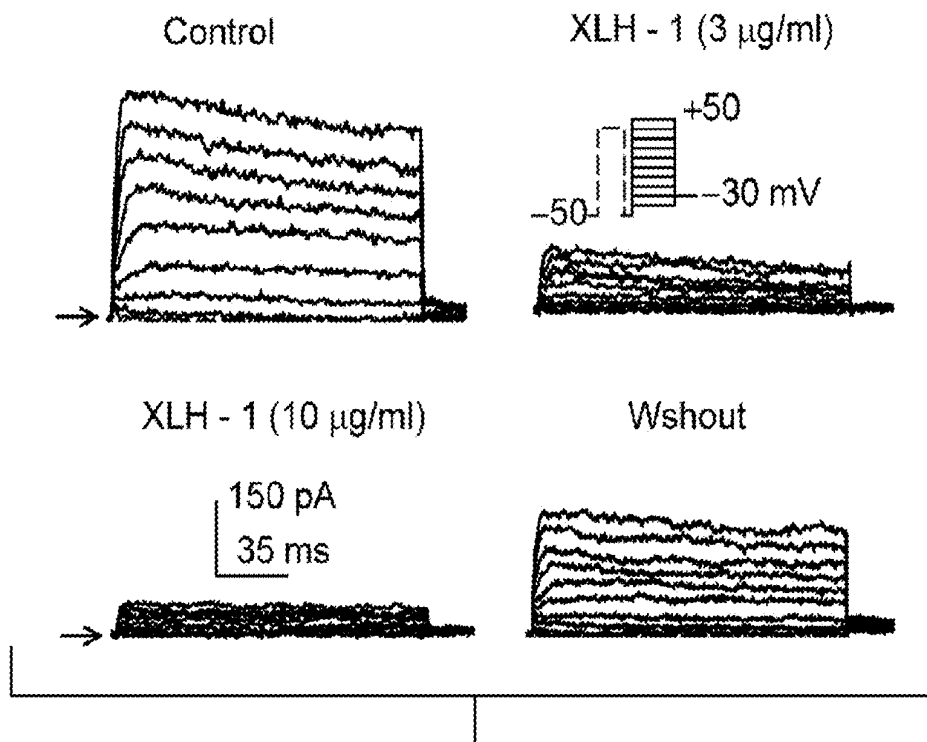XLH -1 (3 μg/ml)
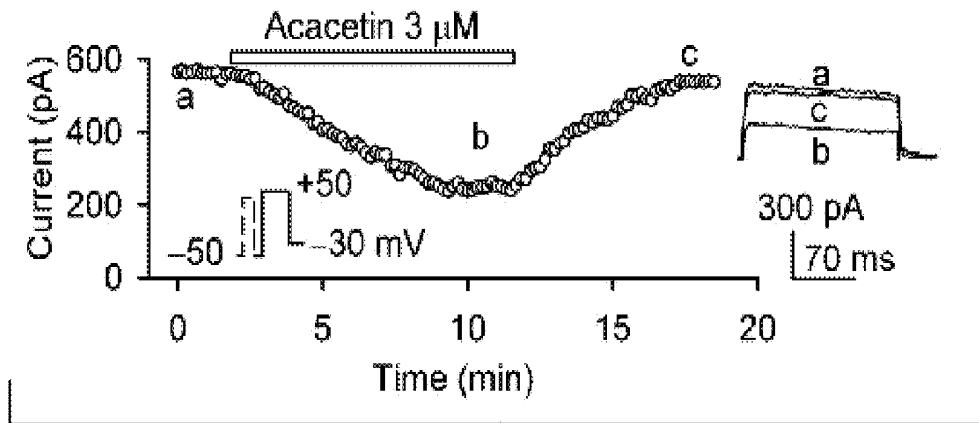
+60

−50 mV

XLH - 1 (10 μg/ml)

200 pA

60 ms

Washout

FIG. 1A

Control

XLH - 1 (3 μg/ml)

+50

−50

−30 mV

XLH - 1 (10 μg/ml)

150 pA

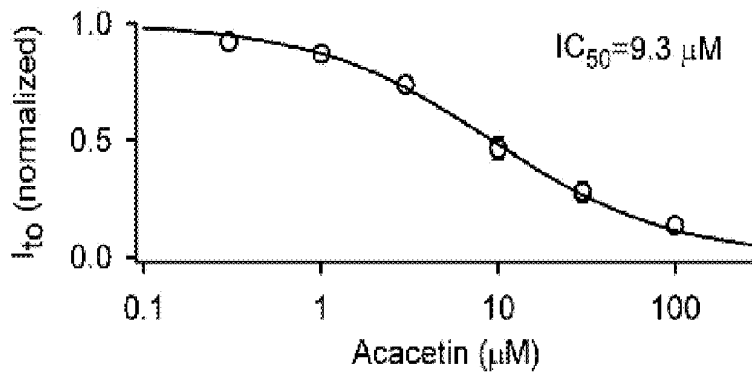35 ms

Wshout

FIG. 1B

FIG. 2A
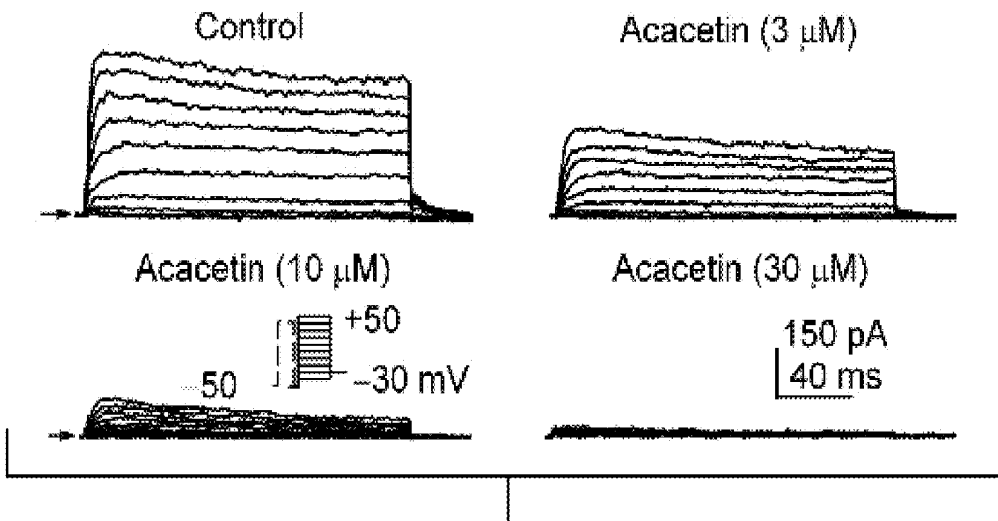
FIG. 2B
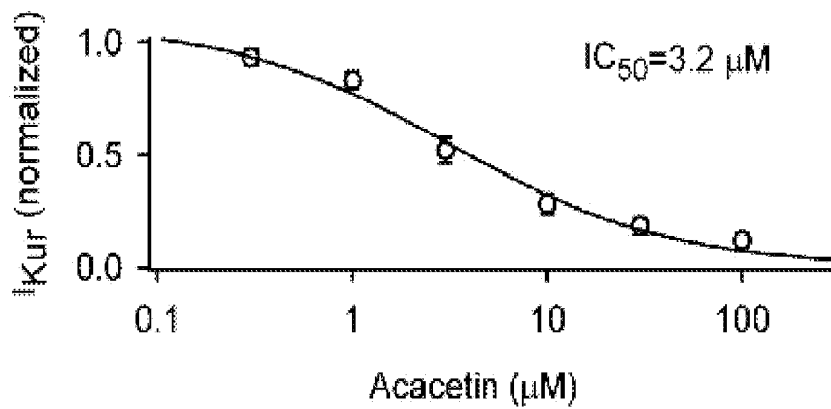
FIG. 2C
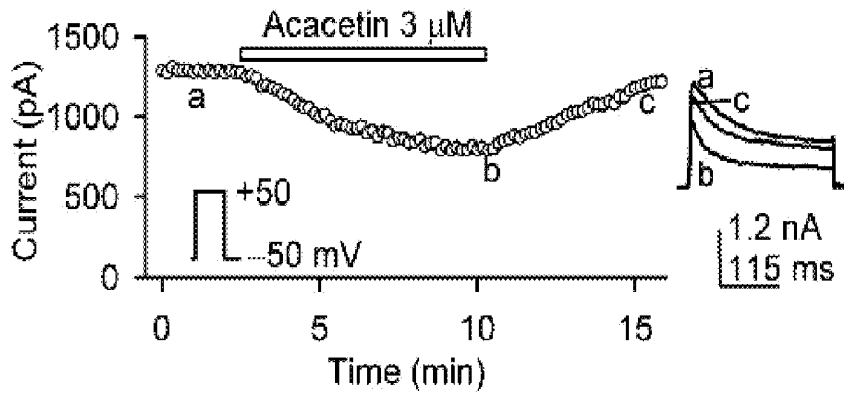
FIG. 3A
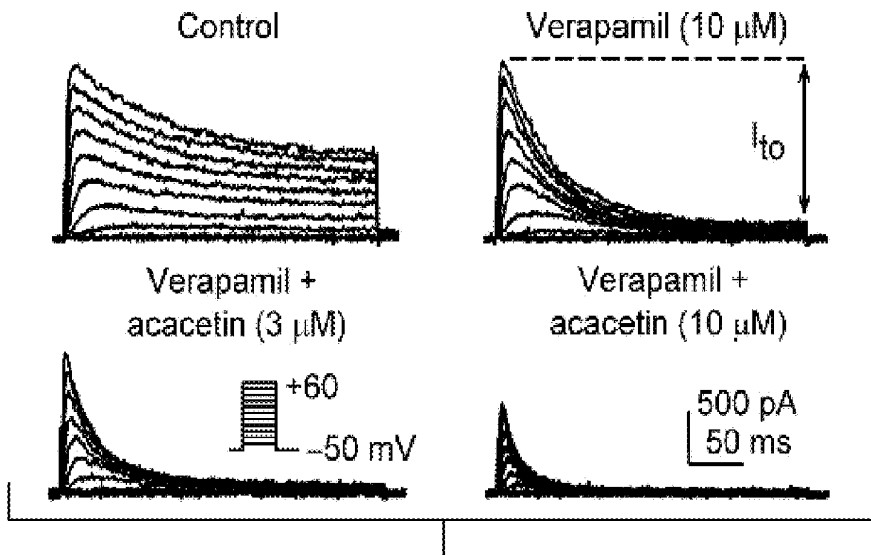
FIG. 3B

