(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 576 914 A2**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **93109611.9**

(22) Date of filing: **16.06.93**

(51) Int. Cl.[5]: **C07J 43/00**, A61K 31/58, C07J 41/00, C07J 31/00, //C07J19/00

(30) Priority: **01.07.92 DE 4221538**

(43) Date of publication of application:
05.01.94 Patentblatt 94/01

(84) Designated Contracting States:
AT BE CH DE DK ES FR GB GR IE IT LI LU MC NL PT SE

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(54) 14-Deoxy-14α -cardenolides-3β -thioderivates and pharmaceutical composition comprising same for treating cardiovascular disorders.

(57) 14-Deoxy-14α -cardenolides 3β-thioderivatives and pharmaceutical compositions comprising same for treating cardiovascular disorders, such as heart failure and hypertension are disclosed.

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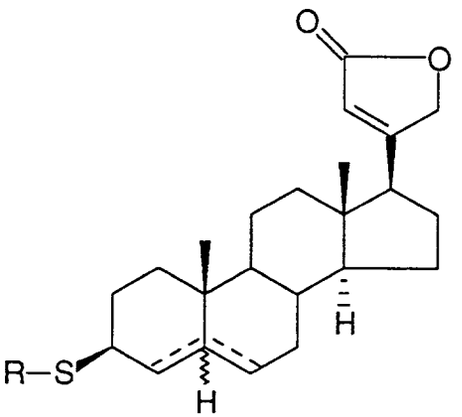
The present invention relates to 14-deoxy-14α-cardenolide 3β -thioderivatives, a process for their preparation and pharmaceutical compositions containing same for the treatment of cardiovascular disorders such as heart failure and hypertension.

The compounds of the present invention have formula (**I**):



(I)

wherein:

the symbol ⎓ represents a single or a double bond;

R is C2-C6 alkyl or C3-C6 alkenyl, unsubstituted or substituted independently by a quaternary ammonium group, a 2-(2-imidazolinyl) group or one or more OR1 or NR2R3 or C(NH)NR4R5;

wherein:

R1 is H, methyl or C2-C4 alkyl substituted by NR6R7 with the proviso that when R1 is H, R is C3-C6 substituted alkyl and at least another group chosen from NR2R3 or C(NH)NR2R3 is also present in the R residue;

R2, R3 are independently H, methyl or C2-C6 alkyl unsubstituted or substituted by NR6R7 or C3-C6 alkenyl or R2 and R3 taken together with the nitrogen atom form an unsubstituted or substituted saturated or unsaturated heteromonocyclic ring optionally containing another heteroatom chosen from oxygen or sulfur or nitrogen, or R2 is hydrogen and R3 is C(NH)NH2;

R4, R5 are independently H, C1-C4 alkyl or C3-C4 alkenyl or R4 and R5 taken together with the nitrogen atom form a penta- or hexa-monoheterocyclic ring;

R6, R7 are independently H, C1-C4 alkyl or R6 and R7 taken together form with the nitrogen atom a saturated or unsaturated penta- or hexa-monoheterocyclic ring optionally containing another heteroatom chosen from oxygen or sulfur or nitrogen or R6 is hydrogen and R7 is C(NH)NH2.

The invention includes within its scope all the possible stereoisomers, in particular E and Z isomers, optical isomers and their mixtures and the metabolites and the metabolic precursors of the compounds of formula (**I**). In particular if ⎓ is a single bond both the 5α and 5β isomers are encompassed within the scope of the present invention.

Pharmaceutical acceptable salts of (**I**) are salts which retain the biologically activity of the base and are derived from such known pharmacologically accetable acids such as e.g. hydrochloric, sulfuric, phosphoric, malic, tartaric, maleic, citric, methanesulfonic or benzoic acid.

The alkyl and alkenyl groups may be branched or straight chain groups.

The C2-C6 alkyl group is preferably a C2-C4 alkyl group, e.g. ethyl, propyl, isopropyl, butyl, sec-butyl.

The C3-C6 alkenyl group is preferably a C3-C4 alkenyl group.

The quaternary ammonium group is preferably a trimethylammonium- or a N-methylpyrrolidinium- or a N-methylpiperidinium- group.

The OR1 group is preferably hydroxy, 2-aminoethoxy, 3-aminopropoxy, 2-dimethylaminoethoxy, 3-dimethylaminopropoxy, 3-amino-2-hydroxypropoxy, 2,3-diaminopropoxy, 2-(1-pyrrolidinyl)ethoxy,3-(1-pyrrolidinyl)propoxy.

The NR2R3 group is preferably amino, methylamino, ethylamino, propylamino, isopropylamino, allylamino, propargylamino, dimethylamino, pyrrolidinyl, morpholino, piperazinyl, imidazolyl, guanidino, 2-aminoethylamino, 3-aminopropylamino, 2-(1-pyrrolidinyl)ethylamino, 3-(1-pyrrolidinyl)propylamino.

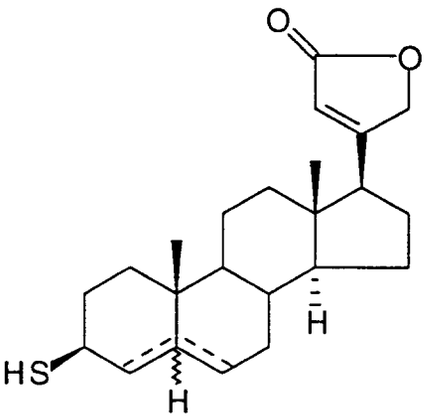
The C(NH)NR4R5 group is preferably a primary amidino group.

The NR6R7 is preferably amino, methylamino, ethylamino, propylamino, dimethylamino, pyrrolidinyl, morpholino, piperazinyl or imidazolyl.

Preferred examples of specific compounds according to the present invention are:

