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RADIOLABELED PEPTIDES

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to therapeutic agents and peptides, radiotherapeutic agents and peptides, radiodiagnostic agents and peptides, and methods for producing such labeled radiodiagnostic and radiotherapeutic agents. Specifically, the invention relates to cyclic peptide derivatives and analogues of somatostatin, and embodiments of such peptides labeled with gamma-radiation emitting isotopes such as technetium-99m (Tc-99m), as well as methods and kits for making, radiolabeling and using such peptides to image sites in a mammalian body. The invention also relates to peptide derivatives and analogues of somatostatin labeled with cytotoxic radioisotopes such as rhenium-186 (^{186}Re) and rhenium-188 (^{188}Re), and methods and kits for making, radiolabeling and using such peptides therapeutically in a mammalian body.

2. Description of the Prior Art

Somatostatin is a tetradecapeptide that is endogenously produced by the hypothalamus and pancreas in humans and other mammals. The peptide has the formula:

Formula I

Ala-Gly-Cys-Lys-Asn-Phe-Phe-Trp-Lys-Thr-Phe-Thr-Ser-Cys

(Single letter abbreviations for amino acids can be found in G. Zubay, Biochemistry (2d ed.), 1988, (MacMillan Publishing: New York), p.33). This peptide exerts a wide variety of biological effects *in vivo*. It is known to act physiologically on the central nervous system, the hypothalamus, the pancreas, and the gastrointestinal tract.

Somatostatin inhibits the release of insulin and glucagon from the

pancreas, inhibits growth hormone release from the hypothalamus, and reduces gastric secretions. Thus, somatostatin has clinical and therapeutic applications for the alleviation of a number of ailments and diseases, both in humans and other animals. Native somatostatin is of limited utility, however, due to its short half-life *in vivo*, where it is rapidly degraded by peptidases. For this reason, somatostatin analogues having improved *in vivo* stability have been developed in the prior art.

Freidinger, U.S. Patent No. 4,235,886 disclose cyclic hexapeptide somatostatin analogues useful in the treatment of a number of diseases in humans.

Coy and Murphy, U.S. Patent No. 4,485,101 disclose synthetic dodecapeptide somatostatin analogues.

Freidinger, U.S. Patent No. 4,611,054 disclose cyclic hexapeptide somatostatin analogues useful in the treatment of a number of diseases in humans.

Nutt, U.S. Patent No. 4,612,366 disclose cyclic hexapeptide somatostatin analogues useful in the treatment of a number of diseases in humans.

Coy *et al.*, U.S. Patent No. 4,853,371 disclose synthetic octapeptide somatostatin analogues.

Coy and Murphy, U.S. Patent No. 4,871,717 disclose synthetic heptapeptide somatostatin analogues.

Coy *et al.*, U.S. Patent No. 4,904,642 disclose synthetic octapeptide somatostatin analogues.

Taylor *et al.*, U.S. Patent No. 5,073,541 disclose a method of treating small cell lung cancer.

Brady, European Patent Application No. 83111747.8 discloses dicyclic hexapeptide somatostatin analogues useful in the treatment of a number of human diseases.

Bauer *et al.*, European Patent Application No. 85810617.2 disclose somatostatin derivatives useful in the treatment of a number of human diseases.

Eck and Moreau, European Patent Application No. 90302760.5 disclose

therapeutic octapeptide somatostatin analogues.

Coy and Murphy, International Patent Application Serial No. PCT/US90/07074 disclose somatostatin analogues for therapeutic uses.

Schally *et al.*, European Patent Application Serial No. EPA 911048445.2 disclose cyclic peptides for therapeutic use.

Bodgen and Moreau, International Patent Application Serial No. PCT/US92/01027 disclose compositions and methods for treating proliferative skin disease.

Somatostatin exerts its effects by binding to specific receptors expressed at the cell surface of cells comprising the central nervous system, the hypothalamus, the pancreas, and the gastrointestinal tract. These high-affinity somatostatin binding sites have been found to be abundantly expressed at the cell surface of most endocrine-active tumors arising from these tissues. Expression of high-affinity binding sites for somatostatin is a marker for these tumor cells, and specific binding with somatostatin can be exploited to locate and identify tumor cells *in vivo*.

Methods for radiolabeling somatostatin analogues that have been modified so as to contain a tyrosine amino acid (Tyr or Y) are known in the prior art.

Albert *et al.*, UK Patent Application 8927255.3 disclose radioimaging using somatostatin derivatives such as octreotide labeled with ¹²³I.

Bakker *et al.*, 1990, J. Nucl. Med. 31: 1501-1509 describe radioactive iodination of a somatostatin analog and its usefulness in detecting tumors *in vivo*.

Bakker *et al.*, 1991, J. Nucl. Med. 32: 1184-1189 teach the usefulness of radiolabeled somatostatin for radioimaging *in vivo*.

Bomanji *et al.*, 1992, J. Nucl. Med. 33: 1121-1124 describe the use of iodinated (Tyr-3) octreotide for imaging metastatic carcinoid tumors.

Alternatively, methods for radiolabeling somatostatin by covalently modifying the peptide to contain a radionuclide-chelating group have been disclosed in the prior art.

Albert *et al.*, UK Patent Application 8927255.3 disclose radioimaging using somatostatin derivatives such as octreotide labeled with ^{111}In via a chelating group bound to the amino-terminus.

Albert *et al.*, European Patent Application No. WO 91/01144 disclose radioimaging using radiolabeled peptides related to growth factors, hormones, interferons and cytokines and comprised of a specific recognition peptide covalently linked to a radionuclide chelating group.

Albert *et al.*, European Patent Application No. 92810381.1 disclose somatostatin peptides having amino-terminally linked chelators.

Lyle *et al.*, PCT International Patent Application, Publication No. WO93/15770 discloses radiolabeled somatostatin peptides.

Faglia *et al.*, 1991, *J. Clin. Endocrinol. Metab.* **73**: 850-856 describe the detection of somatostatin receptors in patients.

Kwekkeboom *et al.*, 1991, *J. Nucl. Med.* **32**: 981 Abstract #305 relates to radiolabeling somatostatin analogues with ^{111}In .

Albert *et al.*, 1991, Abstract LM10, 12th American Peptide Symposium: 1991 describe uses for ^{111}In -labeled diethylene-triaminopentaacetic acid-derivatized somatostatin analogues.

Krenning *et al.*, 1992, *J. Nucl. Med.* **33**: 652-658 describe clinical scintigraphy using $\{^{111}\text{In}\}\{\text{DTPA}\}$ octreotide.

These methods can be readily adapted to enable detection of tumor cells *in vivo* by radioimaging, based on the expression of high affinity binding sites for somatostatin on tumor cells. Radionuclides which emit gamma radiation can be readily detected by scintigraphy after injection into a human or an animal. A variety of radionuclides are known to be useful for radioimaging, including ^{67}Ga , ^{68}Ga , $^{99\text{m}}\text{Tc}$ (Tc-99m), ^{111}In , ^{123}I or ^{125}I . The sensitivity of imaging methods using radioactively-labeled peptides is much higher than other techniques known in the art, since the specific binding of the radioactive peptide concentrates the radioactive signal over the cells of interest, for example, tumor cells. This is particularly important for endocrine-active gastrointestinal tumors, which are usually small, slow-growing and difficult to

detect by conventional methods.

Labeling with technetium-99m (Tc-99m) is advantageous because the nuclear and radioactive properties of this isotope make it an ideal scintigraphic imaging agent. Tc-99m has a single photon energy of 140 keV and a radioactive half-life of about 6 hours, and is readily available from a ^{99}Mo - $^{99\text{m}}\text{Tc}$ generator. Other radionuclides have effective half-lives which are much longer (for example, ^{111}In , which has a half-life of 60-70 h) or are toxic (for example, ^{125}I). Although Tc-99m is an ideal radiolabeling reagent, it has not been widely used for labeling peptides in the art prior to the present invention (see, for example, Lamberts., 1991, *J. Nucl. Med.* 32: 1189-1191).

Somatostatin and radiolabeled somatostatin analogues can also be used therapeutically. For these applications, cytotoxic radioisotopes are advantageous, such as scandium-47, copper-67, gallium-72, yttrium-90, tin-117m, iodine-125, iodine-131, samarium-153, gadolinium-159, dysprosium-165, holmium-166, ytterbium-175, lutetium-177, rhenium-186, rhenium-188, astatine-211 and bismuth-212. The rhenium isotopes ^{186}Re and ^{188}Re , as well as Sn-117m are particularly advantageous.

The use of chelating agents for radiolabeling proteins are known in the prior art, and methods for labeling peptides with Tc-99m are disclosed in co-owned U.S. Patent Serial No. 5,225,180 and in co-pending U.S. Patent Applications Serial Nos. 07/653,012, 07/807,062, 07/851,074, 07/871,282, 07/886,752, 07/893,981, 07/902,935, 07/955,466, 07/977,628, 08/019,864, 08/044,825 and 08/073,577, 08/092,355, 08/095,760, 08/210,822, and PCT International Applications PCT/US92/00757, PCT/US92/10716, PCT/US93/02320, PCT/US93/03687, PCT/US93/04794, PCT/US93/05372, PCT/US93/06029, PCT/US93/09387, and PCT/US94/01894, which are hereby incorporated by reference. ADD ALL THE PATENTS

Fritzberg, U.S. Patent No. 4,444,690 describes a series of technetium-chelating agents based on 2,3-bis(mercaptoacetamido) propanoate.

Gansow *et al.*, U.S. Patent No. 4,472,509 teach methods of manufacturing and purifying Tc-99m chelate-conjugated monoclonal antibodies.

Reno and Bottino, European Patent Application 87300426.1 disclose radiolabeling antibodies with Tc-99m.

Pak *et al.*, European Patent Application No. WO 88/07382 disclose a method for labeling antibodies with Tc-99m.

Cox, International Patent Application No. PCT/US92/04559 discloses radiolabeled somatostatin derivatives containing two cysteine residues.

Rhodes, 1974, *Sem. Nucl. Med.* 4: 281-293 teach the labeling of human serum albumin with technetium-99m.

Khaw *et al.*, 1982, *J. Nucl. Med.* 23: 1011-1019 disclose methods for labeling biologically active macromolecules with Tc-99m.

Byrne and Tolman, *supra*, disclose a bifunctional thiolactone chelating agent for coupling Tc-99m to biological molecules.

Cox *et al.*, 1991, Abstract, 7th International Symposium on Radiopharmacology, p. 16, disclose the use of, Tc-99m-, ¹³¹I- and ¹¹¹In-labeled somatostatin analogues in radiolocalization of endocrine tumors *in vivo* by scintigraphy.

Methods for directly labeling somatostatin, derivatives of somatostatin, analogues of somatostatin or peptides that bind to the somatostatin receptor and contain at least 2 cysteine residues that form a disulfide or wherein the disulfide is reduced to the sulfhydryl form, are disclosed in co-pending U.S. Patent Application Serial No. 07/807,062, now U.S. Patent No. 5,225,180, issued July 6, 1993 which is hereby incorporated by reference.

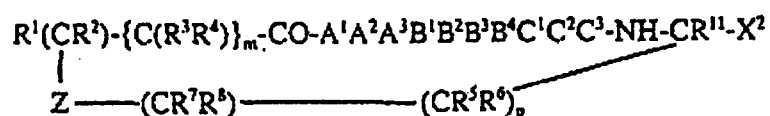
There remains a need for synthetic (to make routine manufacture practicable and to ease regulatory acceptance) somatostatin analogues having increased *in vivo* stability, to be used therapeutically, as scintigraphic agents when radiolabeled with Tc-99m or other detectable radioisotopes for use in imaging tumors *in vivo*, and as radiotherapeutic agents when radiolabeled with a cytotoxic radioisotope such as rhenium-188. Small synthetic somatostatin analogues are provided by this invention that specifically fulfill this need.

SUMMARY OF THE INVENTION

The present invention provides somatostatin analogues that are cyclic peptides for therapeutic applications, including radiotherapeutic applications, and diagnostic applications, including radiodiagnostic applications, in particular scintigraphic imaging applications. Distinct from native somatostatin and somatostatin analogues known in the prior art, the cyclic peptides of the invention do not comprise a disulfide bond. The invention also provides cyclic peptide reagents comprised of the cyclic peptide somatostatin analogues of the invention, wherein such peptides are covalently linked to a radiolabel-binding moiety. The invention provides such cyclic peptides, cyclic peptide reagents and radiolabeled cyclic peptide reagents that are scintigraphic imaging agents, radiodiagnostic agents and radiotherapeutic agents. Scintigraphic imaging agents of the invention comprise cyclic peptide reagents radiolabeled with a radioisotope, preferably technetium-99m. Radiotherapeutic agents of the invention comprise cyclic peptide reagents radiolabeled with a cytotoxic radioisotope, preferably tin-117m, rhenium-186 or rhenium-188. Methods for making and using such cyclic peptides, cyclic peptide reagents and radiolabeled embodiments thereof are also provided.

The invention provides a cyclic peptide that is a somatostatin analogue as a composition of matter comprising a somatostatin-receptor binding peptide having the formula:

Formula II



where R^1 , R^2 , R^5 and R^6 are each independently H, lower alkyl or substituted alkyl, aryl or substituted aryl; R^3 and R^4 are each independently H, lower alkyl or substituted alkyl, aryl or substituted aryl, or wherein either R^3 or R^4 is X^1 ; A^1 and C^3 are independently a bond or a D- or L-amino acid; A^2 , A^3 and C^1 are each independently a bond or a lipophilic D- or L-amino acid; B^1 is D- or L-Phe or D- or L-Tyr or D- or L-2-naphthylalanine (Nal) or 2-aminoindan-2-

carboxylic acid (Ain) or a substituted derivative thereof; B² is D- or L-Trp or a substituted derivative thereof; B³ is D- or L-Lys or homolysine (Hly), 4-amino-cyclohexylalanine (Achxa), 4-aminomethylphenylalanine (Amf), S-(2-aminoethyl)cysteine (Aec), S-(3-aminopropyl)cysteine (Apc), O-(2-aminoethyl)serine (Aes), O-(3-aminopropyl)serine (Aps) or a substituted derivative thereof; B⁴ is Thr, Ser, Val, Phe, Ile, Leu, 2-amino-isobutyric acid (Aib), 2-aminobutyric acid (Abu), norvaline (Nva), or norleucine (Nle); C² is a bond or the D- or L-stereoisomers of Thr, Ser, Val, Phe, Ile, Abu, Nle, Leu, Nva, Nal or Aib or a substituted derivative thereof; X¹ is N(R¹⁰)₂, where each R¹⁰ is independently hydrogen, lower alkyl or substituted lower alkyl, aryl or substituted aryl or a hydrophilic moiety of less than about 1500 daltons; X² is -COOR⁹, -CH₂OH, CH₂COOR⁹, or -CON(R⁹)₂, where each R⁹ is independently H, lower linear or cyclic alkyl or a substituted derivative thereof or a hydrophilic moiety of less than about 1500 daltons; and where m is 0, 1, 2 or 3 and p is 0, 1 or 2; R⁷ and R⁸ are independently H, lower alkyl or substituted lower alkyl, or either R⁷ or R⁸ are -COOH or -CO.N(R¹⁰)₂ or -COOR¹², or R⁷ and R⁸ together are an oxygen atom; R¹² is hydrogen, lower alkyl or substituted lower alkyl, aryl or substituted aryl; Z is a sulfur atom, an oxygen atom, NR¹³, NR¹³NR¹⁴, NR¹³.CO.NR¹³, SO₂, NR¹³SO₂, or the moiety (S=O); and further where R¹³ is hydrogen, lower alkyl or substituted lower alkyl, aryl or substituted aryl; and where Z is NR¹³, R⁷ and R⁸ are not together an oxygen. In a preferred embodiment, the X¹ moiety is an amino acid or a peptide sequence comprising 10 or fewer amino acids, or a monosaccharide or oligosaccharide comprising 10 or fewer saccharide units, or a poly(N-carboxyalkyl)amine or a poly-oxy anion and the X² moiety is poly(N-carboxyalkyl)amine or a polyoxy-anion, or an amino acid or a peptide having an amino acid sequence of no more than 10 residues (including peptides wherein the carboxyl group of the carboxyl-terminal amino acid is reduced to an alcohol), or a monosaccharide or oligosaccharide comprising 10 or fewer saccharide units. In another preferred embodiment, B¹ is phenylalanine or tyrosine, B² is D-tryptophan, B³ is lysine and B⁴ is threonine or valine.