FIG. 3C
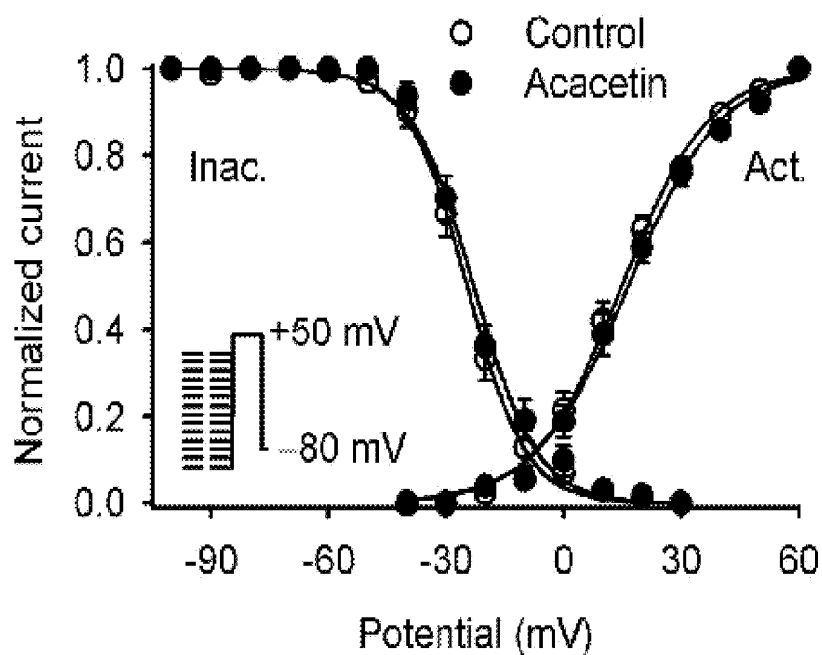
FIG. 4A
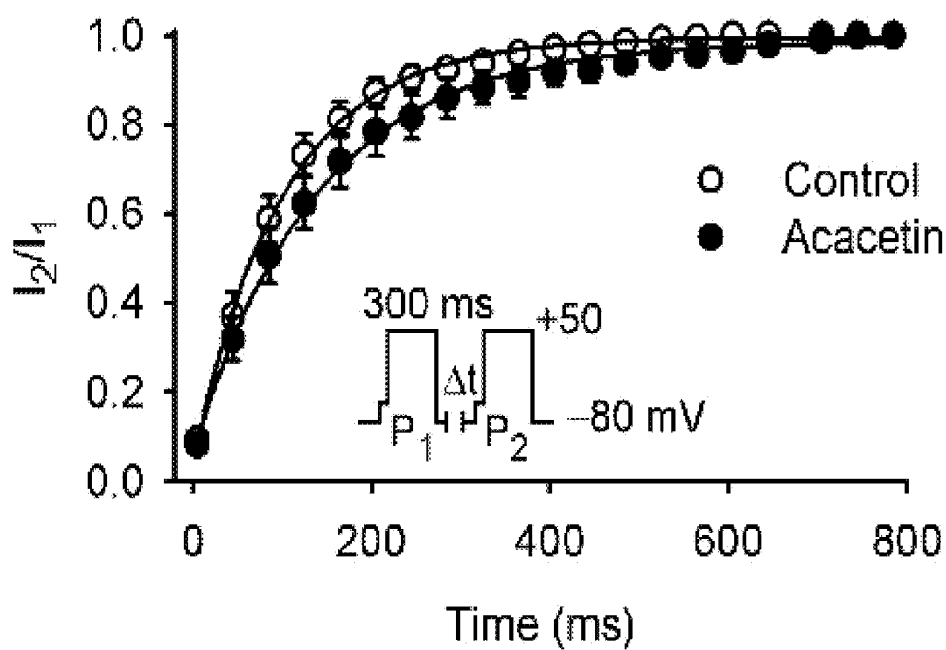
FIG. 4B
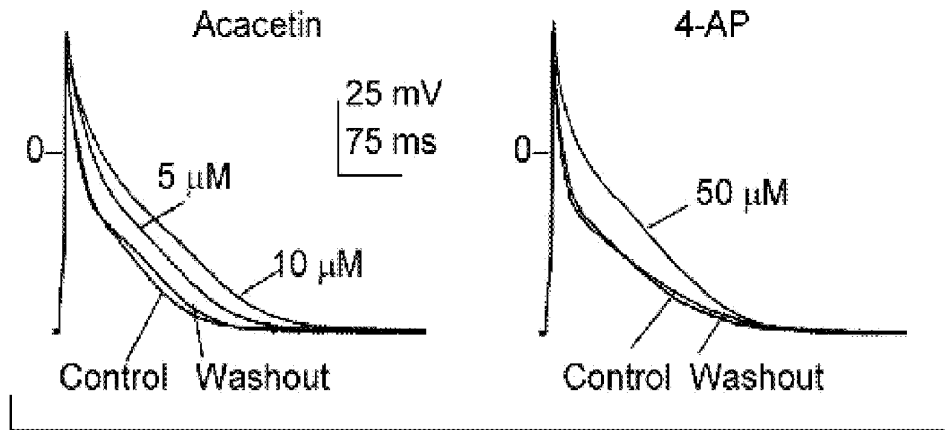
FIG. 5A
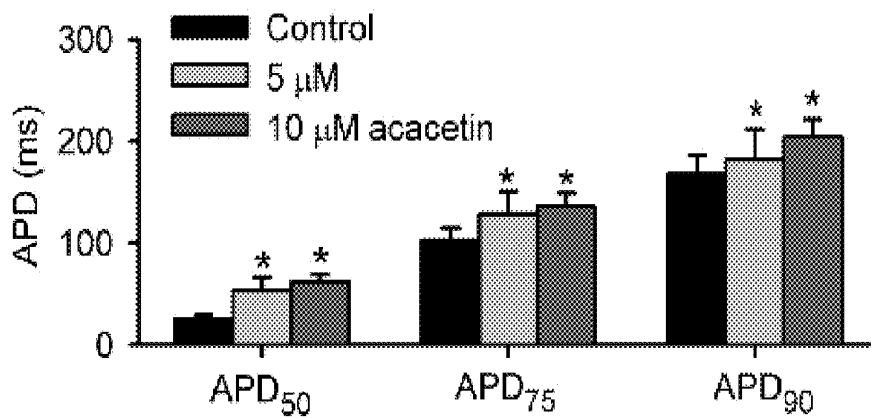
FIG. 5B
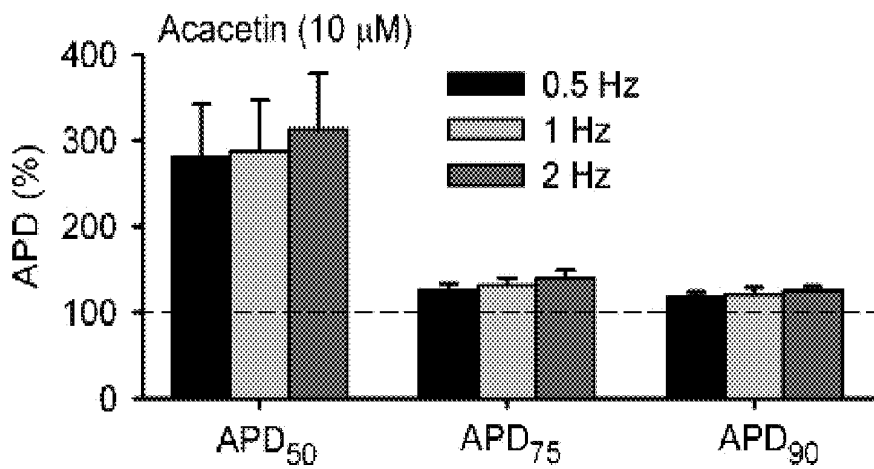
FIG. 5C

FIG. 6A

FIG. 6B

FIG. 6C

FIG. 7A

Control   Acacetin (30 μM)

−5 mV

−120

800 pA

7 ms

FIG. 7B

I_{Na} (pA/pF)

0

−10

−20

−80   −60   −40   −20   0   mV

O   Control
●   30 μM
▲   100 μM acacetin

FIG. 7C

Control   Acacetin (30 μM)

+50 mV

−60

200 pA

65 ms

FIG. 7D

−40   −20   0   20   40   60   mV

1

−2

−3

−4

pA/pF

O   Control
●   30 μM
▲   100 μM acacetin

FIG. 7E

Control   Acacetin (30 μM)

−40

−120 mV

1500 pA

95 ms

FIG. 7F

I_{K1} (pA/pF)

10

0

−10

−20

−30

−40

−120   −100   −80   −60   −40   −20   mV

O   Control
●   30 μM
▲   100 μM acacetin

FIG. 8A

Control   Acacetin   Washout
                 (30 μM)

+60 mV

200 pA

-80   -50   1 s

FIG. 8B

$I_{hERG\ tail}$ (normalized)

1.0

0.5

$IC_{50}=32.4\ \mu M$

0.0

1   10   100   1000

Acacetin (μM)

FIG. 8C

Control   Acacetin   Washout
                 (30 μM)

1 nA

1.5 s

FIG. 8D

I_{Ks} (normalized)

1.0

0.5

$IC_{50}=81.4\ \mu M$

0.0

1   10   100   1000

Acacetin (μM)

FIG. 9A

Control

HR: 157/min; QTc 304.5 ms

Acacetin 30 μM

HR: 156/min; QTc 308.7 ms

FIG. 9B

Control

HR: 175/min; QTc 340.1 ms

Quinidine 10 μM

HR: 136/min; QTc 391.3 ms

FIG. 9C   FIG. 9D

Heart rate (bpm)

**
Acac   Qui

QTc (ms)

**
Acac   Qui

■ Before treatment
▨ After treatment

FIG. 10A

ERP measurement S1   S2
Right atrium
MAP
Left atrium
MAP
ECG
500 ms

FIG. 10B

Control
S1   S2
Right atrium
MAP
Left atrium
MAP
ECG
1000 ms

FIG. 10C

Acacetin (5 mg/kg, 2h)
Right atrium
MAP
Left atrium
MAP
ECG
650 ms
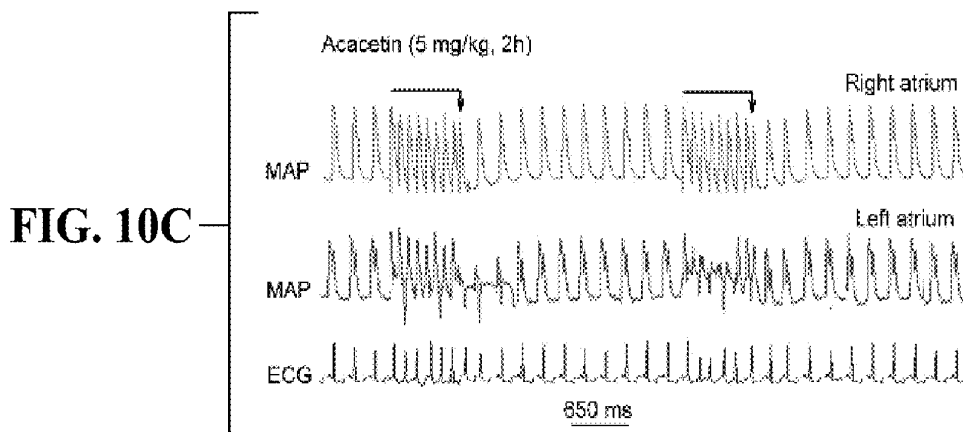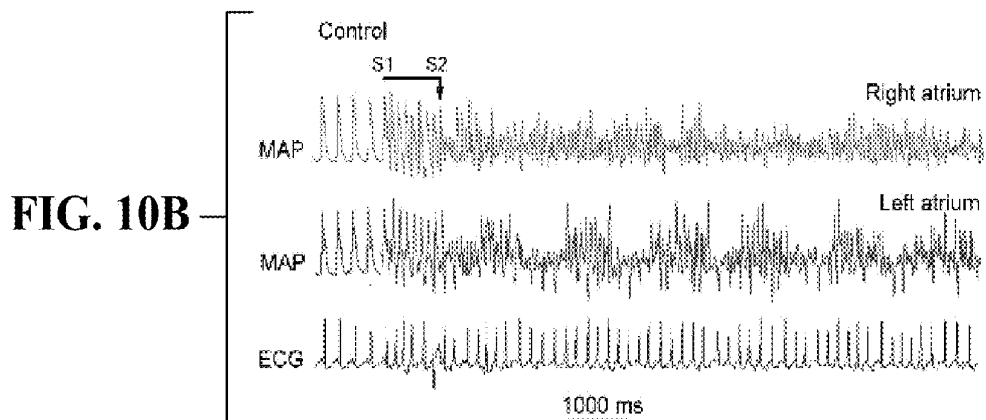
FIG. 11A

FIG. 11B

FIG. 11C

FIG. 12A

MAP

450 ms

right atrium

MAP

left ventricle

ECG

FIG. 12B

MAP

400 ms

right atrium

MAP

left ventricle

ECG
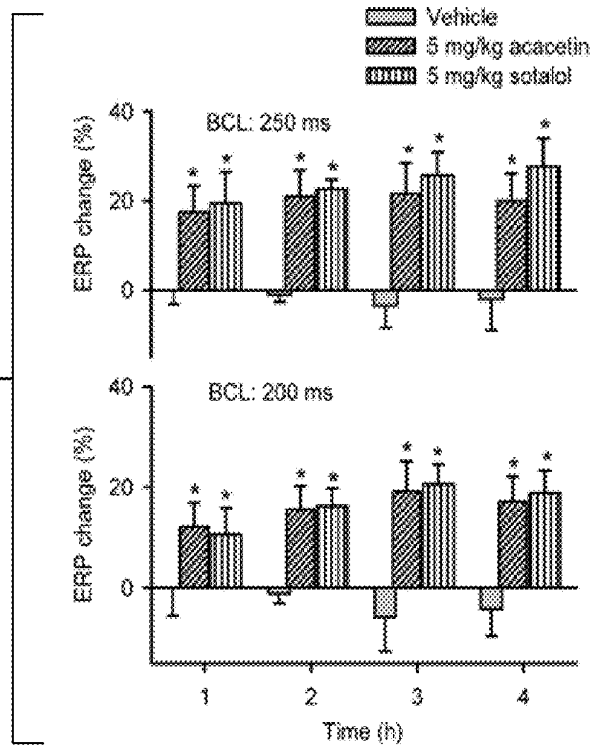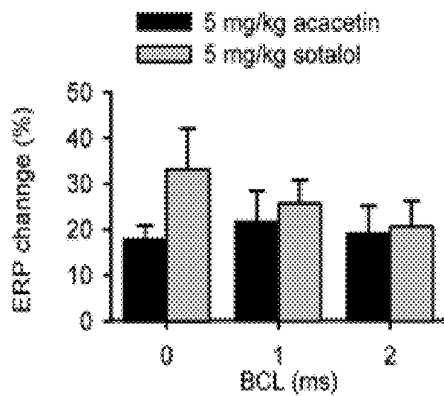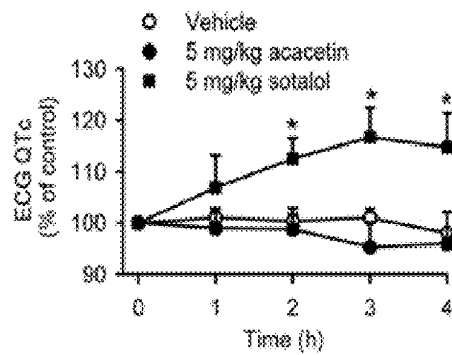
FIG. 13A

FIG. 13B

USE OF ACACETIN AND RELATED COMPOUNDS AS POTASSIUM CHANNEL INHIBITORS

CROSS-REFERENCE TO A RELATED APPLICATION

[0001] This application is a divisional application of co-pending application Ser. No. 12/039,921, filed Feb. 29, 20078; which claims the benefit of U.S. provisional application Ser. No. 60/892,556, filed Mar. 2, 2007, which are incorporated herein by reference in their entirety.

FIELD OF THE INVENTION

[0002] The present invention is directed to the use of the flavone compound acacetin, and its derivatives and analogues, as potassium channel inhibitors and as anti-atrial fibrillation agents.

BACKGROUND OF THE INVENTION

[0003] Atrial fibrillation (AF) is the most common form of cardiac dysrhythmia. The occurrence of AF increases with age: the prevalence rises from 0.5% of people in their 50s, to 5% of people over the age of 65 years, and to nearly 10% of the population over 80 (Benjamin et al., 1998; Wang et al., 2003). AF is a major cause of morbidity and mortality as it increases the risk of death, congestive heart failure, and embolic phenomena including stroke (Benjamin et al., 1998; Wang et al., 2003). AF is believed to be a lifetime risk in an aging population, and therefore is emerging as a major public-health concern (Lloyd-Jones et al., 2004; Lip and Tse, 2007).

