ANTI-PANCREATIC CANCER ANTIBODIES

RELATED APPLICATIONS

[001] This application claims priority to U.S. Patent Application 12/343,655, filed December 24, 2008; and 12/418,877, filed April 6, 2009; and Provisional U.S. Patent Application Serial Nos. 61/087,463, filed August 8, 2008, and 61/144,227, filed January 13, 2009.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[002] This work was supported in part by NIH grant RO1-CA54425. The U.S. Government may have certain rights in this invention.

BACKGROUND OF THE INVENTION

Field of the Invention

[003] This invention relates to murine, chimeric, humanized and human antibodies and fragments thereof that bind with high selectivity and frequency to pancreatic cancer cells and to a lesser extent to other cancer cells and not appreciably to normal pancreatic cells or pancreatitis. In preferred embodiments, the antibodies or fragments are PAM4 antibodies or fragments. The subject antibodies are of use in cancer detection, diagnosis and therapy, particularly for pancreatic cancers. In particular embodiments, the subject antibodies are of use for detection and/or diagnosis of the earliest stages of pancreatic cancer.

Related Art

[004] Pancreatic cancer is a malignant growth of the pancreas that mainly occurs in the cells of the pancreatic ducts. This disease is the ninth most common form of cancer, yet it is the fourth and fifth leading cause of cancer deaths in men and women, respectively. Cancer of the pancreas is almost always fatal, with a five-year survival rate that is less than 3%.

[005] The most common symptoms of pancreatic cancer include jaundice, abdominal pain, and weight loss, which, together with other presenting factors, are nonspecific in

nature. Thus, diagnosing pancreatic cancer at an early stage of tumor growth is often difficult and requires extensive diagnostic work-up, often times including exploratory surgery. Endoscopic ultrasonography and computed tomography are the best noninvasive means available today for diagnosis of pancreatic cancer. However, reliable detection of small tumors, as well as differentiation of pancreatic cancer from focal pancreatitis, is difficult. The vast majority of patients with pancreatic cancer are presently diagnosed at a late stage when the tumor has already extended outside of the capsule to invade surrounding organs and/or has metastasized extensively. Gold et al., Crit. Rev. Oncology/Hematology, 39:147-54 (2001). Late detection of the disease is common, and early pancreatic cancer diagnosis is rare in the clinical setting.

[006] Current treatment procedures available for pancreatic cancer have not led to a cure, nor to a substantially improved survival time. Surgical resection has been the only modality that offers a chance at survival. However, due to a large tumor burden, only 10% to 25% of patients are candidates for "curative resection." For those patients undergoing a surgical treatment, the five-year survival rate is still poor, averaging only about 10%.

[007] Early detection and diagnosis of pancreatic cancer, as well as appropriate staging of the disease, would provide an increased survival advantage. A number of laboratories are proceeding on the development of a diagnostic procedure based upon the release of a tumor-associated marker into the bloodstream as well as detection of the marker substance within biopsy specimens. The best tumor associated marker for pancreatic cancer has been the immunoassay for CA19.9. Elevated levels of this sialylated Le^a epitope structure were found in 70% of pancreatic cancer patients but were not found in any of the focal pancreatitis specimens examined. However, CA19.9 levels were found to be elevated in a number of other malignant and benign conditions, so that currently the assay cannot be used for diagnosis. However, the assay is useful for monitoring, the continued increase in CA19.9 serum levels after surgery being indicative of a poor prognosis. Many other monoclonal antibodies (MAbs) have been reported with immunoassays for diagnosis in varying stages of development. These include but are not limited to DUPAN2, SPAN1, B72.3, Ia3, and various anti-CEA (carcinoembryonic antigen, or CEACAM5) antibodies.

[008] Antibodies, in particular MAbs and engineered antibodies or antibody fragments, have been tested widely and shown to be of value in detection and treatment of various human disorders, including cancers, autoimmune diseases, infectious diseases, inflammatory diseases, and cardiovascular diseases [Filpula and McGuire, Exp. Opin.

Ther. Patents (1999) 9: 231-245]. The clinical utility of an antibody or an antibody-derived agent is primarily dependent on its ability to bind to a specific targeted antigen associated with a particular disorder. Selectivity is valuable for delivering a diagnostic or therapeutic agent, such as drugs, toxins, cytokines, hormones, hormone antagonists, enzymes, enzyme inhibitors, oligonucleotides, growth factors, radionuclides, angiogenesis inhibitors or metals, to a target location during the detection and treatment phases of a human disorder, particularly if the diagnostic or therapeutic agent is toxic to normal tissue in the body. Radiolabeled antibodies have been used with some success in numerous malignancies, including ovarian cancer, colon cancer, medullary thyroid cancer, and lymphomas. This technology may also prove useful for pancreatic cancer. However, previously reported antibodies against pancreatic cancer antigens have not been successfully employed to date for the effective therapy or early detection and/or diagnosis of pancreatic cancer.

[009] One suggested approach for delivering agents to a target site, referred to as direct targeting, is a technique designed to target specific antigens with antibodies carrying diagnostic or therapeutic agents. In the context of tumors, the direct targeting approach utilizes a labeled anti-tumor monospecific antibody that recognizes the target tumor through its antigens. The technique involves injecting the labeled monospecific antibody into the patient and allowing the antibody to localize at the target tumor to obtain diagnostic or therapeutic benefits. The unbound antibody clears the body.

[010] Another suggested solution, referred to as the "Affinity Enhancement System" (AES), is a technique designed to overcome deficiencies of direct tumor targeting by antibodies carrying diagnostic or therapeutic agents [U.S. Pat. No. 5,256,395 (1993), Barbet et al., Cancer Biotherapy & Radiopharmaceuticals 14: 153-166 (1999)]. The AES utilizes a labeled divalent hapten and an anti-tumor/anti-hapten bispecific antibody that recognizes both the target tumor and the labeled hapten. Haptens with higher valency and antibodies with higher specificity may also be utilized for this procedure. The technique involves injecting the antibody into the patient and allowing it to localize at the target tumor. After a sufficient amount of time for the unbound antibody to clear from the blood stream, the labeled hapten is administered. The hapten binds to the antibody-antigen complex located at the site of the target cell to obtain diagnostic or therapeutic benefits, while the unbound hapten rapidly clears from the body. Barbet mentions the possibility that a bivalent hapten may crosslink with bispecific antibodies, when the latter are bound

to the tumor surface. As a result, the labeled complex is more stable and stays at the tumor for a longer period of time.

[011] There remains a need in the art for antibodies that exhibit high selectivity for pancreatic cancer and other types of cancers, compared to normal pancreatic tissues and other normal tissues. Specifically, there remains a need for antibodies that perform as a useful diagnostic and/or therapeutic tool for pancreatic cancer, preferably at the earliest stages of the disease, and that exhibits enhanced uptake at targeted antigens, decreased binding to constituents in the blood of healthy individuals and thereby also optimal protection of normal tissues and cells from toxic therapeutic agents when these are conjugated to such antibodies. Use of such antibodies to detect pancreatic cancer-associated antigens in body fluids, particularly blood, can enable improved earlier diagnosis of this disease, so long as it differentiates well from benign diseases, and can also be used for monitoring response to therapy and potentially also to enhance prognosis by indicating disease burden.

SUMMARY

[011a] In a first aspect, there is provided an antibody construct comprising at least one anti-pancreatic cancer antibody or antigen-binding fragment thereof that binds to pancreatic cancer cells and does not bind to normal pancreatic tissue or pancreatitis or benign pancreatic tissue; wherein the anti-pancreatic cancer antibody or fragment thereof binds to a linear peptide comprising the amino acid sequence WTWNITKAYPLP (SEQ ID NO:29) or to a cyclic peptide comprising the amino acid sequence ACPEWWGTTC (SEQ ID NO:30).

[011b] In a second aspect, there is provided the use of an antibody construct comprising at least one anti-pancreatic cancer antibody or antigen-binding fragment thereof that binds to pancreatic cancer cells and does not bind to normal pancreatic tissue or pancreatitis or benign pancreatic tissue in the manufacture of a medicament for treating pancreatic cancer; wherein the anti-pancreatic cancer antibody or fragment thereof binds to a linear peptide comprising the amino acid sequence WTWNITKAYPLP (SEQ ID NO:29) or to a cyclic peptide comprising the amino acid sequence ACPEWWGTTC (SEQ ID NO:30).

[011c] In a third aspect, there is provided an *in vitro* method of diagnosing pancreatic cancer comprising:

a) obtaining an antibody as defined above, wherein the antibody is either labeled with at least one diagnostic agent or the antibody is part of a bispecific antibody that binds to a targetable construct labeled with at least one diagnostic agent;

b) detecting the presence of antibody bound to pancreatic cancer cells in a sample suspected of containing pancreatic cancer cells that has been exposed to the antibody, wherein binding of antibody to the sample indicates the presence of pancreatic cancer.

[012] In various embodiments, the present disclosure concerns antibodies, antigen-binding antibody fragments and fusion proteins that bind to pancreatic cancer cells, with little or no binding to normal or non-neoplastic pancreatic cells. Preferably, the antibodies bind to the earliest stages of pancreatic cancer, such as PanIN-1A and 1B and PanIN-2. More preferably, the antibodies bind to 80 to 90% or more of human invasive pancreatic adenocarcinoma, intraductal papillary mucinous neoplasia, PanIN-1A, PanIN-1B and PanIN-2 lesions. Most preferably, the antibodies can distinguish between early stage pancreatic cancer and non-malignant conditions such as pancreatitis. Such antibodies are of particular use for early detection of cancer and differential diagnosis between early stage pancreatic cancer and benign pancreatic conditions. In preferred embodiments, such antibodies are of use for *in vivo* or *ex vivo* analysis of samples from individuals suspected of having early stage pancreatic or certain other cancers.

[013] The antibodies, antibody fragments or fusion proteins may be derived by immunization and/or selection with mucin, and are preferably reactive against mucin of pancreatic cancer. Accordingly, the antibodies, antibody fragments and fusion proteins preferably bind to an antigen associated with pancreatic cancer cells. More preferably, the antibodies, antibody fragments or fusion proteins may bind to a mucin expressed in

pancreatic cancer, such as MUC-1 or MUC-5. In certain embodiments, the antibodies, antibody fragments or fusion proteins may bind to cells transfected with and expressing a MUC-1 antigen.

[014] In alternative embodiments, the antibodies, antibody fragments or fusion proteins may bind to synthetic peptide sequences, for example to phage display peptides. Exemplary peptides that may bind to the anti-pancreatic cancer antibodies include, but are not limited to, WTWNITKAYPLP (SEQ ID NO:29) and ACPEWWGTTC (SEQ ID NO:30). Such synthetic peptides may be linear or cyclic and may or may not compete with antibody binding to the endogenous pancreatic cancer antigen. Amino acids in certain positions of the synthetic peptide sequences may be less critical for antibody binding than others. For example, in SEQ ID NO:29 the residues K, A and L at positions 7, 8 and 11 of the peptide sequence may be varied while still retaining antibody binding. Similarly, in SEQ ID NO:30 the threonine residues at positions 8 and 9 of the sequence may be varied, although substitution of the threonine at position 9 may significantly affect antibody binding to the peptide.

[015] In other preferred embodiments, binding of the antibodies to a target pancreatic cancer antigen is inhibited by treatment of the target antigen with reagents such as dithiothreitol (DTT) and/or periodate. Thus, binding of the antibodies to a pancreatic cancer antigen may be dependent upon the presence of disulfide bonds and/or the glycosylation state of the target antigen. In more preferred embodiments, the epitope recognized by the subject antibodies is not cross-reactive with other reported mucin-specific antibodies, such as the MA5 antibody, the CLH2-2 antibody and/or the 45M1 antibody (see, e.g., Major et al., J Histochem Cytochem. 35:139-48, 1987; Dion et al., Hybridoma 10:595-610, 1991).

[016] The subject antibodies or fragments may be naked antibodies or fragments or preferably are conjugated to at least one therapeutic and/or diagnostic agent for delivery of the agent to target tissues. In alternative embodiments, the PAM4 antibodies or fragments may be part of a bispecific fusion protein or antibody with a first binding site for a target cell antigen and a second binding site for a hapten conjugated to a targetable construct. The targetable construct may in turn be attached to at least one therapeutic and/or diagnostic agent, of use in pretargeting techniques.

[017] In preferred embodiments, the subject antibody, antibody fragment or fusion protein comprises a murine, chimeric, humanized or human PAM4 antibody or fragment.

Such PAM4 antibodies or fragments preferably comprise the CDR sequences of a murine PAM4 antibody, such as the light chain variable region CDR sequences CDR1 (SASSSVSSSYLY, SEQ ID NO:1); CDR2 (STSNLAS, SEQ ID NO:2); and CDR3 (HQWNRYPYT, SEQ ID NO:3); and the heavy chain variable region CDR sequences CDR1 (SYVLH, SEQ ID NO:4); CDR2 (YINPYNDGTQYNEKFKG, SEQ ID NO:5)and CDR3 (GFGGSYGFAY, SEQ ID NO:6).

[018] Particular embodiments may concern compositions and methods of use of murine PAM4 antibodies, preferably comprising murine PAM4 variable region sequences as disclosed in FIG. 1A and 1B (SEQ ID NO:9 and SEQ ID NO:11). Such murine PAM4 antibodies or fragments may be of use in *in vitro* or *ex vivo* diagnostic techniques, such as immunohistochemical analysis of tissue samples or immunoassay of body fluid samples from subjects suspected of having pancreatic cancer or other types of cancer.

[019] Other particular embodiments may concern compositions and methods of use of chimeric PAM4 antibodies, comprising murine variable region sequences attached to human antibody constant region sequences. Preferably the chimeric PAM4 antibodies or fragments comprise the cPAM4 variable region sequences shown in FIG. 2A and 2B (SEQ ID NO:12 and SEQ ID NO:13). Such chimeric antibodies are less immunogenic in humans than murine antibodies, while retaining the antigen-binding specificities of the parent murine antibody. Chimeric antibodies are well known in the art for use in diagnostic and/or therapeutic treatment of cancer.

[020] Still other particular embodiments may concern compositions and methods of use of humanized PAM4 antibodies or fragments thereof, comprising the complementarity-determining regions (CDRs) of a murine PAM4 MAb as discussed above and human antibody framework region (FR) and constant region sequences. In a preferred embodiment, the FRs of the light and heavy chain variable regions of the humanized PAM4 antibody or fragment thereof comprise at least one amino acid substituted from the corresponding FRs of a murine PAM4 MAb. Still more preferred, the humanized PAM4 antibody or fragment thereof may comprise at least amino acid residue selected from amino acid residues 5, 27, 30, 38, 48, 66, 67 and 69 of the murine PAM4 heavy chain variable region (FIG. 1B) and/or at least one amino acid selected from amino acid residues 21, 47, 59, 60, 85, 87 and 100 of the murine PAM4 light chain variable region (FIG. 1A). Most preferably, the humanized PAM4 antibody or fragment thereof comprises the

hPAM4 VH amino acid sequence of FIG. 4B (SEQ ID NO:19) and the hPAM4 Vκ amino acid sequence of FIG. 4A (SEQ ID NO:16).

[021] In alternative embodiments, the anti-pancreatic cancer antibodies may be murine, chimeric, humanized or human antibodies that bind to the same antigenic determinant (epitope) as a chimeric PAM4 (cPAM4) antibody. As discussed below, the cPAM4 antibody is one that comprises the light chain variable region CDR sequences CDR1 (SASSSVSSSYLY, SEQ ID NO:1); CDR2 (STSNLAS, SEQ ID NO:2); and CDR3 (HQWNRYPYT, SEQ ID NO:3); and the heavy chain variable region CDR sequences CDR1 (SYVLH, SEQ ID NO:4); CDR2 (YINPYNDGTQYNEKFKG, SEQ ID NO:5)and CDR3 (GFGGSYGFAY, SEQ ID NO:6). Antibodies that bind to the same antigenic determinant may be identified by a variety of techniques known in the art, such as by competitive binding studies using the cPAM4 antibody as the competing antibody and human pancreatic mucin as the target antigen. (See, e.g., Example 1, paragraph [0214] below.) Antibodies that block (compete for) binding to human pancreatic mucin of a cPAM4 antibody are referred to as cross-blocking antibodies. Preferably, such cross-blocking antibodies are prepared by immunization with extracts comprising human pancreatic cancer mucins.

[022] Another embodiment is a cancer cell targeting diagnostic immunoconjugate comprising an anti-pancreatic cancer antibody, antibody fragment or fusion protein that is bound to at least one diagnostic (or detection) agent.

[023] Preferably, the diagnostic agent is selected from the group consisting of a radionuclide, a contrast agent, a fluorescent agent, a chemiluminescent agent, a bioluminescent agent, a paramagnetic ion, an enzyme and a photoactive diagnostic agent. Still more preferred, the diagnostic agent is a radionuclide with an energy between 20 and 4,000 keV or is a radionuclide selected from the group consisting of ^{110}In, ^{111}In, ^{177}Lu, ^{18}F, ^{52}Fe, ^{62}Cu, ^{64}Cu, ^{67}Cu, ^{67}Ga, ^{68}Ga, ^{86}Y, ^{90}Y, ^{89}Zr, ^{94m}Tc, ^{94}Tc, ^{99m}Tc, ^{120}I, ^{123}I, ^{124}I, ^{125}I, ^{131}I, $^{154\text{-}158}Gd$, ^{32}P, ^{11}C, ^{13}N, ^{15}O, ^{186}Re, ^{188}Re, ^{51}Mn, ^{52m}Mn, ^{55}Co, ^{72}As, ^{75}Br, ^{76}Br, ^{82m}Rb, ^{83}Sr, or other gamma-, beta-, or positron-emitters. In a particularly preferred embodiment, the diagnostic radionuclide ^{18}F is used for labeling and PET imaging, as described in the Examples below. The ^{18}F may be attached to an antibody, antibody fragment or peptide by complexation to a metal, such as aluminum, and binding of the ^{18}F-metal complex to a chelating moiety that is conjugated to a targeting protein, peptide or other molecule.