The invention also provides a cyclic peptide that is a somatostatin analogue as a composition of matter comprising a somatostatin-receptor binding peptide having the formula:

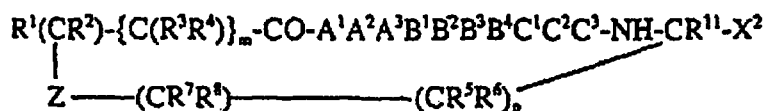
Formula III



where B¹ is D- or L-Phe or D- or L-Tyr or D- or L-Nal or Ain or a substituted derivative thereof; B² is D- or L-Trp or a substituted derivative thereof; B³ is D- or L-Lys or Hly, Achxa, Amf, Aec, Apc, Aes, Aps or a substituted derivative thereof; B⁴ is Thr, Ser, Val, Phe, Ile, Abu, Nle, Leu, Nva or Aib; C⁴ is an L-amino acid comprising a sidechain having a mercapto group; and A⁴ is a lipophilic D-amino acid or a lipophilic L-(α -N-alkyl) amino acid or L-cysteine or L-proline or a substituted derivative thereof. This moiety is a cyclic peptide moiety, where the amino terminus of the A⁴ residue is covalently linked with the carboxyl terminus of the C⁴ residue. In a preferred embodiment, B¹ is phenylalanine or tyrosine, B² is D-tryptophan, B³ is lysine and B⁴ is threonine or valine.

The invention also provides a cyclic peptide reagent comprising a somatostatin-receptor binding peptide having the formula:

Formula IV



where R¹, R², R³ and R⁴ are each independently H, lower alkyl or substituted alkyl, aryl or substituted aryl; R³ and R⁴ are each independently H, lower alkyl or substituted alkyl, aryl or substituted aryl, or wherein either R³ or R⁴ is X¹; A¹ and C³ are independently a bond or a D- or L-amino acid; A², A³ and C¹ are each independently a bond or a lipophilic D- or L-amino acid; B¹ is D- or L-Phe or D- or L-Tyr or D- or L-2-naphthylalanine (Nal) or 2-aminoindan-2-carboxylic acid (Ain) or a substituted derivative thereof; B² is D- or L-Trp or a substituted derivative thereof; B³ is D- or L-Lys or homolysine (Hly), 4-amino-cyclohexylalanine (Achxa), 4-aminomethylphenylalanine (Amf), S-(2-

aminoethyl)cysteine (Aec), *S*-(3-aminopropyl)cysteine (Apc), O-(2-aminoethyl)serine (Aes), O-(3-aminopropyl)serine (Aps) or a substituted derivative thereof; B⁴ is Thr, Ser, Val, Phe, Ile, Leu, 2-amino-isobutyric acid (Aib), 2-aminobutyric acid (Abu), norvaline (Nva), or norleucine (Nle); C² is a bond or the D- or L-stereoisomers of Thr, Ser, Val, Phe, Ile, Abu, Nle, Leu, Nva, Nal or Aib or a substituted derivative thereof; X¹ is N(R¹⁰)₂, where each R¹⁰ is independently hydrogen, lower alkyl or substituted lower alkyl, aryl or substituted aryl or substituted with a hydrophilic moiety of less than about 1500 daltons; X² is -COOR⁹, -CH₂OH, CH₂COOR⁹, or -CON(R⁹)₂, where each R⁹ is independently H, lower linear or cyclic alkyl or a substituted derivative thereof or substituted with a hydrophilic moiety of less than about 1500 daltons; and where m is 0,1,2 or 3 and p is 0, 1 or 2; R⁷ and R⁸ are independently H, lower alkyl or substituted lower alkyl, or either R⁷ or R⁸ are -COOH or -CO.N(R¹⁰)₂ or -COOR¹², or R⁷ and R⁸ together are an oxygen atom; R¹² is hydrogen, lower alkyl or substituted lower alkyl, aryl or substituted aryl; Z is a bond, a sulfur atom, an oxygen atom, NR¹³, NR¹³NR¹³, NR¹³.CO.NR¹³, SO₂, NR¹³SO₂ or the moiety (S=O); and further where R¹³ is hydrogen, lower alkyl or substituted lower alkyl, aryl or substituted aryl; and where Z is NR¹³, R⁷ and R⁸ are not together an oxygen. In a preferred embodiment, the X¹ moiety is an amino acid or a peptide sequence comprising 10 or fewer amino acids, or a monosaccharide or oligosaccharide comprising 10 or fewer saccharide units, or a poly(*N*-carboxyalkyl)amine or a poly-oxy anion and the X² moiety is poly(*N*-carboxyalkyl)amine or a polyoxy-anion, or an amino acid or a peptide having an amino acid sequence of no more than 10 residues (including peptides wherein the carboxyl group of the carboxyl-terminal amino acid is reduced to an alcohol), or a monosaccharide or oligosaccharide comprising 10 or fewer saccharide units. In another preferred embodiment, B¹ is phenylalanine or tyrosine, B² is D-tryptophan, B³ is lysine and B⁴ is threonine or valine. In such preferred embodiments, the cyclic peptide is covalently linked to a radiolabel-binding moiety, wherein the radiolabel-binding moiety is not covalently linked to the moieties B¹, B², B³,

B⁴ or A⁴ of the peptide.

The invention also provides scintigraphic imaging agents comprising the cyclic peptide reagents of the invention wherein the cyclic peptide is covalently linked to a radiolabel-binding moiety, wherein the radiolabel-binding moiety is not covalently linked to the moieties B¹, B², B³, B⁴, or A⁴ of the peptide.

The invention also provides a cyclic peptide that is a somatostatin analogue as a composition of matter comprising a somatostatin-receptor binding peptide having the formula:

Formula V



where B¹ is D- or L-Phe or D- or L-Tyr or D- or L-Nal or Ain or a substituted derivative thereof; B² is D- or L-Trp or a substituted derivative thereof; B³ is D- or L-Lys or Hly, Achxa, Amf, Aec, Apc, Aes, Aps or a substituted derivative thereof; B⁴ is Thr, Ser, Val, Phe, Ile, Abu, Nle, Leu, Nva or Aib; C⁴ is an L-amino acid; and A⁴ is a lipophilic D-amino acid or a lipophilic L-(α -N-alkyl) amino acid or L-cysteine or L-proline or a substituted derivative thereof; . This moiety is a cyclic peptide moiety, where the amino terminus of the A⁴ residue is covalently linked with the carboxyl terminus of the C⁴ residue. In a preferred embodiment, B¹ is phenylalanine or tyrosine, B² is D-tryptophan, B³ is lysine and B⁴ is threonine or valine; and the cyclic peptide is covalently linked to a radiolabel-binding moiety, wherein the radiolabel-binding moiety is not covalently linked to the moieties B¹, B², B³, B⁴ or A⁴ of the peptide.

The invention also provides scintigraphic imaging agents comprising the cyclic peptide reagents of the invention wherein the radiolabel-binding moiety is stably complexed with a radioisotope. In one such embodiment is provided a scintigraphic imaging agent wherein the somatostatin analogue, cyclic peptide reagents of the invention are radiolabeled with technetium-99m. In other embodiments of the scintigraphic imaging agents of the invention the radioisotope is indium-111 or gallium-68. In still other embodiments, the scintigraphic imaging agents of the invention are cyclic peptides that are

radiolabeled with iodine-123 or iodine-125.

The invention also provides radiotherapeutic agents that are the cyclic peptide reagents of the invention radiolabeled with a cytotoxic radioisotope that is selected from the group consisting of scandium-47, copper-67, gallium-72, yttrium-90, tin-117m, samarium-153, gadolinium-159, dysprosium-165, holmium-166, ytterbium-175, lutetium-177, rhenium-186, rhenium-188, and bismuth-212. In preferred embodiments, the radioisotope is tin-117m, rhenium-186 or rhenium-188. In additional preferred embodiments, the cyclic peptides of the invention are radiolabeled with iodine-125, iodine-131 or astatine-211.

The invention further provides therapeutic agents comprising the cyclic peptide reagents of the invention, optionally wherein the reagents form a complex with a non-radioactive metal, preferably rhenium. Combination embodiments, wherein such a complex is also radiolabeled, either directly or *via* a radiolabel-binding moiety, are also provided by the invention and are within its scope.

The invention also provides pharmaceutical compositions comprising the somatostatin receptor-binding peptides of the invention in a pharmaceutically acceptable carrier.

The somatostatin analogues of the invention are therapeutically useful in the alleviation of diseases or other ailments in humans or other animals. The invention provides a method for alleviating somatostatin-related diseases in animals, preferably humans, comprising administering a therapeutically effective amount of the somatostatin analogues of the invention to the animal. In preferred embodiments, the amount of the somatostatin analogue administered is from about 0.1 to about 50 mg/kg body weight/day.

Another aspect of the present invention provides reagents for preparing radiotherapeutic and radiodiagnostic radiopharmaceuticals, including preferably scintigraphic imaging agents. Each such reagent is comprised of a peptide that is somatostatin analogue covalently linked to a radiolabel-binding moiety.

It is an advantage of the somatostatin analogues provided by the invention that the non-disulfide cyclic linkage is stable in the presence of

reducing agents used to form a complex between a radioisotope and a radiolabel binding moiety of the invention comprising a thiol group. The somatostatin analogues of the invention are advantageous over somatostatin and previously-used disulfide-containing somatostatin analogues. These prior art reagents contain a disulfide bond, which disulfide bond is unstable in the presence of reducing agents useful in the production of radiolabel complexes with various radiolabel binding moieties. The biological activity of these previously-known reagents was thereby reduced, and the efficacy of scintigraphic imaging agents derived therefrom compromised, by reduction of these peptide structure-determining disulfide bonds. Such destabilization of the structure of the peptide reagents of this invention does not occur due to the lack of such unstable disulfide bonds in the somatostatin receptor binding compounds comprising the instant invention. Thus, the use of thiol-containing radiolabel chelating moieties and the use of reducing agents to form radioisotope complexes therewith does not result in loss of biological activity of the somatostatin receptor binding compounds of this invention.

It is another advantage of the somatostatin analogues provided by this invention that formation of the covalent conjugate between the peptides and thiol-containing radiolabel binding moieties of the invention does not result in "scrambling" of structurally-important disulfide bonds. Unlike peptide moieties comprising a disulfide bond, the non-disulfide cyclic linkage contained in the peptide reagents of the invention does not interfere with thiol-containing radiolabel binding moieties. Conversely, the thiol-containing radiolabel binding moieties cannot disrupt the three-dimensional structure of the peptide by "scrambling" structurally-important disulfide bonds. In contrast, for example, a thiol-containing Tc-99m binding moiety covalently linked to native somatostatin, or to a somatostatin analogue having a disulfide bond, can result in disulfide bond formation between a sidechain sulfur of a peptide amino acid and the thiol group of the radiolabel binding moiety. Such "scrambling" of disulfide bonds can be accompanied by a loss of biological activity. The present invention is not subject to similar losses in biological activity *in vivo*

because the non-disulfide cyclic linkages in each of the somatostatin analogues of the invention comprise stable covalent bonds.

Such loss of biological activity can also occur *in vivo* using native somatostatin, or to any somatostatin analogue having a disulfide bond. Thus, the peptides of the present invention are *per se* advantageous as somatostatin analogues over native somatostatin or somatostatin analogues comprising a disulfide bond because they are intrinsically more stable and resistant to chemical oxidation.

It is another advantage of the somatostatin analogues provided by this invention that the cyclic covalent linkage acts to protect the peptide from degradation by exopeptidases. Further, the cyclic structure confers a degree of conformational rigidity to the peptide that can act to enhance binding of the peptide to its biological target (i.e., the somatostatin receptor).

A first aspect of the reagents provided by the invention for preparing radiolabeled agents are reagents that are each comprised of a cyclic somatostatin receptor-binding peptide as described above that is covalently linked to a radiolabel-binding moiety having the formula:



where $(pgp)^s$ is hydrogen or a thiol protecting group and (aa) is an α - or β -amino acid not comprising a thiol group. In a preferred embodiment, the amino acid is glycine. In another preferred embodiment, the agent is a scintigraphic imaging agent. In yet another preferred embodiment, the agent is a radiotherapeutic agent.

In a second embodiment, the invention provides cyclic peptide reagents capable of being radiolabeled to form radiodiagnostic and radiotherapeutic agents, each comprising a somatostatin analogue covalently linked to a radiolabel-binding moiety of formula:



wherein A is H, HOOC, H_2NOC , (peptide)-NHOC, (peptide)-OOC, R^2NCO , or R^d ; B is H, SH or $-NHR^c$, $-N(R^c)$ -(peptide) or R^d ; Z is H or R^d ; X is SH or $-NHR^c$, $-N(R^c)$ -(peptide) or R^d ; R^a , R^b , R^c and R^d are independently H or

straight or branched chain or cyclic lower alkyl; n is 0, 1 or 2; R^* is C_1-C_4 alkyl, an amino acid or a peptide comprising 2 to about 10 amino acids; and: (1) where B is $-NHR^e$ or $-N(R^e)-(peptide)$, X is SH and n is 1 or 2; (2) where X is $-NHR^e$ or $-N(R^e)-(peptide)$, B is SH and n is 1 or 2; (3) where B is H or R^d , A is $HOOC$, H_2NOC , $(peptide)-NHOC$, or $(peptide)-OOC$, X is SH and n is 0 or 1; (4) where A is H or R^d , then where B is SH , X is $-NHR^e$ or $-N(R^e)-(peptide)$ and where X is SH , B is $-NHR^e$ or $-N(R^e)-(peptide)$; (5) where X is H or R^d , A is $HOOC$, H_2NOC , $(peptide)-NHOC$, or $(peptide)-OOC$ and B is SH ; (6) where Z is methyl, X is methyl, A is $HOOC$, H_2NOC , $(peptide)-NHOC$, or $(peptide)-OOC$ and B is SH and n is 0; and (7) where Z is SH and X is SH , n is not 0; and wherein the thiol moiety is in the reduced form. In a preferred embodiment, the agent is a scintigraphic imaging agent. In yet another preferred embodiment, the agent is a radiotherapeutic agent.