[0004] Antiarrhythmic drug therapy remains the principal approach for suppressing AF and its recurrence. Class III anti-arrhythmic agents are effective in treating AF (Nademanee, 1992; Roden, 1993), but have major limitations, such as inducing severe ventricular arrhythmia (i.e. long QT syndrome) (Roden and Anderson, 2006). Therefore, a key objective among the current strategies for suppressing AF is the development of antiarrhythmic agents that preferentially affect atrial rather than ventricular electrical parameters (Burashnikov et al., 2007; Blaauw et al., 2004).

[0005] Class III antiarrhythmic agents are drugs that selectively prolong cardiac action potential duration without significant cardiac suppression. Currently available drugs such as sotalol and amiodarone have Class III properties (Sharma et al., 1999; Nattel and Singh, 1999), but they also have other effects. Sotalol also possesses Class II effects (β-adrenoceptor block) causing cardiac depression and is contraindicated in certain susceptible patients (D'Aloia et al., 2005; DeWitt and Waksman, 2004). Amiodarone possesses multiple electrophysiological actions and is limited by side effects (Nademanee, 1992).

[0006] Other class III antiarrhythmic agents include dofetilide (UK-68,798), almokalant (H234/09), and E-4031. These compounds, including sotalol, show a predominant block of I_{Kr}. However, amiodarone is a blocker of I_{Ks} (Balser et al., 1991), and it also blocks I_{Na}, and I_{Ca}.

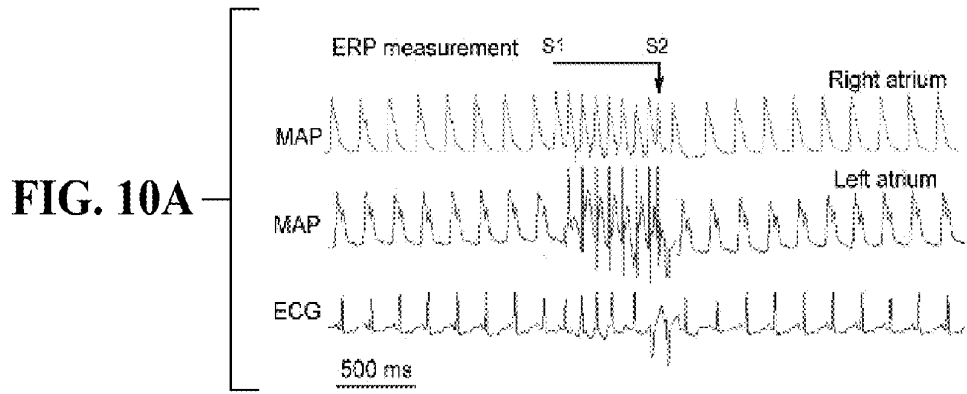[0007] Because I_{Kr} is present in both the atrium and ventricle of the human heart (Wang et al., 1994; Li et al., 1996b), I_{Kr} blockers increase action potential duration and refractoriness in both atria and ventricle. Theoretically they represent potentially useful agents for the treatment of arrhythmias like AF; however, these agents have a liability in that they have an enhanced risk of proarrhythmia at low heart rates. For example, torsades de points has been observed when these compounds are utilized (Roden and Anderson, 2006). This exaggerated effect at low heart rates has been termed "reverse frequency-dependence", and differs from frequency-independent or frequency-dependent actions (Hondeghem, 1992).

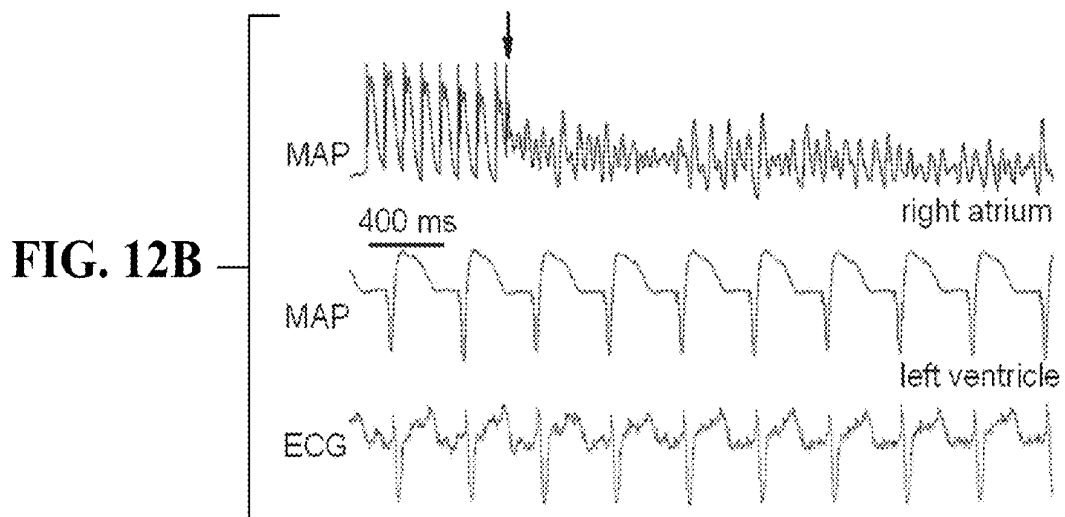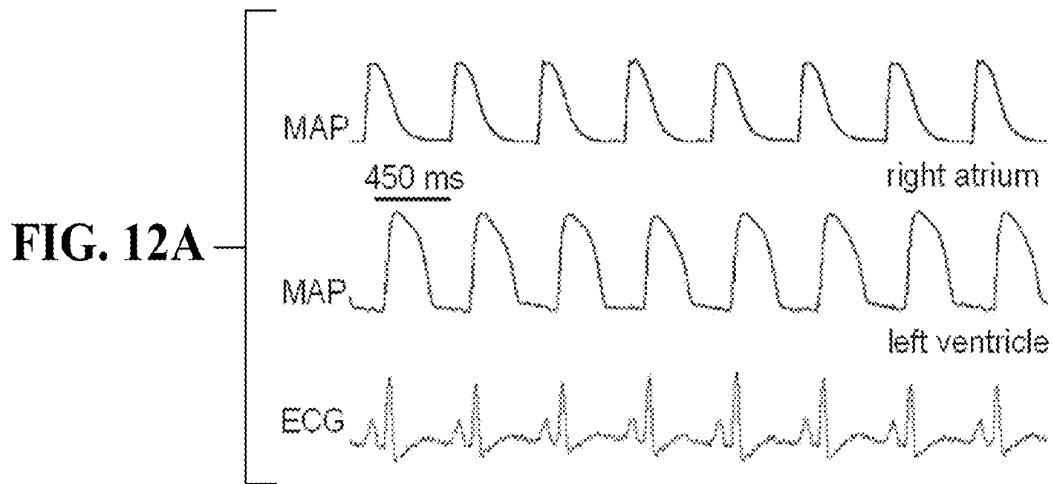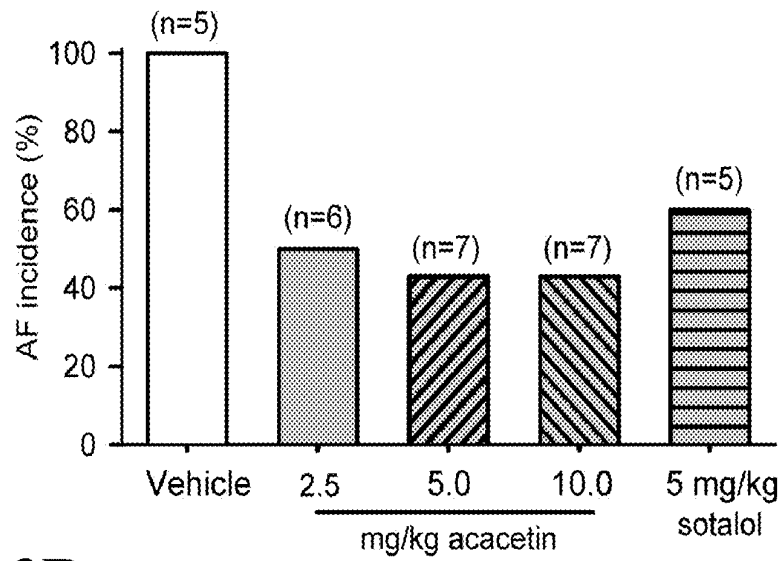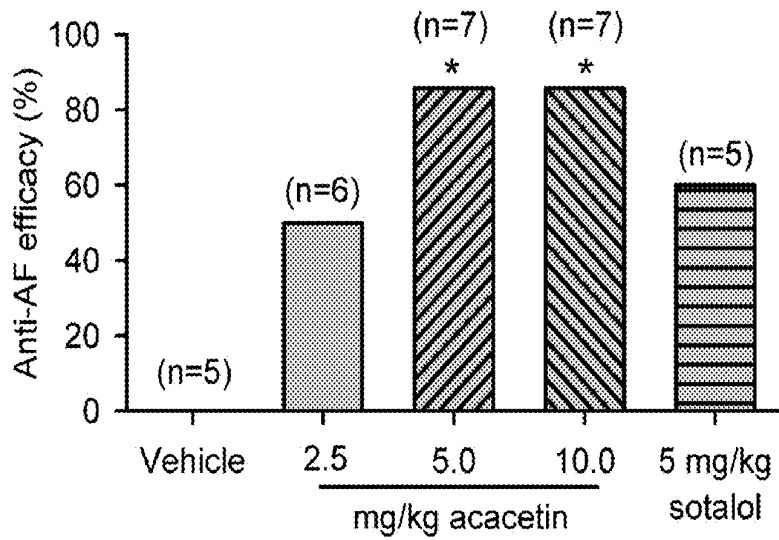[0008] In intact human atrial myocytes, an ultra-rapidly activating delayed rectifier K$^+$ current I_{Kur}, which is also known as the sustained outward K$^+$ current (I_{Ksus} or I_{so}), has been identified (Wang et al., 1993). This current has properties and kinetics similar to those of the cloned human cardiac K$^+$ channel hKv1.5 stably expressed in HEK 293 cells (Fedida et al., 1993). The ultra-rapidly activating delayed rectifier I_{Kur} is found to be functionally present in the atrium, but not in the ventricle of human heart (Li et al, 1996b). Because I_{Kur} is rapidly activated, and has a limited slow inactivation, I_{Kur} is believed to contribute significantly to the repolarization in human atrium. Blockage of I_{Kur} will slow repolarization and prolong refractoriness selectively in the human atrium without causing the delay in ventricular repolarization. A selective I_{Kur} blocker would not produce arrhythmogenic after depolarizations and acquired long QT syndrome observed during treatment with current Class III drugs. Therefore, human atrial I_{Kur} and/or human Kv1.5 are believed to be potential targets for developing selective anti-atrial fibrillation agents (Brendel and Peukert, 2003; Peukert et al., 2003). However, there is no such drug commercially available yet.

BRIEF SUMMARY

[0009] The subject invention provides flavone compounds and their use as inhibitors of potassium channel function. In one embodiment, the subject invention provides compounds that inhibit human atrial I_{Kur} and I_{to} that serve as targets for the treatment of atrial arrhythmias.

[0010] In a specific embodiment, the subject invention pertains to the use of acacetin, and related compounds, for the treatment of atrial fibrillation (AF).

[0011] Acacetin has advantageous properties that make it particularly useful as a preferential I_K, channel blocker. The compounds of the subject invention can be used for the treatment of diseases in mammals, including humans, and especially for the management of human AF.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIGS. 1A and 1B show the effects of XLH-I on transient outward potassium current (I_{to}, FIG. 1A) and sustained potassium current (I_{Kur}, FIG. 1B) in representative human atrial myocytes.

[0013] FIGS. 2A, 2B, and 2C show the effects of acacetin on FIG. 2A. Time-dependent effects of acacetin on I_{Kur}, and the inhibitory effect recovered (by 97%) on washout. FIG. 2B. Voltage-dependent I_{Kur} suppressed by the application of 3, 10 and 30 µM acacetin. FIG. 2C. Concentration-response relationship of I_{Kur} inhibition by acacetin at +40 mV (n=8-20 experiments).

[0014] FIGS. 3A, 3B, 3C show the effect of acacetin on I_{to} in human atrial myocytes. FIG. 3A. Time-dependent effect of acacetin on I_{to} in a representative cell. Acacetin at 3 µM reversibly decreased both I_{to} and I_{Kur}. FIG. 3B. Voltage-dependent I_{to} was recorded with the protocol shown in the inset. I_{Kur} was inhibited by 10 µM verapamil to block I_{Kur}, and the

remaining I_{to} was reduced by 3 and 10 μM acacetin. FIG. 3C. Concentration-response relationship of I_{to} inhibition by acacetin at +40 mV (n=7-16 experiments).

[0015] FIGS. 4A and 4B show the effects of acacetin on kinetics of I_{to}. FIG. 4A. Voltage-dependence of steady-sate activation and inactivation was not affected by 10 μM acacetin. FIG. 4B. Recovery of I_{to} from inactivation was slowed by acacetin.

[0016] FIGS. 5A, 5B, and 5C show the effect of acacetin on action potential in human atrial myocytes. FIG. 5A. Action potentials recorded at 2 Hz with 5 and 10 μM acacetin in a representative cell (left panel), and with 50 μM 4-AP in another cell (right panel). FIG. 5B. Mean values of action potential duration at 50%, 75% and 90% repolarization (APD_{50}, APD_{75}, and APD_{90}). n=6 *P<0.05; P<0.01 vs control. FIG. 5C. Acacetin (10 μM) induced a slight rate-dependent prolongation of APD (n=7, P=NS, 0.5 Hz vs 2 Hz)

[0017] FIGS. 6A, 6B, and 6C show the inhibition of $I_{K.ACh}$ by acacetin in guinea pig atrial myocytes. FIG. 6A. Membrane currents were recorded in a guinea pig atrial cell using a 2-s ramp from −120 to +50 mV. Carbachol at 5 μM significantly augmented the membrane conductance. Acacetin at 3 μM decreased the increased conductance. FIG. 6B. Membrane currents were recorded with a 300-ms voltage step protocol. FIG. 6C. I-V relationships of carbachol-evoked $I_{K.ACh}$ in the absence and presence of acacetin. Acacetin at 3 and 10 μM substantially blocked $I_{K.ACh}$ (n=5, P<0.01 at −100 to −80 mV, −50 to +60 mV).