3β-(2-(N-Methyl-N-pyrrolidinium)ethylthio)-5β,14α-card-20(22)-enolide chloride
3β-(2-Aminoethylthio)-5β,14α-card-20(22)-enolide
3β-(3-Aminopropylthio)-5β,14α-card-20(22)-enolide
3β-(2-Aminoethylthio)-14α-card-4,20(22)-dienolide
3β-(3-Aminopropylthio)-14α-card-4,20(22)-dienolide
3β-(2-(1-Pyrrolidinyl)ethylthio)-14α-card-4,20(22)-dienolide
3β-(3-(1-Pyrrolidinyl)propylthio)-14α-card-4,20(22)-dienolide
3β-(2-Aminoethylthio)-14α-card-5,20(22)-dienolide
3β-(3-Aminopropylthio)-14α-card-5,20(22)-dienolide
3β-(2-(1-Pyrrolidinyl)ethylthio)-14α-card-5,20(22)-dienolide
3β-(3-(1-Pyrrolidinyl)propylthio)-14α-card-5,20(22)-dienolide
3β-(2-Aminoethylthio)-5α,14α-card-20(22)-enolide
3β-(3-Aminopropylthio)-5α,14α-card-20(22)-enolide
3β-(2-(1-Pyrrolidinyl)ethylthio)-5a,14α-card-20(22)-enolide
3β-(3-(1-Pyrrolidinyl)propylthio)-5α,14α-card-20(22)-enolide
3β-(4-Amino-(E)-2-butenylthio)-5β,14α-card-20(22)-enolide
3β-(2-Methylaminopropylthio)-5β,14α-card-20(22)-enolide
3β-(2-Dimethylaminopropylthio)-5β,14α-card-20(22)-enolide
3β-(2-(1-Pyrrolidinyl)ethylthio)-5β,14α-card-20(22)-enolide
3β-(3-(1-Pyrrolidinyl)propylthio)-5β,14α-card-20(22)-enolide
3β-(2-Morpholinoethylthio)-5β,14α-card-20(22)-enolide
3β-(2-(1-Piperazinyl)ethylthio)-5β,14α-card-20(22)-enolide
3β-(3-(1-Piperazinyl)propylthio)-5β,14α-card-20(22)-enolide
3β-(2-(1-Imidazolyl)ethylthio)-5β,14α-card-20(22)-enolide
3β-(2-(2-Amidino)ethylthio)-5β,14α-card-20(22)-enolide
3β-(2-Guanidinoethylthio)-5β,14α-card-20(22)-enolide
3β-(3-Amino-2-hydroxypropylthio)-5β,14α-card-20(22)-enolide
3β-(2,3-Diaminopropylthio)-5β,14α-card-20(22)-enolide
3β-(3-(1-Pyrrolidinyl)-2-hydroxypropylthio)-5β,14α-card-20(22)-enolide
3β-(3-(1-Piperazinyl)-2-hydroxypropylthio)-5β,14α-card-20(22)-enolide
3β-(3-(1-Imidazolyl)-2-hydroxypropylthio)-5β,14α-card-20(22)-enolide
3β-(3-Guanidino-2-hydroxypropylthio)-5β,14α-card-20(22)-enolide
3β-(3-(3-Amino-2-hydroxypropoxy)propylthio)-5β,14α-card-20(22)-enolide
3β-(3-(3-Amino-2-hydroxypropylamino)propylthio)-5β,14α-card-20(22)-enolide

The invention furthermore provides a process for the preparation of said compounds (**I**), which comprises condensing the compounds having formula (**II**) where ⁻⁻⁻ is as above defined



(II)

with a compound of formula (**III**)

R-Y (**III**)

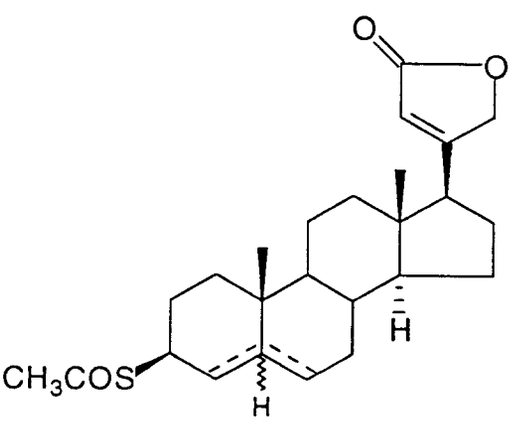
where Y is an electron-withdrawing group, such as halogen, mesyloxy, or tosyloxy group, which confers electrophilic properties to the attached carbon atom, and R is as above defined, the hydroxy and amino groups, if any, present in R being protected, if necessary, with methods well known to those skilled in the art to give, after removal of the protective groups, if any, compounds of general formula (**I**) which may be converted into other compounds of formula (**I**) and optionally converting compounds (**I**) into pharmaceutically acceptable salts thereof and optionally separating a mixture of isomers into single isomers.

The condensation reaction between (**II**) and (**III**) is best carried out in an inert aprotic solvent, such as tetrahydrofuran, dioxane, dimethylformamide, dimethylsulfoxyde or in the neat (**III**) and in the presence of a strong base e.g. sodium or potassium hydride at a temperature ranging from -20 °C to about 60 °C.

Due to the presence of a lactone function, care has to be taken to avoid a basic pH during the work-up.

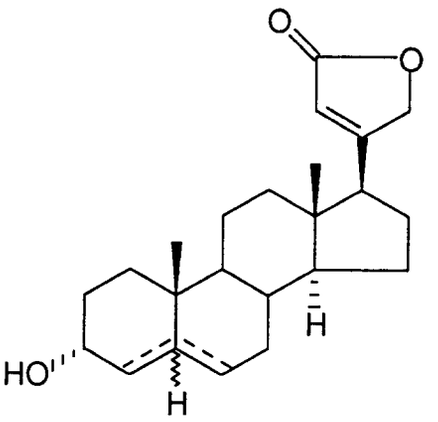
The purifications are best performed by flash-chromatography on silica gel.

In the literature the thiols are normally obtained by reduction of acylthio derivatives with lithium aluminum hydride (Bobbio P.A., *J. Org. Chem.,* **1961**, *26,* 3023), method that cannot be used in this case due to the presence of a reducible lacton function. It has been found that the free thiols can be obtained by ammonolysis of the acetylthio derivative (**IV**).



(IV)

The acetylthio derivatives (**IV**) are new and are obtained by reaction of the 3α-alcohols (**V**) with thiolacetic acid in the presence of a dialkyl azodicarboxylate and triphenylphosphine.



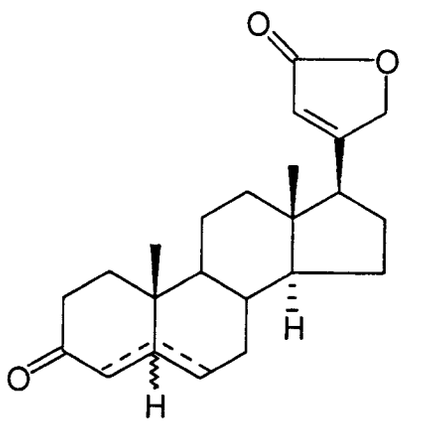
(V)

The 3α-hydroxy-5β,14α-card-20(22)-enolide (formula (**V**) wherein ⁻⁻⁻ are single bonds and the hydrogen in position 5 is β) is a known compound (Stake U., *Tetr. Lett.,* **1971**, 3877) and is obtained by selective reduction of the corresponding 3-keto derivative (Donovan S.F., *Tetr. Lett.,* **1979,** 387) with a complex hydride.

The 3α-hydroxy-14α-card-4,20(22)-dienolide (formula (**V**) wherein ⁻⁻⁻ is a double bond in position 4; see **Prep. 9**) is new and is obtained by selective reduction of the corresponding 3-keto derivative with a complex hydride.

The 3α-hydroxy-14α-card-5,20(22)-dienolide (formula (**V**) wherein ⁻⁻⁻ is a double bond in position 5; see **Prep. 10**) is new and is obtained by selective reduction of the corresponding 3-keto derivative (**VIa**) (see **Prep. 12**) with a complex hydride.

The 3α-hydroxy-5α,14α-card-20(22)-enolide (formula (**V**) wherein ⁻⁻⁻ are single bonds and the hydrogen in position 5 is α; see **Prep. 11**) is new and is obtained by selective reduction of the corresponding 3-keto derivative (**VIb**) (see **Prep. 13**) with a complex hydride.



(VI)

The intermediate 3-oxo-14α-card-4,20(22)-dienolide (formula (**VI**) wherein ⁻⁻⁻ is a double bond in position 4) is a known compound (Fritsch W. et al., *Liebigs Ann. Chem.* **1966**, *699*, 195). The 3-oxo-14α-card-5,20(22)-dienolide (formula (**VI**) wherein ⁻⁻⁻ is a double bond in position 5; see **Prep. 12**) is a new compound and is obtained by oxidation of the corresponding known 3β-hydroxy derivative (Fritsch W. et al., *Liebigs Ann. Chem.* **1966**, *699,* 195) with morpholine-N-oxide in the presence of a perruthenate salt.