[024] Also preferred, the diagnostic agent is a paramagnetic ion, such as chromium (III), manganese (II), iron (III), iron (II), cobalt (II), nickel (II), copper (II), neodymium (III), samarium (III), ytterbium (III), gadolinium (III), vanadium (II), terbium (III), dysprosium (III), holmium (III) and erbium (III), or a radiopaque material, such as barium, diatrizoate, ethiodized oil, gallium citrate, iocarmic acid, iocetamic acid, iodamide, iodipamide, iodoxamic acid, iogulamide, iohexol, iopamidol, iopanoic acid, ioprocemic acid, iosefamic acid, ioseric acid, iosulamide meglumine, iosemetic acid, iotasul, iotetric acid, iothalamic acid, iotroxic acid, ioxaglic acid, ioxotrizoic acid, ipodate, meglumine, metrizamide, metrizoate, propyliodone, and thallous chloride.

[025] In still other embodiments, the diagnostic agent is a fluorescent labeling compound selected from the group consisting of fluorescein isothiocyanate, rhodamine, phycoerytherin, phycocyanin, allophycocyanin, o-phthaldehyde and fluorescamine, a chemiluminescent labeling compound selected from the group consisting of luminol, isoluminol, an aromatic acridinium ester, an imidazole, an acridinium salt and an oxalate ester, or a bioluminescent compound selected from the group consisting of luciferin, luciferase and aequorin. In another embodiment, the diagnostic immunoconjugates are used in intraoperative, endoscopic, or intravascular tumor diagnosis.

[026] Another embodiment is a cancer cell-targeting therapeutic immunoconjugate comprising an antibody or fragment thereof or fusion protein bound to at least one therapeutic agent. Preferably, the therapeutic agent is selected from the group consisting of a radionuclide, an immunomodulator, a hormone, a hormone antagonist, an enzyme, an oligonucleotide such as an anti-sense oligonucleotide or a siRNA, an enzyme inhibitor, a photoactive therapeutic agent, a cytotoxic agent such as a drug or toxin, an angiogenesis inhibitor and a pro-apoptotic agent. In embodiments where more than one therapeutic agent is used, the therapeutic agents may comprise multiple copies of the same therapeutic agent or else combinations of different therapeutic agents.

[027] In one embodiment, an oligonucleotide, such as an antisense molecule or siRNA inhibiting bcl-2 expression as described in U.S. Pat. No. 5,734,033, may be conjugated to, or form the therapeutic agent portion of an immunoconjugate or antibody fusion protein. Alternatively, the oligonucleotide may be administered concurrently or sequentially with a naked or conjugated anti-pancreatic cancer antibody or antibody fragment, such as a PAM4 antibody. In a preferred embodiment, the oligonucleotide is an antisense

oligonucleotide that is directed against an oncogene or oncogene product, such as bcl-2, p53, ras or other well-known oncogenes.

[028] In a preferred embodiment, the therapeutic agent is a cytotoxic agent, such as a drug or a toxin. Also preferred, the drug is selected from the group consisting of nitrogen mustards, ethylenimine derivatives, alkyl sulfonates, nitrosoureas, gemcitabine, triazenes, folic acid analogs, anthracyclines, taxanes, COX-2 inhibitors, pyrimidine analogs, purine analogs, antibiotics, enzyme inhibitors, epipodophyllotoxins, platinum coordination complexes, vinca alkaloids, substituted ureas, methyl hydrazine derivatives, adrenocortical suppressants, hormone antagonists, endostatin, taxols, camptothecins, SN-38, doxorubicins and their analogs, antimetabolites, alkylating agents, antimitotics, anti-angiogenic agents, tyrosine kinase inhibitors, mTOR inhibitors, heat shock protein (HSP90) inhibitors, proteosome inhibitors, HDAC inhibitors, pro-apoptotic agents, methotrexate, CPT-11, and a combination thereof.

[029] In another preferred embodiment, the therapeutic agent is a toxin selected from the group consisting of ricin, abrin, alpha toxin, saporin, ribonuclease (RNase), DNase I, Staphylococcal enterotoxin-A, pokeweed antiviral protein, gelonin, diphtheria toxin, Pseudomonas exotoxin, and Pseudomonas endotoxin and combinations thereof. Or an immunomodulator selected from the group consisting of a cytokine, a stem cell growth factor, a lymphotoxin, a hematopoietic factor, a colony stimulating factor (CSF), an interferon (IFN), a stem cell growth factor, erythropoietin, thrombopoietin and a combinations thereof.

[030] In other preferred embodiments, the therapeutic agent is a radionuclide selected from the group consisting of ^{111}In, ^{177}Lu, ^{212}Bi, ^{213}Bi, ^{211}At, ^{62}Cu, ^{67}Cu, ^{90}Y, ^{125}I, ^{131}I, ^{32}P, ^{33}P, ^{47}Sc, ^{111}Ag, ^{67}Ga, ^{142}Pr, ^{153}Sm, ^{161}Tb, ^{166}Dy, ^{166}Ho, ^{186}Re, ^{188}Re, ^{189}Re, ^{212}Pb, ^{223}Ra, ^{225}Ac, ^{59}Fe, ^{75}Se, ^{77}As, ^{89}Sr, ^{99}Mo, ^{105}Rh, ^{109}Pd, ^{143}Pr, ^{149}Pm, ^{169}Er, ^{194}Ir, ^{198}Au, ^{199}Au, and ^{211}Pb, and combinations thereof. Also preferred are radionuclides that substantially decay with Auger-emitting particles. For example, Co-58, Ga-67, Br-80m, Tc-99m, Rh-103m, Pt-109, In-111, Sb-119, 1-125, Ho-161, Os-189m and Ir-192. Decay energies of useful beta-particle-emitting nuclides are preferably <1,000 keV, more preferably <100 keV, and most preferably <70 keV. Also preferred are radionuclides that substantially decay with generation of alpha-particles. Such radionuclides include, but are not limited to: Dy-152, At-211, Bi-212, Ra-223, Rn-219, Po-215, Bi-211, Ac-225, Fr-221, At-217, Bi-213 and Fm-255. Decay energies of useful

alpha-particle-emitting radionuclides are preferably 2,000-10,000 keV, more preferably 3,000-8,000 keV, and most preferably 4,000-7,000 keV. Additional potential radioisotopes of use include ^{11}C, ^{13}N, ^{15}O, ^{75}Br, ^{198}Au, ^{224}Ac, ^{126}I, ^{133}I, ^{77}Br, ^{113m}In, ^{95}Ru, ^{97}Ru, ^{103}Ru, ^{105}Ru, ^{107}Hg, ^{203}Hg, ^{121m}Te, ^{122m}Te, ^{125m}Te, ^{165}Tm, ^{167}Tm, ^{168}Tm, ^{197}Pt, ^{109}Pd, ^{105}Rh, ^{142}Pr, ^{143}Pr, ^{161}Tb, ^{166}Ho, ^{199}Au, ^{57}Co, ^{58}Co, ^{51}Cr, ^{59}Fe, ^{75}Se, ^{201}Tl, ^{225}Ac, ^{76}Br, ^{169}Yb, and the like. In other embodiments the therapeutic agent is a photoactive therapeutic agent selected from the group consisting of chromogens and dyes.

[031] Alternatively, the therapeutic agent is an enzyme selected from the group consisting of malate dehydrogenase, staphylococcal nuclease, delta-V-steroid isomerase, yeast alcohol dehydrogenase, alpha-glycerophosphate dehydrogenase, triose phosphate isomerase, horseradish peroxidase, alkaline phosphatase, asparaginase, glucose oxidase, beta-galactosidase, ribonuclease, urease, catalase, glucose-6-phosphate dehydrogenase, glucoamylase and acetylcholinesterase. Such enzymes may be used, for example, in combination with prodrugs that are administered in relatively non-toxic form and converted at the target site by the enzyme into a cytotoxic agent. In other alternatives, a drug may be converted into less toxic form by endogenous enzymes in the subject but may be reconverted into a cytotoxic form by the therapeutic enzyme.

[032] Also contemplated are multivalent, multispecific antibodies or fragments thereof comprising at least one binding site having an affinity toward a PAM4 target antigen and one or more hapten binding sites having affinity towards hapten molecules. Preferably, the antibody or fragment thereof is a chimeric, humanized or fully human antibody or fragment thereof. The hapten molecule may be conjugated to a targetable construct for delivery of one or more therapeutic and/or diagnostic agents. In certain preferred embodiments, the multivalent antibodies or fragments thereof may be prepared by the dock-and-lock (DNL) technique, as described in the Examples below. An exemplary DNL construct incorporating hPAM4 antibody fragments is designated TF10, as described below.

[033] Also contemplated is a bispecific antibody or fragment thereof comprising at least one binding site with an affinity toward a PAM4 target antigen and at least one binding site with an affinity toward a targetable construct/conjugates selected from the group consisting of:

DOTA-D-Asp-D-Lys(HSG)-D-Asp-D-Lys(HSG)-NH_2 (IMP 271);

DOTA-D-Glu-D-Lys(HSG)-D-Glu-D-Lys(HSG)-NH_2 (IMP 277);

DOTA-D-Tyr-D-Lys(HSG)-D-Glu-D-Lys(HSG)-NH_2 (IMP 288);

DOTA-D-Ala-D-Lys(HSG)-D-Glu-D-Lys(HSG)-NH_2 (IMP 0281);

NOTA-ITC benzyl-D-Ala-D-Lys(HSG)-D-Tyr-D-Lys(HSG)-NH_2 (IMP 449);

NODA-Ga-D-Ala-D-Lys(HSG)-D-Tyr-D-Lys(HSG)-NH_2 (IMP 460);

NOTA-D-Ala-D-Lys(HSG)-D-Tyr-D-Lys(HSG)-NH_2 (IMP 461);

NOTA-D-Asp-D-Lys(HSG)-D-Tyr-D-Lys(HSG)-NH_2 (IMP 462);

NOTA-D-Ala-D-Lys(HSG)-D-Tyr-D-Lys(HSG)-NH_2 (IMP 465);

C-NETA-succinyl-D-Lys(HSG)-D-Tyr-D-Lys(HSG)-NH_2 (IMP 467);

S-NETA-D-Lys(HSG)-D-Tyr-D-Lys(HSG)-NH_2 (IMP 469); and

L-NETA-succinyl-D-Lys(HSG)-D-Tyr-D-Lys(HSG)-NH_2 (IMP 470)

that is capable of carrying at least one diagnostic and/or therapeutic agent. Other targetable constructs suitable for use are disclosed, for example, in U.S. Patent Nos. 6,576,746; 6,962,702; 7,052,872; 7,138,103; 7,172,751 and 7,405,320 and U.S. Patent Application Serial No. 12/112,289.

[034] Other embodiments concern fusion proteins or fragments thereof comprising at least two anti-pancreatic cancer antibodies and fragments thereof as described herein. Alternatively, the fusion protein or fragment thereof may comprise at least one first anti-pancreatic cancer antibody or fragment thereof and at least one second MAb or fragment thereof. Preferably, the second MAb binds to a tumor-associated antigen, for example selected from the group consisting of CA19.9, DUPAN2, SPAN1, Nd2, B72.3, CC49, CEA (CEACAM5), CEACAM6, Le^a, the Lewis antigen Le(y), CSAp, insulin-like growth factor (ILGF), epithelial glycoprotein-1 (EGP-1), epithelial glycoprotein-2 (EGP-2), CD-80, placental growth factor (PlGF), carbonic anhydrase IX, tenascin, IL-6, HLA-DR, CD40, CD74 (e.g., milatuzumab), CD138 (syndecan-1), MUC-1, MUC-2, MUC-3, MUC-4, MUC-5ac, MUC-16, MUC-17, TAG-72, EGFR, platelet-derived growth factor (PDGF), angiogenesis factors (e.g., VEGF and PlGF), products of oncogenes (e.g., bcl-2, Kras, p53), cMET, HER2/neu, and antigens associated with gastric cancer and colorectal cancer. The antibody fusion protein or fragments thereof may further comprise at least one diagnostic and/or therapeutic agent.

[035] Also described herein are DNA sequences comprising a nucleic acid encoding an anti-pancreatic cancer antibody, fusion protein, multispecific antibody, bispecific antibody or fragment thereof as described herein. Other embodiments concern expression vectors

and/or host cells comprising the antibody encoding DNA sequences. In certain preferred embodiments, the host cell may be an Sp2/0 cell line transformed with a mutant Bcl-2 gene, for example with a triple mutant Bcl-2 gene (T69E, S70E, S87E), that has been adapted to cell transformation and growth in serum free medium. (See, e.g., U.S. Patent Application Nos. 11/187,863 (now issued U.S. Patent No. 7,531,327), filed July 25, 2005; 11/487,215 (now issued U.S. Patent No. 7,537,930), filed July 14, 2006; and 11/877,728, filed October 24, 2007.)

[036] Another embodiment concerns methods of delivering a diagnostic or therapeutic agent, or a combination thereof, to a target comprising (i) providing a composition that comprises an anti-pancreatic cancer antibody or fragment, such as a PAM4 antibody or fragment, conjugated to at least one diagnostic and/or therapeutic agent and (ii) administering to a subject in need thereof the diagnostic or therapeutic conjugate of any one of the antibodies, antibody fragments or fusion proteins claimed herein.

[037] Also contemplated is a method of delivering a diagnostic agent, a therapeutic agent, or a combination thereof to a target, comprising: (a) administering to a subject any one of the multivalent, multispecific or bispecific antibodies or fragments thereof that have an affinity toward a PAM4 antigen and comprise one or more hapten binding sites; (b) waiting a sufficient amount of time for antibody that does not bind to the PAM4 antigen to clear the subject's blood stream; and (c) administering to said subject a carrier molecule comprising a diagnostic agent, a therapeutic agent, or a combination thereof, that binds to a binding site of the antibody. Preferably, the carrier molecule binds to more than one binding site of the antibody.

[038] Described herein is a method for diagnosing or treating cancer, comprising: (a) administering to a subject any one of the multivalent, multispecific antibodies or fragments thereof claimed herein that have an affinity toward a PAM4 antigen and comprise one or more hapten binding sites; (b) waiting a sufficient amount of time for an amount of the non-bound antibody to clear the subject's blood stream; and (c) administering to said subject a carrier molecule comprising a diagnostic agent, a therapeutic agent, or a combination thereof, that binds to a binding site of the antibody. In a preferred embodiment the cancer is pancreatic cancer. Also preferred, the method can be used for intraoperative identification of diseased tissues, endoscopic identification of diseased tissues, or intravascular identification of diseased tissues.

[039] Another embodiment is a method of treating a malignancy in a subject comprising administering to said subject a therapeutically effective amount of an antibody or fragment thereof that binds to a PAM4 antigen, optionally conjugated to at least one therapeutic agent. The antibody or fragment thereof may alternatively be a naked antibody or fragment thereof. In more preferred embodiments, the antibody or fragment is administered either before, simultaneously with, or after administration of another therapeutic agent as described above.

[040] Contemplated herein is a method of diagnosing a malignancy in a subject, particularly a pancreatic cancer, comprising (a) administering to said subject a diagnostic conjugate comprising an antibody or fragment thereof that binds to a PAM4 antigen, wherein said MAb or fragment thereof is conjugated to at least one diagnostic agent, and (b) detecting the presence of labeled antibody bound to pancreatic cancer cells or other malignant cells, wherein binding of the antibody is diagnostic for the presence of pancreatic cancer or another malignancy. In preferred embodiments, the antibody or fragment binds to pancreatic cancer and not to normal pancreatic tissue, pancreatitis or other non-malignant conditions. In less preferred embodiments, the antibody or fragment binds at a significantly higher level to cancer cells than to non-malignant cells, allowing differential diagnosis of cancer from non-malignant conditions. In a most preferred embodiment, the diagnostic agent may be an F-18 labeled molecule that is detected by PET imaging.

[041] In more preferred embodiments, the use of anti-pancreatic cancer antibodies, such as the hPAM4 antibody, allows the detection and/or diagnosis of pancreatic cancer with high specificity and sensitivity at the earliest stages of malignant disease. Preferably, the diagnostic antibody or fragment is capable of labeling at least 70%, more preferably at least 80%, more preferably at least 90%, more preferably at least 95%, most preferably about 100% of well differentiated, moderately differentiated and poorly differentiated pancreatic cancer and 90% or more of invasive pancreatic adenocarcinomas. The anti-pancreatic cancer antibody of use is preferably capable of detecting 85% or more of PanIN-1A, PanIN-1B, PanIN-2, IPMN and MCN precursor lesions. Most preferably, immunoassays using the anti-pancreatic cancer antibody are capable of detecting 89% or more of total PanIN, 86% or more of IPMN, and 92% or more of MCN.

[042] An alternative embodiment is a method of detecting PAM4 antigen and/or diagnosing pancreatic cancer in an individual by *in vitro* analysis of blood, plasma or

serum samples. Preferably, the sample is subjected to an organic phase extraction, using an organic solvent such as butanol, before it is processed for immunodetection using an anti-pancreatic cancer antibody, such as a PAM4 antibody. Following organic phase extraction, aqueous phase is analyzed for the presence of PAM4 antigen in the sample, using any of a variety of immunoassay techniques known in the art, such as ELISA, sandwich immunoassay, solid phase RIA, and similar techniques.

[043] Another embodiment is a method of treating a cancer cell in a subject comprising administering to said subject a composition comprising a naked antibody or fragment thereof or a naked antibody fusion protein or fragment thereof that binds to a PAM4 antigen. Preferably, the method further comprises administering a second naked antibody or fragment thereof selected from the group consisting of CA19.9, DUPAN2, SPAN1, Nd2, B72.3, CC49, anti-CEA, anti-CEACAM6, anti-EGP-1, anti-EGP-2, anti-Le^a, antibodies defined by the Lewis antigen Le(y), and antibodies against CSAp, MUC-1, MUC-2, MUC-3, MUC-4, MUC-5ac, MUC-16, MUC-17, TAG-72, EGFR, CD40, HLA-DR, CD74, CD138, angiogenesis factors (e.g., VEGF and placenta-like growth factor (PlGF), insulin-like growth factor (ILGF), tenascin, platelet-derived growth factor, IL-6, products of oncogenes, cMET, and HER2/neu.

[044] Still other embodiments concern a method of diagnosing a malignancy in a subject comprising (i) performing an *in vitro* diagnosis assay on a specimen from said subject with a composition comprising an antibody or fragment thereof that binds to a PAM4 antigen; and (ii) detecting the presence of antibody or fragment bound to malignant cells in the specimen. Preferably, the malignancy is a cancer. Still preferred, the cancer is pancreatic cancer.