[0018] FIGS. 7A-7F show no effects of acacetin on I_{Na}, $I_{Ca.L}$, and I_{KI} in guinea pig ventricular myocytes. FIG. 7A. I_{Na} traces recorded in a representative cell. FIG. 7B. I-V relationships of I_{Na} in the absence and presence of 30 and 100 μM acacetin (n=5-6). FIG. 7C. $I_{Ca.L}$ traces recorded in a cardiac cell. FIG. 7D. I-V relationships of $I_{Ca.L}$ in the absence and presence of 30 and 100 μM acacetin (n=5-7). FIG. 7E. I_{KI} traces recorded in a representative cell with the voltage protocol shown in the inset. FIG. 7F. I-V relationships of I_{KI} in the absence and presence of 30 and 100 μM acacetin (n=6).

[0019] FIGS. 8A, 8B, 8C, and 8D show the effects of acacetin on I_{hERG} and I_{Ks} stably expressed in HEK 293 cells. FIG. 8A. Voltage-dependent I_{hERG} was reversibly inhibited by 30 μM acacetin. FIG. 8B. Concentration-response relationship of $I_{hERG.tail}$ block by acacetin (+40 mV, n=8-14 experiments). FIG. 8C. Voltage-dependent I_{Ks} was inhibited by 30 μM acacetin in a HEK 293 cell stably expressing the hKCNQ1/hKCNE1 genes. FIG. 8D. Concentration-response relationship of $I_{Ks.step}$ inhibition by acacetin at +40 mV (n=7-12 experiments).

[0020] FIGS. 9A, 9B, 9C, and 9D show the effects of acacetin and quinidine on heart rate and QTc interval of ECG in isolated rabbit hearts. FIG. 9A. Acacetin at 30 μM did not affect ECG parameters. FIG. 9B. Quinidine at 10 μM slowed heart rate, and prolonged QTc interval of ECG. FIG. 9C. Mean values of heart rate before and after 30 μM acacetin or 10 μM quinidine (P<0.01 vs before treatment). FIG. 9D. Mean values of QTc interval of ECG before and after 30 μM acacetin or 10 μM quinidine (P<0.01 vs before treatment).

[0021] FIGS. 10A, 10B, and 10C show the mono-phasic action potentials (MAPs) used to measure left and right atrial ERP and S2-induced AF is prevented by acacetin in anesthetized dogs. FIG. 10A. ERP measurement by S1 and S2 stimuli. FIG. 10B. Sustained AF was triggered by the S2

when right atrial ERP was measured at 200 ms BCL. FIG. 10C. The AF was no longer triggered 2 h post-treatment with 5 mg/kg acacetin.

[0022] FIGS. 11A, 11B, and 11C show the effects of acacetin and sotalol on left atrial ERP and QTc in anesthetized dogs. FIG. 11A. Percent changes in left atrial ERP at BCLs of 250 and 200 ms relative to the basal level (before intraduodenal administration, *P<0.05 vs vehicle, ANOVA). FIG. 11B. Sotalol, but not acacetin, showed 'reverse-rate dependent' prolongation of ERP (data from three hours post administration). FIG. 11C. Sotalol, but not acacetin, prolonged the QTc interval in anesthetized dogs (P<0.05).

[0023] FIGS. 12A and 12B show the AF induction in anesthetized dogs. FIG. 12A. Typical recordings show ECG (lead II) and MAP traces recorded using MAP recording and pacing catheters introduced into right atrium and left ventricle, respectively. FIG. 12B. AF was generated using S1-S2 stimuli (arrow) at 100 ms BCL with continuous bilateral vagal stimulation and ventricular pacing. ECG follows ventricular pacing rhythm.

[0024] FIGS. 13A and 13B show the incidence of AF and drugs effects on the AF induction in anesthetized dogs. FIG. 13A. Acacetin at 2.5, 5, and 10 mg/kg, but not vehicle, reduced the incidence of AF 1.5-2.5 h after intraduodenal administration. Sotalol also reduced the incidence of AF in anesthetized dogs. FIG. 13B. Acacetin at 5 and 10 mg/kg significantly prevented AF (*P<0.05 vs vehicle, Fisher exact test).

DETAILED DESCRIPTION OF THE INVENTION

[0025] The subject invention provides flavone compounds and their use as inhibitors of potassium channel function. In one embodiment, the subject invention provides compounds that inhibit human atrial I_{Kur} and I_{to} that serve as targets for the treatment of atrial arrhythmias.

[0026] In an embodiment specifically exemplified herein, a flavone compound is used to treat atrial fibrillation. In a preferred embodiment, acacetin is used to treat atrial fibrillation in humans.

[0027] In accordance with the subject invention, it has been found that the natural flavone acacetin is a novel, orally-effective, atrial-selective, anti-arrhythmic agent for the treatment of AF. Advantageously, it has been found that acacetin preferentially inhibits I_{Kur} and I_{to}, prolongs APD in human atrial myocytes, prolongs ERP, and prevents AF induction in anesthetized dogs. In addition to the blockade of atrial I_{Kur}, I_{to} and I_{KACh}, the anti-peroxidative and anti-inflammatory effects of acacetin are also be of benefit.

[0028] The effects of ethanol extracts from the Snow-Lotus-Flowers namely "Xue-Lian-Hua" in Chinese (the whole herb of *Saussurea laniceps*) on cardiac membrane currents in human atrial myocytes were studied. The chloroform fraction extract (XLH-I) of the ethanol extracts showed a substantial inhibition of I_{Kur} and I_{to} in human atrial myocytes (FIG. 1). Then, several compounds (Compounds A, B, C, and D) were isolated from the XLH-I extract. After a series of tests in human atrial myocytes, compound A was found to have a blocking effect on I_{Kur} and I_{to} in human atrial myocytes. The chemical structure of compound A was then determined to be acacetin.

[0029] Acacetin is a flavone compound (5,7-dihydroxy-4'-methoxyflavone) that is broadly distributed in plant pigments, universally present in vascular plants and responsible for much of the colors in nature (Cody, 1988). Acacetin has been

reported to possess anti-peroxidative, anti-inflammatory, and antiplasmodial effects (Liao et al., 1999; Kraft et al., 2003), to enhance differentiation-inducing activity in HL-60 cells (Kawaii et al., 2000), and to exert an anti-cancer action in several types of cancers, including human prostate cancer, lung cancer, and HepG2 (Singh et al., 2005; Pan et al., 2006; Hsu et al., 2004). In addition, acacetin can also inhibit glutathione reductase, cytochrome P450 and topoisomerase I-catalyzed DNA religation (Zhang et al., 1997; Doostdar et al., 2000).

[0030] In addition to acacetin, the subject invention further contemplates the use of derivatives, analogs, salts, glycosides, esters, amide and/or stereoisomers thereof.

[0031] In accordance with the present invention, acacetin inhibits I_{Kur} and I_{to}, prolongs action potential duration in human atrial myocytes, and blocks $I_{K.ACh}$ in guinea pig atrial cells. This compound has no effect on I_{Na}, $I_{Ca.L}$, and I_{K1} in guinea pig ventricular myocytes, and shows a weak inhibition of hERG channels and I_{Ks} channels stably expressed in HEK 293 cells. Importantly, acacetin dose not increase QTc interval of EGC in anesthetized dogs and isolated rabbit hearts.

[0032] It is generally accepted that cardiac repolarization and refractoriness are determined by the balance of inward Ca^{2+} and outward K^+ currents. I_{Kur} and I_{to} are major outward currents in the human atrium, and therefore play important roles in human atrial repolarization (Courtemanche et al., 1999). Previous work has demonstrated that I_{Kur} is functionally present in the atrium, but not in the ventricle of the human heart (Li et al., 1996b). Therefore, I_{Kur} is an attractive target for selective anti-AF agents (Nattel et al., 2002).

[0033] In accordance with the subject invention, it has been found that acacetin inhibits human atrial I_{Kur} in a concentration-dependent manner with an IC_{50} of 3.2 µM (FIG. 2). This concentration is lower than those observed previously in anti-peroxidative, anti-inflamatory and anti-mutagenic studies (Pan et al., 2006; Cholbi et al., 1991; Kraft et al., 2003). In addition, acacetin blocked I_{to} with an IC_{50} of 9.2 µM (FIG. 3), and slowed the recovery of I_{to} from inactivation without affecting the voltage-dependence of the current (FIG. 4). The inhibition of I_{to} by acacetin can also contribute to the prolongation of APD in human atrium. Acacetin at 5 and 10 µM significantly prolonged APD at 50%, 75% and 90% repolarization at 0.5, 1.0, and 2.0 Hz (FIG. 5). The prolongation of APD increases effective refractory period and terminates AF.

[0034] Vagal stimulation shortens the atrial APD and effective refractory period, and therefore vagal nerve tone plays a crucial role in AF (Schauerte et al., 2000; Zipes et al., 1974). The acetylcholine-activated potassium current $I_{K.ACh}$ mediates much of the cardiac response to vagal nerve stimulation via muscarinic M-receptors activation (Hashimoto et al., 2006; Liu and Nattel, 1997). $I_{K.ACh}$ and/or M-receptor expression are up-regulated in AF patients (Bosch et al., 1999) and in AF induced by experimental heart failure in the dog (Shi et al., 2004). Therefore, the blockage of $I_{K.ACh}$ should terminate AF induced by the increased vagal nerve tone. The selective $I_{K.ACh}$ blocker tertiapin, a bee venom peptide, terminated AF caused by stimulating vagal nerve in dogs (Hashimoto et al., 2006).

[0035] In accordance with the subject invention, it has been found that acacetin at 3 and 10 µM substantially inhibits carbachol-elicited $I_{K.ACh}$ in guinea pig atrial myocytes (FIG. 6), indicating that acacetin is effective in terminating AF induced by $I_{K.ACh}$ activation.

[0036] Acacetin at 30-100 µM showed no inhibition of cardiac I_{Na}, $I_{Ca.L}$, and I_{K1} in guinea pig ventricular myocytes (FIG. 7). These results suggest that acacetin should not reduce cardiac conduction velocity or contractility, and should not depolarize cell membrane as observed in class I and class IV anti-arrhythmic drugs.

[0037] On the other hand, acacetin inhibited I_{hERG} with an IC_{50} of 32.4 µM in HEK 293 cell line, and also suppressed human cardiac I_{Ks} with an IC_{50} of 81.4 µM in HEK 293 cells stably expressing hKCNQ1/hKCNE1 channels (FIG. 8). However, acacetin (30 µM), in contrast to quinidine (10 µM), did not affect heart rate, and did not cause a QTc prolongation in isolated hypokalemic rabbit hearts (FIG. 9).

[0038] Blockade of the ultra-rapid delayed rectifier current I_{Kur} (or Kv1.5) channel has been proposed as a novel target for the development of safer and potentially more effective atrial antiarrhythmic agents (Pecini et al., 2005). There are four structurally distinct synthesized antiarrhythmic agents that have been described as possessing I_{Kur} block as part of their spectra of actions: NIP-141 (Seki et al., 2002), AVE0118 (de Haan et al., 2006; Gogelein et al., 2004), RSD1235 (Fedida et al., 2005), and DPO-1 (Regan et al., 2006).

[0039] As discussed above, it has been determined that acacetin, a I_{Kur} blocker, also blocks I_{to} and $I_{K.ACh}$. These properties are favorable for terminating AF.

[0040] Acacetin (5 mg/kg) significantly prolonged atrial ERP without prolonging QTc interval in anesthetized dogs after intraduodenal administration (FIGS. 10 & 11, Tables 1 & 2), which differs from sotalol, in that it prolonged both atrial ERP and QTc. These results suggest that acacetin has an anti-AF potential effect with no proarrhythmic potential. Indeed, the anti-AF effect was proven in anesthetized dogs, since acacetin at 5 and 10 mg/kg significantly prevented AF induction (FIG. 13).

[0041] In addition, no animal death is found in mice with a maximal oral administration of acacetin (900 mg/kg) during a two-week observation period, indicating that acacetin has low or no acute toxicity.

[0042] Finally, a comparative study (Table 3) shows that the derivatives/analogs studied have less ion channel selectivity for Kv1.5 and hERG channels (A-2) or have less effect (A-4, A-5, A-6, A-2-11, A-2-12, A-2-13, A-2-14) or no effects (A-9, A-10, A-11, A-12) on Kv1.5.

Table 1 shows the effects of acacetin and sotalol on the right atrial ERP in anesthetized dogs.