The 3-oxo-5α,14α-card-20(22)-enolide (formula (**VI**) wherein ⁻⁻⁻ are single bonds and the hydrogen in position 5 is α; see **Prep. 13**) is a new compound and is obtained by oxidation of the corresponding known 3β-hydroxy derivative (Kreiser W. and Nazir M., *Liebigs Ann. Chem.* **1972**, *755*, 1) with morpholine-N-oxide in the presence of a perruthenate salt.

The compounds of general formula (**III**) are known compounds, generally commercially available or preparable from known compounds by known methods

The 14-deoxy-14α-derivatives of digitoxigenin was expected from the literature data (Naidoo B.K., et al., *J. Pharm. Sciences,* **1974**, *63*, 1391) to be practically devoid of inotropic effect; however, unexpectedly, the thioderivatives (**I**), prepared according to the invention and their pharmaceutically acceptable salts are useful agents for the treatment of cardiovascular disorders such as heart failure and hypertension and have low toxicity. Moreover said compounds (**I**) show high affinity for the receptor site of the Na^+,K^+-ATPase and behave as partial agonists on the enzymatic activity of the Na^+,K^+-ATPase.

To test the affinity for the receptor site of the Na^+,K^+-ATPase and the agonist or inhibitory activity on the enzyme, the following tests were used: **a**) displacement of the specific ^{3}H-ouabain binding from the Na^+,K^+-ATPase receptor purified according to Jorghensen (Jorghensen P., *BBA,* **1974,** *356*, 36) and Erdmann (Erdmann E. et al., *Arzneim. Forsh.,* **1984**, *34 (II),* 1314); **b**) inhibition of the activity of the purified Na^+,K^+-ATPase measured as % of hydrolysis of ^{32}P-ATP in presence and in absence of the tested compound (Mall F. et al., *Biochem. Pharmacol.,* **1984,** *33*, 47).

The ability of these compounds to lower blood pressure in adult hypertensive MHS rats was tested by the following method:

systolic blood pressure (SBP) and heart rate (HR) were measured by an indirect tail-cuff method in three-month old hypertensive MHS rats before beginning treatment (basal values). The rats were then subdivided in two groups of 7 animals each, one receiving the compound and the other, the control group, receiving only the vehicle. The compound, suspended in METHOCEL® 0.5% (w/v), for ten days, was administered daily by mouth. SBP and HR were measured daily 6 and 24 hours after the treatment. When ten-day treatment washout had been under way for at least two days, whether the treatment mantains SBP low or re-establish the basal values was verified.

The affinity and the inhibitory activity of some basic thioethers on the two tests are shown in the following table:

Compound	Binding ^{3}H-Ouab. Displacement -log. IC_{50}	Inhibitory Activity -log. IC_{50}
DIGI	6.5	6.5
Comp. I-a	5.5	5.3
Comp. I-b	6.0	5.5
Comp. I-c	6.1	5.8
Comp. I-d	5.9	5.7
Comp. I-e	5.7	5.4
Comp. I-f	5.9	5.5
Comp. I-g	6.0	5.7
Comp. I-h	5.8	5.4

The activity of the aglycone digitoxigenin (**DIGI**) and some basic thioethers in preventing the development of hypertension is shown in the following table:

SYSTOLIC BLOOD PRESSURE FALL IN SPONTANEOUS HYPERTENSIVE RATS (MHS)				
Compound	RATS	DOSE* mg/Kg os	SBP mm Hg	HR beats/min.
Controls	7	METHOCEL®	174 +/- 5.5	378 +/- 11.0
DIGI	7	20	173 +/- 4.0	380 +/- 10.0
I-c	7	20	144 +/- 6.2	390 +/- 12.0
I-d	7	20	154 +/- 5.2	384 +/- 10.3
I-f	7	20	148 +/- 5.6	386 +/- 9.3
I-g	7	20	150 +/- 5.2	383 +/- 9.6
I-h	7	20	158 +/- 5.4	379 +/- 10.4

* in METHOCEL® 0.5% w/v

The following examples illustrate the invention without limiting it.

Example 1

3β-(2-(1-Pyrrolidinyl)ethylthio)-5β,14α-card-20(22) -enolide oxalate (I-a)

a) To a solution of 0.13 g of 3β-mercapto-5β,14α-card-20(22)-enolide (**II-a, Prep. 1**) and 0.13 g of 1-(2-chloroethyl)pyrrolidine in 3.5 ml of dimethylformamide under nitrogen atmosphere at room temperature, 0.017 g of sodium hydride (60% dispersion in mineral oil) were added. The reaction mixture was stirred for 2.5 hrs, then 1.74 ml of 0.5 N hydrochloric acid were added and the temperature was raised to 25 °C. The mixture was extracted with methylene chloride, the organic layer was washed with water, dried over sodium sulfate, filtered and evaporated to dryness under reduced pressure. The crude product was purified by flash-chromatography (SiO_2) using methylene chloride/methanol/30% ammonia solution 95/5/1 as eluant; the pure compound (0.143 g) so obtained was dissolved in 2 ml of diethyl ether and a solution of 0.027 g of oxalic acid in 1.5 ml of diethyl ether was added to give 0.15 g of the title compound (**I-a**) as a white solid, mp 164-166 °C.

^{1}H-NMR (300 MHz, $CDCl_3$, ppm from TMS): 0.62 (3H, s); 0.98 (3H, s); 2.38 (1H, bt); 2.75-2.95 (4H, m); 3.20-3.42 (3H, m); 4.69 (1H, dd); 4.82 (1H, dd); 5.86 (1H, bs).

b) To 3β-mercapto-5β,14α-card-20(22)-enolide (**II-a, Prep. 1**) (0.35 g) in 5 ml of dimethylformamide under nitrogen atmosphere, 2-bromoethanol (0.2 ml) and 0.050 g of sodium hydride (60% dispersion in mineral oil) were added at 0 °C and the temperature left to raise to 25 °C. After 5 hrs the reaction mixture was quenched with 0.5 M HCl (0.22 ml) to neutralize the excess base and extracted with methylene chloride. The organic layer was washed with a 5% sodium bicarbonate solution, dried over anhydrous sodium sulfate and evaporated to dryness under reduced pressure. The crude product was purified by flash-cromatography (SiO_2) using n-hexane/ethyl acetate 50/50 as eluant to obtain 0.28 g of **3β-(2-hydroxyethylthio)-5β,14α-card-20(22)-enolide** as a white solid.

^{1}H-NMR (300 MHz, $CDCl_3$, ppm from TMS): 0.62 (3H, s); 0.99 (3H, s); 2.75 (2H, t); 3.25 (1H, bs); 3.73 (2H, t); 4.69 (1H, dd); 4.80 (1H, dd); 5.85 (1H, dd).

