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(54) Title: FATTY ACID ANALOGS FOR DIAGNOSIS OF CORONARY ARTERY DISEASE			
(57) Abstract			
Radioimaging agents, which exhibit high uptake and retention in the myocardium are disclosed.			



FATTY ACID ANALOGS FOR DIAGNOSIS OF CORONARY ARTERY DISEASE

5

BACKGROUND OF THE INVENTION

Coronary artery disease (CAD) is the leading cause of death in the United States, accounting for roughly 24% of all deaths. The health care cost of cardiovascular diseases in 1999 is estimated by the AHA at \$286.5 billion, a figure which includes direct costs, such as physicians, other professionals, hospital and nursing home services, the cost of medications, home health and lost productivity. Many of the deaths resulting from CAD may have been prevented if a valid, standardized technique existed which assessed the condition of the myocardium and allowed the use of appropriate therapy. Hence, there is a need for sensitive, reliable, and low cost techniques for early detection of heart disease and for monitoring the course of treatment.

Long-chain fatty acids are a major source of energy for the heart muscle and are rapidly metabolized by beta-oxidation under normal conditions. At rest and during exercise, non-esterified fatty acids supply approximately 65% of the energy requirement for myocardial metabolism while the remainder of myocardial energy needs are provided by glucose (15%), lactate and pyruvate (12%), and amino acids (5%) [Zieler et al. 1976, Neely et al. 1972, Opie et al. 1969, Mostet et al. 1969]. Non-esterified fatty acids are taken up by the myocardium with an extraction of 40-60% and either transiently esterified to triglyceride or oxidized for energy [Schon et al. 1982, Poe et al. 1975, Machulla et al. 1978, Westera et al. 1980; Gately et al. 1983, Van der Wall et al. 1981]. In contrast, under conditions of reduced oxygen delivery to heart tissue such as ischemia and hypoxia, there is a dramatic decrease in fatty acid metabolism.

Fatty acid molecules have a unique structure and do not require carrier mediation for their transport. Fatty acids are bound to albumin and enter into the cell mainly by free diffusion through the capillary wall and sarcolemma into the intracellular space. This extraction is dependent mainly on the following parameters: the chain length of the fatty acid (double bonds and branching have secondary effects), the blood flow to the myocardium, the concentration of the fatty acid in plasma, and the metabolic state of the myocardial tissue. In addition, both lipophilic and carboxylic sides of the fatty acid molecule must be free of bonding in order to retain the transport and the biochemical

properties of the molecule. Fatty acid interaction in the heart tissue is not of a receptor-ligand type. Therefore the rigidity of the fatty acid structure may not be the main determinant of their transport and biochemical degradation process.

Two compounds currently used in the U.S. and Europe for cardiac imaging are Tl-201 (DuPont/Mallinckrodt) and Cardiolite (DuPont). Both agents are useful and provide important information on myocardial function. However, these radiopharmaceuticals have certain important limitations. The main drawbacks are: (1) these agents are mainly flow tracers and do not directly address the metabolic viability of the injured myocardium, and (2) image sensitivity is low for single vessel obstruction, however, it is improved with increased damage.

Many fatty acids or their analogs have been labeled with positron and gamma emitting radionuclides to non-invasively assess changes in fatty acid metabolism [Schon et al. 1982, Machulla et al. 1978, Lerch et al. 1982, Schon et al. 1986, Weiss et al. 1976, Sobel et al. 1977, Goldstein et al. 1980, Livni et al., 1982, Dudczak et al. 1984, Reske et al. 1984, Livni et al. 1985, U.S. Patent No. 4,746,505]. These fatty acids have the radiolabel on the carboxylic carbon, in the middle, or on the terminal alkyl carbon. As a result, all of these agents are always subject to loss of the label during the degradation steps of the fatty acid beta-oxidation process.

A significant departure from the structure of a normal fatty acid, e.g. palmitate, or iodophenyl, did not result in a significant change in the fatty acid behavior of the compound. For example, 15-(p-iodophenyl)pentadecanoic acid [Goodman et al. 1984] and, even more notably, a series of phenyleneiodophenyl fatty acids [Liefhold and Eisenhut, 1986] all demonstrated moderate myocardial uptake. Members of the latter group differed in molecular weight from palmitate (mol. wt = 256) by about 260 Dalton.

Although fatty acids labeled with positron emitting radionuclides in conjunction with tomographic techniques may be an excellent means of quantifying *in vivo* regional myocardial metabolism, they remain the exclusive research tool of a limited number of institutions. Iodine-123 labeled BMPPA showed promise in animal and human studies [Goodman et al. 1984, Miller et al. 1985], however, since ¹²³I requires a cyclotron for production, it is unlikely that ¹²³I-labeled fatty acids (uncontaminated with I-124) will become widely available for routine diagnostic use.

The excellent nuclear properties of Tc-99m and its widespread availability from a generator have made this radionuclide the most frequently used nuclide in nuclear medicine. Several groups over the past 20 years have attempted to develop a myocardial imaging agent in which a technetium chelating moiety was incorporated into a long chain

fatty acid [Eckelman et al. 1975, Livni et al. 1981, Davison et al. 1985, Kelso et al. 1988, Cumming et al. 1988, Mach et al. 1986, 1988, 1989]. In all these cases, the radiolabeled fatty acids contained structural modifications wherein one side of the molecule, carboxyl or w-alkyl moiety, was chemically involved in the chelate moiety.