BRIEF DESCRIPTION OF THE DRAWINGS

[045] **FIG. 1.** Variable region cDNA sequences and the deduced amino acid sequences of the murine PAM4 antibody. FIG. 1A shows the DNA (SEQ ID NO:8) and amino acid (SEQ ID NO:9) sequences of the murine PAM4 Vk. FIG. 1B shows the DNA (SEQ ID NO:10) and amino acid (SEQ ID NO:11) sequences of the murine PAM4 VH. Amino acid sequences encoded by the corresponding DNA sequences are given as one-letter codes below the nucleotide sequence. Numbering of the nucleotide sequence is on the right side. The amino acid residues in the CDR regions are shown in bold and underlined. Kabat's Ig molecule numbering is used for amino acid residues as shown by the numbering

above the amino acid residues. The amino acid residues numbered by a letter are the insertion residues defined by Kabat numbering scheme. The insertion residues have the same preceding digits as that of the previous residue. For example, residues 82, 82A, 82B, and 82C in FIG. 1B are indicated as 82, A, B, and C, respectively.

[046] FIG. 2. Amino acid sequences of the chimeric PAM4 (cPAM4) heavy and light chain variable regions expressed in Sp2/0 cells. FIG. 2A shows the amino acid sequence (SEQ ID NO:12) of the cPAM4 Vk. FIG. 2B shows the amino acid sequence (SEQ ID NO:13) of the cPAM4 VH. The sequences are given as one letter codes. The amino acid residues in the CDR regions are shown in bold and underlined. The numbering of amino acids is the same as in FIG. 1.

[047] FIG. 3. Alignment of the amino acid sequences of heavy and light chain variable regions of a human antibody, PAM4 and hPAM4. FIG. 3A shows the Vκ amino acid sequence alignment of the human antibody Walker (SEQ ID NO:14) with PAM4 (SEQ ID NO:9) and hPAM4 (SEQ ID NO:16), and FIG. 3B shows the VH amino acid sequence alignment of the human antibody Wil2 (FR1-3) (SEQ ID NO:17) and NEWM (FR4) (SEQ ID NO:28) with PAM4 (SEQ ID NO:11) and hPAM4 (SEQ ID NO:19). Dots indicate the residues of PAM4 that are identical to the corresponding residues of the human or humanized antibodies. Boxed regions represent the CDR regions. Both N- and C-terminal residues (underlined) of hPAM4 are fixed by the staging vectors used. Kabat's Ig molecule number scheme is used to number the residues as in FIG. 1.

[048] FIG. 4. DNA and amino acid sequences of the humanized PAM4 (hPAM4) heavy and light chain variable regions expressed in Sp2/0 cells. FIG. 4A shows the DNA (SEQ ID NO:15) and amino acid (SEQ ID NO:16) sequences of the hPAM4 Vκ and FIG. 4B shows the DNA (SEQ ID NO:18) and amino acid (SEQ ID NO:19) sequences of the hPAM4VH. Numbering of the nucleotide sequence is on the right side. Amino acid sequences encoded by the corresponding DNA sequences are given as one-letter codes. The amino acid residues in the CDR regions are shown in bold and underlined. Kabat's Ig molecule numbering scheme is used for amino acid residues as in FIG. 1A and FIG. 1B.

[049] FIG. 5. Binding activity of humanized PAM4 antibody, hPAM4, as compared to the chimeric PAM4, cPAM4. hPAM4 is shown by diamonds and cPAM4 is shown by closed circles. Results indicate comparable binding activity of the hPAM4 antibody and cPAM4 when competing with ^{125}I-cPAM4 binding to CaPan1 antigens.

[050] FIG. 6. PET/CT fusion images for a patient with inoperable metastatic pancreatic cancer treated with fractionated ^{90}Y-hPAM4 plus gemcitabine, before therapy (left side) and post-therapy (right side). The circle indicates the location of the primary lesion, which shows a significant decrease in PET/CT intensity following therapy.

[051] FIG. 7. 3D PET images for a patient with inoperable metastatic pancreatic cancer treated with fractionated ^{90}Y-hPAM4 plus gemcitabine, before therapy (left side) and post-therapy (right side). Arrows point to the locations of the primary lesion (on right) and metastases (on left), each of which shows a significant decrease in PET image intensity after therapy with radiolabeled hPAM4 plus gemcitabine.

[052] FIG. 8. *In vivo* imaging of tumors using an ^{111}In-labeled diHSG peptide (IMP 288) with or without pretargeting TF10 bispecific anti-pancreatic cancer mucin antibody. FIG. 8A - mice showing location of tumors (arrow). FIG. 8B shows the detected tumors with ^{111}In-labeled IMP 288 in the presence (above) or absence (below) of TF10 bispecific antibody.

[053] FIG. 9. Exemplary binding curves for TF10, PAM4-IgG, PAM4-F(ab')$_2$ and a monovalent bsPAM4 chemical conjugate (PAM4-Fab' x anti-DTPA-Fab'). Binding to target mucin antigen was measured by ELISA assay.

[054] FIG. 10. Immunoscintigraphy of CaPan1 human pancreatic cancer xenografts (~ 0.25 g). **(A)** An image of mice that were injected with bispecific TF10 (80 μg, 5.07 x 10^{-10} mol) followed 16 h later by administration of ^{111}In-IMP-288 (30 μCi, 5.07 x 10^{-11} mol). The image was taken 3 h later. The intensity of the image background was increased to match the intensity of the image obtained when ^{111}In-IMP-288 was administered alone (30 μCi, 5.07 x 10^{-11} mol). **(B)** No targeting was observed in mice given ^{111}In-IMP-288 alone. **(C)** An image of mice that were given ^{111}In-DOTA-PAM4-IgG (20 μCi, 50 μg) with imaging done 24 h later. Although tumors are visible, considerable background activity is still present at this time point.

[055] FIG. 11. Extended biodistribution of ^{111}In-DOTA-PAM4-IgG (20 μCi, 50 μg) and TF10-pretargeted ^{111}In-IMP-288 (80 μg, 5.07 x 10^{-10} mol TF10 followed 16 h later with 30 μCi, 5.07 x 10^{-11} mol ^{111}In-IMP-288) in nude mice bearing CaPan1 human pancreatic cancer xenografts (mean tumor weight +/- SD, 0.28 +/- 0.21 and 0.10 +/- 0.06 g for the pretargeting and IgG groups of animals, respectively)

[056] FIG. 12. Therapeutic activity of a single treatment of established (~0.4 cm^3) CaPan1 tumors with 0.15 mCi of ^{90}Y-hPAM4 IgG, or 0.25 or 0.50 mCi of TF10-pretargeted ^{90}Y-IMP-288.

[057] FIG. 13. Effect of gemcitabine potentiation of PT-RAIT therapy.

[058] FIG. 14. Effect of combination of cetuximab with gemcitabine and PT-RAIT.

[059] FIG. 15. Differential diagnosis of pancreatic cancer using PAM4-based immunoassay. The red line shows the cutoff level selected for a positive result, based on ROC analysis.

[060] FIG. 16. Frequency distribution of PAM4 antigen in patient sera from healthy volunteers and individuals with varying stages of pancreatic cancer.

[061] FIG. 17. ROC curve for PAM4 serum immunoassay.

DETAILED DESCRIPTION

Definitions

[062] Unless otherwise specified, "a" or "an" means one or more.

[063] As used herein, "about" means plus or minus 10%. For example, "about 100" would include any number between 90 and 110.

[064] The term "substantially less" means at least 90%, more preferably 95%, more preferably 98%, more preferably 99%, more preferably 99.9% less.

[065] As described herein, the term "PAM4 antibody" includes murine, chimeric, humanized and human PAM4 antibodies. In preferred embodiments, the PAM4 antibody or antigen-binding fragment thereof comprises the CDR sequences of SEQ ID NO:1 to SEQ ID NO:6.

[066] As used herein, a "PAM4 antigen" is an antigen bound by a PAM4 antibody. In preferred embodiments, treatment of PAM4 antigen with DTT or periodate inhibits or prevents binding of the PAM4 antibody. In more preferred embodiments, the PAM4 antigen is an epitope of a mucin expressed by a pancreatic cancer cell, such as MUC-1 or MUC-5.

[067] As used herein, an "anti-pancreatic cancer antibody" is an antibody that exhibits the same diagnostic, therapeutic and binding characteristics as the PAM4 antibody. In preferred embodiments, the "anti-pancreatic cancer antibody" binds to the same epitope as the PAM4 antibody.

[068] A "non-endocrine pancreatic cancer" generally refers to cancers arising from the exocrine pancreatic glands. The term excludes pancreatic insulinomas and includes pancreatic carcinoma, pancreatic adenocarcinoma, adenosquamous carcinoma, squamous cell carcinoma and giant cell carcinoma and precursor lesions such as pancreatic intra-epithelial neoplasia (PanIN), mucinous cyst neoplasms (MCN) and intrapancreatic mucinous neoplasms (IPMN), which are neoplastic but not yet malignant. The terms "pancreatic cancer" and "non-endocrine pancreatic cancer" are used interchangeably herein.

[069] An antibody, as described herein, refers to a full-length (i.e., naturally occurring or formed by normal immunoglobulin gene fragment recombinatorial processes) immunoglobulin molecule (e.g., an IgG antibody) or an immunologically active (i.e., specifically binding) portion of an immunoglobulin molecule, like an antibody fragment.

[070] An antibody fragment is a portion of an antibody such as $F(ab')_2$, Fab', Fab, Fv, sFv and the like. Regardless of structure, an antibody fragment binds with the same antigen that is recognized by the full-length antibody. The term "antibody fragment" also includes isolated fragments consisting of the variable regions of antibodies, such as the "Fv" fragments consisting of the variable regions of the heavy and light chains and recombinant single chain polypeptide molecules in which light and heavy variable regions are connected by a peptide linker ("scFv proteins").

[071] A naked antibody is an antibody or fragment thereof that is not conjugated to a therapeutic or diagnostic agent. Generally, the Fc portion of the antibody molecule provides effector functions, such as complement-mediated cytotoxicity (CDC) and ADCC (antibody-dependent cellular cytotoxicity), which set mechanisms into action that may result in cell lysis. However, the Fc portion may not be required for therapeutic function, with other mechanisms, such as signaling-induced apoptosis, coming into play. Naked antibodies include both polyclonal and monoclonal antibodies, as well as fusion proteins and certain recombinant antibodies, such as chimeric, humanized or human antibodies.

[072] A chimeric antibody is a recombinant protein that contains the variable domains including the complementarity determining regions (CDRs) of an antibody derived from one species, preferably a rodent antibody, while the constant domains of the antibody molecule are derived from those of a human antibody. For veterinary applications, the constant domains of the chimeric antibody may be derived from that of other species, such as a cat or dog.

[073] A humanized antibody is a recombinant protein in which the CDRs from an antibody from one species; e.g., a rodent antibody, are transferred from the heavy and light variable chains of the rodent antibody into human heavy and light variable domains (e.g., framework region sequences). The constant domains of the antibody molecule are derived from those of a human antibody. In certain embodiments, a limited number of framework region amino acid residues from the parent (rodent) antibody may be substituted into the human antibody framework region sequences.

[074] A human antibody is, e.g., an antibody obtained from transgenic mice that have been "engineered" to produce specific human antibodies in response to antigenic challenge. In this technique, elements of the human heavy and light chain loci are introduced into strains of mice derived from embryonic stem cell lines that contain targeted disruptions of the endogenous murine heavy chain and light chain loci. The transgenic mice can synthesize human antibodies specific for particular antigens, and the mice can be used to produce human antibody-secreting hybridomas. Methods for obtaining human antibodies from transgenic mice are described by Green et al., Nature Genet. 7:13 (1994), Lonberg et al., Nature 368:856 (1994), and Taylor et al., Int. Immun. 6:579 (1994). A fully human antibody also can be constructed by genetic or chromosomal transfection methods, as well as phage display technology, all of which are known in the art. See for example, McCafferty et al., Nature 348:552-553 (1990) for the production of human antibodies and fragments thereof *in vitro*, from immunoglobulin variable domain gene repertoires from unimmunized donors. In this technique, antibody variable domain genes are cloned in-frame into either a major or minor coat protein gene of a filamentous bacteriophage, and displayed as functional antibody fragments on the surface of the phage particle. Because the filamentous particle contains a single-stranded DNA copy of the phage genome, selections based on the functional properties of the antibody also result in selection of the gene encoding the antibody exhibiting those properties. In this way, the phage mimics some of the properties of the B cell. Phage display can be performed in a variety of formats, for review, see e.g. Johnson and Chiswell, Current Opiniion in Structural Biology 3:5564-571 (1993). Human antibodies may also be generated by *in vitro* activated B cells. See U.S. Pat. Nos. 5,567,610 and 5,229,275.

[075] A therapeutic agent is a compound, molecule or atom which is administered separately, concurrently or sequentially with an antibody moiety or conjugated to an

antibody moiety, i.e., antibody or antibody fragment, or a subfragment, and is useful in the treatment of a disease. Examples of therapeutic agents include antibodies, antibody fragments, drugs, toxins, nucleases, hormones, immunomodulators, pro-apoptotic agents, anti-angiogenic agents, boron compounds, photoactive agents or dyes and radioisotopes. Therapeutic agents of use are described in more detail below.

[076] A diagnostic agent is a molecule, atom or other detectable moiety which may be administered conjugated to an antibody moiety or targetable construct and is useful in detecting or diagnosing a disease by locating cells containing the target antigen. Useful diagnostic agents include, but are not limited to, radioisotopes, dyes (such as with the biotin-streptavidin complex), contrast agents, fluorescent compounds or molecules and enhancing agents (e.g., paramagnetic ions) for magnetic resonance imaging (MRI) or positron emission tomography (PET) scanning. Preferably, the diagnostic agents are selected from the group consisting of radioisotopes, enhancing agents for use in magnetic resonance imaging, and fluorescent compounds. In order to load an antibody component with radioactive metals or paramagnetic ions, it may be necessary to react it with a reagent having a long tail to which are attached a multiplicity of chelating groups for binding the ions. Such a tail can be a polymer such as a polylysine, polysaccharide, or other derivatized or derivatizable chain having pendant groups to which can be bound chelating groups such as, e.g., ethylenediaminetetraacetic acid (EDTA), diethylenetriaminepentaacetic acid (DTPA), DOTA, NOTA, NETA, porphyrins, polyamines, crown ethers, bis-thiosemicarbazones, polyoximes, and like groups known to be useful for this purpose. Chelates are coupled to the antibodies using standard chemistries. The chelate is normally linked to the antibody by a group which enables formation of a bond to the molecule with minimal loss of immunoreactivity and minimal aggregation and/or internal cross-linking. Other, more unusual, methods and reagents for conjugating chelates to antibodies are disclosed in U.S. Pat. No. 4,824,659. Particularly useful metal-chelate combinations include 2-benzyl-DTPA and its monomethyl and cyclohexyl analogs, used with diagnostic isotopes in the general energy range of 60 to 4,000 keV, such as ^{125}I, ^{131}I, ^{123}I, ^{124}I, ^{62}Cu, ^{64}Cu, ^{18}F, ^{111}In, ^{67}Ga, ^{68}Ga, ^{99m}Tc, ^{94m}Tc, ^{11}C, ^{13}N, ^{15}O, ^{76}Br, for radioimaging. The same chelates, when complexed with non-radioactive metals, such as manganese, iron and gadolinium are useful for MRI, when used along with the antibodies of the invention. Macrocyclic chelates such as NOTA (1,4,7-triazacyclononane-N,N',N"-

triacetic acid), DOTA (1,4,7,10-tetraazacyclododecanetetraacetic acid), and TETA (p-bromoacetamido-benzyl-tetraethylaminetetraacetic acid) are of use with a variety of metals and radiometals, most particularly with radionuclides of gallium, yttrium and copper, respectively. Such metal-chelate complexes can be made very stable by tailoring the ring size to the metal of interest. Other ring-type chelates such as macrocyclic polyethers, which are of interest for stably binding nuclides, such as ^{223}Ra for radioimmunotherapy (RAIT) are encompassed by the invention. More recently, techniques of general utility for labeling virtually any molecule with an ^{18}F atom of use in PET imaging have been described in U.S. Patent Application Serial No. 12/112,289 (now issued U.S. Patent No. 7,563,433).

[077] An immunoconjugate is an antibody, antibody fragment or fusion protein conjugated to at least one therapeutic and/or diagnostic agent. The diagnostic agent can comprise a radionuclide or non-radionuclide, a contrast agent (such as for magnetic resonance imaging, computed tomography or ultrasound), and the radionuclide can be a gamma-, beta-, alpha-, Auger electron-, or positron-emitting isotope. The therapeutic agent may be any agent of use to treat a disease state such as cancer, described in more detail below.

[078] An expression vector is a DNA molecule comprising a gene that is expressed in a host cell. Typically, gene expression is placed under the control of certain regulatory elements, including constitutive or inducible promoters, tissue-specific regulatory elements and enhancers. Such a gene is said to be "operably linked to" the regulatory elements.

[079] A recombinant host may be any prokaryotic or eukaryotic cell that contains either a cloning vector or expression vector. This term also includes those prokaryotic or eukaryotic cells, as well as transgenic animals, that have been genetically engineered to contain the cloned gene(s) in the chromosome or genome of the host cell. Suitable mammalian host cells include myeloma cells, such as SP2/0 cells, and NS0 cells, as well as Chinese Hamster Ovary (CHO) cells, hybridoma cell lines and other mammalian host cell useful for expressing antibodies. Also particularly useful to express mAbs and other fusion proteins are Sp2/0 cells transfected with an apoptosis inhibitor, such as a Bcl-EEE gene, and adapted to grow and be further transfected in serum free conditions, as described in U11/187,863 (now issued U.S. Patent No. 7,531,327), filed July 25, 2005; 11/487,215

(now issued U.S. Patent No. 7,537,930), filed July 14, 2006; and 11/877,728, filed October 24, 2007.)