BCL	ERP (ms)		
	300	250	200 ms
	Acacetin 5 mg/kg (n = 5)		
Pre-treatment	100.8 ± 7.9	96.5 ± 6.9	87.2 ± 7.9
1	108.5 ± 3.7	98.8 ± 3.6	89.5 ± 2.7
2	118.5 ± 5.3*	118.5 ± 11.6*	104.5 ± 8.9*
3	124.1 ± 9.7*	112.3 ± 6.3*	106.5 ± 7.9*
4 post-treatment	125.2 ± 11.2*	116.4 ± 11.2*	105.1 ± 7.5*
	Sotalol 5 mg/kg (n = 5)		
Pre-treatment	100.3 ± 9.4	96.3 ± 8.3	88.7 ± 3.9
1	128.1 ± 8.6*	122.5 ± 6.6*	99.4 ± 3.2
2	143.1 ± 12.2*	128.6 ± 8.9*	105.1 ± 5.1*
3	138.5 ± 8.7*	128.2 ± 7.6*	111.3 ± 9.3*
4 post-treatment	139.4 ± 8.3*	126.3 ± 6.9*	112.8 ± 9.1*

4

-continued

	ERP (ms)		
BCL	300	250	200 ms
Vehicle (n = 4)			
Pre-treatment	108.1 ± 6.2	99.1 ± 6.4	93.1 ± 6.1
1	111.9 ± 6.5	106.3 ± 5.9	98.1 ± 7.1
2	108.8 ± 7.3	100.1 ± 9.2	93.2 ± 8.2
3	108.2 ± 9.0	98.1 ± 10.4	91.8 ± 9.2
4 post-treatment	100.5 ± 8.9	96.9 ± 9.8	91.3 ± 8.7

*P < 0.05 vs pre-treatment

Table 2 shows the effects of acacetin and sotalol on the right atrial ERP in anesthetized dogs.

	ERP (ms)		
BCL	300	250	200 ms
Acacetin 5 mg/kg (n = 5)			
Pre-treatment	105.1 ± 3.9	89.9 ± 3.5	94.4 ± 3.4
1	122.1 ± 9.4*	116.5 ± 8.3*	106.5 ± 7.2*
2	125.1 ± 7.8*	119.8 ± 8.0*	110.1 ± 6.8*
3	126.7 ± 8.6*	122.5 ± 8.9*	113.5 ± 7.9*
4 post-treatment	125.1 ± 7.8*	118.9 ± 7.5*	111.5 ± 6.5*
Sotalol 5 mg/kg (n = 5)			
Pre-treatment	99.4 ± 3.7	94.3 ± 3.1	88.8 ± 3.7
1	115.6 ± 5.7	113.8 ± 9.2*	99.4 ± 3.2*
2	125.6 ± 8.5*	116.9 ± 3.2*	105.1 ± 5.1*
3.	132.5 ± 12.4*	120.1 ± 2.6*	109.3 ± 7.5*
4 post-treatment	135.6 ± 6.9*	121.9 ± 6.7*	107.6 ± 4.2*
Vehicle control (n = 4)			
Pre-treatment	107.8 ± 7.4	100.1 ± 7.7	94.5 ± 7.1
1	107.5 ± 8.2	104.3 ± 8.1	97.5 ± 6.9
2	103.8 ± 6.3	101.9 ± 6.5	97.3 ± 5.9
3	99.9 ± 6.7	92.5 ± 5.3	88.2 ± 5.8
4	100.1 ± 7.1	92.5 ± 4.1	86.3 ± 6.8

*P < 0.05 vs pre-treatment

[0043] Table 3 shows the comparative observation of acacetin with its derivatives/analogs for the effects of blocking Kv1.5 and hERG channels

Compounds/derivatives	Kv1.5 (IC$_{50}$, μM)	hERG (IC$_{50}$, μM)
Acacetin	3.4	32.4
A-2	2.04	4.1
A-4	9.0	21.9
A-5	23.5	13.0
A-6	13.7	57.9
A-9	NE	NE
A-10	NE	NT
A-11	NE	NE
A-12	NE	NE
A-2-11	WE	NT
A-2-12	WE	NT
A-2-13	WE	NT
A-2-14	WE	NT

Note:
NE, no effect;
NT, not tested;
WE, weak effect (<50% inhibition at 100 μM)

Acacetin, and its Derivatives and Analogues

Structure of Acacetin

[0044]
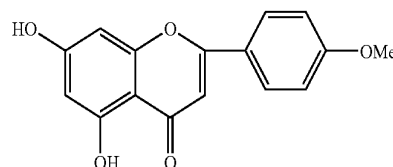
Derivatives from Synthesis

	R$_1$	R$_2$	R$_3$
A	OH	H	OH
A-02-11-11	CH$_3$COO	H	OH
A-02-11-12	benzoate	H	OH
A-02-11-13	CH$_3$O	H	OH
A-02-11-14	CH$_3$CH$_2$O	H	OH
A-2	OH	H	p-methoxybenzoate
A-3	p-methoxybenzoate	H	OH
A-4	H	H	H
A-5	H	Cl	H
A-6	H	CH$_3$	H

Analogues from Natural Resources

A-9

A-10

A-11

5

-continued
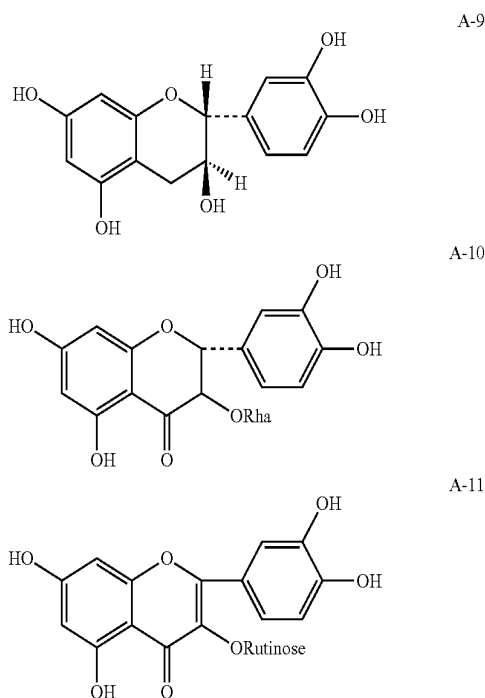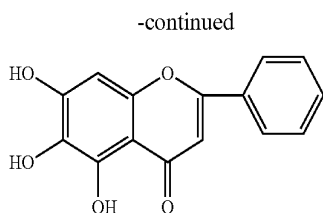
A-12

Physical Data of Acacetin and its Derivatives

Acacetin

[0045] Acacetin: a pale yellow powder; $C_{16}H_{12}O_5$; MW. 284; mp 263° C.; ^{1}H-NMR (400 MHz, DMSO): 6.82 (s, H-3), 6.47 (d, J=1.9 Hz, H-8), 6.18 (d, J=1.9 Hz, H-6), 7.98 (d, J=8.8 Hz, H-2', 6'), 7.07 (d, J=8.8 Hz, H-3', 5'), 3.85 (s, 4'-OCH$_3$).

Derivatives from Synthesis

[0046] A-02-11-11: a pale yellow powder; $C_{18}H_{14}O_6$; MW. 326; mp 279° C.; ^{1}H-NMR (400 MHz, DMSO): 6.82 (s, H-3), 6.45 (d, J=1.9 Hz, H-8), 6.12 (d, J=1.9 Hz, H-6), 7.98 (d, J=8.8 Hz, H-2', 6'), 7.07 (d, J=8.8 Hz, H-3', 5'), 3.85 (s, 4'-OCH$_3$), 2.01 (s).

[0047] A-02-11-12: a pale yellow powder; $C_{23}H_{16}O_6$; MW. 388; mp 282° C.; ^{1}H-NMR (400 MHz, DMSO): 6.81 (s, H-3), 6.43 (d, J=1.9 Hz, H-8), 6.16 (d, J=1.9 Hz, H-6), 7.97 (d, J=8.8 Hz, H-2', 6'), 7.02 (d, J=8.8 Hz, H-3', 5'), 3.85 (s, 4'-OCH$_3$), 7.20-7.42 (m).

[0048] A-02-11-13: a pale yellow powder; $C_{17}H_{14}O_5$; MW. 298; mp 174° C.; ^{1}H-NMR (400 MHz, DMSO): 6.80 (s, H-3), 6.46 (d, J=1.9 Hz, H-8), 6.16 (d, J=1.9 Hz, H-6), 7.97 (d, J=8.8 Hz, H-2', 6'), 7.02 (d, J=8.8 Hz, H-3', 5'), 3.86 (s, 4'-OCH$_3$), 3.84 (s, 7-OCH$_3$).

[0049] A-02-11-14: a pale yellow powder; $C_{18}H_{16}O_5$; MW. 312; mp 165° C.; ^{1}H-NMR (400 MHz, DMSO): 6.80 (s, 6.45 (d, J=1.9 Hz, H-8), 6.17 (d, J=1.9 Hz, H-6), 7.96 (d, J=8.8 Hz, H-2', 6'), 7.01 (d, J=8.8 Hz, H-3', 5'), 3.83 (s, 4'-OCH$_3$), 3.89 (dd, J=5.0 Hz), 1.33 (t, J=5.1 Hz).

[0050] A-2: a pale yellow powder; $C_{24}H_{18}O_7$; MW. 418; mp 275° C.; ^{1}H-NMR (400 MHz, DMSO): 6.80 (s, H-3), 6.42 (d, J=1.9 Hz, H-8), 6.13 (d, J=1.9 Hz, H-6), 7.93 (d, J=8.8 Hz, H-2', 6'), 7.01 (d, J=8.8 Hz, H-3', 5'), 3.85 (s, 4'-OCH$_3$), 7.79 (d, J=8.2 Hz, 2H), 6.92 (d, J=8.2 Hz, 2H), 3.74 (s, —OCH$_3$).

[0051] A-3: a pale yellow powder; $C_{24}H_{18}O_7$; MW. 418; mp 265° C.; ^{1}H-NMR (400 MHz, DMSO): 6.85 (s, H-3), 6.32 (d, J=1.9 Hz, H-8), 6.21 (d, J=1.9 Hz, H-6), 7.92 (d, J=8.8 Hz, H-2', 6'), 7.03 (d, J=8.8 Hz, H-3', 5'), 3.85 (s, 4'-OCH$_3$), 7.75 (d, J=8.2 Hz, 2H), 6.99 (d, J=8.2 Hz, 2H), 3.82 (s, —OCH$_3$).

[0052] A-4: a yellow powder; $C_{16}H_{12}O_3$; MW. 252; mp 164° C.; ^{1}H-NMR (400 MHz, DMSO): 6.71 (s, H-3), 6.92-7.64 (m, H-5, 6, 7, 8), 7.86 (d, J=8.8 Hz, H-2', 6'), 6.82 (d, J=8.8 Hz, H-3', 5'), 3.73 (s, 4'-OCH$_3$).

[0053] A-5: a yellow powder; $C_{16}H_{11}ClO_3$; MW. 286; mp 194° C.; ^{1}H-NMR (400 MHz, DMSO): 6.67 (s, H-3), 7.34 (d, J=1.2 Hz, H-5), 7.12 (m, H-7), 6.89 (m, H-8), 7.56 (d, J=8.8 Hz, H-2', 6'), 6.82 (d, J=8.8 Hz, H-3', 5'), 3.75 (s, 4'-OCH$_3$).

[0054] A-6: a yellow powder; $C_{17}H_{14}O_3$; MW. 266; mp 179° C.; ^{1}H-NMR (400 MHz, DMSO): 6.73 (s, H-3), 7.21 (d, J=1.2 Hz, H-5), 7.02 (m, H-7), 6.72 (m, H-8), 7.83 (d, J=8.8 Hz, H-2', 6'), 6.80 (d, J=8.8 Hz, H-3', 5'), 3.71 (s, 4'-OCH$_3$), 2.35 (s, 6-CH$_3$).

Analogues from Natural Resources

[0055] A-9: a white amorphous powder; $C_{15}H_{14}O_6$; mp 246-247° C.; [a]$^{20}_D$ 52.3° (c 0.128, in MeOH); LC-MS: 290 [M]$^+$; ^{1}H-NMR (400 MHz, CD$_3$OD): 6.92 (1H, d, J=2.0 Hz, 2'-H), 6.69 (1H, d, J=8.0 Hz, 5'-H), 6.74 (1H, dd, J=8.0, 2.0 Hz, 6'-H), 5.88 (1H, d, J=2.0 Hz, 8-H), 5.86 (1H, d, J=2.0 Hz, 6-H), 4.76 (1H, s, 2-H), 4.11 (1H, m, 3-H), 2.80 (1H, dd, J=17.0, 4.5 Hz, 4-H), 2.68 (1H, dd, J=17.0, 3.0 Hz, 4-H).

[0056] A-10: white needles; $C_{21}H_{22}O_{11}$; LC-MS: 466 [M]$^+$; m.p. 166-168° C.; [a]$^{25}_d$: +110.5° (0.15, MeOH); ^{1}H-NMR (DMSO, 400 MHz): 12.60 (1H, s, 5-OH), 10.5 (1H, s, 7-OH), 7.13 (1H, Ar—H), 6.85 (2H, m, Ar—H), 5.93 (2H, s, 6, 8-H), 5.30 (1H, d, =10 Hz, 2-H), 4.97 (1H, d, J=10 Hz, 3-H), 4.70 (1H, d, J=7 Hz, 1"-H).

[0057] A-11: a yellow powder; $C_{24}H_{16}O_9$; mp 190-192° C.; LC-MS: 610 [M]$^+$, ^{1}H-NMR (CD$_3$OD, 400 MHz): 6.13 (111, d, J=1.8 Hz, H-6), 6.32 (1H, d, J=1.8 Hz, H-8), 7.61 (1H, d, J=2.1 Hz, H-2'), 6.81 (1H, d, 8.4 Hz, H-5'), 7.57 (1H, dd, J=2.1, 8.4 Hz, H-6'), 5.05 (1H, d, J=7.2 Hz, H-1"); 4.47 (1H, s, H-1"), 1.07 (3H, d, J=6 Hz, CH$_3$-6").

[0058] A-12: a yellow powder; $C_{15}H_{10}O_5$; mp 273-275° C.; LC-MS: 270 [M]$^+$; ^{1}H-NMR (CD$_3$OD, 400 MHz): 12.70 (1H, s, C$_5$—OH), 10.60 (1H, s, C$_7$—OH), 8.48 (1H, s, C$_6$—OH), 8.04 (2H, m, C$_{2',6'}$—H), 7.57 (3H, m, C$_{3',4',5'}$—H), 6.91 (1H, s, C$_3$—H), 6.62 (1H, s, C$_8$—H).