5 As a result, these agents did not show heart uptake.

An agent that allows for noninvasive delineation of myocardial metabolism and which could be routinely prepared at most clinical institutions or purchased from a distribution center would be of considerable benefit in the diagnosis and treatment of heart disease. Myocardial energy demand is met primarily by fatty acid oxidation.

10 Radiolabeled fatty acids that display efficient myocardial uptake and adequate myocardial retention are attractive candidates for clinical evaluation of regional discrepancies in fatty acid metabolism which occur in ischemic heart disease and cardiomyopathies.

SUMMARY OF THE INVENTION

15 The instant invention features radiolabeled fatty acids which exhibit high uptake and retention in the myocardium. In preferred embodiments the radiolabel is selected from the group consisting of ^{99m}Tc , Re, ^{68}Ga , ^{67}Ga and ^{111}In . The instant claimed fatty acid analogs are designed to be transported into myocardial cells by the same long chain fatty acid carrier protein mechanism as natural fatty acids. In addition, the agents

20 provide stable chelation of the metal and cannot be completely catabolized in vivo. In this manner, transport/delivery and metabolism can be imaged after the tracer is retained intracellularly. Particularly preferred imaging agents show a heart-to-lung ratio of at least 2:1 within 30 minutes of administration.

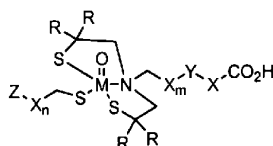
The transport mechanism of the molecules described herein is a function of

25 lipophilicity and neutrality derived from the fatty acid structure and the metal complex, respectively. Variation of the 1,2-dithio-5,8-diazacyclodecan moiety position within the fatty acid chain results in molecules that mimic fatty acids with respect to transport, and consequently, with reduced lung uptake. Separation of stereoisomers also improves the myocardial uptake and kinetics. Particularly preferred stereoisomers (R or S) are

30 substantially pure (e.g. greater than about 75% isomeric purity).

According to the present invention, there is provided a range of radiolabeled fatty acids, wherein the radiolabeled fatty acid comprises at least one ligand complexed to a radioisotope wherein the radioisotope has a neutral charge, the analog comprises an alkyl terminus and a carboxylic acid terminus, and the carboxylic acid is remote from the radioisotope. In another embodiment, the alkyl terminus comprises at least 5 carbons. In another embodiment, the radiolabeled fatty acid localizes to a heart in preference to a lung when administered to an organism. In another embodiment, the radiolabeled fatty acid comprises one ligand with three donor atoms complexed to the radioisotope and one ligand with one donor atom complexed to the radioisotope. In another embodiment, the radiolabeled fatty acid comprises one ligand with four donor atoms complexed to the radioisotope.

According to the present invention, there is provided a radiolabeled fatty acid having the formula:



wherein R represents H or Me;

X represents $-CH_2-$ or $-CH=$;

Y represents $-CH(R)-$ or $-C(R)=$;

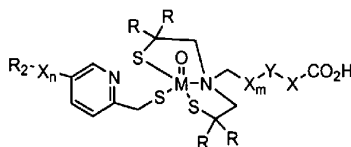
Z represents CH_3- or $CH_2=$;

M represents a radioisotope;

and the sum of $m+n$ is in the range of 0 to 15.

In a further embodiment, the sum of $m+n$ is in the range of 3 to 11.

According to the present invention, there is provided a radiolabeled fatty acid having the formula:



wherein R represents H or Me;

X represents -CH₂- or -CH=;

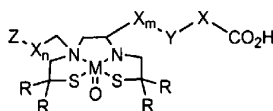
5 Y represents -CH(R)- or -C(R)=;

M represents a radioisotope;

and the sum of m+n is in the range of 0 to 14.

In a further embodiment, the sum of m+n is in the range of 3 to 7. In a further embodiment, the sum of m+n is in the range of 5 to 9.

10 According to the present invention, there is provided a radiolabeled fatty acid having the formula:



wherein R represents H or Me;

X represents -CH₂- or -CH=;

15 Y represents -CH(R)- or -C(R)=;

Z represents CH₃- or CH₂=;

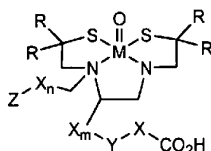
M represents a radioisotope;

and the sum of m+n is in the range of 8 to 17.

In a further embodiment, the sum of m+n is in the range of 9 to 14.

20 According to the present invention, there is provided a radiolabeled fatty acid having the formula:

- 3c -



wherein R represents H or Me;

X represents -CH₂- or -CH=;

5 Y represents -CH(R)- or -C(R)=;

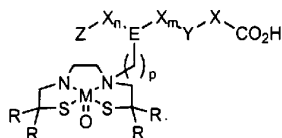
Z represents CH₃- or CH₂=;

M represents a radioisotope;

and the sum of m+n is in the range of 8 to 17.

In a further embodiment, the sum of m+n is in the range of 9 to 14.

10 According to the present invention, there is provided a radiolabeled fatty acid having the formula:



wherein R represents H or Me;

X represents -CH₂- or -CH=;

15 Y represents -CH(R)- or -C(R)=;

Z represents CH₃- or CH₂=;

E represents -CH- or -C=;

M represents a radioisotope;

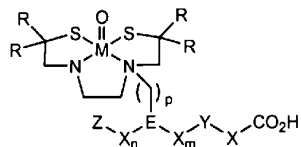
p represents 1, 2, or 3;

20 and the sum of m+n is in the range of 8 to 17.