[080] As used herein, the term antibody fusion protein is a recombinantly produced antigen-binding molecule in which two or more of the same or different natural antibody, single-chain antibody or antibody fragments with the same or different specificities are linked. Valency of the fusion protein indicates the total number of binding arms or sites the fusion protein has to an antigen or epitope; i.e., monovalent, bivalent, trivalent or multivalent. The multivalency of the antibody fusion protein means that it can take advantage of multiple interactions in binding to an antigen, thus increasing the avidity of binding to the antigen. Specificity indicates how many antigens or epitopes an antibody fusion protein is able to bind; i.e., monospecific, bispecific, trispecific, multispecific. Using these definitions, a natural antibody, e.g., an IgG, is bivalent because it has two binding arms but is monospecific because it binds to one antigen. Monospecific, multivalent fusion proteins have more than one binding site for an epitope but only bind with the same or different epitopes on the same antigen, for example a diabody with two binding sites reactive with the same antigen. The fusion protein may comprise a multivalent or multispecific combination of different antibody components or multiple copies of the same antibody component. The fusion protein may additionally comprise a therapeutic agent. Examples of therapeutic agents suitable for such fusion proteins include immunomodulators ("antibody-immunomodulator fusion protein") and toxins ("antibody-toxin fusion protein"). One preferred toxin comprises a ribonuclease (RNase), preferably a recombinant RNase.

[081] A multispecific antibody is an antibody that can bind simultaneously to at least two targets that are of different structure, e.g., two different antigens, two different epitopes on the same antigen, or a hapten and/or an antigen or epitope. Multispecific, multivalent antibodies are constructs that have more than one binding site, and the binding sites are of different specificity.

[082] A bispecific antibody is an antibody that can bind simultaneously to two different targets. Bispecific antibodies (bsAb) and bispecific antibody fragments (bsFab) may have at least one arm that specifically binds to, for example, a tumor-associated antigen and at least one other arm that specifically binds to a targetable conjugate that bears a therapeutic

or diagnostic agent. A variety of bispecific fusion proteins can be produced using molecular engineering.

PAM4 Antibodies

[083] Various embodiments of the invention concern antibodies that react with very high selectivity with pancreatic cancer as opposed to normal or benign pancreatic tissues. The anti-pancreatic cancer antibodies and fragments thereof are preferably raised against a crude mucin preparation from a tumor of the human pancreas, although partially purified or even purified mucins may be utilized. A non-limiting example of such antibodies is the PAM4 antibody.

[084] The murine PAM4 (mPAM4) antibody was developed by employing pancreatic cancer mucin derived from the xenografted RIP-1 human pancreatic carcinoma as immunogen. (Gold et al., Int. J. Cancer, 57:204-210, 1994.) As discussed below, antibody cross-reactivity and immunohistochemical staining studies indicate that the PAM4 antibody recognizes a unique and novel epitope on a target pancreatic cancer antigen. Immunohistochemical staining studies, such as those described in Example 2, have shown that the PAM4 MAb binds to an antigen expressed by breast, pancreas and other cancer cells, with limited binding to normal human tissue; however, the highest expression is usually by pancreatic cancer cells. Thus, the PAM4 antibodies are relatively specific to pancreatic cancer and preferentially bind pancreatic cancer cells. The PAM4 antibody is reactive with a target epitope which can be internalized. This epitope is expressed primarily by antigens associated with pancreatic cancer and not with focal pancreatitis or normal pancreatic tissue. Binding of PAM4 antibody to the PAM4 epitope is inhibited by treatment of the antigen with DTT or periodate. Localization and therapy studies using a radiolabeled PAM4 MAb in animal models have demonstrated tumor targeting and therapeutic efficacy.

[085] The PAM4 antibodies bind to PAM4 antigen, which is expressed by many organs and tumor types, but is preferentially expressed in pancreatic cancer cells. Studies with a PAM4 MAb, such as in Example 3, indicate that the antibody exhibits several important properties, which make it a good candidate for clinical diagnostic and therapeutic applications. The PAM4 antigen provides a useful target for diagnosis and therapy of pancreatic and other cancers. The PAM4 antibody apparently recognizes an epitope of a pancreatic cancer antigen that is distinct from the epitopes recognized by non-PAM4 anti-

pancreatic cancer antibodies (CA19.9, DUPAN2, SPAN1, Nd2, CEACAM5, B72.3, anti-Le^a, and other anti-Lewis antigens).

[086] Antibodies suitable for use in combination or conjunction with PAM4 antibodies include, for example, the antibodies CA19.9, DUPAN2, SPAN1, Nd2, B72.3, CC49, anti-CEA, anti-CEACAM6, anti-Le^a, anti-HLA-DR, anti-CD40, anti-CD74, anti-CD138, and antibodies defined by the Lewis antigen Le(y), or antibodies against colon-specific antigen-p (CSAp), MUC-1, MUC-2, MUC-3, MUC-4, MUC-5ac, MUC-16, MUC-17, EGP-1, EGP-2, HER2/neu, EGFR, angiogenesis factors (e.g., VEGF and PlGF), insulin-like growth factor (ILGF), tenascin, platelet-derived growth factor, and IL-6, as well as products of oncogenes (bcl-2, Kras, p53), cMET, and antibodies against tumor necrosis substances, such as described in patents by Epstein et al. (U.S. Pat. Nos. 6,071,491, 6.017,514, 5,019,368 and 5,882,626). Such antibodies would be useful for complementing PAM4 antibody immunodetection and immunotherapy methods. These and other therapeutic agents could act synergistically with anti-pancreatic cancer antibodies, such as PAM4 antibody, when administered before, together with or after administration of PAM4 antibody.

[087] In therapeutic applications, antibodies that are agonistic or antagonistic to immunomodulators involved in effector cell function against tumor cells could also be useful in combination with PAM4 antibodies alone or in combination with other tumor-associated antibodies, one example being antibodies against CD40. Todryk et al., J. Immunol Methods, 248:139-147 (2001); Turner et al., J. Immunol, 166:89-94 (2001). Also of use are antibodies against markers or products of oncogenes (e.g., bcl-2, Kras, p53, cMET), or antibodies against angiogenesis factors, such as VEGFR and placenta-like growth factor (PlGF).

[088] The availability of another PAM4-like antibody that binds to a different epitope of the PAM4 antigen is important for the development of a double-determinant enzyme-linked immunosorbent assay (ELISA), of use for detecting a PAM4 antigen in clinical samples. ELISA experiments are described in Example 1 and 5.

[089] The murine, chimeric, humanized and fully human PAM4 antibodies and fragments thereof described herein are exemplary of anti-pancreatic cancer antibodies of use for diagnostic and/or therapeutic methods. The Examples below disclose a preferred embodiment of the construction and use of a humanized PMA4 antibody. Because non-human monoclonal antibodies can be recognized by the human host as a foreign protein,

and repeated injections can lead to harmful hypersensitivity reactions, humanization of a murine antibody sequences can reduce the adverse immune response that patients may experience. For murine-based monoclonal antibodies, this is often referred to as a Human Anti-Mouse Antibody (HAMA) response. Preferably some human residues in the framework regions of the humanized anti-pancreatic cancer antibody or fragments thereof are replaced by their murine counterparts. It is also preferred that a combination of framework sequences from two different human antibodies is used for VH. The constant domains of the antibody molecule are derived from those of a human antibody.

[090] Another preferred embodiment is a human anti-pancreatic cancer antibody, such as a human PAM4 antibody. A human antibody is an antibody obtained, for example, from transgenic mice that have been "engineered" to produce specific human antibodies in response to antigenic challenge. In this technique, elements of the human heavy and light chain locus are introduced into strains of mice derived from embryonic stem cell lines that contain targeted disruptions of the endogenous heavy chain and light chain loci. The transgenic mice can synthesize human antibodies specific for human antigens, and the mice can be used to produce human antibody-secreting hybridomas. Methods for obtaining human antibodies from transgenic mice are described by Green et al., Nature Genet. 7:13 (1994), Lonberg et al., Nature 368:856 (1994), and Taylor et al., Int. Immun. 6:579 (1994).

[091] A fully human antibody also can be constructed by genetic or chromosomal transfection methods, as well as phage display technology, all of which are known in the art. See for example, McCafferty et al., Nature 348:552-553 (1990) for the production of human antibodies and fragments thereof *in vitro*, from immunoglobulin variable domain gene repertoires from unimmunized donors. In this technique, antibody variable domain genes are cloned in-frame into either a major or minor coat protein gene of a filamentous bacteriophage, and displayed as functional antibody fragments on the surface of the phage particle. Because the filamentous particle contains a single-stranded DNA copy of the phage genome, selections based on the functional properties of the antibody also result in selection of the gene encoding the antibody exhibiting those properties. In this way, the phage mimics some of the properties of the B cell. Phage display can be performed in a variety of formats, for their review, see e.g. Johnson and Chiswell, Current Opinion in Structural Biology 3:5564-571 (1993).

Antibody Preparation

[092] Monoclonal antibodies for specific antigens may be obtained by methods known to those skilled in the art. See, for example, Kohler and Milstein, Nature 256: 495 (1975), and Coligan et al. (eds.), CURRENT PROTOCOLS IN IMMUNOLOGY, VOL. 1, pages 2.5.1-2.6.7 (John Wiley & Sons 1991) (hereinafter "Coligan"). Briefly, anti-pancreatic cancer MAbs can be obtained by injecting mice with a composition comprising mucins from pancreatic cancer, such as the PAM4 antigen, verifying the presence of antibody production by removing a serum sample, removing the spleen to obtain B-lymphocytes, fusing the B-lymphocytes with myeloma cells to produce hybridomas, cloning the hybridomas, selecting positive clones which produce antibodies to PAM4 antigen, culturing the clones that produce antibodies to PAM4 antigen, and isolating anti-pancreatic cancer antibodies from the hybridoma cultures.

[093] After the initial raising of antibodies to the immunogen, the antibodies can be sequenced and subsequently prepared by recombinant techniques to produce chimeric or humanized antibodies. Chimerization of murine antibodies and antibody fragments are well known to those skilled in the art. The use of antibody components derived from chimerized monoclonal antibodies reduces potential problems associated with the immunogenicity of murine constant regions.

[094] General techniques for cloning murine immunoglobulin variable domains are described, for example, by the publication of Orlandi et al., Proc Nat'l Acad. Sci. USA 86: 3833 (1989). In general, the V_K (variable light chain) and V_H (variable heavy chain) sequences for murine antibodies can be obtained by a variety of molecular cloning procedures, such as RT-PCR, 5'-RACE, and cDNA library screening. Specifically, the V_H and V_K sequences of the murine PAM4 MAb were cloned by PCR amplification from the hybridoma cells by RT-PCR, and their sequences determined by DNA sequencing. To confirm their authenticity, the cloned V_K and V_H genes can be expressed in cell culture as a chimeric Ab as described by Orlandi et al., (Proc Natl. Acad. Sci., USA, 86: 3833, 1989).

[095] In a preferred embodiment, a chimerized PAM4 antibody or antibody fragment comprises the complementarity-determining regions (CDRs) and framework regions (FR) of a murine PAM4 MAb and the light and heavy chain constant regions of a human antibody, wherein the CDRs of the light chain variable region of the chimerized PAM4 comprises CDR1 comprising an amino acid sequence of SASSSVSSSYLY (SEQ ID NO:1); CDR2 comprising an amino acid sequence of STSNLAS (SEQ ID NO:2); and

CDR3 comprising an amino acid sequence of HQWNRYPYT (SEQ ID NO:3); and the CDRs of the heavy chain variable region of the chimerized PAM4 MAb comprises CDR1 comprising an amino acid sequence of SYVLH (SEQ ID NO:4); CDR2 comprising an amino acid sequence of YINPYNDGTQYNEKFKG (SEQ ID NO:5) and CDR3 comprising an amino acid sequence of GFGGSYGFAY (SEQ ID NO:6). The use of antibody components derived from chimerized monoclonal antibodies reduces potential problems associated with the immunogenicity of murine constant regions.

[096] Humanization of murine antibodies and antibody fragments is also well known to those skilled in the art. Techniques for producing humanized MAbs are disclosed, for example, by Carter et al., Proc Nat'l Acad. Sci. USA 89: 4285 (1992), Singer et al., J. Immun. 150: 2844 (1992), Mountain et al. Biotechnol Genet Eng Rev. 10:1 (1992), and Coligan at pages 10.19.1-10.19.11. For example, humanized monoclonal antibodies may be produced by transferring murine complementary determining regions from heavy and light variable chains of the mouse immunoglobulin into a human variable domain, and then, substituting human residues in the framework regions of the murine counterparts. The use of human framework region sequences, in addition to human constant region sequences, further reduces the chance of inducing HAMA reactions.

[097] Based on the PAM4 variable region sequences, obtained as described above, a humanized PAM4 antibody can be designed and constructed as described by Leung et al. (Mol Immunol. 32: 1413 (1995)). Example 1 describes the humanization process utilized for construction of the hPAM4 MAb.

[098] The nucleotide sequences of the primers used to prepare the hPAM4 antibodies are discussed in Example 1, below. In a preferred embodiment, a humanized PAM4 antibody or antibody fragment comprises the light and heavy chain CDR sequences (SEQ ID NO:1 to SEQ ID NO:6) disclosed above. Also preferred, the FRs of the light and heavy chain variable regions of the humanized antibody comprise at least one amino acid substituted from said corresponding FRs of the murine PAM4 MAb.

[099] A fully human antibody, e.g., human PAM4 can be obtained from a transgenic non-human animal. See, e.g., Mendez et al., Nature Genetics, 15: 146-156 (1997); U.S. Pat. No. 5,633,425. For example, a human antibody can be recovered from a transgenic mouse possessing human immunoglobulin loci. The mouse humoral immune system is humanized by inactivating the endogenous immunoglobulin genes and introducing human

immunoglobulin loci. The human immunoglobulin loci are exceedingly complex and comprise a large number of discrete segments which together occupy almost 0.2% of the human genome. To ensure that transgenic mice are capable of producing adequate repertoires of antibodies, large portions of human heavy- and light-chain loci must be introduced into the mouse genome. This is accomplished in a stepwise process beginning with the formation of yeast artificial chromosomes (YACs) containing either human heavy- or light-chain immunoglobulin loci in germline configuration. Since each insert is approximately 1 Mb in size, YAC construction requires homologous recombination of overlapping fragments of the immunoglobulin loci. The two YACs, one containing the heavy-chain loci and one containing the light-chain loci, are introduced separately into mice via fusion of YAC-containing yeast spheroblasts with mouse embryonic stem cells. Embryonic stem cell clones are then microinjected into mouse blastocysts. Resulting chimeric males are screened for their ability to transmit the YAC through their germline and are bred with mice deficient in murine antibody production. Breeding the two transgenic strains, one containing the human heavy-chain loci and the other containing the human light-chain loci, creates progeny which produce human antibodies in response to immunization.

[0100] Antibodies can be produced by cell culture techniques using methods known in the art. In one example transfectoma cultures are adapted to serum-free medium. For production of humanized antibody, cells may be grown as a 500 ml culture in roller bottles using HSFM. Cultures are centrifuged and the supernatant filtered through a 0.2 μm membrane. The filtered medium is passed through a protein-A column (1 x 3 cm) at a flow rate of 1 ml/min. The resin is then washed with about 10 column volumes of PBS and protein A-bound antibody is eluted from the column with 0.1 M glycine buffer (pH 3.5) containing 10 mM EDTA. Fractions of 1.0 ml are collected in tubes containing 10 μl of 3 M Tris (pH 8.6), and protein concentrations determined from the absorbance at 280/260 nm. Peak fractions are pooled, dialyzed against PBS, and the antibody concentrated, for example, with a Centricon 30 filter (Amicon, Beverly, MA). The antibody concentration is determined by ELISA and its concentration adjusted to about 1 mg/ml using PBS. Sodium azide, 0.01% (w/v), is conveniently added to the sample as preservative.

[0101] Antibodies can be isolated and purified from hybridoma cultures by a variety of well-established techniques. Such isolation techniques include affinity chromatography with Protein-A Sepharose, size-exclusion chromatography, and ion-exchange

chromatography. See, for example, Coligan at pages 2.7.1-2.7.12 and pages 2.9.1-2.9.3. Also, see Baines et al., "Purification of Immunoglobulin G (IgG)," in METHODS IN MOLECULAR BIOLOGY, VOL. 10, pages 79-104 (The Humana Press, Inc. 1992).

[0102] Anti-pancreatic cancer MAbs can be characterized by a variety of techniques that are well-known to those of skill in the art. For example, the ability of an antibody to bind to the PAM4 antigen can be verified using an indirect enzyme immunoassay, flow cytometry analysis, ELISA or Western blot analysis.

Antibody Fragments

[0103] Antibody fragments are antigen binding portions of an antibody, such as $F(ab')_2$, Fab', $F(ab)_2$, Fab, Fv, sFv, scFv and the like. Antibody fragments which recognize specific epitopes can be generated by known techniques. $F(ab')_2$ fragments, for example, can be produced by pepsin digestion of the antibody molecule. These and other methods are described, for example, by Goldenberg, U.S. Pat. Nos. 4,036,945 and 4,331,647 and references contained therein. Also, see Nisonoff et al., Arch Biochem. Biophys. 89: 230 (1960); Porter, Biochem. J. 73: 119 (1959), Edelman et al., in METHODS IN ENZYMOLOGY VOL. 1, page 422 (Academic Press 1967), and Coligan at pages 2.8.1-2.8.10 and 2.10.-2.10.4. Alternatively, Fab' expression libraries can be constructed (Huse et al., 1989, Science, 246:1274-1281) to allow rapid and easy identification of monoclonal Fab' fragments with the desired specificity.

[0104] A single chain Fv molecule (scFv) comprises a VL domain and a VH domain. The VL and VH domains associate to form a target binding site. These two domains are further covalently linked by a peptide linker (L). A scFv molecule is denoted as either VL-L-VH if the VL domain is the N-terminal part of the scFv molecule, or as VH-L-VL if the VH domain is the N-terminal part of the scFv molecule. Methods for making scFv molecules and designing suitable peptide linkers are described in U.S. Pat. No. 4,704,692, U.S. Pat. No. 4,946,778, R. Raag and M. Whitlow, "Single Chain Fvs." FASEB Vol 9:73-80 (1995) and R. E. Bird and B. W. Walker, Single Chain Antibody Variable Regions, TIBTECH, Vol 9: 132-137 (1991).