Preferred embodiments of this radiolabel-binding moiety have a chemical formula that is:

I.



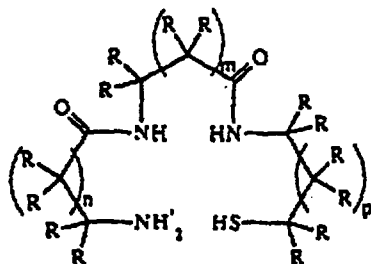
wherein $(amino\ acid)^1$ and $(amino\ acid)^2$ are each independently any primary α - or β -amino acid that does not comprise a thiol group, Z is a thiol-containing moiety that is cysteine, homocysteine, isocysteine, penicillamine, 2-mercaptoethylamine or 3-mercaptoethylamine, and R^1 is lower (C^1-C^4) alkyl, an amino acid or a peptide comprising 2 to 10 amino acids. When Z is cysteine, homocysteine, isocysteine or penicillamine, the carbonyl group of said moiety is covalently linked to a hydroxyl group, a NR^3R^4 group, wherein each of R^3 and R^4 are independently H or lower (C^1-C^4) alkyl, an amino acid or a peptide comprising 2 to 10 amino acids; or

II.

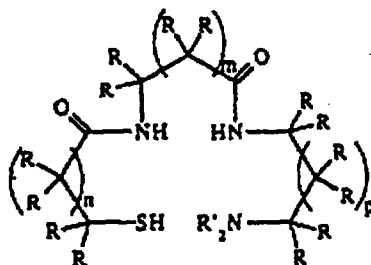


wherein Y is a thiol-containing moiety that is cysteine, homocysteine, isocysteine, penicillamine, 2-mercaptoacetate or 3-mercaptoacetate, $(amino\ acid)^1$ and $(amino\ acid)^2$ are each independently any primary α - or β -amino

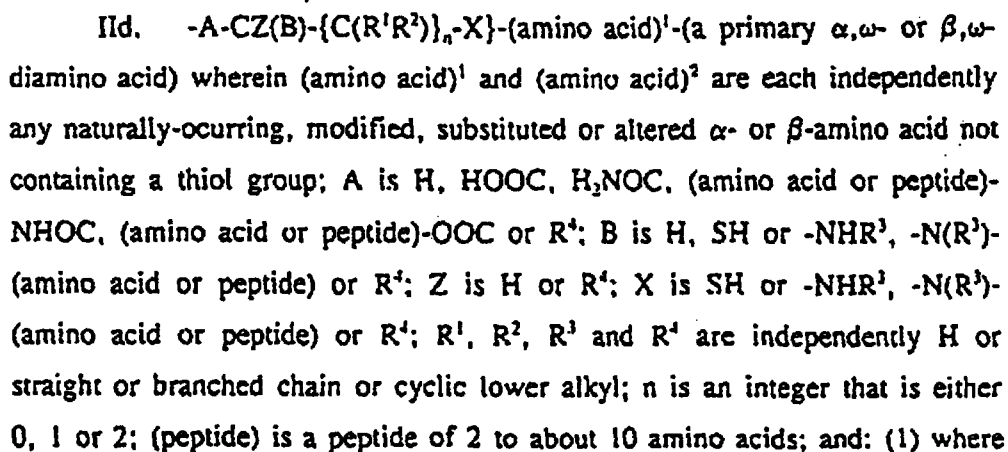
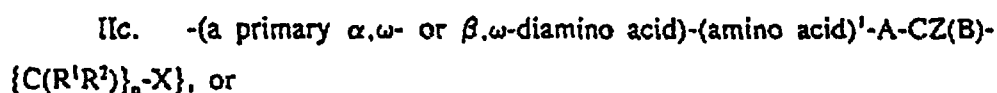
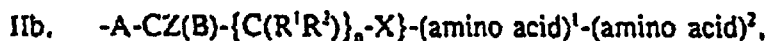
acid that does not comprise a thiol group, and R^2 is H or lower (C^1-C^4) alkyl, an amino acid or a peptide comprising 2 to 10 amino acids. When Y is cysteine, homocysteine, isocysteine or penicillamine, the amino group of said moiety is covalently linked to -H, an amino acid or a peptide comprising 2 to 10 amino acids; or



or



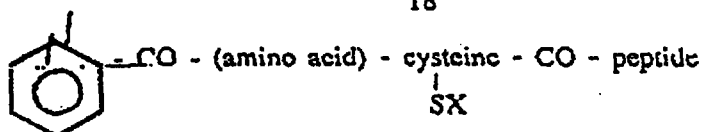
In particular embodiments of this aspect of the invention, the radiolabel-binding moiety has a formula that is:



B is -NHR^3 or $\text{-N(R}^3\text{)-(amino acid or peptide)}$, X is SH and n is 1 or 2; (2) where X is -NHR^3 or $\text{-N(R}^3\text{)-(amino acid or peptide)}$, B is SH and n is 1 or 2; (3) where B is H or R^4 , A is HOOC , H_2NOC , (amino acid or peptide)- NHOC , (amino acid or peptide)- OOC , X is SH and n is 0 or 1; (4) where A is H or R^4 , then where B is SH, X is -NHR^3 or $\text{-N(R}^3\text{)-(amino acid or peptide)}$ and where X is SH, B is -NHR^3 or $\text{-N(R}^3\text{)-(amino acid or peptide)}$; (5) where X is H or R^4 , A is HOOC , H_2NOC , (amino acid or peptide)- NHOC , (amino acid or peptide)- OOC and B is SH; (6) where Z is methyl, X is methyl, A is HOOC , H_2NOC , (amino acid or peptide)- NHOC , (amino acid or peptide)- OOC and B is SH and n is 0; and (7) where Z is SH and X is SH, n is not 0; and wherein the thiol group is in the reduced form.

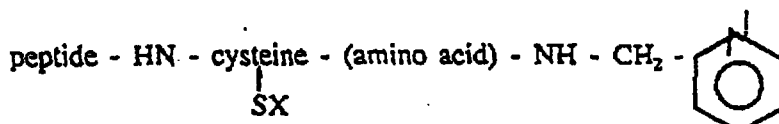
Additional preferred embodiments include radiolabel binding moieties having the formula: -Gly-Gly-Cys- , Cys-Gly-Gly- , Gly-Gly-Cys- , $\text{-(}\epsilon\text{-Lys)-Gly-Cys-}$, $\text{-(}\delta\text{-Orn)-Gly-Cys-}$, $\text{-(}\gamma\text{-Dab)-Gly-Cys-}$, and $\text{-(}\beta\text{-Dap)-Gly-Cys-}$. (In these formulae, it will be understood that $\epsilon\text{-Lys}$ represents a lysine residue in which the ϵ -amino group, rather than the typical α -amino group, is covalently linked to the carboxyl group of the adjacent amino acid to form a peptide bond; $\delta\text{-Orn}$ represents an ornithine residue in which the δ -amino group, rather than the typical α -amino group, is covalently linked to the carboxyl group of the adjacent amino acid to form a peptide bond; $\gamma\text{-Dab}$ represents a 2,4-diaminobutyric acid residue in which the γ -amino group is covalently linked to the carboxyl group of the adjacent amino acid to form a peptide bond; and $\beta\text{-Dap}$ represents a 1,3-diaminopropionic acid residue in which the β -amino group is covalently linked to the carboxyl group of the adjacent amino acid to form a peptide bond.)

In another embodiment, the invention provides cyclic somatostatin receptor-binding peptide reagents capable of being radiolabeled with a radioisotope to form radiodiagnostic and radiotherapeutic agents, each comprising a somatostatin analogue that is covalently linked to a radiolabel-binding moiety of formula:



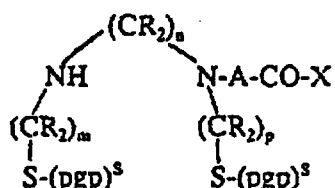
{for purposes of this invention, radiolabel-binding moieties having this structure will be referred to as picolinic acid (Pic)-based moieties}

or

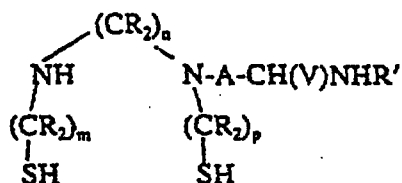


wherein X is H or a protecting group; (amino acid) is any amino acid and the radiolabel-binding moiety is covalently linked to the peptide. For purposes of this invention, radiolabel-binding moieties having this structure will be referred to as picolylamine (Pica)-based moieties. In a preferred embodiment, the amino acid is glycine and X is an acetamidomethyl protecting group. In another preferred embodiment, the agent is a scintigraphic imaging agent. In yet another preferred embodiment, the agent is a radiotherapeutic agent.

Yet another embodiment of the invention provides cyclic peptide reagents capable of being radiolabeled with a radioisotope for imaging sites within a mammalian body or for radiotherapeutic purposes, each comprising a somatostatin analogue that is covalently linked to a radiolabel-binding moiety that is a bisamino-bisthiol radiolabel-binding moiety. The bisamino bisthiol radiolabel-binding moiety in this embodiment of the invention has the formula:



wherein each R can be independently H, CH₃ or C₂H₅; each (pgp)^s can be independently a thiol protecting group or H; m, n and p are independently 2 or 3; A is linear or cyclic lower alkyl, aryl, heterocyclyl, combinations or substituted derivatives thereof; and X is peptide; or



wherein each R is independently H, CH₃, or C₂H₅; m, n and p are independently 2 or 3; A is linear or cyclic lower alkyl, aryl, heterocyclyl, combinations or substituted derivatives thereof; V is H or CO-peptide; R' is H or peptide; provided that when V is H, R' is peptide and when R' is H, V is peptide. For purposes of this invention, radiolabel-binding moieties having these structures will be referred to as "BAT" moieties. In a preferred embodiment, the agent is a scintigraphic imaging agent. In yet another preferred embodiment, the agent is a radiotherapeutic agent.

This invention provides methods for preparing peptide reagents of the invention by chemical synthesis *in vitro*. In a preferred embodiment, cyclic peptides are synthesized by solid phase peptide synthesis.

This invention provides reagents for preparing a radiolabeled somatostatin receptor-binding agent comprising the somatostatin receptor-binding cyclic peptides of the invention covalently linked to a radiolabel-binding moiety. In a preferred embodiment, the reagent is radioactively labeled with Tc-99m. In another preferred embodiment, the reagent is radioactively labeled with ^{117m}Sn, ¹⁸⁶Re or ¹⁸⁸Re.

The invention also comprises agents that are complexes of the cyclic somatostatin receptor-binding peptide reagents of the invention with a radioisotope, as well as methods for radiolabeling the peptide reagents of the invention. For example, scintigraphic imaging agents provided by the invention comprise Tc-99m labeled complexes formed by reacting the peptide reagents of the invention with Tc-99m in the presence of a reducing agent. Preferred reducing agents include but are not limited to dithionite ion, stannous ion and ferrous ion. Such Tc-99m complexes of the invention are also formed by labeling the peptide reagents of the invention with Tc-99m by ligand exchange of a prereduced Tc-99m complex as provided herein.

The invention also provides kits for preparing radiolabeled somatostatin-analogue, cyclic peptides from the peptide reagents of the invention. Kits for radiolabeling the peptide reagents of the invention are comprised of a sealed vial containing a predetermined quantity of a peptide reagent of the invention and a sufficient amount of reducing agent to radiolabel the reagent. In a preferred embodiment, the radiolabeled somatostatin analogue is a scintigraphic imaging agent. Also preferred is radiolabeling the peptide reagents of the invention with Tc-99m. Kits for preparing radiotherapeutic agents are also provided, wherein the preferred radioisotopes are tin-117m, rhenium-186 and rhenium-188.

This invention provides methods for using the radiolabeled somatostatin receptor-binding peptide reagents of the invention diagnostically and therapeutically. In one embodiment of the invention, methods are provided for using scintigraphic imaging agents that are Tc-99m labeled peptide reagents for imaging sites within a mammalian body by obtaining *in vivo* gamma scintigraphic images. These methods comprise administering an effective diagnostic amount of radiolabeled peptide reagents of the invention and detecting the gamma radiation emitted by the radiolabel localized at the site within the mammalian body.

The invention also provides methods for alleviating somatostatin-related diseases in animals, preferably humans, comprising administering a therapeutically effective amount of the radiolabeled somatostatin-binding peptide reagents of the invention to the animal. In preferred embodiments, the reagent is radioactively labeled with ^{117m}Sn , ^{186}Re or ^{188}Re .

This invention also provides somatostatin receptor-binding peptides covalently linked to a metal-binding moiety that are complexed with a magnetic, paramagnetic, supermagnetic, or superparamagnetic metal atom, ion or particle, and methods for using such complexes for magnetic-based detection of localization of such somatostatin receptor binding peptide complexes at tumor or other tissue sites *in vivo*. Thus, the invention provides non-radioactive methods for localizing tumor and other somatostatin receptor

expressing tissues *in vivo*.

The cyclic peptides and cyclic peptide reagents of the invention may also be comprised of a polyvalent linking moiety. Polyvalent linking moieties of the invention are comprised of at least 2 identical linker functional groups capable of covalently bonding to somatostatin analogue cyclic peptides or radiolabel-binding moieties or both. Preferred linker functional groups are primary or secondary amines, hydroxyl groups, carboxylic acid groups or thiol-reactive groups. In preferred embodiments, the polyvalent linking moieties are comprised of *bis*-succinimidylmethylether (BSME), 4-(2,2-dimethylacetyl)benzoic acid (DMBA), *N*-{2-(*N'*,*N'*-*bis*(2-succinimido-ethyl)aminoethyl)}-*N*⁶,*N*⁹-*bis*(2-methyl-2-mercapto-propyl)-6,9-diazanonanamide (BAT-BS), *tris*(succinimidylethyl)amine (TSEA), *bis*-succinimidohexane (BSH), 4-(O-CH₂CO-Gly-Gly-Cys.amide)-2-methylpropiophenone (ETAC), *tris*(acetamidoethyl)amine, *bis*-acetamidomethyl ether, *bis*-acetamidoethyl ether, α,ϵ -*bis*-acetyllysine, lysine and 1,8-*bis*-acetamido-3,6-dioxa-octane, or derivatives thereof.

Specific preferred embodiments of the present invention will become evident from the following more detailed description of certain preferred embodiments and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates localization of a somatostatin receptor expressing tumor in a tumor-bearing rat *in vivo*.

DETAILED DESCRIPTION OF THE INVENTION

The present invention provides cyclic peptides that are somatostatin analogues and that are not comprised of a disulfide bond. Such somatostatin analogues thereby possess increased *in vivo* stability compared with native somatostatin or somatostatin analogues that comprise a disulfide bond. These cyclic peptides are themselves therapeutic agents for alleviating diseases and other ailments in animals including humans.

Also provided by the invention are cyclic peptides that may be radioiodinated or radioastatinated and which are thereby useful in radiotherapeutic and radiodiagnostic applications.