In a further embodiment, the sum of m+n is in the range of 9 to 14.

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According to the present invention, there is provided a radiolabeled fatty acid having the formula:



5 wherein R represents H or Me;

X represents -CH₂- or -CH=;

Y represents -CH(R)- or -C(R)=;

Z represents CH₃- or CH₂=;

E represents -CH- or -C=;

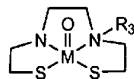
10 M represents a radioisotope;

p represents 1, 2, or 3;

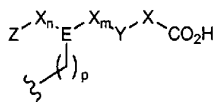
and the sum of m+n is in the range of 8 to 17.

In a further embodiment, the sum of m+n is in the range of 9 to 14.

15 According to the present invention, there is provided a radiolabeled fatty acid having the formula:



wherein R₃ represents



wherein

20 X represents -CH₂- or -CH=;

Y represents -CH(R)- or -C(R)=;

Z represents CH_3 - or $\text{CH}_2=$;

E represents $-\text{CH}-$ or $-\text{C}=$;

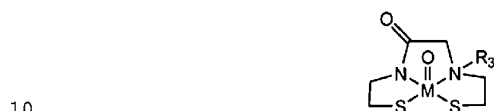
M represents a radioisotope;

5 p represents 1, 2, or 3;

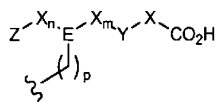
and the sum of $m+n$ is in the range of 7 to 16.

In a further embodiment, the sum of $m+n$ is in the range of 8 to 15.

According to the present invention, there is provided a radiolabeled fatty acid having the formula:



wherein R_3 represents



wherein

X represents $-\text{CH}_2-$ or $-\text{CH}=$;

15 Y represents $-\text{CH}(\text{R})-$ or $-\text{C}(\text{R})=$;

Z represents CH_3 - or $\text{CH}_2=$;

E represents $-\text{CH}-$ or $-\text{C}=$;

M represents a radioisotope;

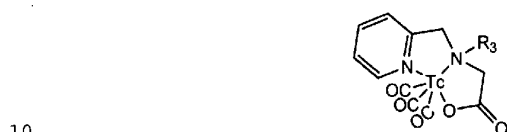
p represents 1, 2, or 3;

20 and the sum of $m+n$ is in the range of 7 to 16.

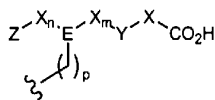
In a further embodiment, the sum of $m+n$ is in the range of 8 to 15.

In a further embodiment, the present invention provides for any of the radiolabeled fatty acids described above, wherein the radioisotope is selected from technetium, rhenium, gallium, or indium. In a further embodiment, the radioisotope is selected from ^{99m}Tc , Re , ^{68}Ga , ^{67}Ga , or ^{111}In . In a further embodiment, the present invention provides for any of the radiolabeled fatty acids described above, wherein the radioisotope has an oxo ligand.

According to the present invention, there is also provided a radiolabeled fatty acid having the formula:



wherein R_3 represents



wherein

X represents $-\text{CH}_2-$ or $-\text{CH}=-$;

Y represents $-\text{CH}(\text{R})-$ or $-\text{C}(\text{R})=-$;

Z represents CH_3- or $\text{CH}_2=-$;

E represents $-\text{CH}-$ or $-\text{C}=-$;

M represents a radioisotope;

p represents 1, 2, or 3;

and the sum of $m+n$ is in the range of 7 to 16.

In a further embodiment, the sum of $m+n$ is in the range of 8 to 15.

In a further embodiment, the present invention provides for any of the radiolabeled fatty acids described above, wherein the radiolabeled fatty acid is chiral and is a substantially pure (S) diastereomer.

5 In a further embodiment, the present invention provides for any of the radiolabeled fatty acids described above, wherein the radiolabeled fatty acid is chiral and is a substantially pure (R) diastereomer.

The present invention also provides for a pharmaceutical composition comprising any of the radiolabeled fatty acids described above and a pharmaceutically acceptable excipient.

The present invention also provides for a method of detecting coronary artery disease comprising administering to a subject any of the radiolabeled fatty acids described above.

The present invention also provides for a kit comprising any of the radiolabeled fatty acids described above and instructions for use thereof.

The present invention also provides for the use of any of the radiolabeled fatty acids described above in the detection of coronary artery disease.

The present invention also provides for the use of any of the radiolabeled fatty acids described above in the manufacture of a pharmaceutical composition for the detection of coronary artery disease.

The instant claimed radiolabeled fatty acid can be used alone or in conjunction with myocardial flow agents. Other features and advantages of the instant invention will be apparent from the following Detailed Description and Claims.

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DETAILED DESCRIPTION OF THE INVENTION

Imaging Agents and Methods for Making the Same

5 The instant claimed myocardial imaging agents have been designed, so that the termini of the fatty acid molecule is available or free of bonding and thus retains the transport and biochemical properties of the molecule. In addition, after being labeled with a suitable metal, the metal-chelate complex results in a neutral species, which therefore does not interfere with fatty acid transport to the heart tissue.

10 Two different routes have been used to develop radiolabeled fatty acids that do not drastically alter the predictable biological behavior of the carrier fatty acid. The first approach directly incorporates the radionuclide and chelating moiety into the very structure of the bio-molecule. Although this approach requires more skill on the design level, it preserves the size, shape, and structure of the driving bio-molecule. The key to this technique is in keeping the size of the metal and chelator as small as possible, thereby maintaining the natural properties and biodistribution of the bio-molecule.