[0105] Other antibody fragments, for example single domain antibody fragments, are known in the art and may be used in the claimed constructs. Single domain antibodies (VHH) may be obtained, for example, from camels, alpacas or llamas by standard immunization techniques. (See, e.g., Muyldermans et al., TIBS 26:230-235, 2001; Yau et al., J Immunol Methods 281:161-75, 2003; Maass et al., J Immunol Methods 324:13-25,

2007). The VHH may have potent antigen-binding capacity and can interact with novel epitopes that are inacessible to conventional VH-VL pairs. (Muyldermans et al., 2001). Alpaca serum IgG contains about 50% camelid heavy chain only IgG antibodies (HCAbs) (Maass et al., 2007). Alpacas may be immunized with known antigens, such as TNF-α, and VHHs can be isolated that bind to and neutralize the target antigen (Maass et al., 2007). PCR primers that amplify virtually all alpaca VHH coding sequences have been identified and may be used to construct alpaca VHH phage display libraries, which can be used for antibody fragment isolation by standard biopanning techniques well known in the art (Maass et al., 2007).

[0106] An antibody fragment can also be prepared by proteolytic hydrolysis of a full-length antibody or by expression in E. coli or another host of the DNA coding for the fragment. An antibody fragment can be obtained by pepsin or papain digestion of full-length antibodies by conventional methods. For example, an antibody fragment can be produced by enzymatic cleavage of antibodies with pepsin to provide an approximate 100 Kd fragment denoted $F(ab')_2$. This fragment can be further cleaved using a thiol reducing agent, and optionally a blocking group for the sulfhydryl groups resulting from cleavage of disulfide linkages, to produce an approximate 50 Kd Fab' monovalent fragment. Alternatively, an enzymatic cleavage using papain produces two monovalent Fab fragments and an Fc fragment directly.

[0107] Another form of antibody fragment is a peptide coding for a single complementarity-determining region (CDR). A CDR is a segment of the variable region of an antibody that is complementary in structure to the epitope to which the antibody binds and is more variable than the rest of the variable region. Accordingly, a CDR is sometimes referred to as a hypervariable region. A variable region comprises three CDRs. CDR peptides can be obtained by constructing genes encoding the CDR of an antibody of interest. Such genes are prepared, for example, by using the polymerase chain reaction (PCR) to synthesize the variable region from RNA of antibody-producing cells. See, for example, Larrick et al., Methods: A Companion to Methods in Enzymology 2: 106 (1991); Courtenay-Luck, "Genetic Manipulation of Monoclonal Antibodies," in MONOCLONAL ANTIBODIES: PRODUCTION, ENGINEERING AND CLINICAL APPLICATION, Ritter et al. (eds.), pages 166-179 (Cambridge University Press 1995); and Ward et al., "Genetic Manipulation and Expression of Antibodies," in MONOCLONAL

ANTIBODIES: PRINCIPLES AND APPLICATIONS, Birch et al., (eds.), pages 137-185 (Wiley-Liss, Inc. 1995).

[0108] Other methods of cleaving antibodies, such as separation of heavy chains to form monovalent light-heavy chain fragments, further cleavage of fragments, or other enzymatic, chemical or genetic techniques may also be used, so long as the fragments bind to the antigen that is recognized by the intact antibody.

Antibody Fusion Proteins

[0109] Fusion proteins comprising the anti-pancreatic cancer antibodies of interest can be prepared by a variety of conventional procedures, ranging from glutaraldehyde linkage to more specific linkages between functional groups. The antibodies and/or antibody fragments that comprise the fusion proteins described herein are preferably covalently bound to one another, directly or through a linker moiety, through one or more functional groups on the antibody or fragment, e.g., amine, carboxyl, phenyl, thiol, or hydroxyl groups. Various conventional linkers in addition to glutaraldehyde can be used, e.g., diisocyanates, diiosothiocyanates, bis(hydroxysuccinimide)esters, carbodiimides, maleimidehydroxy succinimide esters, and the like.

[0110] A simple method for producing fusion proteins is to mix the antibodies or fragments in the presence of glutaraldehyde. The initial Schiff base linkages can be stabilized, e.g., by borohydride reduction to secondary amines. A diiosothiocyanate or carbodiimide can be used in place of glutaraldehyde as a non-site-specific linker. In one embodiment, an antibody fusion protein comprises an anti-pancreatic cancer MAb, or fragment thereof, wherein the MAb binds to the PAM4 antigen. This fusion protein and fragments thereof preferentially bind pancreatic cancer cells. This monovalent, monospecific MAb is useful for direct targeting of an antigen, where the MAb is attached to a therapeutic agent, a diagnostic agent, or a combination thereof, and the protein is administered directly to a patient.

[0111] The fusion proteins may instead comprise at least two anti-pancreatic cancer MAbs that bind to distinct epitopes of the PAM4 antigen. For example, the MAbs can produce antigen specific diabodies, triabodies and tetrabodies, which are multivalent but monospecific to the PAM4 antigen. The non-covalent association of two or more scFv molecules can form functional diabodies, triabodies and tetrabodies. Monospecific diabodies are homodimers of the same scFv, where each scFv comprises the VH domain from the selected antibody connected by a short linker to the VL domain of the same

antibody. A diabody is a bivalent dimer formed by the non-covalent association of two scFvs, yielding two Fv binding sites. A triabody results from the formation of a trivalent trimer of three scFvs, yielding three binding sites, and a tetrabody is a tetravalent tetramer of four scFvs, resulting in four binding sites. Several monospecific diabodies have been made using an expression vector that contains a recombinant gene construct comprising VH1-linker-VL1. See Holliger et al., Proc Natl. Acad. Sci USA 90: 6444-6448 (1993); Atwell et al., Molecular Immunology 33: 1301-1302 (1996); Holliger et al., Nature Biotechnology 15: 632-631(1997); Helfrich et al., Int J Cancer 76: 232-239 (1998); Kipriyanov et al., Int J Cancer 77: 763-772 (1998); Holiger et al., Cancer Research 59: 2909-2916(1999)). Methods of constructing scFvs are disclosed in U.S. Pat. No. 4,946,778 (1990) and U.S. Pat. No. 5,132,405 (1992). Methods of producing multivalent, monospecific antibodies based on scFv are disclosed in U.S. Pat. No. 5,837,242 (1998), U.S. Pat. No. 5,844,094 (1998) and WO-98/44001 (1998). The multivalent, monospecific antibody fusion protein binds to two or more of the same type of epitopes that can be situated on the same antigen or on separate antigens. The increased valency allows for additional interaction, increased affinity, and longer residence times. These antibody fusion proteins can be utilized in direct targeting systems, where the antibody fusion protein is conjugated to a therapeutic agent, a diagnostic agent, or a combination thereof, and administered directly to a patient in need thereof.

[0112] A preferred embodiment is a multivalent, multispecific antibody or fragment thereof comprising one or more antigen binding sites having an affinity toward a PAM4 target epitope and one or more additional binding sites for other epitopes associated with pancreatic cancer. This fusion protein is multispecific because it binds at least two different epitopes, which can reside on the same or different antigens. For example, the fusion protein may comprise more than one antigen binding site, the first with an affinity toward a PAM4 antigen epitope and the second with an affinity toward another target antigen such as TAG-72 or CEA. Another example is a bispecific antibody fusion protein which may comprise a CA19.9 MAb (or fragment thereof) and a PAM4 MAb (or fragment thereof). Such a fusion protein will have an affinity toward CA19.9 as well as the PAM4 antigen. The antibody fusion proteins and fragments thereof can be utilized in direct targeting systems, where the antibody fusion protein is conjugated to a therapeutic agent, a

diagnostic agent, or a combination thereof, and administered directly to a patient in need thereof.

[0113] Another preferred embodiment is a multivalent, multispecific antibody comprising at least one binding site having affinity toward a PAM4 target epitope and at least one hapten binding site having affinity towards hapten molecules. For example, a bispecific fusion protein may comprise the 679 MAb (or fragment thereof) and the PAM4 MAb (or fragment thereof). The monoclonal 679 antibody binds with high affinity to molecules containing the tri-peptide moiety histamine succinyl glycyl (HSG). Such a bispecific PAM4 antibody fusion protein can be prepared, for example, by obtaining a $F(ab')_2$ fragment from 679, as described above. The interchain disulfide bridges of the 679 $F(ab')_2$ fragment are gently reduced with DTT, taking care to avoid light-heavy chain linkage, to form Fab'-SH fragments. The SH group(s) is (are) activated with an excess of bis-maleimide linker (1,1'-(methylenedi-4,1-phenylene)b-is-malemide). The PAM4 MAb is converted to Fab'-SH and then reacted with the activated 679 Fab'-SH fragment to obtain a bispecific antibody fusion protein. Bispecific antibody fusion proteins such as this one can be utilized in affinity enhancing systems, where the target antigen is pretargeted with the fusion protein and is subsequently targeted with a diagnostic or therapeutic agent attached to a carrier moiety (targetable construct) containing one or more HSG haptens. In alternative preferred embodiments, a DNL-based hPAM4-679 construct, such as TF10, may be prepared and used as described in the Examples below.

[0114] Bispecific antibodies can be made by a variety of conventional methods, e.g., disulfide cleavage and reformation of mixtures of whole IgG or, preferably $F(ab')_2$ fragments, fusions of more than one hybridoma to form polyomas that produce antibodies having more than one specificity, and by genetic engineering. Bispecific antibody fusion proteins have been prepared by oxidative cleavage of Fab' fragments resulting from reductive cleavage of different antibodies. This is advantageously carried out by mixing two different $F(ab')_2$ fragments produced by pepsin digestion of two different antibodies, reductive cleavage to form a mixture of Fab' fragments, followed by oxidative reformation of the disulfide linkages to produce a mixture of $F(ab')_2$ fragments including bispecific antibody fusion proteins containing a Fab' portion specific to each of the original epitopes. General techniques for the preparation of antibody fusion proteins may be found, for example, in Nisonoff et al., Arch Biochem Biophys. 93: 470 (1961), Hmmerling et al., J Exp Med. 128: 1461 (1968), and U.S. Pat. No. 4,331,647.

[0115] More selective linkage can be achieved by using a heterobifunctional linker such as maleimidehydroxysuccinimide ester. Reaction of the ester with an antibody or fragment will derivatize amine groups on the antibody or fragment, and the derivative can then be reacted with, e.g., an antibody Fab fragment having free sulfhydryl groups (or, a larger fragment or intact antibody with sulfhydryl groups appended thereto by, e.g., Traut's Reagent). Such a linker is less likely to crosslink groups in the same antibody and improves the selectivity of the linkage.

[0116] It is advantageous to link the antibodies or fragments at sites remote from the antigen- binding sites. This can be accomplished by, e.g., linkage to cleaved interchain sulfydryl groups, as noted above. Another method involves reacting an antibody having an oxidized carbohydrate portion with another antibody that has at lease one free amine function. This results in an initial Schiff base linkage, which is preferably stabilized by reduction to a secondary amine, e.g., by borohydride reduction, to form the final composite. Such site-specific linkages are disclosed, for small molecules, in U.S. Pat. No. 4,671,958, and for larger addends in U.S. Pat. No. 4,699,784.

[0117] ScFvs with linkers greater than 12 amino acid residues in length (for example, 15- or 18-residue linkers) allow interactions between the VH and VL domains on the same chain and generally form a mixture of monomers, dimers (termed diabodies) and small amounts of higher mass multimers, (Kortt et al., Eur J Biochem. (1994) 221: 151-157). ScFvs with linkers of 5 or less amino acid residues, however, prohibit intramolecular pairing of the VH and VL domains on the same chain, forcing pairing with VH and VL domains on a different chain. Linkers between 3- and 12-residues form predominantly dimers (Atwell et al., Protein Engineering (1999) 12: 597-604). With linkers between 0 and 2 residues, trimeric (termed triabodies), tetrameric (termed tetrabodies) or higher oligomeric structures of scFvs are formed; however, the exact patterns of oligomerization appear to depend on the composition as well as the orientation of the V-domains, in addition to the linker length.

[0118] More recently, a novel technique for construction of mixtures of antibodies, antibody fragments and/or other effector moieties in virtually any combination desired has been described in U.S. Patent Application Serial No. 11/389,358 (now issued U.S. Patent 7,550,143), filed 3/24/06; 11/391,584 (now issued U.S. Patent 7,521,056), filed 3/28/06; 11/478,021 (now issued U.S. Patent 7,534,866), filed 6/29/06; 11/633,729 (now issued

U.S. Patent 7,527,787), filed 12/5/06; and 11/925,408, filed 10/26/07. The technique, known generally as dock-and-lock (DNL) involves the production of fusion proteins that comprise at their N- or C-terminal ends one of two complementary peptide sequences, called dimerization and docking domain (DDD) and anchoring domain (AD) sequences. In preferred embodiments, the DDD sequences are derived from the regulatory subunits of cAMP-dependent protein kinase and the AD sequence is derived from the sequence of A-kinase anchoring protein (AKAP). The DDD sequences form dimers that bind to the AD sequence, which allows formation of trimers, tetramers, hexamers or any of a variety of other complexes. By attaching effector moieties, such as antibodies or antibody fragments, to the DDD and AD sequences, complexes may be formed of any selected combination of antibodies or antibody fragments. The DNL complexes may be covalently stabilized by formation of disulfide bonds or other linkages.

[0119] Bispecific antibodies comprising the antigen-binding variable region sequences of any known anti-TAA antibody may be utilized, including but not limited to hPAM4 (U.S. Patent No. 7,282,567), hA20 (U.S. Patent No. 7,251,164), hA19 (U.S. Patent No. 7,109,304), hIMMU31 (U.S. Patent No. 7,300,655), hLL1 (U.S. Patent No. 7,312,318,), hLL2 (U.S. Patent No. 7,074,403), hMu-9 (U.S. Patent No. 7,387,773), hL243 (U.S. Patent Application No. 11/368,296), hMN-14 (U.S. Patent No. 6,676,924), hRS7 (U.S. Patent No. 7,238,785), hMN-3 (U.S. Patent Application Serial No. 10/672,278) and hR1 (U.S. Provisional Patent Application Serial No. 61/145,896, filed 1/20/09).

[0120] Other antibodies of use may be commercially obtained from a wide variety of known sources. For example, a variety of antibody secreting hybridoma lines are available from the American Type Culture Collection (ATCC, Manassas, VA). A large number of antibodies against various disease targets, including but not limited to tumor-associated antigens, have been deposited at the ATCC and/or have published variable region sequences and are available for use in the claimed methods and compositions. See, e.g., U.S. Patent Nos. 7,312,318; 7,282,567; 7,151,164; 7,074,403; 7,060,802; 7,056,509; 7,049,060; 7,045,132; 7,041,803; 7,041,802; 7,041,293; 7,038,018; 7,037,498; 7,012,133; 7,001,598; 6,998,468; 6,994,976; 6,994,852; 6,989,241; 6,974,863; 6,965,018; 6,964,854; 6,962,981; 6,962,813; 6,956,107; 6,951,924; 6,949,244; 6,946,129; 6,943,020; 6,939,547; 6,921,645; 6,921,645; 6,921,533; 6,919,433; 6,919,078; 6,916,475; 6,905,681; 6,899,879;

6,893,625; 6,887,468; 6,887,466; 6,884,594; 6,881,405; 6,878,812; 6,875,580; 6,872,568; 6,867,006; 6,864,062; 6,861,511; 6,861,227; 6,861,226; 6,838,282; 6,835,549; 6,835,370; 6,824,780; 6,824,778; 6,812,206; 6,793,924; 6,783,758; 6,770,450; 6,767,711; 6,764,688; 6,764,681; 6,764,679; 6,743,898; 6,733,981; 6,730,307; 6,720,15; 6,716,966; 6,709,653; 6,693,176; 6,692,908; 6,689,607; 6,689,362; 6,689,355; 6,682,737; 6,682,736; 6,682,734; 6,673,344; 6,653,104; 6,652,852; 6,635,482; 6,630,144; 6,610,833; 6,610,294; 6,605,441; 6,605,279; 6,596,852; 6,592,868; 6,576,745; 6,572;856; 6,566,076; 6,562,618; 6,545,130; 6,544,749; 6,534,058; 6,528,625; 6,528,269; 6,521,227; 6,518,404; 6,511,665; 6,491,915; 6,488,930; 6,482,598; 6,482,408; 6,479,247; 6,468,531; 6,468,529; 6,465,173; 6,461,823; 6,458,356; 6,455,044; 6,455,040, 6,451,310; 6,444,206' 6,441,143; 6,432,404; 6,432,402; 6,419,928; 6,413,726; 6,406,694; 6,403,770; 6,403,091; 6,395,276; 6,395,274; 6,387,350; 6,383,759; 6,383,484; 6,376,654; 6,372,215; 6,359,126; 6,355,481; 6,355,444; 6,355,245; 6,355,244; 6,346,246; 6,344,198; 6,340,571; 6,340,459; 6,331,175; 6,306,393; 6,254,868; 6,187,287; 6,183,744; 6,129,914; 6,120,767; 6,096,289; 6,077,499; 5,922,302; 5,874,540; 5,814,440; 5,798,229; 5,789,554; 5,776,456; 5,736,119; 5,716,595; 5,677,136; 5,587,459; 5,443,953, 5,525,338. These are exemplary only and a wide variety of other antibodies and their hybridomas are known in the art. The skilled artisan will realize that antibody sequences or antibody-secreting hybridomas against almost any disease-associated antigen may be obtained by a simple search of the ATCC, NCBI and/or USPTO databases for antibodies against a selected disease-associated target of interest. The antigen binding domains of the cloned antibodies may be amplified, excised, ligated into an expression vector, transfected into an adapted host cell and used for protein production, using standard techniques well known in the art.

Pretargeting

[0121] Bispecific or multispecific antibodies may be utilized in pre-targeting techniques. Pre-targeting is a multistep process originally developed to resolve the slow blood clearance of directly targeting antibodies, which contributes to undesirable toxicity to normal tissues such as bone marrow. With pre-targeting, a radionuclide or other therapeutic agent is attached to a small delivery molecule (targetable construct or targetable conjugate) that is cleared within minutes from the blood. A pre-targeting bispecific or multispecific antibody, which has binding sites for the targetable construct as

well as a target antigen, is administered first, free antibody is allowed to clear from circulation and then the targetable construct is administered.