To a solution of 3β-(2-hydroxyethylthio)-5β,14α-card-20(22)-enolide (0.45 g) in 9 ml of dry pyridine, 0.31 ml of mesyl chloride were added dropwise at 0 °C. The reaction mixture was stirred for 3 hrs at room temperature and then diluted with ethyl acetate and washed with water. The organic layer was dried over sodium sulfate and evaporated to dryness under reduced pressure to give 0.50 g of the mesylate derivative, which was submitted to the subsequent reaction with 2.5 ml of pyrrolidine in 2.5 ml of absolute ethanol without further purification. The solution was refluxed under nitrogen atmosphere for 3 hrs, then 5 ml of water were added and the resulting mixture extracted with methylene chloride. The organic layer was dried over sodium sulfate and evaporated to dryness under reduced pressure. The crude product was purified by flash-cromatography (SiO_2) using methylene chloride/methanol/30%ammonia solution 95/5/1 as eluant; the pure compound so obtained was dissolved in 2 ml of diethyl ether and a solution of 0.080 g of oxalic acid in 1 ml of diethyl ether was added to give 0.31 g of the title compound (**I-a)** as a white solid, mp 164-166 °C.

^{1}H-NMR (300 MHz, $CDCl_3$, ppm from TMS): 0.62 (3H, s); 0.98 (3H, s); 2.38 (1H, bt); 2.75-2.95 (4H, m); 3.20-3.42 (3H, m); 4.69 (1H, dd); 4.82 (1H, dd); 5.86 (1H, bs).

Example 2

3β-(3-Dimethylaminopropylthio)-5β,14α-card-20(22)-enolide oxalate (I-b)

3β-Mercapto-5β,14α-card-20(22)-enolide (**II-a, Prep. 1**) (0.13 g) was reacted with 3-dimethylaminopropyl-chloride (0.16 g) in the presence of sodium hydride as described in **Ex. 1** to give 0.12 g of the title compound (**I-b**) as a white solid, mp 136-138 °C.

^{1}H-NMR (300 MHz, $CDCl_3$, ppm from TMS): 0.62 (3H, s); 0.99 (3H, s); 2.20 (1H, dt); 2.38 (1H, bt); 2.58 (2H, t); 2.85 (6H, s); 3.10-3.24 (3H, m); 4.69 (1H, dd); 4.82 (1H, dd); 5.86 (1H, bs).

Example 3

3β-(3-(1-Piperazinyl)propylthio)-5β,14α-card-20(22)-enolide dioxalate (I-c)

3β-Mercapto-5β,14α-card-20(22)-enolide (**II-a, Prep. 1**) (0.13 g) was reacted with 1-(3-chloropropyl)-piperazine dihydrochloride (0.24 g) in the presence of sodium hydride as described in **Ex. 1** to give 0.10 g of the title compound (**I-c**) as a white solid, mp 195-198 °C.

^{1}H-NMR (300 MHz, DMSO-d_6, ppm from TMS): 0.55 (3H, s); 0.89 (3H, s); 2.18 (1H, bdt); 3.19 (1H, bs); 4.78 (1H, dd); 4.89 (1H, dd); 5.85 (1H, bs).

Example 4

3β-(3-Aminopropylthio)-5β,14α-card-20(22)-enolide oxalate (I-d)

3β-Mercapto-5β,14α-card-20(22)-enolide (**II-a, Prep. 1**) (0.15 g) was reacted with 3-chloropropylamine hydrochloride (0.16 g) in the presence of sodium hydride as described in **Ex. 1** to give 0.13 g of the title compound (**I-d**) as a white solid, mp 152-154 °C.

^{1}H-NMR (300 MHz, DMSO-d_6, ppm from TMS): 0.55 (3H, s); 0.92 (3H, s); 2.18 (1H, bdt); 2.39 (2H, bt); 2.85 (2H, bt); 3.20 (1H, bt); 4.78 (1H, dd); 4.89 (1H, dd); 5.97 (1H, bs).

Example 5

3β-(3-(1-Pirrolidinyl)-2-hydroxypropylthio)-5β,14α-card-20(22)-enolide (I-e)

To a solution of 0.40 g of 3β-mercapto-5β,14α-card-20(22)-enolide (**II-a, Prep. 1**) and 0.25 g of epichlorohydrin in 8 ml of dimethylformamide under nitrogen atmosphere, 0.055 g of sodium hydride (60% dispersion in mineral oil) were added at -15 °C. The reaction mixture was stirred for one hr, then 5.24 ml of 0.5 N hydrochloric acid were added and the temperature was left to raise to 25 °C. The mixture was extracted with methylene chloride, the organic layer washed with water, dried over sodium sulfate, filtered and evaporated to dryness under reduced pressure. The crude product was purified by flash-chromatography (SiO_2) using n-hexane/ethyl acetate 60/40 as eluant to give 0.30 g of **3β-(2,3-epoxy)propylthio-5β,14α-card-20(22)-enolide** as a white pasty solid.

^{1}H-NMR (300 MHz, $CDCl_3$, ppm from TMS): 0.62 (3H, s); 0.99 (3H, s); 2.05-2.25 (3H, m); 2.28 (1H, dt); 2.53-2.85 (5H, m); 3.45 (1H, bs); 4.69 (1H, dd); 4.80 (1H, dd); 5.85 (1H, bs).

A solution of 0.30 g of 3β-(2,3-epoxy)propylthio-5β,14α-card-20(22)-enolide in 2.5 ml of pyrrolidine was stirred for 48 hrs at room temperature, then the excess base was evaporated and the crude product was dissolved in 1 ml of ethyl acetate. To this solution, 0.063 g of oxalic acid in 2 ml of diethyl ether were added. The precipitate was filtered and washed with diethyl ether, giving 0.26 g of the title compound (**I-e**) as an amorphous white solid.

^{1}H-NMR (300 MHz, CD_3OD, ppm from TMS): 0.64 (3H, s); 0.98 (3H, s); 2.40-2.60 (2H, m); 3.10-3.30 (6H, m); 3.50 (1H, bs); 3.70-3.78 (1H, m); 4.70 (1H, dd); 4.78 (1H, dd); 5.86 (1H, bs).

Example 6

3β-(3-Aminopropylthio)-14α-card-4,20(22)-dienolide oxalate (I-f)

3β-Mercapto-14α-card-4,20(22)-dienolide (**II-b, Prep. 2**) (0.15 g) was reacted with 3-chloropropylamine hydrochloride (0.15 g) in the presence of sodium hydride as described in **Ex. 1** to give 0.11 g of the title

compound (**I-f**) as a white amorphous solid.

^{1}H-NMR (300 MHz, DMSO-d_6, ppm from TMS): 0.56 (3H, s); 1.05 (3H, s); 2.18 (1H, bdt); 2.37 (2H, bt); 2.85 (2H, bt); 3.40 (1H, bt); 4.75 (1H, dd); 4.86 (1H, dd); 5.35 (1H, s); 5.97 (1H, bs).

Example 7

3β-(3-Aminopropylthio)-14α-card-5,20(22)-dienolide oxalate (I-g)

3β-Mercapto-14α-card-5,20(22)-dienolide (**II-c, Prep. 3**) (0.17 g) was reacted with 3-chloropropylamine hydrochloride (0.17 g) in the presence of sodium hydride as described in **Ex. 1** to give 0.11 g of the title compound (**I-g**) as a pale yellow amorphous solid.

^{1}H-NMR (300 MHz, DMSO-d_6, ppm from TMS): 0.55 (3H, s); 1.07 (3H, s); 2.19 (1H, bdt); 2.40 (2H, bt); 2.86 (2H, bt); 3.00 (1H, bt); 4.78 (1H, dd); 4.89 (1H, dd); 5.46 (1H, s); 5.97 (1H, bs).