Salts

[0059] Salts are also within the scope of this invention. Reference to a flavone compound of the subject invention is understood to include reference to salts thereof, unless otherwise indicated. The term "salt(s)", as employed herein, denotes acidic and/or basic salts formed with inorganic and/or organic acids and bases. In addition, when a compound contains both a basic moiety and an acidic moiety, zwitterions ("inner salts") may be formed and are included within the term "salt(s)" as used herein.

[0060] Pharmaceutically acceptable (i.e., non-toxic, physiologically acceptable) salts are preferred, although other salts are also useful, e.g., in isolation or purification steps which may be employed during preparation. Salts of the compounds may be formed, for example, by reacting a compound with an amount of acid or base, such as an equivalent amount, in a medium such as one in which the salt precipitates or in an aqueous medium followed by lyophilization.

[0061] Salts that are contemplated according to the subject invention include those described in U.S. Patent Application No. 2007/0203157, which is incorporated by reference herein in its entirety.

Stereoisomers

[0062] All stereoisomers of the present compounds, such as those which may exist due to asymmetric carbons, including enantiomeric forms (which may exist even in the absence of asymmetric carbons) and diastereomeric forms, are contemplated within the scope of this invention. Individual stereoisomers of the compounds of the invention may, for example, be substantially (i.e. more than 90% and, preferably, more than 95%) free of other isomers, or may be admixed, for example, as racemates or with all other, or other selected, stereoisomers. The chiral centers of the present invention can have the S or R configuration as defined by the IUPAC 1974 Recommendations.

Pharmaceutical Compositions

[0063] The present invention also provides pharmaceutical compositions comprising at least one of the flavone com-

pounds or salts thereof capable of preventing or treating one or more of the aforementioned disorders in an amount effective therefor, and a pharmaceutically acceptable vehicle or diluent. The compositions of the present invention may contain other therapeutic agents as described below, and may be formulated, for example, by employing conventional solid or liquid vehicles or diluents, as well as pharmaceutical additives of a type appropriate to the mode of desired administration (for example, excipients, binders, preservatives, stabilizers, flavors, etc.) according to techniques such as those well known in the art of pharmaceutical formulation.

[0064] As used herein, unless the context or explicit language dictates otherwise, reference to a "pharmaceutical carrier" or "pharmaceutical vehicle" or other such term, excludes the compounds and materials with which acacetin (and/or the other flavones, analogs, derivatives, etc) are associated in nature. Thus, unless the context or explicit language dictates otherwise, reference to a "pharmaceutical carrier" or "pharmaceutical vehicle" would not include, for example, a plant or natural unaltered plant material associated with flavones in nature. Reference herein to "isolated" acacetin (or other "isolated" compound) refers to acacetin (or other compound) that has been produced synthetically or has been isolated to remove it from some or all of the other compounds with which it exists in nature.

[0065] The compounds of the subject invention may be administered by any suitable means, for example, orally, such as in the form of tablets, capsules, granules or powders; sublingually; bucally; parenterally, such as by subcutaneous, intravenous, intramuscular, or intrasternal injection or infusion techniques (e.g., as sterile injectable aqueous or non-aqueous solutions or suspensions); nasally such as by inhalation spray; topically, such as in the form of a cream or ointment; or rectally such as in the form of suppositories; in dosage unit formulations containing non-toxic, pharmaceutically acceptable vehicles or diluents.

[0066] The present compounds may, for example, be administered in a form suitable for immediate release or extended release. Immediate release or extended release may be achieved by the use of suitable pharmaceutical compositions comprising the present compounds, or, particularly in the case of extended release, by the use of devices such as subcutaneous implants or osmotic pumps. In the case where the compounds are being administered to prevent or treat arrhythmias, the compounds may be administered to achieve chemical conversion to normal sinus rhythm, or may optionally be used in conjunction with electrical cardioconversion.

[0067] Exemplary compositions for oral administration include suspensions which may contain, for example, micro-crystalline cellulose for imparting bulk, alginic acid or sodium alginate as a suspending agent, methylcellulose as a viscosity enhancer, and sweeteners or flavoring agents such as those known in the art; and immediate release tablets which may contain, for example, microcrystalline cellulose, dicalcium phosphate, starch, magnesium stearate and/or lactose and/or other excipients, binders, extenders, disintegrants, diluents and lubricants such as those known in the art. The compounds may also be delivered through the oral cavity by sublingual and/or buccal administration. Molded tablets, compressed tablets or freeze-dried tablets are exemplary forms which may be used.

[0068] Exemplary compositions include those formulating the present compound(s) with fast dissolving diluents such as mannitol, lactose, sucrose and/or cyclodextrins. Also included in such formulations may be high molecular weight excipients such as celluloses (avicel) or polyethylene glycols (PEG). Such formulations may also include an excipient to aid mucosal adhesion such as hydroxy propyl cellulose (HPC), hydroxy propyl methyl cellulose (HPMC), sodium carboxy methyl cellulose (SCMC), maleic anhydride copolymer (e.g., Gantrez), and agents to control release such as polyacrylic copolymer (e.g., Carbopol 934). Lubricants, glidants, flavors, coloring agents and stabilizers may also be added for ease of fabrication and use.

[0069] Exemplary compositions for nasal aerosol or inhalation administration include solutions in saline which may contain, for example, benzyl alcohol or other suitable preservatives, absorption promoters to enhance bioavailability, and/or other solubilizing or dispersing agents such as those known in the art.

[0070] Exemplary compositions for parenteral administration include injectable solutions or suspensions which may contain, for example, suitable non-toxic, parenterally acceptable diluents or solvents, such as mannitol, 1,3-butanediol, water, Ringer's solution, an isotonic sodium chloride solution, or other suitable dispersing or wetting and suspending agents, including synthetic mono- or diglycerides, and fatty acids, including oleic acid.

[0071] Exemplary compositions for rectal administration include suppositories which may contain, for example, a suitable non-irritating excipient, such as cocoa butter, synthetic glyceride esters or polyethylene glycols, which are solid at ordinary temperatures, but liquefy and/or dissolve in the rectal cavity to release the drug.

[0072] Exemplary compositions for topical administration include a topical carrier such as Plastibase (mineral oil gelled with polyethylene).

[0073] The effective amount of a compound of the present invention may be determined by one of ordinary skill in the art, and includes exemplary dosage amounts for an adult human of from about 0.001 to 100 mg/kg of body weight of active compound per day, which may be administered in a single dose or in the form of individual divided doses, such as from 1 to 4 times per day. It will be understood that the specific dose level and frequency of dosage for any particular subject may be varied and will depend upon a variety of factors including the activity of the specific compound employed, the metabolic stability and length of action of that compound, the species, age, body weight, general health, sex and diet of the subject, the mode and time of administration, rate of excretion, drug combination, and severity of the particular condition. Preferred subjects for treatment include animals, most preferably mammalian species such as humans, and domestic animals such as dogs, cats and the like, subject to the aforementioned disorders.

[0074] The compounds of the present invention may be employed alone or in combination with each other and/or other suitable therapeutic agents useful in the treatment of the aforementioned disorders or other disorders, including: other antiarrhythmic agents such as Class I agents (e.g., propafenone), Class II agents (e.g., carvadiol and propranolol), Class III agents (e.g., sotalol, dofetilide, amiodarone, azimilide and ibutilide), Class IV agents (e.g., diltiazem and verapamil), 5HT antagonists (e.g., sulamserod, serraline and tropsetron); calcium channel blockers; cyclooxygenase inhibitors (i.e., COX-1 and/or COX-2 inhibitors) such as aspirin, indomethacin, ibuprofen, piroxicam, Naproxen®, Celebrex®, Vioxx® and NSAIDs; anti-platelet agents; diruetics;

and other agents as set forth in U.S. Published Patent Application No. 2007-0203157 A1 which is incorporated herein in its entirety.

[0075] The above other therapeutic agents, when employed in combination with the compounds of the present invention, may be used, for example, in those amounts indicated in the Physicians' Desk Reference (PDR) or as otherwise determined by one of ordinary skill in the art.

Materials and Methods

1.1. Human Cardiac Myocyte Preparation

[0076] Atrial cells were isolated from specimens of human right atrial appendage obtained from patients (56.1±4.7 years old) undergoing coronary artery bypass grafting. The procedure for obtaining the human tissue was approved by the Ethics Committee of the University of Hong Kong based on the patients' consent. All patients were free from supraventricular tachyarrythmias, and the atria were grossly normal at the time of surgery. After excision, the samples were quickly immersed in oxygenated, normally Ca^{2+}-free cardioplegic solution for transport to the laboratory. Atrial myocytes were enzymatically dissociated as described previously (Tian et al., 2006; Gao et al., 2004). Briefly, the atrial tissue was minced, and gently agitated by continuous bubbling with 100% O_2 in a Ca^{2+}-free Tyrode solution for 15 mM (5 min at a time in fresh solutions), and then incubated for 50 mM in a similar solution containing 150-200 U/ml collagenase (CLS II, Worthington Biochemical, Freehold, N.J., UAS), 0.2 mg/ml protease (type XXIV, Sigma-Aldrich Chemical, St Louis, Mo., USA.) and 1 mg/ml bovine serum albumin (Sigma-Aldrich). After then, the chunks were re-incubated in a fresh enzyme solution of the same composition but no protease. The quantity and quality of isolated cells were monitored under a microscope. When the cell yield appeared optimal, the chunks were suspended in a high K^+ medium containing (mM) 10 KCl, 120 K-glutamate, 10 KH_2PO_4, 1.8 $MgSO_4$, 10 taurine, 10 HEPES, 0.5 EGTA, 20 glucose, 10 mannitol, pH was adjusted to 7.3 with KOH and gently blown with a pipette. The isolated myocytes were kept at room temperature in the medium at least 1 h before use.

1.2. Guinea Pig Cardiac Myocyte Preparation

[0077] Guinea pigs of either gender (250-300 g) were sacrificed by cervical dislocation after anesthetization with pentobarbital (40 mg/kg, i.p.). The procedure related to the use of animals in this invention was approved by the Animal Care and Use Committee for Teaching and Research of University of Hong Kong in accordance with the Guide for the Care and Use of Laboratory Animals (Institute of Laboratory Animal Resources, Commission on Life Sciences, National Research Council, 1996). Left atrial and ventricular myocytes from guinea pig hearts were enzymatically dissociated by the procedure described previously (Li et al., 2002a) and the isolated myocytes were kept in the K^+ storage medium.

1.3. Cell Line Culture

[0078] The established HEK 293 cell lines stably expressing the hERG channel gene, Kv1.5 (Tang et al., 2007), or recombinant human cardiac KCNQ1/KCNE1 channel current (I_{Ks}) (Dong et al., 2006) was maintained separately in Dulbecco's modified eagle medium (Invitrogen) supple-

mented with 10% fetal bovine serum and containing 400 μg/ml G418 (for hERG or Kv1.5 channels) or 100 μg/ml hygromycin (for I_{Ks}).

1.4. Solutions and Drugs

[0079] The Ca^+-free cardioplegic solution for specimen transport contained (in mM) 50 KH_2PO_4, 8 $MgSO_4$, 5 adenosine, 10 HEPES, 140 glucose, 100 mannitol, 10 taurine, pH was adjusted to 7.3 with KOH. Tyrode solution contained (in mM) 140 NaCl, 5.4 KCl, 1 $MgCl_2$, 1 $CaCl_2$, 0.33 NaH_2PO_4, 10 HEPES, 10 glucose, pH was adjusted to 7.4 with NaOH. The pipette solution contained (in mM) 20 KCl, 110 K-aspartate, 1 $MgCl_2$, 10 HEPES, 5 EGTA, 0.1 GTP, 5 Na_2-phosphocreatine, and 5 Mg_2-ATP, pH was adjusted to 7.2 with KOH. For I_{to} and I_{Kur} recording, $BaCl_2$ (200 μM) and $CdCl_2$ (200 μM) were added to the superfusion to block I_{K1} and $I_{Ca.L}$. Atropine (1.0 μM) was used to minimize possible $I_{K.ACh}$ contamination during the current recording. For $I_{Ca.L}$ recording, K^+ in pipette and Tyrode solution was replaced by CsCl. I_{Na} was recorded under conditions of K^+-free and a symmetrical Na^+ (5 mM) in pipette and superfusion solutions as described previously (Li at al., 2002a).

[0080] Acacetin was initially isolated and purified from the TCM Xuelianhua (*Saussurea tridactyla*), and then synthesized in the laboratory as the described above in the section of chemical study on compound A. A 100 mM stock solution of acacetin or its derivative/analogue was made in DMSO, and stored at 4° C.

1.5. Data Acquisition and Analysis

[0081] A small aliquot of the solution containing the isolated cells was placed in an open perfusion chamber (1-ml) mounted on the stage of an inverted microscope. Myocytes were allowed to adhere to the bottom of the chamber for 5-10 mM and were the superfused at 2-3 ml/min with Tyrode solution. Only quiescent rod-shaped cells with clear cross-striations were used. The studies were conducted at room temperature (21-22° C.) for current recording or 36° C. for action potential recording.