[0122] Pre-targeting methods are well known in the art, for example, as disclosed in Goodwin et al., U.S. Pat. No. 4,863,713; Goodwin et al., J. Nucl. Med. 29:226, 1988; Hnatowich et al., J. Nucl. Med. 28:1294, 1987; Oehr et al., J. Nucl. Med. 29:728, 1988; Klibanov et al., J. Nucl. Med. 29:1951, 1988; Sinitsyn et al., J. Nucl. Med. 30:66, 1989; Kalofonos et al., J. Nucl. Med. 31:1791, 1990; Schechter et al., Int. J. Cancer 48:167, 1991; Paganelli et al., Cancer Res. 51:5960, 1991; Paganelli et al., Nucl. Med. Commun. 12:211, 1991; U.S. Pat. No. 5,256,395; Stickney et al., Cancer Res. 51:6650, 1991; Yuan et al., Cancer Res. 51:3119, 1991; U.S. Pat. No. 6,077,499; U.S. Ser. No. 09/597,580; U.S. Ser. No. 10/361,026; U.S. Ser. No. 09/337,756; U.S. Ser. No. 09/823,746; U.S. Ser. No. 10/116,116; U.S. Ser. No. 09/382,186; U.S. Ser. No. 10/150,654; U.S. Pat. No. 6,090,381; U.S. Pat. No. 6,472,511; U.S. Ser. No. 10/114,315; U.S. Provisional Application No. 60/386,411; U.S. Provisional Application No. 60/345,641; U.S. Provisional Application No. 60/3328,835; U.S. Provisional Application No. 60/426,379; U.S. Ser. No. 09/823,746; U.S. Ser. No. 09/337,756; U.S. Provisional Application No. 60/342,103; and U.S. Patent No. 6,962,702.

[0123] A pre-targeting method of treating or diagnosing a disease or disorder in a subject may be provided by: (1) administering to the subject a bispecific antibody or antigen binding antibody fragment; (2) optionally administering to the subject a clearing composition, and allowing the composition to clear the antibody from circulation; and (3) administering to the subject the targetable construct, containing one or more chelated or chemically bound therapeutic or diagnostic agents. The technique may also be utilized for antibody dependent enzyme prodrug therapy (ADEPT) by administering an enzyme conjugated to a targetable construct, followed by a prodrug that is converted into active form by the enzyme.

Expression Vectors and Host Cells

[0124] An expression vector is a DNA molecule comprising a gene that is expressed in a host cell. Typically, gene expression is placed under the control of certain regulatory elements, including constitutive or inducible promoters, tissue-specific regulatory elements, and enhancers. Such a gene is said to be "operably linked to" the regulatory elements. A promoter is a DNA sequence that directs the transcription of a structural gene. A structural gene is a DNA sequence that is transcribed into messenger RNA

(mRNA) which is then translated into a peptide or protein. If a promoter is an inducible promoter, then the rate of transcription increases in response to an inducing agent. In contrast, the rate of transcription is not regulated by an inducing agent if the promoter is a constitutive promoter. An enhancer is a DNA regulatory element that can increase the efficiency of transcription, regardless of the distance or orientation of the enhancer relative to the start site of transcription.

[0125] An isolated DNA molecule is a fragment of DNA that is not integrated in the chromosomal DNA of a cell or organism. In preferred embodiments, a DNA sequence to be expressed will be packaged into an expression vector and transfected into a host cell, where it is preferably integrated into the host cell chromosomal DNA. Methods for construction of nucleic acids of any selected sequence, for example by chemical synthesis of shorter oligonucleotides and assembly into a protein encoding sequence, are well known in the art. Alternatively, DNA sequences of interest may be cut using restriction endonucleases and spliced together to make a selected protein encoding sequence. Other techniques for producing specific changes in encoded protein sequences, such as site-directed mutagenesis, are also well known.

[0126] A cloning vector is a DNA molecule, such as a plasmid, cosmid, or bacteriophage, that has the capability of replicating autonomously in a host cell. Cloning vectors typically contain one or a small number of restriction endonuclease recognition sites at which foreign DNA sequences can be inserted in a determinable fashion without loss of an essential biological function of the vector, as well as a marker gene that is suitable for use in the identification and selection of cells transformed with the cloning vector. Marker genes typically include genes that provide resistance to tetracycline, ampicillin, kanamycin or other antibiotics. A recombinant host may be any prokaryotic or eukaryotic cell that contains either a cloning vector or expression vector. This term also includes those prokaryotic or eukaryotic cells that have been genetically engineered to contain the cloned gene(s) in the chromosome or genome of the host cell.

[0127] Suitable host cells include microbial or mammalian host cells. A preferred host is the human cell line, PER.C6, which was developed for production of MAbs, and other fusion proteins. Accordingly, a preferred embodiment is a host cell comprising a DNA sequence encoding the anti-pancreatic cancer MAb, conjugate, fusion protein or fragments thereof. PER.C6 cells (WO 97/00326) were generated by transfection of primary human embryonic retina cells, using a plasmid that contained the Adserotype 5 (Ad5) E1A- and

E1B-coding sequences (Ad5 nucleotides 459-3510) under the control of the human phosphoglycerate kinase (PGK) promoter.

[0128] Other mammalian host cells may be used, including myeloma cells, such as SP2/0 cells, and NS0 cells, as well as Chinese Hamster Ovary (CHO) cells, hybridoma cell lines and other mammalian host cell useful for expressing antibodies. Also particularly useful to express mAbs and other fusion proteins are Sp2/0 cells transfected with an apoptosis inhibitor, such as a Bcl-EEE gene, and adapted to grow and be further transfected in serum free conditions, as described in U.S. Patent Application Serial Nos. 11/187,863 (now issued U.S. Patent No. 7,531,327), filed July 25, 2005; 11/487,215 (now issued U.S. Patent No. 7,537,930), filed July 14, 2006; and 11/877,728, filed October 24, 2007.) In certain cases, the apoptosis inhibitor and/or structural gene to be expressed may be amplified by exposing the host cell to an appropriate concentration of methotrexate. Sp2/0 cells transfected with Bcl-EEE and conditioned to grow in serum-free medium have been reported to exhibited prolonged longevity in culture, higher cell density, and significantly higher rates of protein production (U.S. Patent No. 7,531,327; U.S. Patent No. 7,537,930); USSN 11/877,728, filed October 24, 2007).

Antibody Use for Treatment and Diagnosis

[0129] Certain embodiments concern methods of diagnosing or treating a malignancy in a subject, comprising administering to the subject an anti-pancreatic cancer MAb, fusion protein or fragment thereof, wherein the MAb, fusion protein or fragment is bound to at least one diagnostic and/or therapeutic agent. Also preferred is a method for diagnosing or treating cancer, comprising administering to a subject a multivalent, multispecific antibody or fragment thereof comprising one or more antigen binding sites toward a PAM4 antigen and one or more hapten binding sites, waiting a sufficient amount of time for non-bound antibody to clear the subject's blood stream; and then administering to the subject a carrier molecule comprising a diagnostic agent, a therapeutic agent, or a combination thereof, that binds to the hapten-binding site of the localized antibody. In a more preferred embodiment, the cancer is a non-endocrine pancreatic cancer.

[0130] The use of MAbs for *in vitro* diagnosis is well-known. See, for example, Carlsson et al., Bio/Technology 7 (6): 567 (1989). For example, MAbs can be used to detect the presence of a tumor-associated antigen in tissue from biopsy samples. MAbs also can be used to measure the amount of tumor-associated antigen in clinical fluid samples using

techniques such as radioimmunoassay, enzyme-linked immunosorbent assay, and fluorescence immunoassay.

[0131] Conjugates of tumor-targeted MAbs and toxins can be used to selectively kill cancer cells *in vivo* (Spalding, Bio/Technology 9(8): 701 (1991); Goldenberg, Scientific American Science & Medicine 1(1): 64 (1994)). For example, therapeutic studies in experimental animal models have demonstrated the anti-tumor activity of antibodies carrying cytotoxic radionuclides. (Goldenberg et al., Cancer Res. 41: 4354 (1981), Cheung et al., J. Nat'l Cancer Inst. 77: 739 (1986), and Senekowitsch et al., J. Nucl. Med. 30: 531 (1989)). In a preferred embodiment, the conjugate comprises a ^{90}Y-labeled hPAM4 antibody. The conjugate may optionally be administered in conjunction with one or more other therapeutic agents. In a preferred embodiment, ^{90}Y-labeled hPAM4 is administered together with gemcitabine or 5-fluorouracil to a patient with pancreatic cancer. In a further preferred embodiment, ^{90}Y is conjugated to a DOTA chelate for attachment to hPAM4. In a still further preferred embodiment, the ^{90}Y-DOTA-hPAM4 is combined with gemcitabine in fractionated doses comprising a treatment cycle, such as with repeated, lower, less-toxic doses of gemcitabine combined with lower, fractionated doses of ^{90}Y-DOTA-hPAM4.

[0132] As tolerated, repeated cycles of this fractionated dose schedule are indicated. By way of example, 4 weekly doses of 200 mg/m^2 of gemcitabine are combined with three weekly doses of 8 mg/m^2 of ^{90}Y-DOTA-hPAM4, with the latter commencing in the second week of gemcitabine administration; this constitutes a single therapy cycle. Still other doses, higher and lower of each component, may constitute a fractionated dose, which is determined by conventional means of assessing hematopoietic toxicity, since myelosuppressive effects of both agents can be cumulative. A skilled physician in such therapy interventions can adjust these doses based on the patient's bone marrow status and general health status based on many factors, including prior exposure to myelosuppressive therapeutic agents. These principles can also apply to combinations of radiolabeled hPAM4 with other therapeutic agents, including radiosensitizing drugs such as 5-fluorouracil and cisplatin.

[0133] Chimeric, humanized and human antibodies and fragments thereof have been used for *in vivo* therapeutic and diagnostic methods. Accordingly contemplated is a method of delivering a diagnostic or therapeutic agent, or a combination thereof, to a target comprising (i) providing a composition that comprises an anti-pancreatic cancer antibody

or fragment thereof, such as a chimeric, humanized or human PAM4 antibody, conjugated to at least one diagnostic and/or therapeutic agent and (ii) administering to a subject the diagnostic or therapeutic antibody conjugate. In a preferred embodiment, the anti-pancreatic cancer antibodies and fragments thereof are humanized or fully human.

[0134] Also described herein is a cancer cell targeting diagnostic or therapeutic conjugate comprising, for example, a chimeric, humanized or human PAM4 MAb or fragment thereof bound to at least one diagnostic or at least one therapeutic agent. Preferably, the diagnostic conjugate is a photoactive diagnostic agent, an ultrasound detectable agent, an MRI contrast agent or a PET radionuclide, such as ^{18}F or ^{68}Ga. Still preferred, the diagnostic agent is a radionuclide with an energy between 20 and 4,000 keV.

[0135] Another embodiment concerns a method for treating a malignancy comprising administering a naked anti-pancreatic cancer antibody, antibody fragment or fusion protein, such as a PAM4 antibody, either alone or in conjunction with one or more other therapeutic agents. The other therapeutic agent may be added before, simultaneously with or after the antibody. In a preferred embodiment, the therapeutic agent is gemcitabine, and in a more preferred embodiment, gemcitabine is given with the hPAM4 radioconjugate in a fractionated dose schedule at lower doses than the conventional 800-1,000 mg/m^2 doses of gemcitabine given weekly for 6 weeks. For example, when combined with fractionated therapeutic doses of ^{90}Y-PAM4, repeated fractionated doses intended to function as a radiosensitizing agent of 200-380 mg/m^2 gemcitabine are infused. The skilled artisan will realize that the antibodies, fusion proteins and/or fragments thereof described and claimed herein may be administered with any known or described therapeutic agent, including but not limited to heat shock protein 90 (Hsp90)

[0136] The compositions for treatment contain at least one humanized or fully human anti-pancreatic cancer antibody or fragment thereof either alone and unconjugated, or conjugated or unconjugated and in combination with other antibodies or fragments thereof, such as other humanized or chimeric antibodies, human antibodies, therapeutic agents or immunomodulators. Naked or conjugated antibodies to the same or different epitope or antigen may also be combined with one or more of the anti-pancreatic cancer antibodies or fragments thereof.

[0137] Accordingly, the present invention contemplates the administration of anti-pancreatic cancer antibodies and fragments thereof, including fusion proteins and fragments thereof, alone, as a naked antibody or antibody fragment, or administered as a

multimodal therapy. Preferably, the antibody is a humanized or fully human PAM4 antibody or fragment thereof. Multimodal therapies further include immunotherapy with a naked anti-pancreatic cancer antibody supplemented with administration of other antibodies in the form of naked antibodies, fusion proteins, or as immunoconjugates. For example, a humanized or fully human PAM4 antibody may be combined with another naked antibody, or a humanized PAM4 or other antibody conjugated to an isotope, one or more chemotherapeutic agents, cytokines, toxins or a combination thereof. For example, the present invention contemplates treatment of a naked or conjugated PAM4 antibody or fragments thereof before, in combination with, or after other pancreatic tumor associated antibodies such as CA19.9, DUPAN2, SPAN1, Nd2, B72.3, CC49, anti-Le^a antibodies, and antibodies to other Lewis antigens (e.g., Le(y)), as well as antibodies against carcinoembryonic antigen (CEA or CEACAM5), CEACAM6, colon-specific antigen-p (CSAp), MUC-1, MUC-2, MUC-3, MUC-4, MUC-5ac, MUC-16, MUC-17, HLA-DR, CD40, CD74, CD138, HER2/neu, EGFR, EGP-1, EGP-2, angiogenesis factors (e.g., VEGF, PlGF), insulin-like growth factor (ILGF), tenascin, platelet-derived growth factor, and IL-6, as well as products of oncogenes (e.g., bcl-2, Kras, p53), cMET, and antibodies against tumor necrosis substances. These solid tumor antibodies may be naked or conjugated to, *inter alia*, drugs, toxins, isotopes, radionuclides or immunomodulators. Many different antibody combinations may be constructed and used in either naked or conjugated form. Alternatively, different naked antibody combinations may be employed for administration in combination with other therapeutic agents, such as a cytotoxic drug or with radiation, given consecutively, simultaneously, or sequentially.

[0138] The antibodies described herein directly target PAM4 positive tumors. The antibodies bind selectively to pancreatic cancer or other cancer antigens and as the number of binding sites on the molecule increases, the affinity for the target cell increases and a longer residence time is observed at the desired location. Moreover, non-antigen bound molecules are cleared from the body quickly and exposure of normal tissues is minimized. A use of multispecific antibodies is in AES systems, where anti-PAM4 antibodies pre-target positive tumors for subsequent specific delivery of diagnostic or therapeutic agents. The agents may be carried by histamine succinyl glycyl (HSG) containing peptides. The murine monoclonal antibody designated 679 binds with high affinity to molecules containing the tri-peptide HSG hapten (Morel et al, Molecular Immunology, 27, 995-1000, 1990) and may be used to form a bispecific antibody with hPAM4; but even more

preferred is the use of a humanized version of 679. Alternative haptens may also be utilized, such as In-DTPA or NOTA. The bispecific antibodies bind selectively to targeted antigens allowing for increased affinity and a longer residence time at the desired location. Moreover, non-antigen bound antibodies are cleared from the body quickly and exposure of normal tissues is minimized. PAM4 and other antibodies against pancreatic cancer can be used to diagnose and/or treat mammalian cancer. Diagnosis requires the further step of detecting the bound, labeled antibodies or fragments using known techniques.

[0139] In the context of this application, the terms "diagnosis" or "detection" can be used interchangeably. Whereas diagnosis usually refers to defining a tissue's specific histological status, detection recognizes and locates a tissue, lesion or organism containing a particular antigen.

[0140] Administration of the antibodies and their fragments can be effected by intravenous, intraarterial, intraperitoneal, intramuscular, subcutaneous, intrapleural, intrathecal, perfusion through a regional catheter, or direct intralesional injection. When administering the antibody by injection, the administration may be by continuous infusion or by single or multiple boluses.

Naked Antibody Therapy

[0141] The efficacy of the naked anti-pancreatic cancer antibodies and their fragments can be enhanced by supplementing these naked antibodies with one or more other naked antibodies, or with one or more immunoconjugates conjugated with one or more therapeutic agents, including drugs, toxins, immunomodulators, hormones, oligonucleotides, hormone antagonists, enzymes, enzyme inhibitors, therapeutic radionuclides, angiogenesis inhibitors, etc., administered concurrently or sequentially or according to a prescribed dosing regimen. Alternatively, naked antibodies may be administered in conjunction with therapeutic agents that are not attached to other antibodies. Antibodies that may be used to supplement the naked anti-pancreatic cancer antibodies may be directed against either the same cancer cells or against immunomodulator cells (e.g., CD40+ cells) that can be recruited to enhance the antitumor effects of the naked antibodies of choice.

Immunoconjugates, Therapeutic and Diagnostic Agents

[0142] Anti-pancreatic cancer antibodies and fragments thereof may be conjugated to at least one therapeutic and/or diagnostic agent for therapy or diagnosis. For immunotherapy, the objective is to deliver cytotoxic doses of radioactivity, toxin, antibody

and/or drug to target cells, while minimizing exposure to non-target tissues. Preferably, anti-pancreatic cancer antibodies are be used to diagnose and/or treat pancreatic tumors.

[0143] Any of the antibodies, antibody fragments and fusion proteins can be conjugated with one or more therapeutic or diagnostic agents, using a variety of techniques known in the art. One or more therapeutic or diagnostic agents may be attached to each antibody, antibody fragment or fusion protein. If the Fc region is absent (for example with certain antibody fragments), it is possible to introduce a carbohydrate moiety into the light chain variable region of either an antibody or antibody fragment to which a therapeutic or diagnostic agent may be attached. See, for example, Leung et al., J Immunol. 154: 5919 (1995); Hansen et al., U.S. Pat. No. 5,443,953 (1995), Leung et al., U.S. Pat. No. 6,254,868.

[0144] Methods for conjugating peptides to antibody components via an antibody carbohydrate moiety are well-known to those of skill in the art. See, for example, Shih et al., Int J Cancer 41: 832 (1988); Shih et al., Int J Cancer 46: 1101 (1990); and Shih et al., U.S. Pat. No. 5,057,313. The general method involves reacting an antibody component having an oxidized carbohydrate portion with a carrier polymer that has at least one free amine function and that is loaded with a plurality of therapeutic agents, such as peptides or drugs. This reaction results in an initial Schiff base (imine) linkage, which can be stabilized by reduction to a secondary amine to form the final conjugate.