15 In the second approach, the radionuclide is conjugated to the bio-molecule via a pendant chain. In this case, the radionuclide gets "carried" to the area of interest by the intact bio-molecule which has a known affinity for the target. Some advantages of this design include the unaltered active sites of the bio-molecule, the ability to change the length and location of the pendant chain, and the versatility of the chelating moiety at the end of the pendant chain.

20 The feasibility of attaching a pendant chain to the fatty acid is based on studies where fatty acids branched at position 3, 5 and 9 with Te-123m moieties were shown to have myocardial uptake equal to or higher than straight chain fatty acid [Elmaleh et al. 1981]. In addition, branching of one of the odd carbons of the fatty acid molecule will leave the termini of fatty acid molecule free. A metal-chelating group branched at these positions may allow the molecule to retain its fundamental properties, for example avoiding β -oxidation.

25 The feasibility of attaching a pendant chain to the fatty acid is based on studies where fatty acids branched at position 3, 5 and 9 with Te-123m moieties were shown to have myocardial uptake equal to or higher than straight chain fatty acid [Elmaleh et al. 1981]. In addition, branching of one of the odd carbons of the fatty acid molecule will leave the termini of fatty acid molecule free. A metal-chelating group branched at these positions may allow the molecule to retain its fundamental properties, for example avoiding β -oxidation.

30 A preferred metal chelating moiety is N_2S_2 bisaminothiol system along with the "3+1" chemistry involved in thiol conjugation. The "3+1" chemistry refers to fatty acids, which are assembled around the chelating moiety as described below, with the two separate ligands using 3 coordinating groups on one and one coordinating group on the other. Both systems allow for predictability and stable sequestration of the metal.

35 The added advantage of the N_2S_2 chelator is that it exists as one geometric isomer which

has been proven effective for chelation [Kung et al. 1997]. The "3+1" chelator system has advantages of versatility and derivatization. By applying both schools of thought, integration and conjugation, to both distinct chelating moieties, fatty acids are labeled with minimal effect on the biodistribution of the fatty acid.

5 The optimization of the relationship between various chelating groups and chain lengths may require the use of alkyl chains shorter or longer than C16 or C18, which are optimal in the case of straight and branched chain fatty acids.

To provide lipophilicity the alkyl chain should be 5 or more carbons. This optimal number was ascertained in the study of the hetero-atom Te in the Te fatty acid series [Elmaleh et al. 1981]. In addition, when labeled with the metal, the charge of
10 the metal chelate moiety on the molecule must be neutral to facilitate initial membrane translocation into the heart tissue. Neither the older derivatives (Livni et al., 1979, Eckelman et al., 1975) nor the newer reported ones (Jones et al., 1990, Kelso et al., 1988, Mach et al., 1986, Davison et al., 1985) have possessed these properties.

15 The characterization of the metabolic fate of the claimed analogs can be accomplished by analysis of heart, blood and liver tissue at various times following administration of the labeled fatty acids to rats. A comparison of heart uptake characteristics of the labeled fatty acid analogs with those of [I-123]-(15-p-iodophenyl)-methylpentadecanoic acid (I-BMPPA) can then be performed.

20 R or S stereoisomers of the imaging agents may be purified from racemic mixtures as described in WO 97/19705 to Elmaleh, the teachings of which are incorporated herein by reference.

The following schemes generate labeled fatty acids that closely mimic the carrier fatty acid and therefore are stable, predictable and neutral. Scheme 1 utilizes the
25 well established N_2S_2 system to provide a robust, neutral metal(V)-oxo core.

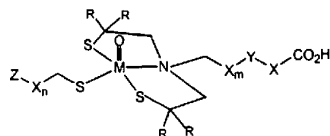
Whereas in the past [Jones et al. 1994] the N_2S_2 fatty acid derivatives were prepared without regard to charge potential, the N_2S_2 chelator in the instant claimed compounds have been designed to possess a formal 3- charge. Therefore, upon addition
30 of the metal-oxo (3+) core, the overall charge remains predictably neutral. Use of the neutral diaminodithiol analogs, of the type shown in Scheme 1, has a number of advantages: a) the acid and alkyl moieties are free and remote from the metal chelation site, b) the product is neutral and is expected to retain the general properties of a fatty acid, c) derivatives of diaminodithiol have proven to be good ligands for chelating metals, such as Tc-99m at room temperature with high radiochemical yield and
35 radiochemical purity, d) the ligand core keeps the metal in a favored +5 oxidation state,

and finally e) according to Davison and Jones, the size of the Tc-99m-diaminodithio chelate is similar to that of the phenyl group [Warren et al. 1986], which should not perturb the system. Another advantage of using this chelating strategy is that the N_2S_2 position on the molecule can be altered in order to determine its optimal location.

5 The structural modifications proposed for the instant described fatty acid derivatives will allow the compounds to retain their fundamental properties. The two series of N_2S_2 -metal-fatty acids are shown in Scheme 1. In **B** one of the nitrogen donors, along with an ethylene bridge of the N_2S_2 chelating moiety, are part of the fatty acid chain, therefore keeping the molecular weight similar to that of the original
10 physiological analog. The number of stereogenic centers created in **B**, produces a mixture of two erythro forms which can be separated by HPLC. Structure **C** provides an alternative route to a N_2S_2 -Tc-labeled fatty acid. In this case the N_2S_2 chelating moiety is pendant to the fatty acid chain simplifying the stereo-chemical complexity involved with the chain of structure **B**.