Another embodiment of these cyclic peptides that is provided by this invention are cyclic peptide reagents wherein the cyclic peptides of the invention are covalently linked to a radiolabel-binding moiety. Such cyclic peptide reagents are capable of being radiolabeled to provide radiodiagnostic or radiotherapeutic agents. One example of a radiodiagnostic application using the radiolabeled agents of the invention is scintigraphic imaging, wherein the location and extent of somatostatin receptor-bearing tumors may be determined. The cyclic peptide reagents of the invention can also advantageously be radiolabeled with cytotoxic radioisotopes such as tin-117m, rhenium-186 or rhenium-188 for radiotherapeutic uses. The cyclic peptide reagents of the invention are also useful in preparing complexes with non-radioactive metals, said complexes being useful diagnostically and therapeutically.

The invention provides a method for using the somatostatin analogues of the invention to alleviate diseases or other ailments in animals, preferably humans. These diseases and ailments include but are not limited to diabetes and diabetes-related retinopathy, cirrhosis of the liver and hepatitis infection, bleeding ulcers and other gastrointestinal bleeding, pancreatitis, central nervous system disorders, endocrine disorders, Alzheimer's disease, acromegaly and other diseases and disorders related to the production of inappropriate levels of growth hormone *in vivo*, and cancer, particularly those cancers whose growth is dependent or influenced by growth hormone or somatostatin production. Dosages of the somatostatin analogues provided by the invention may be the same as those dosages of native somatostatin routinely used for treatment of the above or other diseases, or less of the compounds of the invention may be administered due to their longer *in vivo* half-life.

Labeling with Tc-99m is an advantage of the present invention because the nuclear and radioactive properties of this isotope make it an ideal scintigraphic imaging agent. This isotope has a single photon energy of about

140 keV and a radioactive half-life of about 6 hours, and is readily available from a ^{99}Mo - $^{99\text{m}}\text{Tc}$ generator. Other radionuclides may also be used in the practice of the invention as disclosed herein.

The term scintigraphic imaging agent as used herein is meant to encompass a radiolabeled agent capable of being detected with a radioactivity detecting means (including but not limited to a gamma-camera, a Geiger-Muller counter and a scintillation detector probe).

Radiotherapeutic embodiments of the invention, on the other hand, are advantageously labeled with a cytotoxic radioisotope, including but not limited to scandium-47, copper-67, gallium-72, yttrium-90, tin-117m, iodine-125, iodine-131, samarium-153, gadolinium-159, dysprosium-165, holmium-166, ytterbium-175, lutetium-177, rhenium-186, rhenium-188, astatine-211 and bismuth-212, most preferably ^{186}Re or ^{187}Re . Such embodiments are useful in the treatment of somatostatin-related diseases or other ailments in animals, preferably humans, including but not limited to cancer and other diseases characterized by the growth of malignant or benign tumors capable of binding somatostatin or somatostatin analogues *via* the expression of somatostatin receptors on the cell surface of cells comprising such tumors.

In the radiolabel-binding moieties and cyclic peptides covalently linked to such moieties that contain a thiol covalently linked to a thiol protecting group $\{(\text{pgp})^3\}$ provided by the invention, the thiol-protecting groups may be the same or different and may be but are not limited to:

- CH₂-aryl (aryl is phenyl or alkyl or alkyloxy substituted phenyl);
- CH-(aryl)₂, (aryl is phenyl or alkyl or alkyloxy substituted phenyl);
- C-(aryl)₃, (aryl is phenyl or alkyl or alkyloxy substituted phenyl);
- CH₂-(4-methoxyphenyl);
- CH-(4-pyridyl)(phenyl)₂;
- C(CH₃)₃;
- 9-phenylfluorenyl;
- CH₂NHCOR (R is unsubstituted or substituted alkyl or aryl);
- CH₂NHCOOR (R is unsubstituted or substituted alkyl or aryl);

-CONHR (R is unsubstituted or substituted alkyl or aryl);

-CH₂-S-CH₂-phenyl

Preferred protecting groups have the formula -CH₂-NHCOR wherein R is a lower alkyl having 1 and 8 carbon atoms, phenyl or phenyl-substituted with lower alkyl, hydroxyl, lower alkoxy, carboxy, or lower alkoxycarbonyl. The most preferred protecting group is an acetamidomethyl group.

Each somatostatin receptor-binding cyclic peptide-containing embodiment of the invention is comprised of a sequence of amino acids. The term amino acid as used in this invention is intended to include all L- and D- amino acids, naturally occurring and otherwise. Reagents comprising somatostatin receptor-binding peptides provided by the invention include but are not limited to the following illustrative examples of the peptide embodiments of the invention:

cyclo.(N-CH₂)F.YW_DKV.Hcy
CH₂CO.FYW_DKTFC.amide
CH₂CO.FFW_DKTF.Hhc.amide
cyclo.CYW_DKVC
CH₂CO.FFW_DKTFC.amide
cyclo.(N-CH₂)F.YW_DKV.K.(BAT)
cyclo.(N-CH₂)F.YW_DKV.Hcy(CH₂CO.K(ε-K)GC.amide)
cyclo.(N-CH₂)F.YW_DKV.Hcy(CH₂CO.C_{Ac}GC_{Ac}.amide)
cyclo.(N-CH₂)F.YW_DKV.Hcy(CH₂CO.CGC.amide)
cyclo.(N-CH₂)F.YW_DKV.Hcy(CH₂CO.CGC)
CH₂CO.FFW_DKTFC.(BAM)
cyclo.(N-CH₂)F.YW_DKV.Hcy(CH₂CO.(ε-K)GC.amide)
cyclo.(N-CH₂)F.YW_DKV.Hcy(CH₂CO.GGC.amide)
cyclo.(N-CH₂)F.YW_DKV.E.(BAM)
CH₂CO.NFFW_DKTFTC
CH₂CO.FFW_DKTFC
CH₂CO.FFW_DKTFC(ε-K)GC.amide
CH₂CO.FFW_DKTFC_{Ac}GC_{Ac}.amide
CH₂CO.FFW_DKTF.Hcy
CH₂CO.YW_DKTC
CH₂CO.YW_DKT.Hcy.amide
CH₂CO.YW_DKT.Hhc.T(CH₂OH)
CH₂CO.YW_DKTCTGGC_{Mob}.amide
CH₂CO.YW_DKT.Hhc
D-phenyl-CH₂CH₂CO.YW_DKTC
CH₂CO.FW_DKT.Pen
CH₂CO.FW_DKTHcy.amide
CH₂CO.YW_DKTCT

CH₂CO.YW_nKTCT(CH₂OH)
CH₂CO.YW_nKTCTC_{Ac}GC_{Ac}.amide
CH₂CO.FW_nKTHcy
CH₂CO.YW_nKTC.amide
(N-Me)FYW_nKV.Hcy(CH₂co.CGCE.amide)
CH₂CO.FFW_nKTFCKC_{Ac}GC_{Ac}.amide
CH₂CO.FFW_nKTFCC_{Ac}GC_{Ac}K.amide
CH₂CO.FFW_nKTFCC_{Ac}GC_{Ac}KKKKK.amide
CH₂CO.FFW_nKTFCKKKKK(ε-K)GC.amide
CH₂CO.FFW_nKTFCKKKKK(ε-K)GCKKKKK.amide
cyclo.(N-CH₃)FYW_nKV.Hcy(CH₂co.KKKKK(ε-K)GC.amide)
CH₂CO.FFW_nKTFCKGCGC.amide
cyclo.(N-CH₃)FYW_nKV.Hcy(CH₂co.GGCK.amide)
cyclo.(N-CH₃)FYW_nKV.Hcy(CH₂co.(ε-K)GCK.amide)
cyclo.(N-Me)FYW_nKV.Hcy(CH₂co.GGCR.amide)
cyclo.(N-Me)FYW_nKVHcy(CH₂co.GGCR.amide)
cyclo.(N-Me)FYW_nKV.Hcy(CH₂co.(ε-K)KC.amide)
cyclo.(N-Me)FYW_nKV.Hcy(CH₂co.GGCKK.amide)
cyclo.(N-Me)FYW_nKV.Hcy(CH₂co.GGC.Orn.amide)
cyclo.(N-Me)FYW_nKV.Hcy(CH₂co.GGC.Orn.DOrn..amide)
cyclo.(N-Me)FYW_nKV.Hcy(CH₂co.K(ε-K)KCK.amide)
cyclo.(N-Me)FYW_nKT
cyclo.(N-Me)FYW_nKVHcy(CH₂co.(ε-K)GCKK.amide)
cyclo.(N-CH₃)FYW_nKV.Hcy(CH₂coKKC.amide)
cyclo.(N-CH₃)FYW_nKV.Hcy(CH₂coKKCK.amide)
cyclo.(N-CH₃)FYW_nKV.Hcy(CH₂coGGCKKK.amide)
cyclo.(N-CH₃)FYW_nKV.HcyCH₂co.GGCR.R.amide
cyclo.(N-CH₃)FYW_nKV.HcyCH₂co.GGCRK.amide
cyclo.(N-CH₃)FYW_nKV.HcyCH₂co.GGCRD.amide
cyclo.(N-CH₃)FYW_nKV.HcyCH₂co.(ε-K)DCK.amide
cyclo.(N-CH₃)FYW_nKV.HcyCH₂coGGC.Orn.amide
cyclo.(N-CH₃)FYW_nKV.Hcy(CH₂co.GGCKDKD.amide)
cyclo.(N-CH₃)FYW_nKV.HcyCH₂co.GGCKD.amide
cyclo.(N-CH₃)FYW_nKV.HcyCH₂co.GGCKDK.amide
cyclo.(N-CH₃)FYW_nKV.HcyCH₂co.(ε-K)GCKKK.amide
cyclo.(N-CH₃)FYW_nKV.Hcy(CH₂co.(β-Dap)GCK.amide)
cyclo.(N-CH₃)FYW_nKV.Hcy(CH₂co.(δ-Orn)GCK.amide)
cyclo.(N-CH₃)FYW_nKV.Hcy(CH₂co.(ε-K)GCRK.amide)
cyclo.(N-CH₃)FYW_nKV.Hcy(CH₂co.(ε-K)GCR.amide)
cyclo.(N-CH₃)FYW_nKVC
cyclo.(N-CH₃)FYW_nKT.Hcy
cyclo.PYW_nKV.Hcy
cyclo.(N-CH₃)FYW_nKV.Hcy(CH₂co.(γ-Dab)GCK.amide)
cyclo.(N-CH₃)FYW_nKV.Hcy(CH₂co.GRCK.amide)
cyclo.(N-CH₃)FYW_nKV.Hcy(CH₂co.KRC.amide)
cyclo.(N-CH₃)FYW_nKV.Hcy(CH₂co.GKCR.amide)

cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.RRC.amide)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.GGCE.amide)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.GGC.Apc.amide)
cyclo. (N-CH₃)S_nYW_nKV.Hcy
cyclo. PYW_nKV.Hcy(CH₂co.GGCK.amide)
cyclo. (NMe)FW_nKVC(CH₂co.GGCK.amide)
cyclo. (NMe)FW_nKT.Hcy(CH₂co.GGCK.amide)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.RKC.amide)
cyclo. (N-CH₃)S_nYW_nKV.Hcy(CH₂co.GGCK.amide)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.GKCK.amide)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.KGCK.amide)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.KGGCK.amide)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.KGGC.amide)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.GGGCK.amide)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.RGGC.amide)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.SSC.amide)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.SSCK.amide)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.(β-Dap)KCK.amide)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.(β-Dap)DCK.amide)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.(β-Dap)KCD.amide)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.(β-Dap)KCR.amide)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.(β-Dap)GCR.amide)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.(β-Dap)RCK.amide)
cyclo. (N-CH₃)FYW_nKV.Hcy(GK(-CH₂co.)C.amide)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.GGCR.acid)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.GRC.amide)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.GGCK.acid)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.GKC.acid)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.GRC.acid)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.KKC.acid)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.CG.Dap.Dap.amide)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.(δ-O)GCR.amide)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.GNCR.amide)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.(δ-O)GCN.amide)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.GGC.Dap.amide)
cyclo. (Hvp.YW_nKV.Hcy)
cyclo. (Hvp.YW_nKV.Hcy)(CH₂co.GGCK.amide)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.(γ-Dab)KCK.amide)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.(γ-Dab)KCR.amide)
cyclo. (N-CH₃)FYW_nKV.Hcy(CH₂co.(δ-O)KCK.amide).

As used herein, the following amino acids and amino acid analogues are intended to be represented by the following abbreviations: Ac is an acetyl group; ma is mercaptoacetic acid group; Aca is 6-aminocaproic acid; Hcy is homocysteine; Hhc is homohomocysteine (3-mercaptopropylglycine); Pen is penicillamine; Mob is the sulphydryl protecting group 4-methoxybenzyl; Acn is

the sulfhydryl protecting group acetamidomethyl; Aib is aminoisobutyric acid; Nal is 2-naphthylalanine; Ain is 2-aminoindan-2-carboxylic acid; Hly is homolysine; Achxa is 4-amino-cyclohexylalanine; Amf is 4-aminomethyl-phenylalanine; Aec is S-(2-aminoethyl)cysteine; Apc is S-(3-aminopropyl) cysteine; Aes is O-(2-aminoethyl)serine; Aps is O-(3-aminopropyl)serine; Abu is 2-aminobutyric acid; Nva is norvaline; F_D is D-phenylalanine; W_D is D-tryptophan; Y_D is D-tyrosine; Cpa is L-(4-chlorophenyl) alanine; Thp is 4-amino-tetrahydrothiopyran-4-carboxylic acid; D-Nal is D-2-naphthylalanine; Dpg is dipropylglycine; and Nle is norleucine. All naturally-occurring amino acids are abbreviated using standard abbreviations (which can be found in G. Zubay, *Biochemistry* (2d. ed.), 1988 (MacMillen Publishing: New York) p.33).

For the purposes of this invention, the naturally-occurring amino acids are characterized as lipophilic (alanine, isoleucine, leucine, methionine, phenylalanine, tyrosine, proline, tryptophan and valine, as well as S-alkylated derivatives of cysteine), hydrophilic (asparagine, glutamine, threonine, serine), acidic (glutamic acid and aspartic acid), basic (arginine, histidine and lysine). T(CH₂OH) represents a threoninol residue, wherein the carboxyl group of the amino acid is reduced to a primary alcohol, incorporated into the peptide using the procedure of Neugebauer *et al.* (1990, Peptides: Proceedings of the 11th American Peptide Symposium, pp. 1020-21). ϵ -K is intended to represent a covalent linkage *via* the ϵ -amino group on the sidechain of a lysine residue. δ -Orn represents an ornithine residue in which the δ -amino group, rather than the typical α -amino group, is covalently linked to the carboxyl group of the adjacent amino acid to form a peptide bond. γ -Dab represents a 2,4-diaminobutyric acid residue in which the γ -amino group is covalently linked to the carboxyl group of the adjacent amino acid to form a peptide bond. β -Dap represents a 1,3-diaminopropionic acid residue in which the β -amino group is covalently linked to the carboxyl group of the adjacent amino acid to form a peptide bond. Pic is picolinoyl (pyridine-2-carbonyl); Pica is picolylamine (2-(aminomethyl)pyridine); (BAT) represents *N⁶,N⁹-bis(2-mercapto-2-*

methyl-propyl)-6,9-diazanonanoic acid; K.(BAT) and Lys.(BAT) represent the amino acid lysine, acylated at the ϵ -amino group on the amino acid sidechain to (BAT); (BAM) is $(N',N'$ -bis(2-mercapto-2-methylpropyl)-1,4,10-triazadecane; E.(BAM) and Glu.(BAM) represent the amino acid glutamic acid having a γ -amide linkage between the sidechain carboxylic acid group of glutamic acid and a (BAM)-derived primary amino group; (BAT-BM) is N -{2-(N',N' -bis(2-maleimidoethyl)aminoethyl)- N^6 -(*t*-butoxycarbonyl)- N^8,N^8 -bis(2-methyl-2-triphenylmethylthiopropyl)-6,9-diazanonanamide; (BAT-BS) is N -{2-(N',N' -bis(2-succinimidoethyl)aminoethyl)- N^6,N^8 -bis(2-mercapto-2-methylpropyl)-6,9-diazanonanamide; (BMME) is *bis*-maleimidomethylether; (BSME) is *bis*-succinimidomethylether; and (DTPA) is diethylenetriaminepentaacetic acid. Hcy(alkyl group) is homocysteine, *S*-alkylated with the group in parenthesis.