[0145] Antibody fusion proteins or multispecific antibodies comprise two or more antibodies or fragments thereof, each of which may be attached to at least one therapeutic agent and/or diagnostic agent. Accordingly, one or more of the antibodies or fragments thereof of the antibody fusion protein can have more than one therapeutic and/or diagnostic agent attached. Further, the therapeutic agents do not need to be the same but can be different therapeutic agents, for example, one can attach a drug and a radioisotope to the same fusion protein. Particularly, an IgG can be radiolabeled with ^{131}I and attached to a drug. The ^{131}I can be incorporated into the tyrosine of the IgG and the drug attached to the epsilon amino group of the IgG lysines. Both therapeutic and diagnostic agents also can be attached to reduced SH groups and to the carbohydrate side chains of antibodies. Alternatively, a bispecific antibody may comprise one antibody or fragment thereof against a disease antigen and another against a hapten attached to a targetable construct, for use in pretargeting techniques as discussed above.

[0146] A wide variety of diagnostic and therapeutic reagents can be administered concurrently or sequentially, or advantageously conjugated to the antibodies of the invention, for example, drugs, toxins, oligonucleotides, immunomodulators, hormones, hormone antagonists, enzymes, enzyme inhibitors, radionuclides, angiogenesis inhibitors, etc. The therapeutic agents recited here are those agents that also are useful for administration separately with a naked antibody as described above. Therapeutic agents include, for example, chemotherapeutic drugs such as vinca alkaloids, anthracyclines, gemcitabine, epidophyllotoxins, taxanes, antimetabolites, alkylating agents, antibiotics, SN-38, COX-2 inhibitors, antimitotics, antiangiogenic and apoptotoic agents, particularly doxorubicin, methotrexate, taxol, CPT-11, camptothecans, proteosome inhibitors, mTOR inhibitors, HDAC inhibitors, tyrosine kinase inhibitors, and others from these and other classes of anticancer agents, and the like. Other useful cancer chemotherapeutic drugs for administering concurrently or sequentially, or for the preparation of immunoconjugates and antibody fusion proteins include nitrogen mustards, alkyl sulfonates, nitrosoureas, triazenes, folic acid analogs, COX-2 inhibitors, antimetabolites, pyrimidine analogs, purine analogs, platinum coordination complexes, mTOR inhibitors, tyrosine kinase inhibitors, proteosome inhibitors, HDAC inhibitors, camptothecins, hormones, and the like. Suitable chemotherapeutic agents are described in REMINGTON'S PHARMACEUTICAL SCIENCES, 19th Ed. (Mack Publishing Co. 1995), and in GOODMAN AND GILMAN'S THE PHARMACOLOGICAL BASIS OF THERAPEUTICS, 7th Ed. (MacMillan Publishing Co. 1985), as well as revised editions of these publications. Other suitable chemotherapeutic agents, such as experimental drugs, are known to those of skill in the art.

[0147] In a preferred embodiment, conjugates of camptothecins and related compounds, such as SN-38, may be conjugated to hPAM4 or other anti-pancreatic cancer antibodies, for example as disclosed in U.S. Patent Application Serial No. 12/026,811, filed February 6, 2008; and 11/388,032, filed March 23, 2006.

[0148] In another preferred embodiment, an hPAM4 antibody is conjugated to gemcitabine. In another embodiment, gemcitabine is given before, after, or concurrently with a naked or conjugated chimeric, humanized or human PAM4 antibody. Preferably, the conjugated hPAM4 antibody or antibody fragment is conjugated to a radionuclide.

[0149] A toxin can be of animal, plant or microbial origin. A toxin, such as Pseudomonas exotoxin, may also be complexed to or form the therapeutic agent portion of an immunoconjugate of the anti-pancreatic cancer and hPAM4 antibodies. Other toxins suitably employed in the preparation of such conjugates or other fusion proteins, include ricin, abrin, ribonuclease (RNase), DNase I, Staphylococcal enterotoxin-A, pokeweed antiviral protein, gelonin, diphtheria toxin, Pseudomonas exotoxin, and Pseudomonas endotoxin. See, for example, Pastan et al., Cell 47:641 (1986), Goldenberg, CA--A Cancer Journal for Clinicians 44:43 (1994), Sharkey and Goldenberg, CA--A Cancer Journal for Clinicians 56:226 (2006). Additional toxins suitable for use are known to those of skill in the art and are disclosed in U.S. Pat. No. 6,077,499.

[0150] An immunomodulator, such as a cytokine, may also be conjugated to, or form the therapeutic agent portion of the immunoconjugate, or may be administered with, but unconjugated to, an antibody, antibody fragment or fusion protein. The fusion protein may comprise one or more antibodies or fragments thereof binding to different antigens. For example, the fusion protein may bind the PAM4 antigen as well as immunomodulating cells or factors. Alternatively, subjects can receive a naked antibody, antibody fragment or fusion protein and a separately administered cytokine, which can be administered before, concurrently or after administration of the naked antibodies. As used herein, the term "immunomodulator" includes a cytokine, a lymphokine, a monokine, a stem cell growth factor, a lymphotoxin, a hematopoietic factor, a colony stimulating factor (CSF), an interferon (IFN), parathyroid hormone, thyroxine, insulin, proinsulin, relaxin, prorelaxin, follicle stimulating hormone (FSH), thyroid stimulating hormone (TSH), luteinizing hormone (LH), hepatic growth factor, prostaglandin, fibroblast growth factor, prolactin, placental lactogen, OB protein, a transforming growth factor (TGF), TGF-α, TGF-β, insulin-like growth factor (ILGF), erythropoietin, thrombopoietin, tumor necrosis factor (TNF), TNF- α, TNF-β, a mullerian-inhibiting substance, mouse gonadotropin-associated peptide, inhibin, activin, vascular endothelial growth factor, integrin, interleukin (IL), granulocyte-colony stimulating factor (G-CSF), granulocyte macrophage-colony stimulating factor (GM-CSF), interferon- α, interferon- β, interferon-γ, S1 factor, IL-1, IL-1cc, IL-2, IL-3, IL-4, IL-5, IL-6, IL-7, IL-8, IL-9, IL-10, IL-11, IL-12, IL-13, IL-14, IL-15, IL-16, IL-17, IL-18 IL-21 and IL-25, LIF, kit-ligand, FLT-3, angiostatin, thrombospondin, endostatin and LT, and the like.

[0151] Alternatively, the antibodies and fragments can be detectably labeled by linking the antibody to an enzyme. When the antibody-enzyme conjugate is incubated in the presence of the appropriate substrate, the enzyme moiety reacts with the substrate to produce a chemical moiety which can be detected, for example, by spectrophotometric, fluorometric or visual means. Examples of enzymes that can be used to detectably label antibody include malate dehydrogenase, staphylococcal nuclease, delta-V-steroid isomerase, yeast alcohol dehydrogenase, alpha-glycerophosphate dehydrogenase, triose phosphate isomerase, horseradish peroxidase, alkaline phosphatase, asparaginase, glucose oxidase, alpha-galactosidase, ribonuclease, urease, catalase, glucose-6-phosphate dehydrogenase, glucoamylase and acetylcholinesterase.

[0152] A therapeutic or diagnostic agent can be attached at the hinge region of a reduced antibody component via disulfide bond formation. As an alternative, such agents can be attached to the antibody component using a heterobifunctional cross-linker, such as N-succinyl 3-(2-pyridyldithio)proprionate (SPDP). Yu et al., Int. J. Cancer 56: 244 (1994). General techniques for such conjugation are well-known in the art. See, for example, Wong, CHEMISTRY OF PROTEIN CONJUGATION AND CROSS-LINKING (CRC Press 1991); Upeslacis et al., "Modification of Antibodies by Chemical Methods," in MONOCLONAL ANTIBODIES: PRINCIPLES AND APPLICATIONS, Birch et al. (eds.), pages 187-230 (Wiley-Liss, Inc. 1995); Price, "Production and Characterization of Synthetic Peptide-Derived Antibodies," in MONOCLONAL ANTIBODIES: PRODUCTION, ENGINEERING AND CLINICAL APPLICATION, Ritter et al. (eds.), pages 60-84 (Cambridge University Press 1995). Alternatively, the therapeutic or diagnostic agent can be conjugated via a carbohydrate moiety in the Fc region of the antibody. The carbohydrate group can be used to increase the loading of the same agent that is bound to a thiol group, or the carbohydrate moiety can be used to bind a different peptide.

[0153] The immunoconjugate may comprise one or more radioactive isotopes useful for detecting diseased tissue. Particularly useful diagnostic radionuclides include, but are not limited to, ^{110}In, ^{111}In, ^{177}Lu, ^{18}F, ^{52}Fe, ^{62}Cu, ^{64}Cu, ^{67}Cu, ^{67}Ga, ^{68}Ga, ^{86}Y, ^{90}Y, ^{89}Zr, ^{94m}Tc, ^{94}Tc, ^{99m}Tc, ^{120}I, ^{123}I, ^{124}I, ^{125}I, ^{131}I, $^{154\text{-}158}Gd$, ^{32}P, ^{11}C, ^{13}N, ^{15}O, ^{186}Re, ^{188}Re, ^{51}Mn, ^{52m}Mn, ^{55}Co, ^{72}As, ^{75}Br, ^{76}Br, ^{82m}Rb, ^{83}Sr, or other gamma-, beta-, or positron-emitters, preferably with a decay energy in the range of 20 to 4,000 keV, more preferably in the range of 25 to 4,000 keV, and even more preferably in the range of 25 to 1,000 keV, and still more

preferably in the range of 70 to 700 keV. Total decay energies of useful positron-emitting radionuclides are preferably <2,000 keV, more preferably under 1,000 keV, and most preferably <700 keV. Radionuclides useful as diagnostic agents utilizing gamma-ray detection include, but are not limited to: ^{51}Cr, ^{57}Co, ^{58}Co, ^{59}Fe, ^{67}Cu, ^{67}Ga, ^{75}Se, ^{97}Ru, ^{99m}Tc, ^{111}In, ^{114m}In, ^{123}I, ^{125}I, ^{131}I, ^{169}Yb, ^{197}Hg, and ^{201}Tl. Decay energies of useful gamma-ray emitting radionuclides are preferably 20-2000 keV, more preferably 60-600 keV, and most preferably 100-300 keV.

[0154] The immunoconjugate may comprise one or more radioactive isotopes useful for treating diseased tissue. Particularly useful therapeutic radionuclides include, but are not limited to ^{111}In, ^{177}Lu, ^{212}Bi, ^{213}Bi, ^{211}At, ^{62}Cu, ^{64}Cu, ^{67}Cu, ^{90}Y, ^{125}I, ^{131}I, ^{32}P, ^{33}P, ^{47}Sc, ^{111}Ag, ^{67}Ga, ^{142}Pr, ^{153}Sm, ^{161}Tb, ^{166}Dy, ^{166}Ho, ^{186}Re, ^{188}Re, ^{189}Re, ^{212}Pb, ^{223}Ra, ^{225}Ac, ^{59}Fe, ^{75}Se, ^{77}As, ^{89}Sr, ^{99}Mo, ^{105}Rh, ^{109}Pd, ^{143}Pr, ^{149}Pm, ^{169}Er, ^{194}Ir, ^{198}Au, ^{199}Au, and ^{211}Pb. The therapeutic radionuclide preferably has a decay energy in the range of 20 to 6,000 keV, preferably in the ranges 60 to 200 keV for an Auger emitter, 100-2,500 keV for a beta emitter, and 4,000-6,000 keV for an alpha emitter. Maximum decay energies of useful beta-particle-emitting nuclides are preferably 20-5,000 keV, more preferably 100-4,000 keV, and most preferably 500-2,500 keV. Also preferred are radionuclides that substantially decay with Auger-emitting particles. For example, Co-58, Ga-67, Br-80m, Tc-99m, Rh-103m, Pt-109, In-111, Sb-119, I-125, Ho-161, Os-189m and Ir-192. Decay energies of useful beta-particle-emitting nuclides are preferably <1,000 keV, more preferably <100 keV, and most preferably <70 keV. Also preferred are radionuclides that substantially decay with generation of alpha-particles. Such radionuclides include, but are not limited to: Dy-152, At-211, Bi-212, Ra-223, Rn-219, Po-215, Bi-211, Ac-225, Fr-221, At-217, Bi-213 and Fm-255. Decay energies of useful alpha-particle-emitting radionuclides are preferably 2,000-10,000 keV, more preferably 3,000-8,000 keV, and most preferably 4,000-7,000 keV.

[0155] For example, ^{67}Cu, considered one of the more promising radioisotopes for radioimmunotherapy due to its 61.5-hour half-life and abundant supply of beta particles and gamma rays, can be conjugated to an antibody using the chelating agent, p-bromoacetamido-benzyl-tetraethylaminetetraacetic acid (TETA). Chase, supra. Alternatively, ^{90}Y, which emits an energetic beta particle, can be coupled to an antibody, antibody fragment or fusion protein, using diethylenetriaminepentaacetic acid (DTPA), or more preferably using DOTA. Methods of conjugating ^{90}Y to antibodies or targetable

constructs are known in the art and any such known methods may be used. (See, e.g., U.S. Patent No. 7,259,249. See also Lindén et al., Clin Cancer Res. 11:5215-22, 2005; Sharkey et al., J Nucl Med. 46:620-33, 2005; Sharkey et al., J Nucl Med. 44:2000-18, 2003.)

[0156] Additional potential therapeutic radioisotopes include ^{11}C, ^{13}N, ^{15}O, ^{75}Br, ^{198}Au, ^{224}Ac, ^{126}I, ^{133}I, ^{77}Br, ^{113m}In, ^{95}Ru, ^{97}Ru, ^{103}Ru, ^{105}Ru, ^{107}Hg, ^{203}Hg, ^{121m}Te, ^{122m}Te, ^{125m}Te, ^{165}Tm, ^{167}Tm, ^{168}Tm, ^{197}Pt, ^{109}Pd, ^{105}Rh, ^{142}Pr, ^{143}Pr, ^{161}Tb, ^{166}Ho, ^{199}Au, ^{57}Co, ^{58}Co, ^{51}Cr, ^{59}Fe, ^{75}Se, ^{201}Tl, ^{225}Ac, ^{76}Br, ^{169}Yb, and the like.

[0157] In another embodiment, a radiosensitizer can be used in combination with a naked or conjugated antibody or antibody fragment. For example, the radiosensitizer can be used in combination with a radiolabeled antibody or antibody fragment. The addition of the radiosensitizer can result in enhanced efficacy when compared to treatment with the radiolabeled antibody or antibody fragment alone. Radiosensitizers are described in D. M. Goldenberg (ed.), CANCER THERAPY WITH RADIOLABELED ANTIBODIES, CRC Press (1995). Other typical radionsensitizers of interest for use with this technology include gemcitabine, 5-fluorouracil, and cisplatin, and have been used in combination with external irradiation in the therapy of diverse cancers, including pancreatic cancer. Therefore, we have studied the combination of gemcitabine at what is believed to be radiosensitizing doses (once weekly 200 mg/m^2 over 4 weeks) of gemcitabine combined with fractionated doses of ^{90}Y-hPAM4, and have observed objective evidence of pancreatic cancer reduction after a single cycle of this combination that proved to be well-tolerated (no grade 3-4 toxicities by NCI-CTC v. 3 standard).

[0158] Antibodies or fragments thereof that have a boron addend-loaded carrier for thermal neutron activation therapy will normally be effected in similar ways. However, it will be advantageous to wait until non-targeted immunoconjugate clears before neutron irradiation is performed. Clearance can be accelerated using an anti-idiotypic antibody that binds to the anti-pancreatic cancer antibody. See U.S. Pat. No. 4,624,846 for a description of this general principle. For example, boron addends such as carboranes, can be attached to antibodies. Carboranes can be prepared with carboxyl functions on pendant side chains, as is well-known in the art. Attachment of carboranes to a carrier, such as aminodextran, can be achieved by activation of the carboxyl groups of the carboranes and condensation with amines on the carrier. The intermediate conjugate is then conjugated to the antibody. After administration of the antibody conjugate, a boron addend is activated

by thermal neutron irradiation and converted to radioactive atoms which decay by alpha-emission to produce highly toxic, short-range effects.

[0159] Methods of diagnosing cancer in a subject may be accomplished by administering a diagnostic immunoconjugate and detecting the diagnostic label attached to an immunoconjugate that is localized to a cancer or tumor. The antibodies, antibody fragments and fusion proteins may be conjugated to the diagnostic agent or may be administered in a pretargeting technique using targetable constructs attached to a diagnostic agent. Radioactive agents that can be used as diagnostic agents are discussed above. A suitable non-radioactive diagnostic agent is a contrast agent suitable for magnetic resonance imaging, X-rays, computed tomography or ultrasound. Magnetic imaging agents include, for example, non-radioactive metals, such as manganese, iron and gadolinium, complexed with metal-chelate combinations that include 2-benzyl-DTPA and its monomethyl and cyclohexyl analogs. See U.S. Ser. No. 09/921,290 filed on Oct. 10, 2001. Other imaging agents such as PET scanning nucleotides, preferably ^{18}F, may also be used.

[0160] Contrast agents, such as MRI contrast agents, including, for example, gadolinium ions, lanthanum ions, dysprosium ions, iron ions, manganese ions or other comparable labels, CT contrast agents, and ultrasound contrast agents may be used as diagnostic agents. Paramagnetic ions suitable for use include include chromium (III), manganese (II), iron (III), iron (II), cobalt (II), nickel (II), copper (II), neodymium (III), samarium (III), ytterbium (III), gadolinium (III), vanadium (II), terbium (III), dysprosium (III), holmium (III) and erbium (III), with gadolinium being particularly preferred.

[0161] Ions useful in other contexts, such as X-ray imaging, include but are not limited to lanthanum (III), gold (III), lead (II) and bismuth (III). Fluorescent labels include rhodamine, fluorescein and renographin. Rhodamine and fluorescein are often linked via an isothiocyanate intermediate.

[0162] Metals are also useful in diagnostic agents, including those for magnetic resonance imaging techniques. These metals include, but are not limited to: gadolinium, manganese, iron, chromium, copper, cobalt, nickel, dysprosium, rhenium, europium, terbium, holmium and neodymium. In order to load an antibody with radioactive metals or paramagnetic ions, it may be necessary to react it with a reagent having a long tail to which are attached a multiplicity of chelating groups for binding the ions. Such a tail can be a polymer such as a polylysine, polysaccharide, or other derivatized or derivatizable chain having pendant

groups to which can be bound chelating groups such as, e.g., ethylenediaminetetraacetic acid (EDTA), diethylenetriaminepentaacetic acid (DTPA), porphyrins, polyamines, crown ethers, bis-thiosemicarbazones, polyoximes, and like groups known to be useful for this purpose.