Scheme 1**Series A 3 + 1 Chelation "integration"**

(1)

R = H or CH₃

n+m is in the range of 0 to 15, preferably 3 to 11

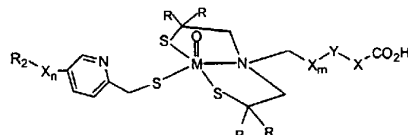
X = -CH₂- or -CH=

Y = -CH(R)- or -C(R)=

Z = CH₃- or CH₂=

M = metal, e.g., Re, Tc

(2)

R = H or CH₃

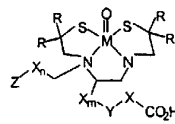
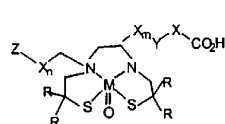
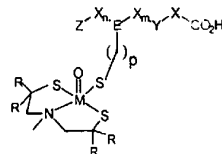
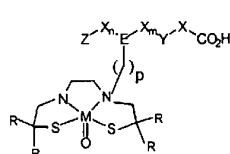
n+m is in the range of 0 to 14, preferably 3 to 7 or 5 to 9

X = -CH₂- or -CH=

Y = -CH(R)- or -C(R)=

R₂ = H if n=0, CH₃ if n>1, orH or CH₃ if n=1

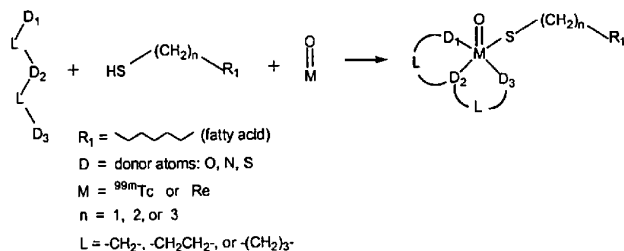
M = metal, e.g., Re, Tc

Series B N₂S₂ Chelation "integration"n+m is in the range of 8 to 17, preferably 9 to 14
X, Y, Z, and M are as defined above**Series C Chelation "pendant conjugation"**n+m is in the range of 8 to 15, preferably 9 to 14
p = 1, 2, or 3
E = -CH- or -C=
X, Y, Z, and M are as defined above

Employing the 3+1 chemistry preserves the metal-oxo core, keeps the metal center in the favorable +5 oxidation state, and allows for easy derivation of both the donor atoms and R-groups of the tridentate, as well as monodentate ligands as illustrated in Scheme 2. In addition, by applying the versatile "3+1" system, the

lipophilicity, size and donor groups can be "fine-tuned" to achieve the optimal biodistribution.

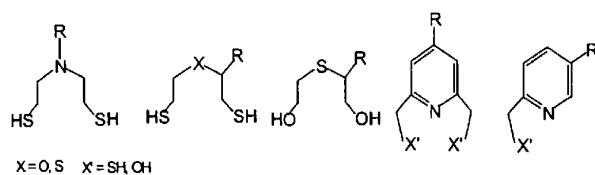
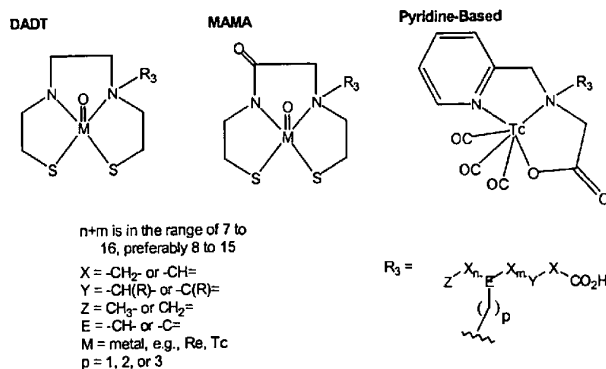
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Scheme 2

10

15

Once again the "3+1" chelation can facilitate either integration or pendant conjugation of the metal center. The "3+1" integration technique involves the joining of two distinct fragments of the fatty acid chain with the metal center positioned in the middle, as depicted in Scheme 1, series A. This technique allows for the obvious variations in the donor atoms, position of the metal center in the chain, and the interchanging of the "3" or "1" donor portions correlating to either the acid or carbon chain containing fragments of the fatty acid. Specifically, one fragment will be modified with a pendant thiol possessing a 1- charge, while the opposite fragment will be derivatized to possess three donor atoms with a 2- charge. The fragments will combine around the $M=O$ center forming the neutral, chelated metal-fatty acid complex. While one fragment will be derivatized to possess a thiol group, the other fragment containing the "3" donors can be derivatized with any of the tridentate ligands shown in Scheme 3.