The convention used herein of representing by underlining a covalent bond between atoms and groups of atoms, such as the amino terminus and carboxyl terminus resulting in the cyclic peptides of the invention, or similar representations of covalent bonding between the sidechain sulfur atom of a cysteine residue or derivative thereof and an amino terminal acyl group or other residue will also be understood by those with skill in the art. The use of the term "*cyclo*" herein is intended to indicate that the peptide is cyclized by formation of a covalent bond between the atoms of the amino terminal substituted or unsubstituted amino group and the carboxyl terminus of the peptide.

For the purposes of this invention the term "poly(*N*-carboxyalkyl)amine" is intended to describe a series of compounds exemplified by nitrilotriacetic acid, iminodiacetic acid, ethylenediaminetetraacetic acid (EDTA) and diethylenepentaacetic acid (DTPA).

For the purposes of this invention the term "polyoxyanion" is intended to encompass sulfates, phosphates, sulfonates, phosphonates, and like compounds.

Somatostatin analogue peptides of the present invention can be chemically synthesized *in vitro*. Peptides of the present invention can generally

advantageously be prepared on a peptide synthesizer. The peptides of this invention can be synthesized wherein the radiolabel-binding moiety is covalently linked to the peptide during chemical synthesis *in vitro*, using techniques well known to those with skill in the art. Such peptides covalently-linked to the radiolabel-binding moiety during synthesis are advantageous because specific sites of covalent linkage can be determined.

Radiolabel binding moieties of the invention may be introduced into the target somatostatin analogue peptides during peptide synthesis. For embodiments comprising picolinic acid (designated (Pic-); *e.g.*, Pic-Gly-Cys(protecting group)-), the radiolabel-binding moiety can be synthesized as the last (*i.e.*, amino-terminal) residue in the synthesis. In addition, the picolinic acid-containing radiolabel-binding moiety may be covalently linked to the ϵ -amino group of lysine to give, for example, α N(Fmoc)-Lys- ϵ N{Pic-Gly-Cys(protecting group)}, which may be incorporated at any appropriate position in the peptide chain. This sequence is particularly advantageous as it affords an easy mode of incorporation into the target somatostatin analogue peptide.

Similarly, the picolylamine (Pica)-containing radiolabel-binding moiety (-Cys(protecting group)-Gly-Pica) can be prepared during peptide synthesis by including the sequence (-Cys(protecting group)-Gly-) at the carboxyl terminus of the peptide chain. Following cleavage of the peptide from the resin the carboxyl terminus of the peptide is activated and coupled to picolylamine. This synthetic route requires that reactive side-chain functionalities remain masked (protected) and do not react during the conjugation of the picolylamine.

This invention also provides small synthetic peptides that are somatostatin analogues and incorporate bisamine bisthiol (BAT) chelators that may be labeled with Tc-99m.

This invention provides for the incorporation of BAT chelators into virtually any position in the peptide, *via* covalently linkage to any appropriate functional group of the peptide, except that the chelating moieties of the invention are not covalently linked to functional groups comprising the amino acid side chains of the

amino acids B¹, B², B³ or B⁴ as defined above.

In forming a complex of radioactive technetium with the reagents of this invention, the technetium complex, preferably a salt of Tc-99m pertechnetate, is reacted with the reagent in the presence of a reducing agent. Preferred reducing agents are dithionite, stannous and ferrous ions; the most preferred reducing agent is stannous chloride. Means for preparing such complexes are conveniently provided in a kit form comprising a sealed vial containing a predetermined quantity of a reagent of the invention to be labeled and a sufficient amount of reducing agent to label the reagent with Tc-99m. Alternatively, the complex may be formed by reacting a reagent of this invention with a pre-formed labile complex of technetium and another compound known as a transfer ligand. This process is known as ligand exchange and is well known to those skilled in the art. The labile complex may be formed using such transfer ligands as tartrate, citrate, gluconate or mannitol, for example. Among the Tc-99m pertechnetate salts useful with the present invention are included the alkali metal salts such as the sodium salt, or ammonium salts or lower alkyl ammonium salts.

In a preferred embodiment of the invention, a kit for preparing technetium-labeled peptides is provided. An appropriate amount of the peptide reagent is introduced into a vial containing a reducing agent, such as stannous chloride, in an amount sufficient to label the peptide with Tc-99m. An appropriate amount of a transfer ligand as described (such as tartrate, citrate, gluconate or mannitol, for example) can also be included. The kit may also contain conventional pharmaceutical adjunct materials such as, for example, pharmaceutically acceptable salts to adjust the osmotic pressure, buffers, preservatives and the like. The components of the kit may be in liquid, frozen or dry form. In a preferred embodiment, kit components are provided in lyophilized form.

Tc-99m labeled imaging reagents according to the present invention may be prepared by the addition of an appropriate amount of Tc-99m or Tc-99m complex into the vials and reaction under conditions described in Example 2 hereinbelow.

Radioactively-labeled scintigraphic imaging agents provided by the present invention are provided having a suitable amount of radioactivity. In forming Tc-99m radioactive complexes, it is generally preferred to form radioactive complexes in solutions containing radioactivity at concentrations of from about 0.01 millicurie (mCi) to 100 mCi per mL.

The imaging reagents provided by the present invention can be used for visualizing organs such as the kidney for diagnosing disorders in these organs, and tumors, in particular gastrointestinal tumors, myelomas, small cell lung carcinoma and other APUDomas, endocrine tumors such as medullary thyroid carcinomas and pituitary tumors, brain tumors such as meningiomas and astrocytomas, and tumors of the prostate, breast, colon, and ovaries can also be imaged. In accordance with this invention, the Tc-99m labeled peptide reagents are administered in a single unit injectable dose. The Tc-99m labeled peptide reagents provided by the invention may be administered intravenously in any conventional medium for intravenous injection such as an aqueous saline medium, or in blood plasma medium. Generally, the unit dose to be administered has a radioactivity of about 0.01 mCi to about 100 mCi, preferably 1 mCi to 20 mCi. The solution to be injected at unit dosage is from about 0.01 mL to about 10 mL. After intravenous administration, imaging *in vivo* can take place in a matter of a few minutes. However, imaging can take place, if desired, in hours or even longer, after the radiolabeled peptide is injected into a patient. In most instances, a sufficient amount of the administered dose will accumulate in the area to be imaged within about 0.1 of an hour to permit the taking of scintiphotos. Any conventional method of scintigraphic imaging for diagnostic purposes can be utilized in accordance with this invention.

The somatostatin receptor-binding cyclic peptides and non-radioactive metal complexes of the cyclic peptide reagents of the invention may be used clinically as therapeutic agents to promote regression of certain types of tumors, particularly those that express somatostatin receptors. The somatostatin analogue cyclic peptides of the invention can also be used to reduce the hormonal hypersecretion

that often accompanies certain cancers, such as the APUDomas. Peptides of the invention used as therapeutic agents may be administered by any appropriate route, including intravenous, intramuscular or by mouth, and in any acceptable pharmaceutical carrier, in doses ranging from about 0.1 to about 49 mg/kg body weight/day.

This invention also provides peptides radiolabeled with cytotoxic radioisotopes such as tin-117m, rhenium-186 or rhenium-188 that may be used for radiotherapy of certain tumors as described above. For this purpose, an amount of radioactive isotope from about 10mCi to about 200mCi may be administered *via* any suitable clinical route, preferably by intravenous injection.

This invention also provides somatostatin receptor-binding peptides covalently linked to a metal-binding moiety that are complexed with a magnetic, paramagnetic, supermagnetic, or superparamagnetic metal atom, ion or particle, and methods for using such complexes for magnetic-based detection of localization of such somatostatin receptor binding peptide complexes at tumor or other tissue sites *in vivo*. Thus, the invention provides non-radioactive methods for localizing tumor and other somatostatin receptor expressing tissues *in vivo*.

This invention provides methods for using the diagnostic and radiodiagnostic and therapeutic and radiotherapeutic agents of the invention. For radiolabeled embodiments of the agents of the invention, for example, Tc-99m labeled scintigraphic imaging agents, an effective diagnostic or therapeutic amount of the diagnostic or radiodiagnostic or therapeutic or radiotherapeutic agent of the invention are administered. In radiodiagnostic embodiments, localization of the radiolabel is detected using conventional methodologies such as gamma scintigraphy. In non-radioactive diagnostic embodiments, localization of sites of accumulation of the paramagnetic metal-labeled diagnostic agents of the invention is achieved using magnetic resonance imaging methodologies. The imaging agents provided by the invention have utility for tumor imaging, particularly for imaging primary and metastatic neoplastic sites wherein said neoplastic cells express somatostatin receptors (SSTR), and in particular such primary and especially

metastatic tumor cells that have been clinically recalcitrant to detection using conventional methodologies. In addition, the imaging agents of the invention are useful in detecting sites of T lymphocyte accumulation associated with occult disease or pathology, e.g., as occurs in patients suffering from tuberculosis.

The methods for making and labeling these compounds are more fully illustrated in the following Examples. These Examples illustrate certain aspects of the above-described method and advantageous results, and are shown by way of illustration and not limitation.

EXAMPLE 1

Solid Phase Peptide Synthesis

Solid phase peptide synthesis (SPPS) was carried out on a 0.25 millimole (mmole) scale using an Applied Biosystems Model 431A Peptide Synthesizer and using 9-fluorenylmethyloxycarbonyl (Fmoc) amino-terminus protection, coupling with dicyclohexylcarbodiimide/hydroxybenzotriazole or 2-(1H-benzotriazol-1-yl)-1,1,3,3-tetramethyluronium hexafluorophosphate/ hydroxybenzotriazole (HBTU/HOBT), and using *p*-hydroxymethyl henoxymethyl-polystyrene (HMP) resin or Sasrin™ resin for carboxyl-terminus acids or Rink amide resin for carboxyl-terminus amides.

Where appropriate, the following amino acid derivatives were synthesized. Homocysteine was prepared by alkaline hydrolysis of L-homocysteine lactone, or by reduction of L-homocystine using metallic sodium in liquid ammonia. Threoninol residues, wherein the carboxyl group of the amino acid is reduced to a primary alcohol, can be introduced into the peptides of the invention where appropriate using the procedure of Neugebauer *et al.* (1990, Peptides: Proceedings of the 11th American Peptide Symposium, pp. 1020-21). Fmoc.Hcy(Trt) and Fmoc.Pen(Trt) were prepared from the appropriate amino acids by tritylation with triphenylmethanol in TFA, followed by Fmoc derivitization as described by Atherton *et al.* (1989, Solid Phase Peptide Synthesis, IRL Press: Oxford).

Fmoc.homohomocysteine(Trt) was prepared by reducing *N,N*-bis-Boc-glutamic acid- α -methyl ester with borane-THF, followed by mesylation and reaction with trityl-mercaptide, followed by removal of the Boc groups with BF_3OEt_2 in acetic acid, and then Fmoc derivitization as described above. *phenyl-CH}_2\text{CHBrCOOH}* was prepared by treating phenylalanine (in a solution of water and TFA/ saturated with NaBr) with sodium nitrite, followed by distillation to recover the pure product.

Where appropriate, 2-chloroacetyl, 2-bromoacetyl and 2-bromo-3-phenylpropionyl groups were introduced either by using the appropriate 2-halo acid as the last residue coupled during SPPS, or by treating the N-terminus free amino acid peptide bound to the resin with either 2-halo acid/ diisopropylcarbodiimide/*N*-hydroxysuccinimide/NMP or 2-halo acid anhydride/ diisopropylethylamine/NMP.

Where appropriate, HPLC-purified 2-haloacylated peptides were cyclized by stirring an 0.1-1.0 mg/mL solution in phosphate or bicarbonate buffer or dilute ammonium hydroxide (pH 8.0), optionally containing 0.5-1.0 mM EDTA, or acetonitrile or THF for 1-48 h followed optionally by acidification with acetic acid, lyophilization and HPLC purification.

Where appropriate, thiol-containing peptides were reacted with chloroacetyl-containing, thiol-protected Tc-99m complexing moieties at pH 10 for 0.5-4 hours at room temperature, followed by acetic acid acidification and evaporation of the solution to give the corresponding peptide-sulfide adduct. Deprotection and purification were routinely performed as described to yield the chelator-peptide conjugate.

Where appropriate, BSME adducts were prepared by reacting single thiol-containing peptides (5 to 50 mg/mL in DMF buffered to pH 7 with *N*-methylmorpholine or *N*-ethyl-morpholine, or 50mM sodium phosphate buffer, pH 7-8, optionally containing 0.5mM EDTA or DMF or THF or acetonitrile) with 0.5 molar equivalents of BMME (*bis*-maleimidomethylether) pre-dissolved in acetonitrile at room temperature for approximately 1-18 hours. The solution was concentrated and the product was purified by HPLC.

Where appropriate, TSEA adducts were prepared by reacting single thiol-

containing peptide (at concentrations of 10 to 100 mg/mL peptide in DMF buffered to pH 7 with N-methylmorpholine or N-ethylmorpholine, or 5 to 50 mg/mL peptide in 50mM sodium phosphate, pH 7-8, optionally containing 0.5mM EDTA or DMF or THF or acetonitrile) with 0.33 molar equivalents of TMEA (*tris*(2-maleimidoethyl)amine) pre-dissolved in acetonitrile or DMF, with or without 1 molar equivalent of triethanolamine, at room temperature for approximately 1-18h. Such reaction mixtures containing adducts were concentrated and the adducts were then purified using HPLC.

Where appropriate, {BAM} (*N',N'*-bis(2-mercapto-2-methylpropyl)-1,4,10-triazadecane) was conjugated to the peptide by first activating the peptide carboxylate with a mixture of diisopropylcarbodiimide/ N-hydroxysuccinimide or HBTU/HOBt in DMF, NMP or methylene chloride, followed by coupling in the presence of diisopropylethylamine. After coupling, the conjugates were deprotected as described above.