Example 8

3β-(3-Aminopropylthio)-5α,14α-card-20(22)-enolide oxalate (I-h)

3β-Mercapto-5α,14α-card-20(22)-enolide (**II-d, Prep. 4**) (0.16 g) was reacted with 3-chloropropylamine hydrochloride (0.16 g) in the presence of sodium hydride as described in **Ex. 1** to give 0.12 g of the title compound (**I-h**) as a white amorphous solid.

^{1}H-NMR (300 MHz, DMSO-d_6, ppm from TMS): 0.54 (3H, s); 0.85 (3H, s); 2.18 (1H, bdt); 2.39 (2H, bt); 2.85 (2H, bt); 3.00 (1H, bt); 4.77 (1H, dd); 4.87 (1H, dd); 5.96 (1H, bs).

PREPARATION OF INTERMEDIATES

Preparation 1

3β-Mercapto-5β,14α-card-20(22)-enolide (II-a)

Into a solution of 5.3 g of 3β-acetylthio-5β,14α-card-20(22)-enolide (**IV-a**) in 65 ml of methanol/tetrahydrofuran 3/1, gaseous ammonia was bubbled in for 30' and then kept on standing for 3 hrs at room temperature. The mixture was evaporated to dryness under reduced pressure and purified by flash-chromatography (SiO_2) using n-hexane/ethyl acetate 77/23 as eluant to give 3.7 g of the title compound (**II-a**) as a white solid, mp 176-177 °C.

^{1}H-NMR (300 MHz, $CDCl_3$, ppm from TMS): 0.62 (3H, s); 0.99 (3H, s); 2.28 (1H, dt); 2.37 (1H, t); 3.59 (1H, bs); 4.69 (1H, dd); 4.82 (1H, dd); 5.86 (1H, bs).

Preparation 2

3β-Mercapto-14α-card-4,20(22)-dienolide (II-b)

2.3 Grams of 3β-acetylthio-14α-card-4,20(22)-dienolide (**IV-b**) were reacted with gaseous ammonia as described in the **Prep. 1** to give 1.0 g of of the title compound (**II-b**) as a white solid.

^{1}H-NMR (300 MHz, $CDCl_3$, ppm from TMS): 0.62 (3H, s); 1.10 (3H, s); 2.28 (1H, dt); 2.37 (1H, t); 3.38 (1H, bs); 4.69 (1H, dd); 4.81 (1H, dd); 5.31 (1H, s); 5.85 (1H, bs).

Preparation 3

3β-Mercapto-14α-card-5,20(22)-dienolide (II-c)

1.4 Grams of 3β-acetylthio-14α-card-5,20(22)-dienolide (**IV-c**) were treated with gaseous ammonia as described in the **Prep. 1** to give 1.1 g of of the title compound (**II-c**) as a white solid.

^{1}H-NMR (300 MHz, $CDCl_3$, ppm from TMS): 0.62 (3H, s); 1.08 (3H, s); 2.28 (1H, dt); 2.37 (1H, t); 3.40 (1H, bs); 4.69 (1H, dd); 4.83 (1H, dd); 5.43 (1H, s); 5.87 (1H, bs).

Preparation 4

3β-Mercapto-5α,14α-card-20(22)-enolide (II-d)

1.3 Grams of 3β-acetylthio-5α,14α-card-20(22)-enolide (**IV-d**) were treated with gaseous ammonia as described in the **Prep. 1** to give 0.90 g of of the title compound (**II-d**) as a white solid.

^{1}H-NMR (300 MHz, $CDCl_3$, ppm from TMS): 0.61 (3H, s); 0.90 (3H, s); 2.30 (1H, dt); 2.36 (1H, t); 3.30 (1H, bs); 4.72 (1H, dd); 4.80 (1H, dd); 5.84 (1H, bs).

Preparation 5

3β-Acetylthio-5β,14α-card-20(22)-enolide (IV-a)

Diisopropyl azodicarboxylate (7.7 ml) was added to a solution of 10.3 g of triphenylphosphine in 160 ml of tetrahydrofuran and the mixture was stirred for 30'. A white precipitate formed. To this mixture a solution of 5.6 g of 3α-hydroxy-5β,14α-card-20(22)-enolide and 2.8 ml of thiolacetic acid in 160 ml of tetrahydrofuran was added dropwise and the resulting mixture was stirred for 2 hrs at room temperature. The solvent was evaporated to dryness under reduced pressure and the crude product was purified by flash-chromatography (SiO_2) using n-hexane/ethyl acetate 87/13 as eluant to give 5.5 g of the title compound (**IV-a**) as a white solid, mp 158-161 °C.

^{1}H-NMR (300 MHz, $CDCl_3$, ppm from TMS): 0.61 (3H, s); 0.98 (3H, s); 2.30 (3H, s); 2.38 (1H, t); 4.05 (1H, bs); 4.69 (1H, dd); 4.82 (1H, dd); 5.85 (1H, bs).

Preparation 6

3β-Acetylthio-14α-card-4,20(22)-dienolide (IV-b)

2.0 Grams of 3α-hydroxy-14α-card-4,20(22)-dienolide was reacted with diisopropyl azodicarboxylate (2.7 ml), 3.6 g of triphenylphosphine and 1.0 ml of thiolacetic acid in tetrahydrofuran as described in the preparation of **IV-a** to give 1.8 g of the title compound (**IV-b**) as a white solid.

^{1}H-NMR (300 MHz, $CDCl_3$, ppm from TMS): 0.60 (3H, s); 1.05 (3H, s); 2.30 (3H, s); 2.36 (1H, t); 4.15 (1H, bs); 4.67 (1H, dd); 4.82 (1H, dd); 5.30 (1H, s); 5.85 (1H, bs).

Preparation 7

3β-Acetylthio-14α-card-5,20(22)-dienolide (IV-c)

1.8 Grams of 3α-hydroxy-14α-card-5,20(22)-dienolide was reacted with diisopropyl azodicarboxylate (2.5 ml), 3.3 g of triphenylphosphine and 0.88 ml of thiolacetic acid in tetrahydrofuran as described in the preparation of **IV-a** to give 1.7 g of the title compound (**IV-c**) as a white solid.

^{1}H-NMR (300 MHz, $CDCl_3$, ppm from TMS): 0.63 (3H, s); 1.10 (3H, s); 2.32 (3H, s); 2.35 (1H, t); 3.85 (1H, bs); 4.72 (1H, dd); 4.82 (1H, dd); 5.40 (1H, s); 5.85 (1H, bs).

Preparation 8

3β-Acetylthio-5α14α-card-20(22)-enolide (IV-d)

2.2 g of 3α-hydroxy-14α-card-5,20(22)-dienolide was reacted with diisopropyl azodicarboxylate (3.0 ml), 4.1 g of triphenylphosphine and 1.1 ml of thiolacetic acid in tetrahydrofuran as described in the preparation of **IV-a** to give 1.9 g of the title compound (**IV-d**) as a white solid.

^{1}H-NMR (300 MHz, $CDCl_3$, ppm from TMS): 0.61 (3H, s); 0.97 (3H, s); 2.31 (3H, s); 2.35 (1H, t); 3.70 (1H, bs); 4.69 (1H, dd); 4.82 (1H, dd); 5.86 (1H, bs).