Scheme 3**Scheme 4**

5

The above, scheme 4 shows the DADT and MAMA N₂S₂ systems, as well as a pyrimidine based system. The pyridine-based chelating system takes advantage of the organometallic Tc(I) carbonyl chemistry recently developed. (Alberto et al., J. Am. Chem. Soc. (1998), 120: 7987-7988; Alberto et al., Transition Met. Chem. (1997) 22: 597-601) The chemistry of [^{99m}Tc(OH₂)₃(CO)₃]⁺ has been elucidated and simplified to the point where the methods are routine and offer a practical alternative to the currently employed Tc(V) chemistry. In contrast to the highly reactive Tc(V)-oxo cores, where the chemistry is sometimes unpredictable, with necessary labeling clean-up steps, the Tc(I) method offers a distinct labeling alternative. The non-polar precursor Tc(CO)₃⁺, with three tightly bound "innocent" carbonyls, provides three open coordination sites, allowing for a large degree of flexibility in the choice of ligands. Recent work has demonstrated the high affinity of the Tc(CO)₃⁺ core for nitrogen

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donors. (Alberto et al., Transition Met. Chem. (1997) 22: 597-601; Leirer et al., Inorg. Chem. Acta (1999) 288: 150-153) The pendant pyridine molecule will provide just the right flexibility in atom donors to provide a stable Tc(I)-fatty acid complex.

In the past, organometallic Tc(I) complexes were extremely difficult to prepare and manipulate, requiring high temperatures and pressures. Today, $[^{99m}\text{Tc}(\text{OH}_2)_3(\text{CO})_3]^+$ can be readily prepared in saline under 1 atm of carbon monoxide (CO). This water- and air-stable Tc(I) complex turns out to be a practical precursor to the formation of highly inert Tc(I) complexes, due in part to the formation of the d6 electron configuration of the metal center. The preparation of the organometallic aqua-
ion is simple and straightforward, allowing for convenient manipulation and product formation. The easy substitution of the labile H_2O ligands has been demonstrated, leaving the $\text{Tc}(\text{CO})_3^+$ core intact. This stable core has the additional advantage of being smaller and less polar than the routinely employed Tc(V)-oxo systems. This could be a big advantage in biologically relevant systems where the addition of the metal center affects the size, shape, and potentially the bioactivity of the compounds.

Metal isotopes that can comprise the claimed structures include gallium and indium (e.g. ^{68}Ga , ^{67}Ga , ^{111}In) in addition to technetium and rhenium. The properties of the Group VII metals technetium and rhenium are very similar due to their periodic relationship. It is anticipated that the metals will demonstrate similar reaction chemistry, which is often the case for the thiol, nitrogen, and oxo-chemistry of these two metals. Likewise, perrhenate and pertechnetate have very similar reaction behaviors. The similar reductions of the M(VII) oxo species by SnCl_2 allow for easy substitution of the nonradioactive rhenium as a model for the medicinally useful technetium-99m, which routinely uses tin reduced ^{99m}Tc .

The "3+1" rhenium complexes are prepared by reacting $[\text{n}-(\text{C}_4\text{H}_9)_4\text{N}]\{\text{ReOBr}_4(\text{OPPh}_3)\}$ [Cotton et al. 1966] with the tridentate thiol forming the $[\text{ReOX}(\text{S}-\text{Y}-\text{S})]$ intermediate, where $\text{X}=\text{Br}$ or Cl and $\text{Y}=\text{N}, \text{S}$, or O [Fietz et al. 1995, Maresca et al. 1999]. The choice of $[\text{n}-(\text{C}_4\text{H}_9)_4\text{N}]\{\text{ReOBr}_4(\text{OPPh}_3)\}$ as starting material was predicated on its potential clinical applications, ease of use, origination from ReCO_4^- , and the finding that the more commonly employed oxorhenium(V)-halide starting material ReOCl_4^- was extremely moisture sensitive [Zubieta et al. 1996]. The halide substitution by the monothiolated fatty acid is the final step in the metal thiolate formation as depicted in Scheme 2. The synthesis can also be performed in a "one-step" procedure with carefully added stoichiometric amounts of both the monothiol and tridentate ligands. Likewise, the N_2S_2 rhenium complexes are easily prepared from both

rhenum starting materials $[n-(C_4H_9)_4N]\{ReOBr_4(OPPh_3)\}$ and $[ReOCl_3(PPh_3)_2]$.

Rhenium reacts at room temperature with the addition of triethylamine as the base in relatively high yields. [Kung et al. 1997].

Vertebrate animals can be used to investigate the biodistribution and pharmacokinetics of new metal labeled fatty acids compounds to determine their ability to accurately measure uptake in the heart. For example, rats (Sprague Dawley, male, 150 at 80-100 grams each) can be used for the whole body biodistribution studies. Compounds can be evaluated with six time points 5, 10, 15, 30, 60, and 120 minutes with five animals per time point, so that accurate statistics in the clearance rate measurements can be obtained, accounting for intraspecies variation.

Pharmaceutical Compositions and Use

The imaging agents of the invention may be prepared as pharmaceuticals and an effective amount (e.g. from about 1 to about 50 mCi, more preferably between 10-30 mCi) administered to a subject to identify cardiac dysfunction, including cardiac ischemia, cardiomyopathy, tissue viability, hybridizing heart and other cardiac abnormalities

Compositions for use in accordance with the present invention may be formulated in a conventional manner using one or more physiologically acceptable carriers or excipients. Thus, the compounds and their physiologically acceptable salts and solvates may be formulated for administration by, for example, injection or parenteral administration.

The compounds of the invention can be formulated for a variety of loads of administration, including systemic and topical or localized administration. Techniques and formulations generally may be found in Remington's Pharmaceutical Sciences, Meade Publishing Co., Easton, PA. For systemic administration, injection is preferred, including intramuscular, intravenous, intraperitoneal, and subcutaneous. For injection, the compounds of the invention can be formulated in liquid solutions, preferably in physiologically compatible buffers such as Hank's solution or Ringer's solution. In addition, the compounds may be formulated in solid form and redissolved or suspended immediately prior to use. Lyophilized forms are also included.