Where appropriate, (BAT) (*N⁶,N⁹*-bis(2-mercapto-2-methylpropyl)-6,9-diazanonanoic acid) was incorporated into peptide as (*N*α(Fmoc)-*N*ε(*N*-Boc)-*S,S'*-bistrityl-BAT)lysine (prepared from *N*α(Fmoc)-lysine and *N*ε(*N*-Boc)-*S,S'*-bistrityl-BAT as described in Example 2 of co-owned and co-pending U.S. Patent Application Serial No. 08/_____, incorporated by reference) during peptide synthesis and then deprotected after cleavage of the completed peptide from the synthetic resin.

Where appropriate, BAT-BS (*N*-{2-(*N',N'*-bis(2-succinimidoethyl)aminoethyl)}-*N⁶,N⁹*-bis(2-methyl-2-mercaptopropyl)-6,9-diazanonanamide) adducts were prepared by reacting single thiol-containing peptide (at concentrations of 2 to 50 mg/mL peptide in DMF buffered to pH 7 with *N*-methylmorpholine or *N*-ethylmorpholine, or in 50mM sodium phosphate (pH 7-8), optionally containing 0.5mM EDTA or DMF or THF or acetonitrile) with 0.5 molar equivalents of BAT-BM (*N*-{2-(*N',N'*-bis(2-maleimidoethyl)aminoethyl)}-*N⁹*-(*t*-butoxycarbonyl)-*N⁶,N⁹*-bis(2-methyl-2-triphenylmethylthiopropyl)-6,9-diaza-nonanamide} pre-dissolved

in acetonitrile or THF, at room temperature for approximately 1-18h. The solution was then evaporated to dryness and (BAT-BS)-peptide conjugates deprotected by treatment with 10mL TFA and 0.2mL triethylsilane for 1h. The solution was concentrated, the product adducts precipitated with ether, and then purified by HPLC.

Where appropriate, the (DTPA) moiety can be introduced using the method of Bakker *et al.* (1991, Life Sci. 49: 1583-1591, hereby incorporated by reference).

Where appropriate, peptide precursors were cyclized (between the amino- and carboxyl-termini) by reaction of the sidechain-protected, N-terminal free amine and C-terminal free acid with diphenylphosphorylazide.

Sasrin™ resin-bound peptides were cleaved using a solution of 1% TFA in dichloromethane to yield the protected peptide. Where appropriate, protected peptide precursors were cyclized between the amino- and carboxyl-termini by reaction of sidechain-protected, amino-terminal free amine and carboxyl-terminal free acid using diphenylphosphorylazide.

HMP or Rink amide resin-bound products were routinely cleaved and protected cyclized peptides deprotected using a solution comprised of trifluoroacetic acid (TFA), or TFA and methylene chloride, optionally comprising water, thioanisole, ethanedithiol, and triethylsilane or trisopropylsilane in ratios of 100 : 5 : 5 : 2.5 : 2, for 0.5 - 3 hours at room temperature. Where appropriate, products were re-*S*-tritylated in triphenolmethanol/ TFA, and *N*-Boc groups re-introduced into the peptide using (Boc)₂O.

Resin-bound products were routinely cleaved using a solution of trifluoroacetic acid or trifluoroacetic acid and methylene chloride, optionally containing water, thioanisole, ethanedithiol, and triethylsilane, prepared in ratios of 100 : 5 : 5 : 2.5 : 2 for 0.5 - 3 h at room temperature. Crude peptides were purified by preparative high pressure liquid chromatography (HPLC) using a Waters Delta Pak C18 column and gradient elution using 0.1% trifluoroacetic acid (TFA) in water modified with acetonitrile. Acetonitrile was evaporated from the

eluted fractions which were then lyophilized. The identity of each product was confirmed by fast atom bombardment mass spectroscopy (FABMS) or by electrospray mass spectroscopy (ESMS).

Somatostatin analogues synthesized as provided herein, as well as the products of such synthesis identified by FABMS, are shown in Table I below.

EXAMPLE 2

A General Method for Radiolabeling with Tc-99m

0.1 mg of a peptide prepared as in Example 1 was dissolved in 0.1 mL of water or 50/50 ethanol/water or phosphate-buffered saline or 50 mM potassium phosphate buffer (pH = 5, 6 or 7.4), or 0.9% saline or 10% hydroxypropylcyclodextrin (HPCD) in water. Tc-99m gluceptate was prepared by reconstituting a Glucoscan vial (E.I. DuPont de Nemours, Inc., Wilmington, DE) with 1.0 mL of Tc-99m sodium pertechnetate containing up to 200 mCi and allowed to stand for 15 minutes at room temperature. 25 μ l of Tc-99m gluceptate was then added to the peptide and the reaction allowed to proceed at room temperature or at 100°C for about 5-30 min and then filtered through a 0.2 μ m filter.

The Tc-99m labeled peptide purity was determined by HPLC using the following conditions: a Waters Delta Pak RP-18, 5 μ , 4.6mm x 220mm analytical column, or a Waters NovaPak Radial Compression C-18, 4 μ m, 8mm x 100mm analytical column was loaded with each radiolabeled peptide, and the peptides eluted at a solvent flow rate equal to 1 mL/min (Delta-Pak) or 3mL/min (NovaPak). Gradient elution was performed beginning with 100% solvent A (0.1% CF₃COOH/H₂O) and ending with 100% solvent B₉₀ (0.1% CF₃COOH/90% CH₃CN/H₂O) over the course of 10-20 min.

Radioactive components were detected using an in-line radiometric detector linked to an integrating recorder. Tc-99m gluceptate and Tc-99m sodium pertechnetate elute between 1 and 4 minutes under these conditions, whereas the Tc-99m labeled peptides eluted after a much greater amount of time, as illustrated in Table I below.

TABLE I

	MH+ FABMS	RCY (%)	R _t (min)
<u>cyclo.CYW₀KVC</u>	783	98 ¹	11.4 ¹
<u>cyclo.(N-CH₃)F.YW₀KV.K(BAT)</u>	1185	90 ¹	13.3, 14.4 ¹
<u>cyclo.(N-CH₃)F.YW₀KV.Hcy(CH₂co.CGC.amide)</u>	1176	99 ⁴	16.1 ³
<u>cyclo.(N-CH₃)F.YW₀KV.Hcy(CH₂co.CGC)</u>	1177	99 ⁴	15.8, 17.8 ³
<u>CH₂CO.FFW₀KTFC.(BAM)</u>	1322	99	18.8
<u>cyclo.(N-CH₃)F.YW₀KV.Hcy(CH₂co.(ε-K)GC.amide)</u>	1201	99 ³	15.3 ³
<u>cyclo.(N-CH₃)F.YW₀KV.Hcy(CH₂co.GGC.amide)</u>	1129	98 ⁴	15.1, 17.2 ³
<u>cyclo.(N-CH₃)F.YW₀KV.E(BAM)</u>	1171	98 ¹	12.3, 13.6 ¹
<u>CH₂CO.FFW₀KTFC(ε-K)GC.amide</u>	1305	99 ⁴	16.5 ³
<u>CH₂CO.FFW₀KTFC_{Acn}GC_{Acn}.amide</u>	1422	99	15.1-16.9
<u>CH₂CO.YW₀KTCTC_{Acn}GC_{Acn}.amide</u>	1246	94 ²	16.6, 16.9 ²
<u>(N-CH₃)FFW₀KTFC_{Acn}GC_{Acn}.amide</u>	1609	92 ⁶	15.5 ³
<u>CH₂CO.FFW₀KTFC_{Acn}GC_{Acn}.amide</u>	1947	99 ⁴	15.8 ³
<u>CH₂CO.FFW₀KTFC(ε-K)GCKKKK.amide</u>	1947	99 ³	14.9 ³
<u>cyclo.(NCH₃)FYW₀KV.Hcy(CH₂co.KKKKK(ε-K)GC.amide)</u>	1841	98 ³	13.4 ³
<u>CH₂CO.YW₀KTC.amide</u>	740	N.D.	N.D.

TABLE I (cont'd.)

<u>Peptide</u>	<u>MH+</u> <u>FABMS</u>	<u>RCY</u> <u>(%)</u>	<u>R_t</u> <u>(min)</u>
<u>CH₃CO.FFW_DKTFCGGC.amide</u>	1434	99 ^d	16.2-17.2 ³
<i>cyclo</i> .(N-CH ₃)FYW _D KV.Hcy(CH ₃ CO.GGCK.amide)	1258	99 ^d	15.0 ³
<i>cyclo</i> .(N-CH ₃)FYW _D KV.Hcy(CH ₃ CO.(ε-K)GCK.amide)	1329	99 ^d	14.7 ³
<i>cyclo</i> .(N-Me)FYW _D KV.Hcy(CH ₃ CO.GGCR.amide)	1285	99 ³	15.1 ³
<i>cyclo</i> .(N-Me)FYW _D KV.Hcy(CH ₃ CO.(ε-K)KC.amide)	1472	99 ^d	14.5 ³
<i>cyclo</i> .(N-Me)FYW _D KV.Hcy(CH ₃ CO.GGC.Orn.amide)	1244	98 ⁵	7.0 ^d
<i>cyclo</i> .(N-CH ₃)FYW _D KV.Hcy(CH ₃ CO.(β-Dap)KCK.amide)	1358	97 ⁵	7.0 ^d

* The following labeling conditions were used with the appropriate peptides:

1. The peptide is dissolved in water and labeled at room temperature.
2. The peptide is dissolved in water and labeled at 100°C (15 min).
3. The peptide is dissolved in 10% hydroxypropylcyclodextrin and labeled at room temperature.
4. The peptide is dissolved in 50% ethanol/water and labeled at room temperature.
5. The peptide is dissolved in 0.9% saline and labeled at 100°C (5 min).
6. The peptide is dissolved in water made pH 9 with bicarbonate and labeled at 100°C.

** HPLC methods:

general: solvent A = 0.1% CF₃COOH/H₂O
 solvent B₉₀ = 0.1% CF₃COOH/90% CH₃CN/H₂O
 solvent flow rate = 1 mL/min or 3mL/min

Vydak column = Vydak 218TP54 RP-18, 5μ x 220mm x 4.6mm analytical column with guard column

Waters column 1 = Waters Delta-Pak C18, 5μm, 39 X 150mm

Waters column 2 = Waters NovaPak Radial Compression C-18, 4μm, 8 X 100mm

Method 1:	Waters column 1	100% A to 100% B ₉₀ in 10 min
Method 2:	Vydak column	100% A to 100% B ₉₀ in 10 min
Method 3:	Waters column 1	100% A to 100% B ₉₀ in 20 min
Method 4:	Waters column 2	100% A to 100% B ₉₀ in 10 min

Single-letter abbreviations for amino acids can be found in G. Zubay, *Biochemistry* (2d. ed.), 1988 (MacMillen Publishing: New York) p.33; Ac = acetyl; Acm = acetamidomethyl; ma = mercaptoacetic acid; Mob = 4-methoxybenzyl; Aca = 6-aminocaproic acid; Hly = homolysine; Apc = L-{S-(3-aminopropyl)cysteine; F_D = D-phenylalanine; W_D = D-tryptophan; Y_D = D-tyrosine; Cpa = L-(4-chlorophenyl)alanine; Thp = 4-amino-tetrahydrothiopyran-4-carboxylic acid; D-Nal = D-2-naphthylalanine; Dpg = dipropylglycine; Nle = norleucine; Hcy = homocysteine; Hhc = homohomocysteine; Pen = penicillamine; Aib = aminoisobutyric acid; Nal = 2-naphthylalanine; D-Nal = D-2-naphthylalanine; Ain = 2-aminoindan-2-carboxylic acid; Achxa = 4-amino-cyclohexylalanine; Amf = 4-aminomethyl-phenylalanine; Aec = S-(2-aminoethyl)cysteine; Apc = S-(3-aminopropyl)cysteine; Aes = O-(2-aminoethyl)serine; Aps = O-(3-aminopropyl)serine; Abu = 2-aminobutyric acid; Nva = norvaline; T(CH₂OH)

= threoninol (on which the carboxylic acid moiety has been reduced to a primary alcohol); ϵ -K = a lysine residue in a peptide in which the peptide bond involves the ϵ -amino group on the lysine sidechain rather than the α -amino group; δ -Orn = an ornithine residue in which the δ -amino group, rather than the typical α -amino group, is covalently linked to the carboxyl group of the adjacent amino acid to form a peptide bond; γ -Dab = a 2,4-diaminobutyric acid residue in which the γ -amino group is covalently linked to the carboxyl group of the adjacent amino acid to form a peptide bond; β -Dap = a 1,3-diaminopropionic acid residue in which the β -amino group is covalently linked to the carboxyl group of the adjacent amino acid to form a peptide bond; Pic = picolinoyl (pyridine-2-carbonyl); Pica = picolylamine (2-(aminomethyl)pyridine); BAT = N^6, N^9 -bis(2-mercapto-2-methylpropyl)-6,9-diazanonanoic acid; BAT acid (protected) = N^9 -(*t*-butoxycarbonyl)- N^6, N^9 -bis(2-methyl-2-triphenylmethylthiopropyl)-6,9-diazanonanoic acid; BAM = N^1, N^4 -bis(2-mercapto-2-methylpropyl)-1,4,10-triazadecane; BAM (protected) = N^1 -(*t*-butoxycarbonyl)- N^1, N^4 -bis(2-methyl-2-triphenylmethylthiopropyl)-1,4,10-triazadecane; {BAT-BM} = N -{2-(N', N' -bis(2-maleimidoethyl)aminoethyl)- N^9 -(*t*-butoxycarbonyl)- N^6, N^9 -bis(2-methyl-2-triphenylmethylthiopropyl)-6,9-diazanonanamide; {BAT-BS} = N -{2-(N', N' -bis(2-succinimidoethyl)aminoethyl)- N^6, N^9 -bis(2-mercapto-2-methylpropyl)-6,9-diazanonanamide; {BMME} = bis-maleimidomethylether; {BSME} = bis-succinimidomethylether; {DTPA} = diethylenetriaminepentaacetic acid.

Non-radioactive rhenium complexes were prepared by co-dissolving each of the peptide reagents of the invention with about one molar equivalent of tetrabutylammonium oxotetra-bromorhenate (+5), prepared as described by Cotton *et al.* (1966, *Inorg. Chem.* 5: 9-16) in dimethylformamide or acetonitrile/water and stirred for 0.5-5 days. The rhenium complexes were isolated by reverse phase HPLC as described above for Tc-99m labeled peptides and were characterized by FABMS or ESMS.

Radioactive rhenium complexes, using for example Re-186 or Re-188, are prepared from the appropriate perrhenate salts using the same protocol as for Tc-99m labeling, or by adding a reducing agent to a solution of the peptide and perrhenate, or optionally using a ligand transfer agent such as citrate and incubating the reaction at a temperature between room temperature and 100°C for between 5 and 60 min.