[0082] The whole-cell patch-clamp technique was used for electrophysiological recording. Borosilicate glass electrodes (1.2-mm OD) were pulled with a Brown-Flamming puller (model P-97, Sutter Instrument Co, Novato, Calif., UAS) and had tip resistances of 2-3 MΩ when filled with pipette solution. Membrane currents were recorded in voltage-clamp mode using an EPC-9 amplifier and Pulse software (HEKA, Lambrecht, Germany). A 3-M KCl-agar salt bridge was used as reference electrode. The tip potentials were compensated before the pipette touched the cell. After a giga-ohm seal was obtained, the cell membrane was ruptured by gentle suction to establish the whole-cell configuration. The cell membrane capacitance (pF) was directly measured using the lock-in module of the Pulse software, and used for normalizing the current in individual cells. The series resistance (R_s) was 3-5 MO and was compensated by 50-70% to minimize voltage errors. Perforated patch configuration was used for recording action potential in human atrial cells and I_{Ks} in HEK 293 cells as described previously (Li et al., 2002b; Dong et al., 2006). Current signals were low-pass filtered at 5 kHz and stored on the hard disk of an IBM compatible computer.

1.6. Isolated Rabbit Heart Preparation

[0083] New Zealand White rabbits of either gender (2-3 kg) were anesthetized with pentobarbital (30 mg/kg, i.v.), and

their hearts were quickly removed and placed in oxygenated Tyrode solution, Hearts were mounted on a Langendorff system and perfused with 37° C. oxygenated (95% O_2-5% CO_2) Tyrode solution containing (in mM) 129 NaCl, 3.0 KCl, 1 $MgCl_2$, 1.5 $CaCl_2$, 20, $NaHCO_3$, 0.9 NaH_2PO_4, 10 glucose (pH 7.3-7.4). ECG was recorded with a Powerlab recording system via two electrodes placed respectively on base and apex of the heart. The averaged QT interval from three measured Q-T intervals of rabbit heart ECG was corrected by heart rate (Q-Tc interval) according to the Van de Water's formula: QTc=QT-87×[(60/heart rate)−1] as described previously (Spence et al., 1998).

1.7. Whole Animal Experiments

[0084] The study conforms with the Guide for the Care and Use of Laboratory Animals published by the US National Institutes of Health (NIH Publication No. 85-23, revised 1996), and approved by the Institutional Ethic Committee.

1.7.1. In Vivo Electrophysiology in Anesthetized Dogs.

[0085] Adult mongrel dogs (12-15 kg) were anesthetized with pentobarbital (30 mg/kg i.v.), supplemented during the experiment when needed. The animal was intubated and ventilated with room air. Body temperature was maintained at 37-38° C. with a temperature control system. The left femoral vein was cannulated for maintenance of anesthesia and introducing the mono-phasic action potential (MAP) recording- and pacing-catheters (Boston Scientific Ltd) to the right atrium. The vagus nerves were isolated and divided in the neck. To block cardiac (3-adrenergic effects, nadolol was administered at 0.25 mg/kg i.v., followed by 0.125 mg/kg i.v. every 2 h. A left thoracotomy was performed in the fourth intercostal space, and the pericardium was incised to provide access to the left atrium for introducing the MAP catheter. The catheters were used for recording MAPs of right and left atria, respectively, and for measurement of effective refractory period (ERP). In addition, a plastic tube (~0.8×12 cm) was introduced to the intraduodenum through the pylorus from stomach for drug administration, because acacetin is not water soluble for injection application. A ligation was made at the pylorus with a thick cotton thread to prevent the possible back flow of the duodenum content.

[0086] Following a 30-mM equilibration period and measurement of atrial excitation threshold with 2-ms duration of stimuli, atrial ERP was determined using a train of 8 basic stimuli (S1, twice-diastolic threshold) followed by an identical premature stimulus (S2). The basic cycle lengths (BCL) of 200, 250 and 300 ms were applied in both right and left atria. S2 was initially delivered late in diastole in 5-ms decrements until a response was not elicited by the S2 indicated on the MAP recording. The ERP was defined as the longest S1-S2 interval failing a propagated response, and the procedure was repeated for three times for each measurement. MAP, ECG and blood pressure signals were continuously monitored and stored on an IBM compatible PC computer using a multiple channels data acquisition system (RM-6280C, Chengdu Instrument Ltd, Chendu, China).

[0087] After the measurement of ERP of both right and left atria, 10% PVP 400 (Sigma-Aldrich, 20 ml with 2 ml DMSO) as vehicle control or 20 ml 10% PVP 400 containing 5 mg/kg acacetin (treatment group) or 20 ml 10% PVP 400 containing 5 mg/kg sotalol (positive control) was injected into the duodenum via the drug administration tube. The ERP measurement

was then repeated every hour post drug administration for 6 hours. Excitation threshold of both right and left atria was verified before ERP each measurement.

1.7.2. Experimental AF in Anesthetized Dogs.

[0088] Vagal nerve plays an important role in genesis of AF (Chiou et al., 1997; Zipes et al., 1974; Liu and Nattel, 1997), and therefore, vagotonic AF model is generally employed to investigate AF and anti-fibrillation. Sustained vagotonic AF was generated in anesthetized dogs by introducing two MAP catheters respectively into the right atrium and the left ventricle along with stimulation of the divided bilateral vagal nerves in the neck. The vagal nerves were stimulated using a bipolar electrodes with 15 Hz, 0.2 ms duration voltage step (60% threshold) to induce a 75% reduction of heart rate. Ventricular pacing was performed with 2 ms voltage pulses (2.5 Hz, 150% diastolic threshold) when vagal nerves were continuously stimulated. AF was generated by the BCL 100-ms S1 followed by S2, lasting for 10 min. No AF occurrence or shortened AF duration during the continuous vagal stimulation was considered to be effective prevention of AF at certain time points of AF generation during 0.5-4 h post intraduodenal drug administration. The sustained AF could be repeatedly generated and terminated by stopping vagal stimulation. AF incidence and AF duration were recorded before and at different time points (0.5, 1, 1.5, 2, 3, and 4 h) after intraduodenal administration of drugs.

1.8. Acute Toxicity Assessment.

[0089] The acute toxicity of acacetin was determined in Kunmin mice (18-20 g, 50% female and 50% male). The maximum concentration stock (263 mg/ml) of acacetin was prepared in DMSO, and then mixed with 10% PVP 400 to make acacetin suspension for oral administration. The animals were observed closely with a two-week duration for death number and activity.

1.9. Statistical Analysis

[0090] Group data are expressed as mean±S.E.M. Statistical analysis was performed using Student's t-test for paired or unpaired observations to evaluate significant differences between two group means, and ANOVA for multiple groups. Quantitative data were analyzed using the Fisher exact test. A two tailed P<0.05 was taken to indicate a statistical significant difference. Nonlinear curve fitting was performed using Pulsefit (HEKA) and Sigmaplot (SPSS, Chicago, Ill.).

[0091] All patents, patent applications, provisional applications, and publications referred to or cited herein are incorporated by reference in their entirety, including all figures and tables, to the extent they are not inconsistent with the explicit teachings of this specification.

[0092] Following are examples which illustrate procedures for practicing the invention. These examples should not be construed as limiting. All percentages are by weight and all solvent mixture proportions are by volume unless otherwise noted.

Example 1

Effects of Acacetin on I_{Kur}, I_{to}, and Action Potential in Human Atrial Myocytes

[0093] To determine the effects of acacetin on I_{Kur}, the time course of the current was recorded in a representative human

atrial cell using a 100-ms prepulse to +40 mV to partially inactivate I_{to}, followed by 160-ms test pulses from −50 to +50 mV after a 10-ms interval, then to −30 mV (Tian et al., 2006; Gao et al., 2004) in the absence and presence of acacetin (FIG. 2A). Acacetin at 3 μM gradually inhibited I_{Kur} with 8 min exposure, and the effect recovered (by 94%) on washout. FIG. 2B shows the voltage-dependent I_{Kur} elicited by voltage protocol shown in the inset. Acacetin at 3, 10, and 30 μM substantially inhibited both tail and step currents of I_{Kur}. The concentration-response relationship for the inhibition of I_{Kur} by acacetin from 0.3 to 100 μM was evaluated at +40 mV (FIG. 2C). Data were fitted to the Hill equation: $E = E_{max}/[1 + (IC_{50}/C)^b]$, where E is the inhibition of the current in percentage at concentration C, E_{max} is the completed inhibition, IC_{50} is the concentration for a half-maximum action, and b is the Hill coefficient. The IC_{50} of acacetin for inhibiting I_{Kur} was 3.2 μM, and its Hill co-efficient was 0.8.

[0094] To examine the effect of acacetin on I_{to}, the time course of I_{to} was recorded in a typical experiment in the absence and presence of acacetin (FIG. 3A). Acacetin at 3 μM reduced I_{to}, and the effect recovered (by 95%) on washout. However, the sustained current (i.e. I_{Kur}) was simultaneously reduced by acacetin. Although the I_{to} measured was peak to the 'quasi'-steady-state level, we suspected that the evaluation of the effect of acacetin on I_{to} might not be accurate. We have recently found that verapamil inhibits I_{Kur} without reduction of I_{to} amplitude, while it induces an increase of measured I_{to} in human atrial myocytes (Gao et al., 2004). Therefore, verapamil at 10 μM was used to separate I_{to} as shown in FIG. 3B. I_{to} amplitude was actually increased by verapamil. Voltage-dependent I_{to} was substantially inhibited by 3 and 10 μM acacetin (FIG. 3B). The inhibitory effect of I_{to} by acacetin was concentration-dependent with an IC_{50} of 9.3 μM (FIG. 3C), and a Hill co-efficient of 0.9.

[0095] Acacetin at 10 μM did not affect voltage-dependence of the steady-state inactivation and activation of I_{to} (FIG. 4A). However, acacetin at 10 μM significantly increased the recovery time constant of I_{to} (τ: 102±12 ms in control; 136±17 ms in acacetin, P<0.01) (FIG. 4B), suggesting that acacetin slows the recovery of I_{to} from inactivation.

[0096] The inhibition of I_{Kur} and I_{to} by acacetin suggests that this compound prolongs the action potential duration (APD) in human atrial myocytes. We therefore recorded action potentials at 36° C. with the perforated patch configuration in current clamp mode to determine the effect of acacetin on human atrial APD. FIG. 5A illustrates action potentials recorded at 2 Hz in representative human atrial myocytes in the absence and presence of acacetin or 4-AP (a well-known blocker of I_{Kur}) (Li et al., 1996b). Acacetin at 5 or 10 μM prolonged the APD in a parallel fashion without affecting the resting membrane potential or the amplitude of action potential. This effect recovered on washout. The APD at 50%, 75%, and 90% repolarization was increased significantly (FIG. 5B). Acacetin induced a slight rate-dependent increase in APD_{50}, APD_{75} and APD_{90}. 4-AP at 50 μM prolonged APD_{50} more than APD_{90} (right panel of FIG. 5A), and induced a reverse rate-dependent prolongation of APD_{50}, APD_{75} and APD_{90} (data not shown). These results suggest that the prolongation of human atrial APD by acacetin is likely not limited to the inhibition of I_{Kur} and I_{to}.

Example 2

Effects of Acacetin on Acetylcholine-Activated Potassium Currents in Guinea Pig Atrial Myocytes

[0097] The effects of acacetin on acetylcholine-activated ($I_{k.ACh}$) were studied in left atrial myocytes from guinea pig

atrial myocytes, because of no expression of (Kv1.5) and I_{to} channels in atria of this species. The membrane currents recorded with a ramp protocol (FIG. 6A) and voltage step protocol (FIG. 6B) showed that carbachol at 5 μM augmented membrane conductance, and acacetin at 3 μM significantly reversed the increased conductance. FIG. 6C displays I-V relationships of carbachol-evoked $I_{K.ACh}$ obtained by digital subtraction of currents before and after carbachol and carbachol plus acacetin. Acacetin at 3 and 10 μM substantially blocked $I_{K.ACh}$ (P<0.01 at −100 to −80 mV and +50 to +60 mV. At test potentials of −100 and +50 mV, $I_{K.ACh}$ was reduced from −338.3±61.5 pA and 147.2±30.1 of control to −180.2±36.7 and 87.8±36.1 pA with 3 μM acacetin (P<0.01, n=5), and −75.6±21.1 and 55.7±26.2 pA with 10 μM acacetin (P<0.01, n=6).

Example 3

Effects of Acacetin on Other Cardiac Ionic Currents

[0098] The effects of acacetin on other cardiac ionic currents, e.g. I_{Na}, $I_{Ca.L}$, and I_{KI}, were studied in guinea pig ventricular myocytes. FIG. 7 illustrates the results of recordings for I_{Na}, $I_{Ca.L}$, and I_{KI} in different cells using the voltage protocols shown in the insets. Acacetin at 30 and 100 μM had no effect on I_{Na}, $I_{Ca.L}$, or I_{KI}.

[0099] The effect of acacetin on I_{Kr} or I_{Ks} was determined in HEK 293 cells stably expressing hERG channels (α-subunit of human cardiac I_{Kr}) or I_{Ks} channels (hKCNQ1/hKCNE1). Acacetin at 30 μM inhibited the amplitude of hERG channel currents elicited by the voltage protocol (inset, FIG. 8A) in a representative cell, and the effect disappeared on washout (FIG. 8A). The IC_{50} of acacetin for inhibiting $I_{hERG.tail}$ was 32.4 μM (FIG. 8B), and its Hill co-efficient was 0.9.

[0100] FIG. 8C displays the effects of acacetin on I_{Ks} stably expressed in an HEK 293 cell line. Acacetin at 30 μM significantly inhibited the amplitude of I_{Ks}, and the effect partially recovered (by 83%) on washout. Acacetin decreased I_{Ks} at +20 to +60 my in a concentration-dependent manner. The IC_{50} of acacetin for inhibiting I_{Ks} (+40 mV) was 81.4 μM (FIG. 8D), and its Hill co-efficient was 0.8.