The compounds may be formulated for parenteral administration by injection, e.g., by bolus injection or continuous infusion. Formulations for injection may be presented in unit dosage form, e.g., in ampoules or in multi-dose containers, with an

added preservative. The compositions may take such forms as suspensions, solutions or emulsions in oily or aqueous vehicles, and may contain formulating agents such as suspending, stabilizing and/or dispersing agents. Alternatively, the active ingredient may be in powder form for constitution with a suitable vehicle, e.g., sterile pyrogen-free water, before use.

Systemic administration can also be by transmucosal or transdermal means. For transmucosal or transdermal administration, penetrants appropriate to the barrier to be permeated are used in the formulation. Such penetrants are generally known in the art, and include, for example, for transmucosal administration bile salts and fusidic acid derivatives. In addition, detergents may be used to facilitate permeation. Transmucosal administration may be through nasal sprays or using suppositories. For topical administration, the oligomers of the invention are formulated into ointments, salves, gels, or creams as generally known in the art. A wash solution can be used locally to treat an injury or inflammation to accelerate healing.

The compositions may, if desired, be presented in a pack or dispenser device which may contain one or more unit dosage forms containing the active ingredient. The pack may for example comprise metal or plastic foil, such as a blister pack. The pack or dispenser device may be accompanied by instructions for administration.

In another embodiment, the invention provides a kit for imaging, which comprises one or more of the imaging agents described above, in combination with a pharmaceutically acceptable solution containing a carrier such as human serum albumin or an auxiliary molecule, such as mannitol or gluconate. The kits of the invention may include additional components, which facilitate practice of the method of the invention, including buffers, syringes, film, instructions, and the like.

The contents of all cited references (including literature references, issued patents, published patent applications as cited throughout this application) are hereby expressly incorporated by reference. The practice of the present invention will employ, unless otherwise indicated, conventional techniques that are within the skill of the art. Such techniques are explained fully in the literature.

- 12a -

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



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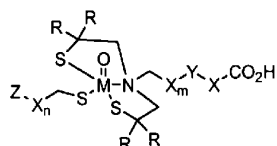
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THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

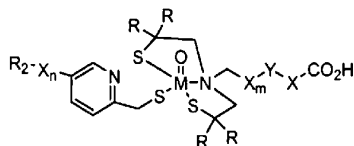
1. A radiolabeled fatty acid comprising at least one ligand complexed to a radioisotope wherein the radioisotope has a neutral charge, the analog comprises
5 an alkyl terminus and a carboxylic acid terminus, and the carboxylic acid is remote from the radioisotope.
2. The radiolabeled fatty acid of claim 1, wherein the alkyl terminus comprises at least 5 carbons.
3. The radiolabeled fatty acid of claim 1, wherein the analog localizes to a heart in
10 preference to a lung when administered to an organism.
4. The radiolabeled fatty acid of claim 1, wherein the radiolabeled fatty acid has the formula:



wherein R represents H or Me;

- 15 X represents -CH₂- or -CH=;
- Y represents -CH(R)- or -C(R)=;
- Z represents CH₃- or CH₂=;
- M represents a radioisotope;
- and the sum of m+n is in the range of 0 to 15.

- 20 5. The radiolabeled fatty acid of claim 4, wherein the sum of m+n is in the range of 3 to 11.
6. The radiolabeled fatty acid of claim 1, wherein the radiolabeled fatty acid has the formula:



wherein R represents H or Me;

X represents -CH₂- or -CH=;

5 Y represents -CH(R)- or -C(R)=;

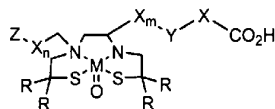
M represents a radioisotope;

and the sum of m+n is in the range of 0 to 14.

7. The radiolabeled fatty acid of claim 6, wherein the sum of m+n is in the range of 3 to 7.

10 8. The radiolabeled fatty acid of claim 6, wherein the sum of m+n is in the range of 5 to 9.

9. The radiolabeled fatty acid of claim 1, wherein the radiolabeled fatty acid has the formula:



15 wherein R represents H or Me;

X represents -CH₂- or -CH=;

Y represents -CH(R)- or -C(R)=;

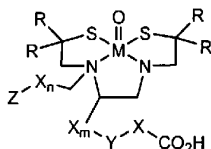
Z represents CH₃- or CH₂=;

M represents a radioisotope;

20 and the sum of m+n is in the range of 8 to 17.

10. The radiolabeled fatty acid of claim 9, wherein the sum of m+n is in the range of 9 to 14.

11. The radiolabeled fatty acid of claim 1, wherein the radiolabeled fatty acid has the formula:



5 wherein R represents H or Me;

X represents -CH₂- or -CH=;

Y represents -CH(R)- or -C(R)=;

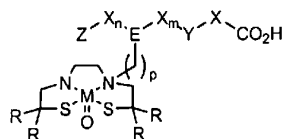
Z represents CH₃- or CH₂=;

M represents a radioisotope;

10 and the sum of m+n is in the range of 8 to 17.