EXAMPLE 3

**Inhibition of Binding of $\{^{125}\text{I-Tyr}^{11}\}$ somatostatin-14
to AR42J Rat Pancreatic Tumor Cell Membranes**

The ability of various somatostatin analogues of the invention to bind to somatostatin receptors *in vitro* was demonstrated by assaying the ability of such analogues to inhibit binding of a radiolabeled somatostatin analogue to somatostatin receptor-containing cell membranes. The rat pancreatic tumor cell line AR42J which expresses the somatostatin receptor was cultured in Dulbecco's minimal essential media (DMEM) supplemented with 10% fetal bovine serum (FBS) and 8mM glutamine in a humidified 5% CO₂ atmosphere at 37°C in T-flasks. Harvested cells were homogenized in cold 50mM Tris-HCl buffer (pH 7.4) and the homogenate then centrifuged at 39,000g for 10min at 4°C. Pellets were washed once with buffer and then resuspended in an ice-cold solution of 10mM Tris-HCl (pH 7.4). Equal aliquots of this cell membrane preparation were incubated with $\{^{125}\text{I-Tyr}^{11}\}$ somatostatin-14 (at a final concentration of 0.5nM and 750,000cpm/mL, at a specific activity of 2000Ci/mmol, Amersham, Arlington Heights, IL) and peptide or peptide-rhenium complex at a final concentration of from 10⁻¹¹M to 10⁻⁶M in a solution of 50mM HEPES (pH 7.4) containing 1% bovine serum albumin (BSA), 5mM MgCl₂, Trasylol (200,000 International Units), bacitracin (0.02mg/mL) and phenylmethylsulfonylfluoride (0.02mg/mL) for 25min at 30°C. Using a filtration manifold, this mixture was filtered through a polyethyleneimine-washed GC/F filter (Whatman, Maidstone, England), and the residue remaining on the filter washed thrice with 5mL cold HEPES buffer. The filter and a sample of the filter washings were then counted in a gamma counter. To assess non-specific binding, the assay was performed in the presence of unlabeled somatostatin-14 at 200nM. Data analysis including Hill plots of the data provided inhibition constants (see Bylund & Yamamura, "Methods of receptor binding", in Methods in Neurotransmitter Receptor Analysis, Yamamura *et al.*, eds., Raven Press: New York, 1990).

These results are presented in the following Tables. The data show that the peptides of the instant invention have a high affinity of binding for

somatostatin receptors.

TABLE II

<u>{Re=O}-complexed Peptides</u>	<u>MH⁺</u>	<u>K_i (nM)</u>
<i>cyclo.</i> (N-CH ₃)F.YW _D KV.Hcy(CH ₂ co.K(ε-K)GC.amide)	1529	0.51
<i>cyclo.</i> (N-CH ₃)F.YW _D KV.Hcy(CH ₂ co.GGC.amide)	1330	0.59
<u>CH₂CO.FFW_DKTFCC_{Acem}GC_{Acem}.amide</u>	1480	0.67
<i>cyclo.</i> (N-CH ₃)F.YW _D KV.Hcy(CH ₂ co.(ε-K)GC.amide)	1401	0.92
<i>cyclo.</i> (N-CH ₃)F.YW _D KV.Hcy(CH ₂ co.CGC.amide)	1375	1.7
<i>cyclo.</i> (N-Me)FYW _D KV.Hcy(CH ₂ co.GGCKK.amide)	1386	0.06
<i>cyclo.</i> (N-CH ₃)FYW _D KV.Hcy(CH ₂ co.GGCK.amide)	1458	0.15
<i>cyclo.</i> (N-Me)FYW _D KVHcy(CH ₂ co.GGCR.amide)	1485	0.23
<u>WLVVLAIVDNLV(ε-K)GCNNNNK.amide</u>	2145	0.33
<i>cyclo.</i> (N-CH ₃)FYW _D KV.Hcy(CH ₂ co.(ε-K)GCK.amide)	1529	0.34
<i>cyclo.</i> (N-Me)FYW _D KV.Hcy(CH ₂ co.(ε-K)KC.amide)	1472	0.42
<u>CH₂CO.FFW_DKTFCCGGC.amide</u>	2042	1.3
<u>CH₂CO.FFW_DKTFC(ε-K)GC</u>	1506	5.6

TABLE III

<u>Peptide</u>	<u>K_i (nM)</u>
<u>cyclo.(N-CH₃)F.YW₆KV.Hcy</u>	< 0.01
<u>CH₂CO.FYW₆KTFC.amide</u>	0.16
<u>CH₂CO.FFW₆KTE.Hhc.amide</u>	0.41
<u>cyclo.CYW₆KVC</u>	0.43
<u>CH₂CO.FFW₆KTFC.amide</u>	0.45
<u>cyclo.(N-CH₃)F.YW₆KV.K.{BAT}</u>	0.46
<u>cyclo.(N-CH₃)F.YW₆KV.Hcy(CH₂CO.K(ε-K)GC.amide)</u>	0.65
<u>cyclo.(N-CH₃)F.YW₆KV.Hcy(CH₂CO.C_{Acem}GC_{Acem}.amide)</u>	0.79
<u>cyclo.(N-CH₃)F.YW₆KV.Hcy(CH₂CO.CGC.amide)</u>	1.5
<u>cyclo.(N-CH₃)F.YW₆KV.Hcy(CH₂CO.CGC)</u>	1.8
<u>CH₂CO.FFW₆KTFC.{BAM}</u>	1.9
<u>cyclo.(N-CH₃)F.YW₆KV.Hcy(CH₂CO.(ε-K)GC.amide)</u>	2.0
<u>cyclo.(N-CH₃)F.YW₆KV.Hcy(CH₂CO.GGC.amide)</u>	2.4
<u>cyclo.(N-CH₃)F.YW₆KV.E.{BAM}</u>	2.6
<u>CH₂CO.NFFW₆KTFTC</u>	2.7
<u>CH₂CO.FFW₆KTFC</u>	4.0
<u>CH₂CO.FFW₆KTFC(ε-K)GC.amide</u>	5.2
<u>CH₂CO.FFW₆KTFC_{Acem}GC_{Acem}.amide</u>	7.5
<u>CH₂CO.FFW₆KTE.Hcy</u>	9.8

TABLE III (cont'd.)

<u>Peptide</u>	<u>K_i (nM)</u>
<i>cyclo</i> -(N-Me)FYW _D KT	0.26
<i>cyclo</i> -(N-Me)FYW _D KV.Hcy(CH ₂ CO.GGCKK.amide)	0.26
<i>cyclo</i> -(N-Me)FYW _D KVHcy(CH ₂ CO.GGCR.amide)	0.29
CH ₂ CO.FFW _D KTECC _{Acem} GC _{Acem} KKKKK.amide	1.4
<i>cyclo</i> -(N-Me)FYW _D KV.Hcy(CH ₂ CO.(ε-K)KC.amide)	2.2
<i>cyclo</i> -(N-CH ₃)FYW _D KV.Hcy(CH ₂ CO.GGCK.amide)	2.5
<i>cyclo</i> -(N-CH ₃)FYW _D KV.Hcy(CH ₂ CO.(ε-K)GCK.amide)	4.2
CH ₂ CO.FFW _D KTECC _{Acem} GC _{Acem} K.amide	8.4
(N-Me)FYW _D KV.Hcy(CH ₂ CO.CGCE.amide)	8.5
CH ₂ CO.FFW _D KTECGGC.amide	9.4

EXAMPLE 5

**Localization and *In Vivo* Imaging of Somatostatin Receptor (SSTR)-
Expressing Tumors in Rats**

In vivo imaging of somatostatin receptors expressed by rat tumor cells was performed essentially as described by Bakker *et al.* (1991, *Life Sciences* 49: 1593-1601).

CA20948 rat pancreatic tumor cells, thawed from frozen harvested tumor brei, were implanted intramuscularly in a suspension of 0.05 to 0.1 mL/animal, into the right hind thigh of 6 week old Lewis rats. The tumors were allowed to grow to approximately 0.5 to 2g, harvested, and tumor brei was used to implant a second, naive set of Lewis rats. Passaging in this fashion was repeated to generate successive generations of tumor-bearing animals. The tumor-bearing animals used for the *in vivo* studies were usually from the third to fifth passage and carried 0.2 to 2g tumors.

For studies of the specificity of radiotracer localization in the tumors, selected animals were given an subcutaneous SSTR-blocking dose (4 mg/kg) of octreotide 30 minutes prior to injection of the radiotracer. (This protocol has been shown by Bakker *et al.* to result in a lowering of ^{111}In -{DTPA}octreotide tumor uptake by 40%.)

Third- to fifth-passage CA20948 tumor-bearing Lewis rats were restrained and injected intravenously *via* the dorsal tail vein with a dose of 0.15-0.20 mCi $^{99\text{m}}\text{Tc}$ -labeled peptide corresponding to 3 to 8 μg peptide in 0.2 to 0.4 mL.

At selected times, the animals were sacrificed by cervical dislocation and selected necropsy was performed. Harvested tissue samples were weighed and counted along with an aliquot of the injected dose in a gamma well-counter.

The 90-minute biodistribution results of selected radiolabeled peptides are presented in Table IV. Notably, $^{99\text{m}}\text{Tc}$ -P587, $^{99\text{m}}\text{Tc}$ -P617, $^{99\text{m}}\text{Tc}$ -P726, and $^{99\text{m}}\text{Tc}$ -P736 showed very high tumor uptake and tumor/blood ratios demonstrating their high specific uptake in target (tumor) tissue.

Figure 1 shows an image of $^{99\text{m}}\text{Tc}$ -P587 in a tumor-bearing rat. The high uptake in the tumor in the lower leg (arrow) is clearly visible.

^{99m}Tc -P587 uptake in tumors in rats was compared with and without pre-injection treatment with octreotide, a somatostatin analogue known to bind to the somatostatin receptor *in vivo*. In these experiments, receptor-blocking by administration of octreotide prior to administration of ^{99m}Tc -P587 reduced specific tumor uptake of the radiolabeled peptide by 76%. These results confirmed that binding of ^{99m}Tc -P587 *in vivo* was SSTR-specific.

TABLE IV

No.	Peptides	%ID/g		
		<u>Tumor</u>	<u>T/B</u>	<u>T/M</u>
P617	<i>cyclo</i> (<i>N</i> -methyl)FYW _D KV.Hcy.(CH ₃ CO.GGCR.amide)	6.7	9.4	36
P587	<i>cyclo</i> (<i>N</i> -methyl)FYW _D KV.Hcy.(CH ₃ CO.GGCK.amide)	3.4	6.0	33
P829	<i>cyclo</i> .(N-CH ₃)FYW _D KV.Hcy(CH ₃ CO.(β-Dap)KCK.amide)	2.7	13	49
P832	<i>cyclo</i> .(N-CH ₃)FYW _D KV.Hcy(CH ₃ CO.(β-Dap)KCR.amide)	2.7	13	37
P625	<i>cyclo</i> .(N-Me)FYW _D KV.Hcy(CH ₃ CO.(ε-K)KC.amide)	0.97	0.85	4.6
P550	KKKK.Nal _D .Cpa.YW _D KTFT(ε-K)GCDDDD.amide	0.74	0.91	7.4

EXAMPLE 6***In Vivo* Imaging of Human Somatostatin Receptor (SSTR)-
Expressing Tumors with Tc-99m Labeled P587**

In a clinical trial, scintigraphic imaging of human patients bearing SSTR-expressing tumors was achieved using the Tc-99m labeled P587 reagent.

A total of 10 patients, four females and six males ranging in age from 27 to 69 years, had been previously diagnosed with growth hormone-secreting pituitary adenoma (4 patients), melanoma (1 subject), medullary thyroid cancer (1 subject), small cell lung carcinoma (SCLC; 1 patient), non-Hodgkin's lymphoma (1 patient) or gastric carcinoid (1 patient). Each of these patients were administered Tc-99m labeled P587 at a dose of 10-22mCi per 0.2-0.5mg by intravenous injection. Scintigraphic imaging was then performed as described herein on each patient for 4 hours post-injection.

Gamma camera imaging is started simultaneously with injection. Anterior images were acquired as a dynamic study (10 sec image acquisitions) over the first 10 min, and then as static images at 1, 2, 3 and 4h post-injection. Anterior images were acquired for 500,000 counts or 20 min (whichever is shorter), at approximately 10-20 min, and at approximately 1, 2, 3 and 4h post-injection.

The scintigraphic imaging agent was found to clear rapidly from the bloodstream, resulting in less than 10% of the injected dose remaining in the circulation within 30 minutes of injection. This allowed image acquisition of tumor sites to be achieved as early as 15-30 min after injection of scintigraphic imaging agent. All known tumors were detected in this study, as well as two previously-undetected metastatic lesions which were later confirmed using computer-assisted tomography (CAT scan).

These results demonstrated that the scintigraphic imaging agents of this invention were highly effective in detecting SSTR-expressing primary and metastatic tumors in humans *in vivo*.

It should be understood that the foregoing disclosure emphasizes certain specific embodiments of the invention and that all modifications or alternatives equivalent thereto are within the spirit and scope of the invention as set forth in the appended claims.



1. A somatostatin receptor-binding peptide having a formula:



wherein B¹ is D- or L-Phe or D- or L-Tyr or D- or L-Nal or Ain or a substituted derivative thereof;
 B² is D- or L-Trp or a substituted derivative thereof;
 B³ is D- or L-Lys or Hly, Achxa, Amf, Aec, Apc, Aes, Aps or a substituted derivative thereof;
 B⁴ is Thr, Ser, Val, Phe, Ile, Abu, Nle, Leu, Nva or Aib;
 C⁴ is an L-amino acid having a sidechain comprising a mercapto group;
 A⁴ is a lipophilic D-amino acid or a lipophilic L-(α -N-alkyl) amino acid or L-proline or a substituted derivative thereof;

wherein A⁴ and C⁴ are covalently linked to form a cyclic peptide.

2. The peptide of claim 1, wherein B¹ is phenylalanine or tyrosine, B² is D-tryptophan, B³ is lysine, and B⁴ is threonine or valine.

3. A reagent comprising:

a) a somatostatin receptor-binding peptide having a formula:



wherein B¹ is D- or L-Phe or D- or L-Tyr or D- or L-Nal or Ain or a substituted derivative thereof;
 B² is D- or L-Trp or a substituted derivative thereof;
 B³ is D- or L-Lys or Hly, Achxa, Amf, Aec, Apc, Aes, Aps or a substituted derivative thereof;
 B⁴ is Thr, Ser, Val, Phe, Ile, Abu, Nle, Leu, Nva or Aib;
 C⁴ is an L-amino acid having a sidechain comprising a mercapto group;



A⁴ is a lipophilic D-amino acid or a lipophilic L-(α -N-alkyl) amino acid or L-cysteine or L-proline or a substituted derivative thereof;

wherein A⁴ and C⁴ are covalently linked to form a cyclic peptide; and

b) a radiolabel-binding moiety covalently linked to the peptide other than through B¹, B², B³, B⁴, or A⁴.

4. The reagent of claim 3, wherein B¹ is phenylalanine or tyrosine, B² is D-tryptophan, B³ is lysine, and B⁴ is threonine or valine.