Example 4

Effects of Acacetin on QTc Interval of ECG in Isolated Rabbit Hearts

[0101] The above results for the inhibition of I_{hERG} and I_{Ks} suggest that acacetin likely has the potential to prolong QT interval of ECG. Rabbit hearts express significant I_{Kr} channels (Salata et al., 1996), and have been used for evaluating proarrhythmia of cardiac active agents (Milberg et al., 2004; Weissenburger et al., 1993; Cahill and Gross, 2004). Therefore the isolated rabbit heart was employed to study whether or not acacetin would increase QTc. The hearts were perfused using a hypokalemic (3 mM K^+) solution. Representative ECG recordings are shown in FIG. 9A for acacetin and FIG. 9B for quinidine. Acacetin at 30 μM had no effect on heart rate or the QTc interval of the ECG, while quinidine at 10 μM slowed heart rate and significantly increased QTc interval. Mean values of heart rate and QTc interval of ECG are illustrated in FIGS. 9C & 9D. These results suggest that acacetin

does not prolong the QTc interval of the ECG of the isolated rabbit heart under hypokalemic conditions.

Example 5

Effects of Acacetin on Atrial Refractory Period in Anesthetized Dogs

[0102] The ERPs were determined in anesthetized dogs using the BCLs of 300, 250, and 200 ms by introducing S1-S2 via a programmed cardiac stimulator (FIG. 10A). We found that left and right atrial ERP was significantly prolonged after the duodenal administration of acacetin (5 mg/kg) or sotalol (5 mg/kg) during a 4-hour observation at basic cycle lengths (BCL) of 300, 250, and 200 ms (Tables 1 and 2). FIG. 11A shows an example of mean values of the percent changes in left atrial ERP. Atrial ERP was increased by 10 to 25% in the drug administration groups, but not in the vehicle control group

[0103] S2 was found to trigger sustained AF (lasting >1 min) when right ERP was measured with 200 ms BCL in anesthetized dogs. In one animal from the acacetin group, AF was induced by S2 before drug administration (FIG. 10B), but not after two hours of acacetin administration (FIG. 10C). In another animal from the vehicle group, AF was always induced by S2 when right atrial ERP was determined during the observation period. This suggests that acacetin likely has an anti-AF effect.

[0104] Sotalol at 5 mg/kg showed a reverse rate-dependent prolongation of ERP and increased QTc interval as reported previously (Nademanee, 1992; Roden, 1993). However, acacetin had no such reverse rate-dependent effect on ERP (FIG. 11B), and did not prolong QTc interval (FIG. 11C). These results suggest that acacetin is likely an anti-AF agent without causing QTc prolongation.

Example 6

Effects of Acacetin on Atrial Fibrillation in Anesthetized Dogs

[0105] The effect of acacetin on experimental AF was then evaluated in anesthetized dogs. AF was induced by S1-S2 stimulation at 100 ms BCL with bilateral vagal stimulation (see Methods & FIG. 12) at certain time points during the 0.5 to 4 h period following intraduodenal administration. AF lasted for 10 min and terminated once vagal stimulation was stopped. No AF occurrence or shortened AF duration during the continuous vagal stimulation were considered to represent prevention of AF. The incidence of AF was reduced in drug treatment groups (FIG. 13A). Sustained AF was observed in 100% of animals (n=5) at each AF induction test in the vehicle group, but not in 50% (3 of 6), 57% (4 of 7), and 57% (4 of 7) of the animals in the 2.5, 5, and 10 mg/kg acacetin groups, and 40% (2 of 5) of animals in the sotalol group (5 mg/kg).

[0106] In addition, in the 5 mg/kg acacetin group, two dogs showed a shorter duration of AF (one lasted for 5 mm and 31 s, and another lasted for 6 mm 12 s) two hours after drug administration. In the 10 mg/kg acacetin group, AF lasted for 4 min and 30 s in one animal, and 7 min and 11 s in another animal. In the sotalol group, shortened AF duration (of 8 mm and 5 s) was observed in one animal. The summarized anti-AF efficacy was 0%, 50%, 85.7%, 85.7%, and 60% in the vehicle group, 2.5 mg/kg acacetin group, 5 mg/kg acacetin group (P<0.05), 10 mg/kg acacetin group (P<0.05), and 5

mg/kg sotalol group, respectively (FIG. 13B). These results indicates that acacetin prevents AF induction in anesthetized dogs.

Example 7

Acute Toxicity in Mice

[0107] Acute in vivo toxicity was assessed in mice with a maximal concentration of acacetin obtainable in suspension of a maximal volume after starvation of the animal for 14 h. The dose of 0.3 g/kg acacetin was administered three times at intervals of 1.5 h. No animal death occurred within a two-week observation period, and there was no abnormal activity compared to vehicle-control animals. This result suggests that oral administration of acacetin has low or no acute toxicity.

Example 8

Comparative Study Upon the Effects of Acacetin and its Derivatives/Analogs on Kv1.5 and hERG Channels

[0108] The comparative study upon the effects of acacetin and its derivatives/analogs on Kv1.5 and hERG channels were performed in HEK 293 cells stabling expressing these channel genes, respectively. As Table 3 shows, the IC_{50} (3.4 µM) of acacetin for blocking Kv1.5 channels is close to that (3.2 µM) of human atrial I_{Kur} (FIG. 2). Although the derivative A-2 has a smaller IC_{50} (2.04 µM) for blocking Kv1.5 channels, the blockade of hERG channels is also stronger than that of acacetin. The IC_{50}s of A-4, A-5, and A-6 are larger than that of acacetin. Other derivatives/analogs studied have no effect or a week inhibitory effect on Kv1.5. These results indicate that the acacetin is an ideal compound to develop for the anti-AF study in humans, although a possible better effect from other derivatives/analogues can not be excluded.
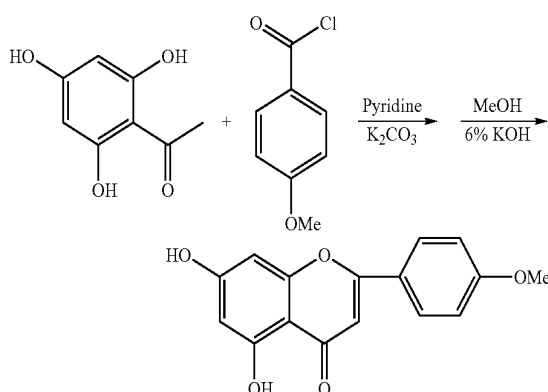
Example 9

Preparation of Acacetin and its Derivatives

Synthesis of Acacetin

[0109]

Reaction scheme:

11

Operation Process:

[0110] To a solution of 80 ml dry pyridine was added 9.62 g 2',4',6'-trihydroxyacetophenone and 30 g anhydrous K$_2$CO$_3$ and 31 g 4-methoxybenzoyl chloride successively, then extracted reaction solution with chloroform when it was refluxed 3 hours at 120° C. by oil bath, and washed the chloroform extraction by water (100 ml), the chloroform was dried by anhydrous K$_2$CO$_3$ and decoloured by active carbon, then concentrated it in vacuo. The residue was dissolved with 60 ml anhydrous ethanol, and have deposition in solution, filtered it, afforded 13.53 g intermediate.

[0111] To a solution of 50 ml methanol was added 6.3 g above intermediate and 6% KOH solution, stirred and refluxed it 20 hours, then recovered most of methanol in vacuo, and extracted it with chlorofolin to remove some extraneous component, the deposit was obtained after the water phase was acidified pH 9 by 10% acetic acid, and filtered it, washed by water, dried it, 1.83 g acacetin was obtained at last.

Preparation of A-02-11-11

[0112] To a 0.75 ml pyridine was added 30 mg acacetin and 0.50 ml acetic anhydride, stirred it 2 hours at room temperature, the residue was chromatographed, and eluted with petrol ether:acetone=2:1, afforded A-02-11-11.

Preparation of A-02-11-12

[0113] To a 0.75 ml pyridine was added 30 mg acacetin and 0.50 ml benzoic anhydride, stirred it 2 hours at room temperature, the residue was chromatographed, and eluted with petrol ether:acetone=2:1, afforded A-02-11-12.

Preparation of A-02-11-13

[0114] To a 0.75 ml pyridine was added 30 mg acacetin and several drops methyl iodide, stirred it 2 hours at room temperature, the residue was chromatographed, and eluted with petrol ether:acetone=2:1, afforded A-02-11-13.

Preparation of A-02-11-14

[0115] To a 0.75 ml pyridine was added 30 mg acacetin and several drops bromethyl, stirred it 24 hours at room temperature, the residue was chromatographed, and eluted with petrol ether:acetone=2:1, afforded A-02-11-14.

Preparation of A-2 and A-3

[0116] To a solution of 80 ml dry pyridine was added 9.62 g 2', 4', 6'-trihydroxyacetophenone and 30 g anhydrous K$_2$CO$_3$ and 31 g 4-methoxybenzoyl chloride successively, then extracted reaction solution with chloroform when it was refluxed 3 hours at 120° C. by oil bath, and washed the chloroform extraction by water (100 ml), the chloroform was dried by anhydrous K$_2$CO$_3$ and decoloured by active carbon, then concentrated it in vacuo. The residue was dissolved with 60 ml anhydrous ethanol, and have deposition in solution, filtered it, afforded 13.53 g intermediate. The residue have three spots assayed by TLC, then chromatographed, and eluted with petrol ether:acetone=2:1, afforded A-2 (203 mg), A-3 (50 mg) and acacetin (1.83 g).

Preparation of A-4

[0117] To a solution of 0.8 ml dry pyridine was added 100 mg 2'-hydroxyacetophenone and 300 mg anhydrous K$_2$CO$_3$

and 125 mg 4-methoxybenzoyl chloride successively, then extracted reaction solution with chloroform when it was refluxed 3 hours at 120° C. by oil bath, and washed the chloroform extraction (10 ml) by water (5 ml), the chloroform was dried by anhydrous K$_2$CO$_3$ and decoloured by active carbon, then concentrated it in vacuo. The residue was dissolved with 3 ml anhydrous ethanol, and have deposition in solution, filtered it, afforded 31 mg A-4.

Preparation of A-5

[0118] To a solution of 0.8 ml dry pyridine was added 100 mg 5'-chloro-2'-hydroxyacetophenone and 300 mg anhydrous K$_2$CO$_3$ and 100 mg 4-methoxybenzoyl chloride successively, then extracted reaction solution with chloroform when it was refluxed 3 hours at 120° C. by oil bath, and washed the chloroform extraction (10 ml) by water (5 ml), the chloroform was dried by anhydrous K$_2$CO$_3$ and decoloured by active carbon, then concentrated it in vacuo. The residue was dissolved with 3 ml anhydrous ethanol, and have deposition in solution, filtered it, afforded 35 mg A-5.

Preparation of A-6

[0119] To a solution of 0.8 ml dry pyridine was added 100 mg 2'-hydroxy-5'-methylacetophenone and 300 mg anhydrous K$_2$CO$_3$ and 100 mg 4-methoxybenzoyl chloride successively, then extracted reaction solution with chloroform when it was refluxed 3 hours at 120° C. by oil bath, and washed the chloroform extraction (10 ml) by water (5 ml), the chloroform was dried by anhydrous K$_2$CO$_3$ and decoloured by active carbon, then concentrated it in vacuo. The residue was dissolved with 3 ml anhydrous ethanol, and have deposition in solution, filtered it, afforded 25 mg A-6.

[0120] It should be understood that the examples and embodiments described herein are for illustrative purposes only and that various modifications or changes in light thereof will be suggested to persons skilled in the art and are to be included within the spirit and purview of this application
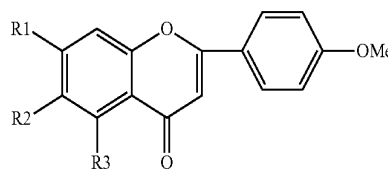
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We claim:

1. A pharmaceutical composition comprising an amount of acacetin, or a pharmaceutically active derivative, analog, salt, glycoside, ester, amide or stereoisomer thereof, effective to inhibit potassium channel function in a patient in need thereof, formulated with a pharmaceutically acceptable vehicle.

2. The composition, according to claim 1, comprising acacetin, or an analog thereof isolated from a plant source.

3. The composition, according to claim 1, wherein the composition is acacetin, or a derivative thereof obtained by chemical synthesis.

4. The composition, according to claim 1, which comprises isolated acacetin.

5. The composition, according to claim 1, which comprises an isolated or synthesized compound having the following formula:

	R_1	R_2	R_3
A	OH	H	OH
A-02-11-11	CH_3COO	H	OH
A-02-11-12	benzoate	H	OH
A-02-11-13	CH_3O	H	OH
A-02-11-14	CH_3CH_2O	H	OH
A-2	OH	H	p-methoxybenzoate

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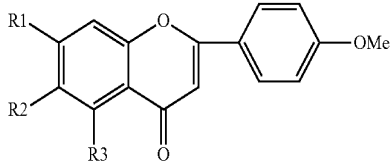
	R$_1$	R$_2$	R$_3$
A-3	p-methoxybenzoate	H	OH
A-4	H	H	H
A-5	H	Cl	H
A-6	H	CH$_3$	H

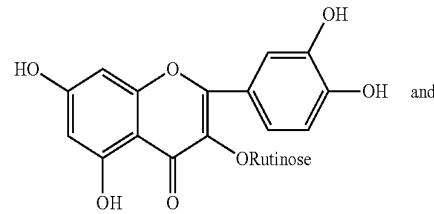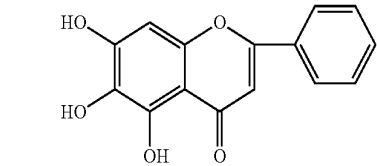6. The composition, according to claim 1, comprising an isolated compound selected from the group consisting of:
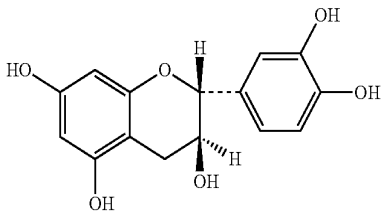
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