12. The radiolabeled fatty acid of claim 11, wherein the sum of m+n is in the range of 9 to 14.

13. The radiolabeled fatty acid of claim 1, wherein the radiolabeled fatty acid has the formula:



15

wherein R represents H or Me;

X represents -CH₂- or -CH=;

Y represents -CH(R)- or -C(R)=;

Z represents CH₃- or CH₂=;

20 E represents -CH- or -C=;

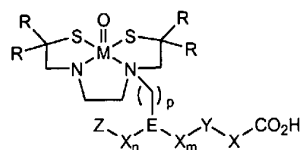
M represents a radioisotope;

p represents 1, 2, or 3;

and the sum of m+n is in the range of 8 to 17.

14. The radiolabeled fatty acid of claim 13, wherein the sum of m+n is in the range of 9 to 14.

15. The radiolabeled fatty acid of claim 1, wherein the radiolabeled fatty acid has the formula:



wherein R represents H or Me;

10 X represents -CH₂- or -CH=;

Y represents -CH(R)- or -C(R)=;

Z represents CH₃- or CH₂=;

E represents -CH- or -C=;

M represents a radioisotope;

15 p represents 1, 2, or 3;

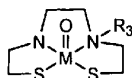
and the sum of m+n is in the range of 8 to 17.

16. The radiolabeled fatty acid of claim 15, wherein the sum of m+n is in the range of 9 to 14.

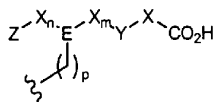
17. The radiolabeled fatty acid of any one of claims 1 to 16, wherein the radioisotope is selected from technetium, rhenium, gallium, or indium.

18. The radiolabeled fatty acid of any one of claim 1 to 17, wherein the radioisotope is selected from ^{99m}Tc, Re, ⁶⁸Ga, ⁶⁷Ga, or ¹¹¹In.

19. The radiolabeled fatty acid of claim 1, wherein the radioisotope complex comprises one ligand with three donor atoms complexed to the radioisotope and one ligand with one donor atom complexed to the radioisotope.
20. The radiolabeled fatty acid of claim 1, wherein the radioisotope complex comprises one ligand with four donor atoms complexed to the radioisotope.
21. The radiolabeled fatty acid of claim 1, wherein the radiolabeled fatty acid has the formula:



- wherein R_3 represents



wherein

X represents $-CH_2-$ or $-CH=$;

Y represents $-CH(R)-$ or $-C(R)=$;

Z represents CH_3- or $CH_2=$;

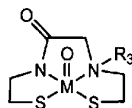
E represents $-CH-$ or $-C=$;

M represents a radioisotope;

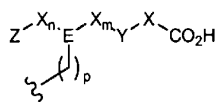
p represents 1, 2, or 3;

and the sum of $m+n$ is in the range of 7 to 16.

22. The radiolabeled fatty acid of claim 21, wherein the sum of $m+n$ is in the range of 8 to 15.
23. The radiolabeled fatty acid of claim 1, wherein the radiolabeled fatty acid has the formula:



wherein R₃ represents



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wherein

X represents -CH₂- or -CH=;

Y represents -CH(R)- or -C(R)=;

Z represents CH₃- or CH₂=;

E represents -CH- or -C=;

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M represents a radioisotope;

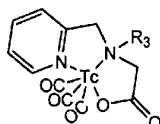
p represents 1, 2, or 3;

and the sum of m+n is in the range of 7 to 16.

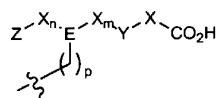
24. The radiolabeled fatty acid of claim 23, wherein the sum of m+n is in the range of 8 to 15.

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25. The radiolabeled fatty acid of claim 1, wherein the radiolabeled fatty acid has the formula



wherein R₃ represents



wherein

X represents -CH₂- or -CH=;

Y represents -CH(R)- or -C(R)=;

5 Z represents CH₃- or CH₂=;

E represents -CH- or -C=;

M represents a radioisotope;

p represents 1, 2, or 3;

and the sum of m+n is in the range of 7 to 16.

- 10 26. The radiolabeled fatty acid of claim 25, wherein the sum of m+n is in the range of 8 to 15.
27. The radiolabeled fatty acid of claim 1, wherein the radioisotope has an oxo ligand.
28. The radiolabeled fatty acid of any one of claims 1 to 27, wherein the
15 radiolabeled fatty acid is chiral and is a substantially pure (S) diastereomer.
29. The radiolabeled fatty acid of any one of claims 1 to 27, wherein the radiolabeled fatty acid is chiral and is a substantially pure (R) diastereomer.
30. A pharmaceutical composition comprising the radiolabeled fatty acid of any one of claims 1 to 29 and a pharmaceutically acceptable excipient.
- 20 31. A method of detecting coronary artery disease comprising administering to a subject the radiolabeled fatty acid of any one of claims 1 to 29.
32. A kit comprising the radiolabeled fatty acid of any one of claims 1 to 29 and instructions for use thereof.
33. Use of the radiolabeled fatty acid of any one of claims 1 to 29 in the detection of
25 coronary artery disease.

34. Use of the radiolabeled fatty acid of any one of claims 1 to 29 in the manufacture of a pharmaceutical composition for the detection of coronary artery disease.
- 5 35. Radiolabeled fatty acids, pharmaceutical compositions comprising them, kits comprising them, or methods or uses involving them, substantially as herein described with reference to the accompanying schemes.

Dated this 28th day of October 2004

10 BIOSTREAM, INC.

By their Patent Attorneys

GRIFFITH HACK

Fellows Institute of Patent and

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