Preparation 9

3α-Hydroxy-14α-card-4,20(22)-dienolide (V-a)

To a solution of 5.0 g 3-oxo-14α-card-4,20(22)-dienolide (Fritsch W. et al., *Liebigs Ann. Chem.* **1966**, *699,* 195) in 250 ml of anhydrous tetrahydrofuran kept at 0 °C and under nitrogen 14.5 ml of a 1M solution of Li-selectride© in tetrahydrofuran were added. The mixture was kept at this temperature for 8 hrs and then poured into 500 ml of 10% acetic acid and extracted with ethyl acetate. The organic layer was washed with a saturated solution of sodium bicarbonate, with water, dried over sodium sulfate, filtered and evaporated to dryness under reduced pressure. The crude product was purified by flash-chromatography (SiO_2) using ethyl acetate as eluant to give 3.5 g of the title compound **(V-a)**.

^{1}H-NMR (300 MHz, $CDCl_3$, ppm from TMS): 0.62 (3H, s); 1.10 (3H, s); 2.28 (1H, dt); 2.37 (1H, t); 4.08 (1H, bs); 4.69 (1H, dd); 4.81 (1H, dd); 4.92 (1H, bs); 5.85 (1H, bs).

Preparation 10

3α-Hydroxy-14α-card-5,20(22)-dienolide (V-b)

To a solution of 7.5 g 3-oxo-14α-card-5,20(22)-dienolide in 370 ml of anhydrous tetrahydrofuran kept at °C and under nitrogen 21.8 ml of a 1M solution of Li-selectride© in tetrahydrofuran were added. The mixture was kept at this temperature for 12 hrs and then poured into 750 ml of 10% acetic acid and extracted with ethyl acetate. The organic layer was washed with a saturated solution of sodium bicarbonate, water, dried over sodium sulfate, filtered and evaporated to dryness. The crude product was purified by flash-chromatography (SiO_2) using ethyl acetate as eluant to give 5.5 g of the title compound **(V-b)**.

^{1}H-NMR (300 MHz, $CDCl_3$, ppm from TMS): 0.60 (3H, s); 1.05 (3H, s); 4.16 (1H, m); 4.76 (2H, m); 5.42 (1H, m); 5.87 (1H, bs).

Preparation 11

3α-Hydroxy-5α,14α-card-20(22)-enolide (V-c)

To a solution of 6.0 g 3-oxo-5α,14α-card-20(22)-enolide in 250 ml of anhydrous tetrahydrofuran kept at °C and under nitrogen 17.3 ml of a 1M solution of Li-selectride© in tetrahydrofuran were added. The mixture was kept at this temperature for 8 hrs and then poured into 600 ml of 10% acetic acid and extracted with ethyl acetate. The organic layer was washed with a saturated solution of sodium bicarbonate, with water, dried over sodium sulfate, filtered and evaporated to dryness under reduced pressure. The crude product was purified by flash-chromatography (SiO_2) using ethyl acetate as eluant to give 4.80 g of the title compound **(V-c)**.

^{1}H-NMR (300 MHz, $CDCl_3$, ppm from TMS): 0.61 (3H, s); 0.97 (3H, s); 2.35 (1H, t); 4.28 (1H, m); 4.69 (1H, dd); 4.82 (1H, dd); 5.86 (1H, bs).

Preparation 12

3-Oxo-14α-card-5,20(22)-dienolide (VI-a)

To a solution of 10 g of 3β-hydroxy-14α-card-5,20(22)-dienolide (Fritsch W. et al., *Liebigs Ann. Chem.* **1966**, *699*, 195) in 300 ml of methylene chloride 4.7 g of morpholine-N-oxyde, 0.40 g of tetrapropylammonium perruthenate and 5.0 g of powdered 4 Å molecular sieves were added at room temperature. After 10 hrs the mixture was evaporated to dryness under reduced pressureand the crude product was purified by flash-chromatography (SiO_2) using ethyl acetate as eluant to give 8.6 g of the title compound **(VI-a)**.

^{1}H-NMR (300 MHz, $CDCl_3$, ppm from TMS): 0.60 (3H, s); 0.93 (3H, s); 4.76 (2H, m); 5.42 (1H, m); 5.87 (1H, bs).

Preparation 13

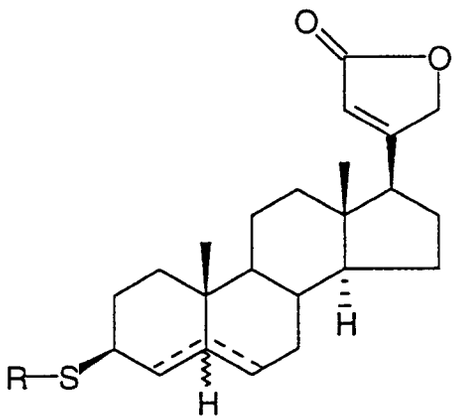
3-Oxo-5α,14α-card-20(22)-enolide (VI-b)

To a solution of 10 g of 3β-hydroxy-5α,14α-card-20(22)-enolide (Kreiser W. and Nazir M., *Liebigs Ann. Chem.* **1972**, *755*, 1) in 300 ml of methylene chloride 4.7 g of morpholine-N-oxyde, 0.40 g of tetrapropylammonium perruthenate and 5.0 g of powdered 4 Å molecular sieves were added at room temperature. After 10 hrs the mixture was evaporated to dryness under reduced pressureand the crude product was purified by flash-chromatography (SiO_2) using ethyl acetate as eluant to give 8.5 g of the title compound **(VI-b)**.

^{1}H-NMR (300 MHz, $CDCl_3$, ppm from TMS): 0.61 (3H, s); 1.03 (3H, s); 4.69 (1H, dd); 4.82(1H, dd); 4.92 (1H, bs); 5.86 (1H, bs).

Claims

1. 14-deoxy-14α-cardenolides 3β-thioderivatives, having formula (**I**):



I

wherein:

the symbol ⁻⁻⁻ represents a single or a double bond;

R is C2-C6 alkyl or C3-C6 alkenyl, unsubstituted or substituted independently by a quaternary ammonium group, 2-(2-imidazolinyl) group or one or more OR1 or NR2R3 or C(NH)NR4R5;

wherein:

R1 is H, methyl or C2-C4 alkyl substituted by NR6R7 with the proviso that when R1 is H, R is C3-C6 substituted alkyl and at least another group chosen from NR2R3 or C(NH)NR2R3 is also present in the R residue;

R2, R3 are independently H, methyl or C2-C6 alkyl unsubstituted or substituted by NR6R7 or C3-C6 alkenyl or R2 and R3 taken together with the nitrogen atom form an unsubstituted or substituted saturated or unsaturated heteromonocyclic ring optionally containing another heteroatom chosen from oxygen or sulfur or nitrogen, or R2 is hydrogen and R3 is C(NH)NH2;

R4, R5 are independently H, C1-C4 alkyl or C3-C4 alkenyl or R4 and R5 taken together with the nitrogen atom form a penta- or hexa-monoheterocyclic ring;

R6, R7 are independently H, C1-C4 alkyl or R6 and R7 taken together form with the nitrogen atom a saturated or unsaturated penta- or hexa-monoheterocyclic ring optionally containing another heteroatom chosen from oxygen or sulfur or nitrogen or R6 is hydrogen and R7 is C(NH)NH2, and the pharmaceutically acceptable salts thereof.