5. The reagent of any of claims 3 or 4, wherein the radiolabel-binding moiety is selected from the group consisting of:

(a) $C(pgp)^s-(aa)-C(pgp)^s$

wherein (pgp)^s is H or a thiol protecting group and (aa) is an amino acid;

(b) a radiolabel-binding moiety comprising a single thiol containing moiety having a formula:



wherein A is H, HOOC, H₂NOC, (peptide)-NHOC, R^e, NCO, (peptide)-OOC or R^d;

B is H, SH, -NHR^c, -N(R^c)-(peptide), or R^d;

X is H, SH, -NHR^c, -N(R^c)-(peptide) or R^d;

Z is H or R^d;

R^a, R^b, R^c and R^d are independently H or lower straight or branched chain or cyclic alkyl;

R^e is C₁-C₄ alkyl, an amino acid or a peptide comprising 2 to about 10 amino acids;

n is 0, 1 or 2;

and where B is -NHR^c or -N(R^c)-(peptide), X is SH, and n is 1 or 2;

where X is -NHR^c or -N(R^c)-(peptide), B is SH, and n is 1 or 2;



where B is H or R^d, A is HOOC, H₂NOC, (peptide)-NHOC, or (peptide)-OOC, X is SH, and n is 0 or 1;

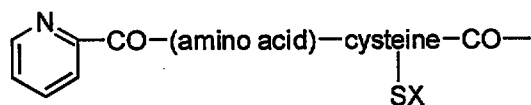
where A is H or R^d, then where B is SH, X is -NHR^c or -N(R^c)-(peptide) and where X is SH, B is -NHR^c or -N(R^c)-(peptide);

where X is H or R^d, A is HOOC, H₂NOC, (peptide)-NHOC, or (peptide)-OOC and B is SH;

where Z is methyl, X is methyl, A is HOOC, H₂NOC, (peptide)-NHOC, or (peptide)-OOC, B is SH and n is 0;

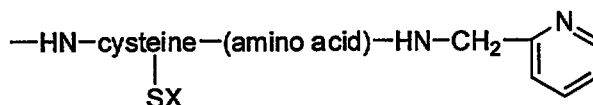
and wherein the thiol moiety is in the reduced form;

(c)



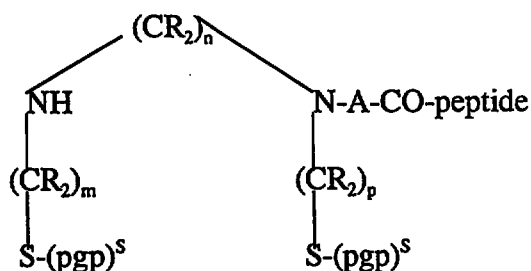
wherein X = H or a protecting group;
(amino acid) = any amino acid;

(d)



wherein X = H or a protecting group;
(amino acid) = any amino acid;

(e)

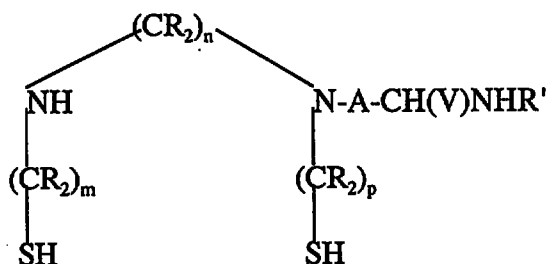




wherein each R is independently H, CH₃ or C₂H₅;
each (pgp)^s is independently a thiol protecting group or H;
m, n and p are independently 2 or 3;
A = linear or cyclic lower alkyl, aryl, heterocyclyl, a combination thereof or a substituted derivative thereof;

and

(f)



wherein each R is independently H, CH₃ or C₂H₅;
m, n and p are independently 2 or 3;
A = linear or cyclic lower alkyl, aryl, heterocyclyl, a combination thereof or a substituted derivative thereof;
V = H or -CO-peptide;
R' = H or peptide;

and wherein when V = H, R' = peptide and when R' = H, V = -CO-peptide.

6. A composition comprising a peptide having a formula selected from the group consisting of:

cyclo-(N-CH₃)FYW_DKV.K;
cyclo-(N-CH₃)FYW_DKV.E;
cyclo-(N-CH₃)F.YW_DKV.Hcy;
cyclo.CYW_DKVC;
cyclo-(N-CH₃)F.YW_DKV.K.(BAT);
cyclo-(N-CH₃)F.YW_DKV.Hcy(CH₂CO.K(ε-K)GC.amide);
cyclo-(N-CH₃)F.YW_DKV.Hcy(CH₂CO.C_{Ac}m GC_{Ac}m.amide);
cyclo-(N-CH₃)F.YW_DKV.Hcy(CH₂CO.CGC.amide);
cyclo-(N-CH₃)F.YW_DKV.Hcy(CH₂CO.CGC);
cyclo-(N-CH₃)F.YW_DKV.Hcy(CH₂CO.(ε-K)GC.amide);



cyclo.(*N*-CH₃)F.YW_DKV.Hcy(CH₂CO.GGC.amide);
cyclo.(*N*-CH₃)F.YW_DKV.E.(BAM);
cyclo.(*N*-CH₃)FYW_DKV.Hcy(CH₂CO.KKKKK(ε-K)GC.amide);
cyclo.(*N*-CH₃)FYW_DKV.Hcy(CH₂CO.(ε-K)GCK.amide);
cyclo.(*N*-Me)FYW_DKV.Hcy(CH₂CO.(ε-K)KC.amide);
cyclo.(*N*-Me)FYW_DKV.Hcy(CH₂CO.GGC.Orn.amide);
cyclo.(*N*-Me)FYW_DKV.Hcy(CH₂CO.GGC.Orn.DOrn..amide);
cyclo.(*N*-Me)FYW_DKV.Hcy(CH₂CO.K(ε-K)KCK.amide);
cyclo.(*N*-Me)FYW_DKT;
cyclo.(*N*-Me)FYW_DKVHcy(CH₂CO.(ε-K)GCKK.amide);
cyclo.(*N*-CH₃)FYW_DKV.Hcy(CH₂CO.KKCK.amide);
cyclo.(*N*-CH₃)FYW_DKV.Hcy(CH₂CO.GGCKKK.amide);
cyclo.(*N*-CH₃)FYW_DKV.HcyCH₂CO.(ε-K)DCK.amide;
cyclo.(*N*-CH₃)FYW_DKV.Hcy(CH₂CO.GGCKDKD.amide);
cyclo.(*N*-CH₃)FYW_DKV.HcyCH₂CO.GGCKD.amide;
cyclo.(*N*-CH₃)FYW_DKV.HcyCH₂CO.GGCKDK.amide;
cyclo.(*N*-CH₃)FYW_DKV.HcyCH₂CO.(ε-K)GCKKK.amide;
cyclo.(*N*-CH₃)FYW_DKV.Hcy(CH₂CO.(β-Dap)GCK.amide);
cyclo.(*N*-CH₃)FYW_DKV.Hcy(CH₂CO.(δ-Orn)GCK.amide);
cyclo.(*N*-CH₃)FYW_DKV.Hcy(CH₂CO.(ε-K)GCRK.amide);
cyclo.(*N*-CH₃)FYW_DKV.Hcy(CH₂CO.(ε-K)GCR.amide);
cyclo.(*N*-CH₃)FYW_DKVC;
cyclo.(*N*-CH₃)FYW_DKT.Hcy;
cyclo.PYW_DKV.Hcy;
cyclo.(*N*-CH₃)FYW_DKV.Hcy(CH₂CO.(γ-Dab)GCK.amide);
cyclo.(*N*-CH₃)FYW_DKV.Hcy(CH₂CO.GRCK.amide);
cyclo.(*N*-CH₃)FYW_DKV.Hcy(CH₂CO.KRC.amide);
cyclo.(*N*-CH₃)FYW_DKV.Hcy(CH₂CO.GKCR.amide);
cyclo.(*N*-CH₃)FYW_DKV.Hcy(CH₂CO.RRC.amide);
cyclo.(*N*-CH₃)FYW_DKV.Hcy(CH₂CO.GGCE.amide);
cyclo.(*N*-CH₃)FYW_DKV.Hcy(CH₂CO.GGC.Apc.amide);
cyclo.(*N*-CH₃)S_{Bn}YW_DKV.Hcy;
cyclo.PYW_DKV.Hcy(CH₂CO.GGCK.amide);
cyclo.(*N*Me)FW_DKVC(CH₂CO.GGCK.amide);
cyclo.(*N*Me)FW_DKT.Hcy(CH₂CO.GGCK.amide);
cyclo.(*N*-CH₃)FYW_DKV.Hcy(CH₂CO.RKC.amide);
cyclo.(*N*-CH₃)S_{Bn}YW_DKV.Hcy(CH₂CO.GGCK.amide);
cyclo.(*N*-CH₃)FYW_DKV.Hcy(CH₂CO.GKCK.amide);
cyclo.(*N*-CH₃)FYW_DKV.Hcy(CH₂CO.KGCK.amide);
cyclo.(*N*-CH₃)FYW_DKV.Hcy(CH₂CO.KGGCK.amide);
cyclo.(*N*-CH₃)FYW_DKV.Hcy(CH₂CO.KGGC.amide);
cyclo.(*N*-CH₃)FYW_DKV.Hcy(CH₂CO.GGGCK.amide);
cyclo.(*N*-CH₃)FYW_DKV.Hcy(CH₂CO.RGGC.amide);



cyclo.(N-CH₃)FYW_DKV.Hcy(CH₂CO.SSC.amide);
cyclo.(N-CH₃)FYW_DKV.Hcy(CH₂CO.SSCK.amide);
cyclo.(N-CH₃)FYW_DKV.Hcy(CH₂CO.(β-Dap)KCK.amide);
cyclo.(N-CH₃)FYW_DKV.Hcy(CH₂CO.(β-Dap)DCK.amide);
cyclo.(N-CH₃)FYW_DKV.Hcy(CH₂CO.(β-Dap)KCD.amide);
cyclo.(N-CH₃)FYW_DKV.Hcy(CH₂CO.(β-Dap)KCR.amide);
cyclo.(N-CH₃)FYW_DKV.Hcy(CH₂CO.(β-Dap)GCR.amide);
cyclo.(N-CH₃)FYW_DKV.Hcy(CH₂CO.(β-Dap)RCK.amide);
cyclo.(N-CH₃)FYW_DKV.Hcy(GK(-CH₂CO.)C.amide);
cyclo.(N-CH₃)FYW_DKV.Hcy(CH₂CO.GGCR.acid);
cyclo.(N-CH₃)FYW_DKV.Hcy(CH₂CO.GRC.amide);
cyclo.(N-CH₃)FYW_DKV.Hcy(CH₂CO.GGCK.acid);
cyclo.(N-CH₃)FYW_DKV.Hcy(CH₂CO.GKC.acid);
cyclo.(N-CH₃)FYW_DKV.Hcy(CH₂CO.GRC.acid);
cyclo.(N-CH₃)FYW_DKV.Hcy(CH₂CO.KKC.acid);
cyclo.(N-CH₃)FYW_DKV.Hcy(CH₂CO.CG.Dap.Dap.amide);
cyclo.(N-CH₃)FYW_DKV.Hcy(CH₂CO.(δ-Orn)GCR.amide);
cyclo.(N-CH₃)FYW_DKV.Hcy(CH₂CO.GNCR.amide);
cyclo.(N-CH₃)FYW_DKV.Hcy(CH₂CO.(δ-Orn)GCN.amide);
cyclo.(N-CH₃)FYW_DKV.Hcy(CH₂CO.GGC.Dap.amide);
cyclo.(Hyp.YW_DKV.Hcy);
cyclo.(Hyp.YW_DKV.Hcy)(CH₂CO.GGCK.amide);
cyclo.(N-CH₃)FYW_DKV.Hcy(CH₂CO.(γ-Dab)KCK.amide);
cyclo.(N-CH₃)FYW_DKV.Hcy(CH₂CO.(γ-Dab)KCR.amide); and
cyclo.(N-CH₃)FYW_DKV.Hcy(CH₂CO.(δ-Orn)KCK.amide).

7. The composition of claim 6, wherein the peptide has the formula:

cyclo.(N-CH₃)FYW_DKV.Hcy(CH₂CO.(δ-Orn)GCK.amide).

8. The composition of claim 6, wherein the peptide has the formula:

cyclo.(N-CH₃)FYW_DKV.Hcy(CH₂CO.(β-Dap)KCK.amide).

9. A radiotherapeutic agent comprising the peptide of any of claims 1 or 2 radiolabeled with iodine-123, iodine-125, iodine-131 or astatine-211.



10. A radiotherapeutic agent comprising the reagent of any of claims 3 through 5 radiolabeled with a radioisotope selected from the group consisting of scandium-47, copper-67, gallium-72, yttrium-90, tin-117m, iodine-125, iodine-131, samarium-153, gadolinium-159, dysprosium-165, holmium-166, ytterbium-175, lutetium-177, rhenium-186, rhenium-188, astatine-211, and bismuth-212.

11. A radiotherapeutic agent comprising the composition of claim 6, wherein the peptide is radiolabeled with a radioisotope selected from the group consisting of scandium-47, copper-67, gallium-72, yttrium-90, tin-117m, iodine-125, iodine-131, samarium-153, gadolinium-159, dysprosium-165, holmium-166, ytterbium-175, lutetium-177, rhenium-186, rhenium-188, astatine-211, and bismuth-212.

12. Use of the peptide of any of claims 1 or 2 for preparing a medicament for treatment of a somatostatin-related disease.

13. A scintigraphic imaging agent comprising the peptide of any of claims 1 or 2 radiolabeled with iodine-123 or iodine-125.

14. A scintigraphic imaging agent comprising the reagent of any of claims 3 through 5 radiolabeled with a radioisotope selected from the group consisting of gallium-68, technetium-99m, indium-111, and iodine-123.

15. A scintigraphic imaging agent comprising the composition of any of claims 6 through 8 and a radioisotope selected from the group consisting of gallium-68, technetium-99m, indium-111, and iodine-123.

16. The agent of claim 15, wherein the radioisotope is technetium-99m.



17. Use of the agent of any of claims 13 through 16 to prepare a medicament for imaging a site within a mammalian body.
18. A pharmaceutical composition comprising the peptide of any of claims 1 or 2 and a pharmaceutically acceptable carrier.
19. A pharmaceutical composition comprising the reagent of any of claims 3 through 5 and a pharmaceutically acceptable carrier.
20. The composition of any of claims 6 through 8, further comprising a pharmaceutically acceptable carrier.
21. A kit for preparing a radiopharmaceutical preparation, said kit comprising a sealed vial containing a predetermined quantity of the composition of any of claims 19 or 20.
22. A kit for preparing a radiopharmaceutical preparation, said kit comprising a sealed vial containing a predetermined quantity of the composition of claim 20 and a sufficient amount of a reducing agent to label the composition with technetium-99m, rhenium-186, or rhenium-188.
23. A method for labeling a reagent according to any of claims 3 through 5 comprising reacting the reagent with technetium-99m, rhenium-186, or rhenium-188 in the presence of a reducing agent.
24. A composition comprising a complex formed by reacting the reagent of any of claims 3 through 5 with a non-radioactive metal.
25. The complex of claim 24, wherein the non-radioactive metal is rhenium.



26. A composition comprising a complex formed by reacting the radiotherapeutic agent of any of claims 15 through 17 with a non-radioactive metal.

27. A composition comprising a complex formed by reacting the scintigraphic imaging agent of any of claims 9 through 11 with a non-radioactive metal.