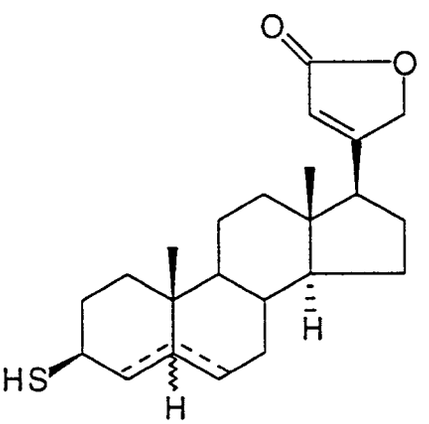
2. A compound according to claim 1, which is selected from:

3β-(2-(N-Methyl-N-pyrrolidinium)ethylthio)-5β,14α-card-20(22)-enolide chloride

3β-(2-Aminoethylthio)-5β,14α-card-20(22)-enolide

3β-(3-Aminopropylthio)-5β,14α-card-20(22)-enolide
3β-(2-Aminoethylthio)-14α-card-4,20(22)-dienolide
3β-(3-Aminopropylthio)-14α-card-4,20(22)-dienolide
3β-(2-(1-Pyrrolidinyl)ethylthio)-14α-card-4,20(22)-dienolide
3β-(3-(1-Pyrrolidinyl)propylthio)-14α-card-4,20(22)-dienolide
3β-(2-Aminoethylthio)-14α-card-5,20(22)-dienolide
3β-(3-Aminopropylthio)-14α-card-5,20(22)-dienolide
3β-(2-(1-Pyrrolidinyl)ethylthio)-14α-card-5,20(22)-dienolide
3β-(3-(1-Pyrrolidinyl)propylthio)-14α-card-5,20(22)-dienolide
3β-(2-Aminoethylthio)-5α,14α-card-20(22)-enolide
3β-(3-Aminopropylthio)-5α,14α-card-20(22)-enolide
3β-(2-(1-Pyrrolidinyl)ethylthio)-5α,14α-card-20(22)-enolide
3β-(3-(1-Pyrrolidinyl)propylthio)-5α,14α-card-20(22)-enolide
3β-(4-Amino-(E)-2-butenylthio)-5β,14α-card-20(22)-enolide
3β-(2-Methylaminopropylthio)-5β,14α-card-20(22)-enolide
3β-(2-Dimethylaminopropylthio)-5β,14α-card-20(22)-enolide
3β-(2-(1-Pyrrolidinyl)ethylthio)-5β,14α-card-20(22)-enolide
3β-(3-(1-Pyrrolidinyl)propylthio)-5β,14α-card-20(22)-enolide
3β-(2-Morpholinoethylthio)-5β,14α-card-20(22)-enolide
3β-(2-(1-Piperazinyl)ethylthio)-5β,14α-card-20(22)-enolide
3β-(3-(1-Piperazinyl)propylthio)-5β,14α-card-20(22)-enolide
3β-(2-(1-Imidazolyl)ethylthio)-5β,14α-card-20(22)-enolide
3β-(2-(2-Amidino)ethylthio)-5β,14α-card-20(22)-enolide
3β-(2-Guanidinoethylthio)-5β,14α-card-20(22)-enolide
3β-(3-Amino-2-hydroxypropylthio)-5β,14α-card-20(22)-enolide
3β-(2,3-Diaminopropylthio)-5β,14α-card-20(22)-enolide
3β-(3-(1-Pyrrolidinyl)-2-hydroxypropylthio)-5β,14α-card-20(22)-enolide
3β-(3-(1-Piperazinyl)-2-hydroxypropylthio)-5β,14α-card-20(22)-enolide
3β-(3-(1-Imidazolyl)-2-hydroxypropylthio)-5β,14α-card-20(22)-enolide
3β-(3-Guanidino-2-hydroxypropylthio)-5β,14α-card-20(22)-enolide
3β-(3-(3-Amino-2-hydroxypropoxy)propylthio)-5β,14α-card-20(22)-enolide
3β-(3-(3-Amino-2-hydroxypropylamino)propylthio)-5β,14α-card-20(22)-enolide.

3. A process for the preparation of 14α-card-20(22)-enolides of formula **(I)** which comprises condensing a compound of formula **(II)**



(II)

with a compound of formula **(III)**

R-Y **(III)**

where Y is an electron-withdrawing group, and R is as above defined, and optionally converting the compound of formula **(I)** into a pharmacologically acceptable salt thereof.

4. A process according to claim **3** where the reaction is carried out in an inert aprotic solvent or in the neat **(III)** and in the presence of a strong base, at a temperature ranging from -20 °C to about 60 °C.

5. A pharmaceutical composition comprising a compound of formula (**I**) or a pharmaceutically acceptable salt thereof and a pharmaceutically acceptable carrier and/or diluent thereof.

6. The use of a compound of formula (I) or a pharmaceutically acceptable salt thereof for the preparation of a medicament for the treatment of cardiovascular disorders.

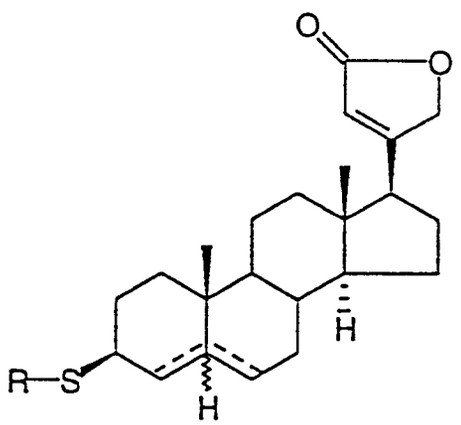
7. The use of a compound of formula (I) or a pharmaceutically acceptable salt thereof for the preparation of a medicament for the treatment of hypertension.

8. The use of a compound of formula (I) or a pharmaceutically acceptable salt thereof for the preparation of a medicament for the treatment of cardiac failure.

9. The use according to claims 6, 7 or 8 wherein the medicament is for oral or parenteral administration.

Claims for the following Contracting States : ES, GR

1. A process for the preparation of
14-deoxy-14α-cardenolides 3β-thioderivatives, having formula (**I**):



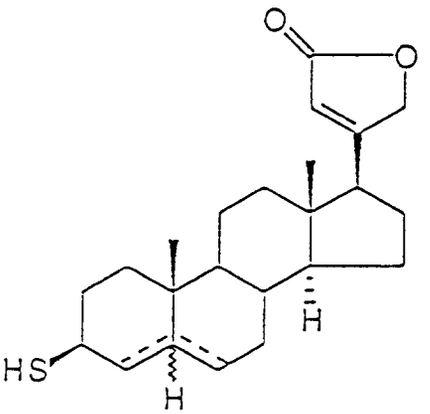
I

wherein:
the symbol ⁻⁻⁻ represents a single or a double bond;
R is C2-C6 alkyl or C3-C6 alkenyl, unsubstituted or substituted independently by a quaternary ammonium group, 2-(2-imidazolinyl) group or one or more OR1 or NR2R3 or C(NH)NR4R5;
wherein:
R1 is H, methyl or C2-C4 alkyl substituted by NR6R7 with the proviso that when R1 is H, R is C3-C6 substituted alkyl and at least another group chosen from NR2R3 or C(NH)NR2R3 is also present in the R residue;
R2, R3 are independently H, methyl or C2-C6 alkyl unsubstituted or substituted by NR6R7 or C3-C6 alkenyl or R2 and R3 taken together with the nitrogen atom form an unsubstituted or substituted saturated or unsaturated heteromonocyclic ring optionally containing another heteroatom chosen from oxygen or sulfur or nitrogen, or R2 is hydrogen and R3 is C(NH)NH2;

R4, R5 are independently H, C1-C4 alkyl or C3-C4 alkenyl or R4 and R5 taken together with the nitrogen atom form a penta- or hexa-monoheterocyclic ring;

R6, R7 are independently H, C1-C4 alkyl or R6 and R7 taken together form with the nitrogen atom a saturated or unsaturated penta- or hexa-monoheterocyclic ring optionally containing another heteroatom chosen from oxygen or sulfur or nitrogen or R6 is hydrogen and R7 is C(NH)NH2, and the pharmaceutically acceptable salts thereof,

which comprises condensing a compound of formula (II)



(II)

with a compound of formula (**III**)

R-Y (**III**)

where Y is an electron-withdrawing group, and R is as above defined, and optionally converting the compound of formula (**I**) into a pharmacologically acceptable salt thereof.

2. A process according to claim 1 where the reaction is carried out in an inert aprotic solvent or in the neat (**III**) and in the presence of a strong base, at a temperature ranging from -20 °C to about 60 °C.

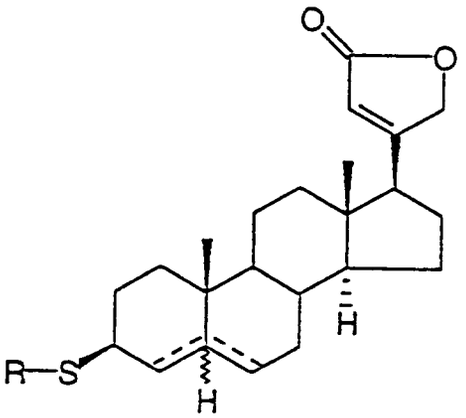
3. The use of a compound of formula (I) or a pharmaceutically acceptable salt thereof for the preparation of a medicament for the treatment of cardiovascular disorders.

4. The use of a compound of formula (I) or a pharmaceutically acceptable salt thereof for the preparation of a medicament for the treatment of hypertension.

5. The use of a compound of formula (I) or a pharmaceutically acceptable salt thereof for the preparation of a medicament for the treatment of cardiac failure.

6. The use according to claims 3, 4 or 5 wherein the medicament is for oral or parenteral administration.

7. 14-deoxy-14α-cardenolides 3β-thioderivatives, having formula (**I**):



I

wherein:

the symbol ⎓ represents a single or a double bond;

R is C2-C6 alkyl or C3-C6 alkenyl, unsubstituted or substituted independently by a quaternary ammonium group, 2-(2-imidazolinyl) group or one or more OR1 or NR2R3 or C(NH)NR4R5;

wherein:

R1 is H, methyl or C2-C4 alkyl substituted by NR6R7 with the proviso that when R1 is H, R is C3-C6 substituted alkyl and at least another group chosen from NR2R3 or C(NH)NR2R3 is also present in the R residue;

R2, R3 are independently H, methyl or C2-C6 alkyl unsubstituted or substituted by NR6R7 or C3-C6 alkenyl or R2 and R3 taken together with the nitrogen atom form an unsubstituted or substituted saturated or unsaturated heteromonocyclic ring optionally containing another heteroatom chosen from oxygen or sulfur or nitrogen, or R2 is hydrogen and R3 is C(NH)NH2;

R4, R5 are independently H, C1-C4 alkyl or C3-C4 alkenyl or R4 and R5 taken together with the nitrogen atom form a penta- or hexa-monoheterocyclic ring;

R6, R7 are independently H, C1-C4 alkyl or R6 and R7 taken together form with the nitrogen atom a saturated or unsaturated penta- or hexa-monoheterocyclic ring optionally containing another heteroatom chosen from oxygen or sulfur or nitrogen or R6 is hydrogen and R7 is C(NH)NH2, and the pharmaceutically acceptable salts thereof.

8. A compound according to claim 7, which is selected from:

3β-(2-(N-Methyl-N-pyrrolidinium)ethylthio)-5β,14α-card-20(22)-enolide chloride
3β-(2-Aminoethylthio)-5β,14α-card-20(22)-enolide
3β-(3-Aminopropylthio)-5β,14α-card-20(22)-enolide
3β-(2-Aminoethylthio)-14α-card-4,20(22)-dienolide
3β-(3-Aminopropylthio)-14α-card-4,20(22)-dienolide
3β-(2-(1-Pyrrolidinyl)ethylthio)-14α-card-4,20(22)-dienolide
3β-(3-(1-Pyrrolidinyl)propylthio)-14α-card-4,20(22)-dienolide
3β-(2-Aminoethylthio)-14α-card-5,20(22)-dienolide
3β-(3-Aminopropylthio)-14α-card-5,20(22)-dienolide
3β-(2-(1-Pyrrolidinyl)ethylthio)-14α-card-5,20(22)-dienolide
3β-(3-(1-Pyrrolidinyl)propylthio)-14α-card-5,20(22)-dienolide
3β-(2-Aminoethylthio)-5α,14α-card-20(22)-enolide
3β-(3-Aminopropylthio)-5α,14α-card-20(22)-enolide
3β-(2-(1-Pyrrolidinyl)ethylthio)-5α,14α-card-20(22)-enolide
3β-(3-(1-Pyrrolidinyl)propylthio)-5α,14α-card-20(22)-enolide
3β-(4-Amino-(E)-2-butenylthio)-5β,14α-card-20(22)-enolide
3β-(2-Methylaminopropylthio)-5β,14α-card-20(22)-enolide
3β-(2-Dimethylaminopropylthio)-5β,14α-card-20(22)-enolide
3β-(2-(1-Pyrrolidinyl)ethylthio)-5β,14α-card-20(22)-enolide

3β-(3-(1-Pyrrolidinyl)propylthio)-5β,14α-card-20(22)-enolide
3β-(2-Morpholinoethylthio)-5β,14α-card-20(22)-enolide
3β-(2-(1-Piperazinyl)ethylthio)-5β,14α-card-20(22)-enolide
3β-(3-(1-Piperazinyl)propylthio)-5β,14α-card-20(22)-enolide
3β-(2-(1-Imidazolyl)ethylthio)-5β,14α-card-20(22)-enolide
3β-(2-(2-Amidino)ethylthio)-5β,14α-card-20(22)-enolide
3β-(2-Guanidinoethylthio)-5β,14α-card-20(22)-enolide
3β-(3-Amino-2-hydroxypropylthio)-5β,14α-card-20(22)-enolide
3β-(2,3-Diaminopropylthio)-5β,14α-card-20(22)-enolide
3β-(3-(1-Pyrrolidinyl)-2-hydroxypropylthio)-5β,14α-card-20(22)-enolide
3β-(3-(1-Piperazinyl)-2-hydroxypropylthio)-5β,14α-card-20(22)-enolide
3β-(3-(1-Imidazolyl)-2-hydroxypropylthio)-5β,14α-card-20(22)-enolide
3β-(3-Guanidino-2-hydroxypropylthio)-5β,14α-card-20(22)-enolide
3β-(3-(3-Amino-2-hydroxypropoxy)propylthio)-5β,14α-card-20(22)-enolide
3β-(3-(3-Amino-2-hydroxypropylamino)propylthio)-5β,14α-card-20(22)-enolide.

9. A pharmaceutical composition comprising a compound of formula (**I**) or a pharmaceutically acceptable salt thereof and a pharmaceutically acceptable carrier and/or diluent thereof.