[0163] Chelates are coupled to an antibody, fusion protein, or fragments thereof using standard chemistries. The chelate is normally linked to the antibody by a group which enables formation of a bond to the molecule with minimal loss of immunoreactivity and minimal aggregation and/or internal cross-linking. Other, more unusual, methods and reagents for conjugating chelates to antibodies are disclosed in U.S. Pat. No. 4,824,659 to Hawthorne, entitled "Antibody Conjugates", issued Apr. 25, 1989. Particularly useful metal-chelate combinations include 2-benzyl-DTPA and its monomethyl and cyclohexyl analogs, used with diagnostic isotopes in the general energy range of 20 to 2,000 keV. The same chelates, when complexed with non-radioactive metals, such as manganese, iron and gadolinium are useful for MRI. Macrocyclic chelates such as NOTA, DOTA, and TETA are of use with a variety of metals and radiometals, most particularly with radionuclides of gallium, yttrium and copper, respectively. Such metal-chelate complexes can be made very stable by tailoring the ring size to the metal of interest. Other ring-type chelates such as macrocyclic polyethers, which are of interest for stably binding nuclides, such as 223Ra for RAIT are encompassed by the invention.

[0164] Radiopaque and contrast materials are used for enhancing X-rays and computed tomography, and include iodine compounds, barium compounds, gallium compounds, thallium compounds, etc. Specific compounds include barium, diatrizoate, ethiodized oil, gallium citrate, iocarmic acid, iocetamic acid, iodamide, iodipamide, iodoxamic acid, iogulamide, iohexol, iopamidol, iopanoic acid, ioprocemic acid, iosefamic acid, ioseric acid, iosulamide meglumine, iosemetic acid, iotasul, iotetric acid, iothalamic acid, iotroxic acid, ioxaglic acid, ioxotrizoic acid, ipodate, meglumine, metrizamide, metrizoate, propyliodone, and thallous chloride.

[0165] The antibodies, antibody fragments and fusion proteins also can be labeled with a fluorescent compound. The presence of a fluorescent-labeled MAb is determined by exposing the antibody to light of the proper wavelength and detecting the resultant fluorescence. Fluorescent labeling compounds include Alexa 350, Alexa 430, AMCA, aminoacridine, BODIPY 630/650, BODIPY 650/665, BODIPY-FL, BODIPY-R6G,

BODIPY-TMR, BODIPY-TRX, 5-carboxy-4',5'-dichloro-2',7'-dimethoxy fluorescein, 5-carboxy-2',4',5',7'-tetrachlorofluorescein, 5-carboxyfluorescein, 5-carboxyrhodamine, 6-carboxyrhodamine, 6-carboxytetramethyl amino, Cascade Blue, Cy2, Cy3, Cy5,6-FAM, dansyl chloride, Fluorescein, fluorescein isothiocyanate, fluorescamine, HEX, 6-JOE, NBD (7-nitrobenz-2-oxa-1,3-diazole), Oregon Green 488, Oregon Green 500, Oregon Green 514, Pacific Blue, phthalic acid, terephthalic acid, isophthalic acid, cresyl fast violet, cresyl blue violet, brilliant cresyl blue, para-aminobenzoic acid, erythrosine, phthalocyanines, phthaldehyde, azomethines, cyanines, xanthines, succinylfluoresceins, rare earth metal cryptates, europium trisbipyridine diamine, a europium cryptate or chelate, diamine, dicyanins, La Jolla blue dye, allopycocyanin, allococyanin B, phycocyanin C, phycocyanin R, thiamine, phycoerythrocyanin, phycoerythrin R, REG, Rhodamine Green, rhodamine isothiocyanate, Rhodamine Red, ROX, TAMRA, TET, TRIT (tetramethyl rhodamine isothiol), Tetramethylrhodamine, and Texas Red. Fluorescently-labeled antibodies are particularly useful for flow cytometry analysis, but can also be used in endoscopic and intravascular detection methods..

[0166] Alternatively, the antibodies, antibody fragments and fusion proteins can be detectably labeled by coupling the antibody to a chemiluminescent compound. The presence of the chemiluminescent-tagged MAb is determined by detecting the presence of luminescence that arises during the course of a chemical reaction. Examples of chemiluminescent labeling compounds include luminol, isoluminol, an aromatic acridinium ester, an imidazole, an acridinium salt and an oxalate ester.

[0167] Similarly, a bioluminescent compound can be used to label the antibodies and fragments there. Bioluminescence is a type of chemiluminescence found in biological systems in which a catalytic protein increases the efficiency of the chemiluminescent reaction. The presence of a bioluminescent protein is determined by detecting the presence of luminescence. Bioluminescent compounds that are useful for labeling include luciferin, luciferase and aequorin.

[0168] Accordingly, a method of diagnosing a malignancy in a subject is described, comprising performing an *in vitro* diagnosis assay on a specimen (fluid, tissue or cells) from the subject with a composition comprising an anti-pancreatic cancer MAb, fusion protein or fragment thereof. Immunohistochemistry can be used to detect the presence of PAM4 antigen in a cell or tissue by the presence of bound antibody. Preferably, the

malignancy that is being diagnosed is a cancer. Most preferably, the cancer is pancreatic cancer.

[0169] Additionally, a chelator such as DTPA, DOTA, TETA, or NOTA or a suitable peptide, to which a detectable label, such as a fluorescent molecule, or cytotoxic agent, such as a heavy metal or radionuclide, can be conjugated to a subject antibody. For example, a therapeutically useful immunoconjugate can be obtained by conjugating a photoactive agent or dye to an antibody fusion protein. Fluorescent compositions, such as fluorochrome, and other chromogens, or dyes, such as porphyrins sensitive to visible light, have been used to detect and to treat lesions by directing the suitable light to the lesion. In therapy, this has been termed photoradiation, phototherapy, or photodynamic therapy (Jori et al. (eds.), PHOTODYNAMIC THERAPY OF TUMORS AND OTHER DISEASES (Libreria Progetto 1985); van den Bergh, Chem. Britain 22:430 (1986)). Moreover, monoclonal antibodies have been coupled with photoactivated dyes for achieving phototherapy. Mew et al., J. Immunol. 130:1473 (1983); idem., Cancer Res. 45:4380 (1985); Oseroff et al., Proc Natl. Acad. Sci. USA 83:8744 (1986); idem., Photochem. Photobiol. 46:83 (1987); Hasan et al., Prog. Clin. Biol. Res. 288:471 (1989); Tatsuta et al., Lasers Surg. Med. 9:422 (1989); Pelegrin et al., Cancer 67:2529 (1991).

[0170] For purposes of therapy, the anti-pancreatic cancer antibodies and fragments thereof are administered to a patient in a therapeutically effective amount. An antibody is said to be administered in a "therapeutically effective amount" if the amount administered is physiologically significant. An agent is physiologically significant if its presence results in a detectable change in the physiology of a recipient patient.

[0171] A diagnostic agent is a molecule or atom, which may be administered conjugated to an antibody, antibody fragment or fusion protein or a targetable construct, and is useful in diagnosing/detecting a disease by locating the cells containing the disease-associated antigen. Useful diagnostic agents include, but are not limited to, radioisotopes, dyes (such as with the biotin-streptavidin complex), radiopaque materials (e.g., iodine, barium, gallium, and thallium compounds and the like), contrast agents, fluorescent compounds or molecules and enhancing agents (e.g., paramagnetic ions) for magnetic resonance imaging (MRI). U.S. Pat. No. 6,331,175 describes MRI technique and the preparation of antibodies conjugated to a MRI enhancing agent. Preferably, the diagnostic agents are selected from the group consisting of radioisotopes for nuclear imaging, endoscopic and intravascular detection, enhancing agents for use in magnetic resonance imaging or in

ultrasonography, radiopaque and contrast agents for X-rays and computed tomography, and fluorescent compounds for fluoroscopy, including endoscopic fluoroscopy. Fluorescent and radioactive agents conjugated to antibodies or used in bispecific, pretargeting methods, are particularly useful for endoscopic, intraoperative or intravascular detection of the targeted antigens associated with diseased tissues or clusters of cells, such as malignant tumors, as disclosed in Goldenberg U.S. Pat. Nos. 5,716,595; 6,096,289 and U.S. application Ser. No. 09/348,818, particularly with gamma-, beta- and positron-emitters. Endoscopic applications may be used when there is spread to a structure that allows an endoscope, such as the colon. Radionuclides useful for positron emission tomography include, but are not limited to: F-18, Mn-51, Mn-52m, Fe-52, Co-55, Cu-62, Cu-64, Ga-68, As-72, Br-75, Br-76, Rb-82m, Sr-83, Y-86, Zr-89, Tc-94m, In-110, I-120, and I-124. Total decay energies of useful positron-emitting radionuclides are preferably <2,000 keV, more preferably under 1,000 keV, and most preferably <700 keV. Radionuclides useful as diagnostic agents utilizing gamma-ray detection include, but are not limited to: Cr-51, Co-57, Co-58, Fe-59, Cu-67, Ga-67, Se-75, Ru-97, Tc-99m, In-111, In-114m, I-123, I-125, I-131, Yb-169, Hg-197, and Tl-201. Decay energies of useful gamma-ray emitting radionuclides are preferably 20-2000 keV, more preferably 60-600 keV, and most preferably 100-300 keV.

***In Vitro* Diagnosis**

[0172] The present invention contemplates the use of anti-pancreatic cancer antibodies to screen biological samples *in vitro* for the presence of the PAM4 antigen. In such immunoassays, the antibody, antibody fragment or fusion protein may be utilized in liquid phase or bound to a solid-phase carrier, as described below. For purposes of *in vitro* diagnosis, any type of antibody such as murine, chimeric, humanized or human may be utilized, since there is no host immune response to consider.

[0173] One example of a screening method for determining whether a biological sample contains the PAM4 antigen is the radioimmunoassay (RIA). For example, in one form of RIA, the substance under test is mixed with PAM4 MAb in the presence of radiolabeled PAM4 antigen. In this method, the concentration of the test substance will be inversely proportional to the amount of labeled PAM4 antigen bound to the MAb and directly related to the amount of free, labeled PAM4 antigen. Other suitable screening methods will be readily apparent to those of skill in the art.

[0174] Alternatively, *in vitro* assays can be performed in which an anti-pancreatic cancer antibody, antibody fragment or fusion protein is bound to a solid-phase carrier. For example, MAbs can be attached to a polymer, such as aminodextran, in order to link the MAb to an insoluble support such as a polymer-coated bead, a plate or a tube.

[0175] Other suitable *in vitro* assays will be readily apparent to those of skill in the art. The specific concentrations of detectably labeled antibody and PAM4 antigen, the temperature and time of incubation, as well as other assay conditions may be varied, depending on various factors including the concentration of the PAM4 antigen in the sample, the nature of the sample, and the like. The binding activity of a sample of anti-pancreatic cancer antibody may be determined according to well-known methods. Those skilled in the art will be able to determine operative and optimal assay conditions for each determination by employing routine experimentation.

[0176] The presence of the PAM4 antigen in a biological sample can be determined using an enzyme-linked immunosorbent assay (ELISA) (e.g., Gold et al. J Clin Oncol. 24:252-58, 2006). In the direct competitive ELISA, a pure or semipure antigen preparation is bound to a solid support that is insoluble in the fluid or cellular extract being tested and a quantity of detectably labeled soluble antibody is added to permit detection and/or quantitation of the binary complex formed between solid-phase antigen and labeled antibody.

[0177] In contrast, a "double-determinant" ELISA, also known as a "two-site ELISA" or "sandwich assay," requires small amounts of antigen and the assay does not require extensive purification of the antigen. Thus, the double-determinant ELISA is preferred to the direct competitive ELISA for the detection of an antigen in a clinical sample. See, for example, the use of the double-determinant ELISA for quantitation of the c-myc oncoprotein in biopsy specimens. Field et al., Oncogene 4: 1463 (1989); Spandidos et al., AntiCancer Res. 9: 821 (1989).

[0178] In a double-determinant ELISA, a quantity of unlabeled MAb or antibody fragment (the "capture antibody") is bound to a solid support, the test sample is brought into contact with the capture antibody, and a quantity of detectably labeled soluble antibody (or antibody fragment) is added to permit detection and/or quantitation of the ternary complex formed between the capture antibody, antigen, and labeled antibody. In the present context, an antibody fragment is a portion of an anti-pancreatic cancer MAb that binds to an epitope of the PAM4 antigen. Methods of performing a double-

determinant ELISA are well-known. See, for example, Field et al., supra, Spandidos et al., supra, and Moore et al., "Twin-Site ELISAs for fos and myc Oncoproteins Using the AMPAK System," in METHODS IN MOLECULAR BIOLOGY, VOL. 10, pages 273-281 (The Humana Press, Inc. 1992).

[0179] In the double-determinant ELISA, the soluble antibody or antibody fragment must bind to a PAM4 epitope that is distinct from the epitope recognized by the capture antibody. The double-determinant ELISA can be performed to ascertain whether the PAM4 antigen is present in a biopsy sample. Alternatively, the assay can be performed to quantitate the amount of PAM4 antigen that is present in a clinical sample of body fluid. The quantitative assay can be performed by including dilutions of purified PAM4 antigen.

[0180] The anti-pancreatic cancer Mabs, fusion proteins, and fragments thereof also are suited for the preparation of an assay kit. Such a kit may comprise a carrier means that is compartmentalized to receive in close confinement one or more container means such as vials, tubes and the like, each of said container means comprising the separate elements of the immunoassay.

[0181] The subject antibodies, antibody fragments and fusion proteins also can be used to detect the presence of the PAM4 antigen in tissue sections prepared from a histological specimen. Such *in situ* detection can be used to determine the presence of the PAM4 antigen and to determine the distribution of the PAM4 antigen in the examined tissue. *In situ* detection can be accomplished by applying a detectably-labeled antibody to frozen tissue sections. Studies indicate that the PAM4 antigen is preserved in paraffin-embedded sections. General techniques of *in situ* detection are well-known to those of ordinary skill. See, for example, Ponder, "Cell Marking Techniques and Their Application," in MAMMALIAN DEVELOPMENT: A PRACTICAL APPROACH 113-38 Monk (ed.) (IRL Press 1987), and Coligan at pages 5.8.1-5.8.8.

[0182] Antibodies, antibody fragments and fusion proteins can be detectably labeled with any appropriate marker moiety, for example, a radioisotope, an enzyme, a fluorescent label, a dye, a chromagen, a chemiluminescent label, a bioluminescent labels or a paramagnetic label.

[0183] The marker moiety can be a radioisotope that is detected by such means as the use of a gamma counter or a scintillation counter or by autoradiography. In a preferred embodiment, the diagnostic conjugate is a gamma-, beta- or a positron-emitting isotope. A marker moiety in the present description refers to a molecule that will generate a signal

under predetermined conditions. Examples of marker moieties include radioisotopes, enzymes, fluorescent labels, chemiluminescent labels, bioluminescent labels and paramagnetic labels.

[0184] The binding of marker moieties to anti-pancreatic cancer antibodies can be accomplished using standard techniques known to the art. Typical methodology in this regard is described by Kennedy et al., Clin Chim Acta 70: 1 (1976), Schurs et al., Clin. Chim. Acta 81: 1 (1977), Shih et al., Int J Cancer 46: 1101 (1990).

[0185] The above-described *in vitro* and *in situ* detection methods may be used to assist in the diagnosis or staging of a pathological condition. For example, such methods can be used to detect tumors that express the PAM4 antigen such as pancreatic cancer.

***In Vivo* Diagnosis/Detection**

[0186] Various methods of *in vivo* diagnostic imaging with radiolabeled MAbs are well-known. In the technique of immunoscintigraphy, for example, antibodies are labeled with a gamma-emitting radioisotope and introduced into a patient. A gamma camera is used to detect the location and distribution of gamma-emitting radioisotopes. See, for example, Srivastava (ed.), RADIOLABELED MONOCLONAL ANTIBODIES FOR IMAGING AND THERAPY (Plenum Press 1988), Chase, "Medical Applications of Radioisotopes," in REMINGTON'S PHARMACEUTICAL SCIENCES, 18th Edition, Gennaro et al. (eds.), pp. 624-652 (Mack Publishing Co., 1990), and Brown, "Clinical Use of Monoclonal Antibodies," in BIOTECHNOLOGY AND PHARMACY 227-49, Pezzuto et al. (eds.) (Chapman & Hall 1993).

[0187] For diagnostic imaging, radioisotopes may be bound to antibody either directly or indirectly by using an intermediary functional group. Useful intermediary functional groups include chelators such as ethylenediaminetetraacetic acid and diethylenetriaminepentaacetic acid. For example, see Shih et al., supra, and U.S. Pat. No. 5,057,313.

[0188] The radiation dose delivered to the patient is maintained at as low a level as possible through the choice of isotope for the best combination of minimum half-life, minimum retention in the body, and minimum quantity of isotope which will permit detection and accurate measurement. Examples of radioisotopes that can be bound to anti-pancreatic cancer antibody and are appropriate for diagnostic imaging include ^{99m}Tc, ^{111}In and ^{18}F.

[0189] The subject antibodies, antibody fragments and fusion proteins also can be labeled with paramagnetic ions and a variety of radiological contrast agents for purposes of *in vivo* diagnosis. Contrast agents that are particularly useful for magnetic resonance imaging comprise gadolinium, manganese, dysprosium, lanthanum, or iron ions. Additional agents include chromium, copper, cobalt, nickel, rhenium, europium, terbium, holmium, or neodymium. Antibodies and fragments thereof can also be conjugated to ultrasound contrast/enhancing agents. For example, one ultrasound contrast agent is a liposome. Also preferred, the ultrasound contrast agent is a liposome that is gas filled.

[0190] In a preferred embodiment, a bispecific antibody can be conjugated to a contrast agent. For example, the bispecific antibody may comprise more than one image-enhancing agent for use in ultrasound imaging. In another preferred embodiment, the contrast agent is a liposome. Preferably, the liposome comprises a bivalent DTPA-peptide covalently attached to the outside surface of the liposome.

Pharmaceutically Suitable Excipients

[0191] Additional pharmaceutical methods may be employed to control the duration of action of an anti-pancreatic cancer antibody in a therapeutic application. Control release preparations can be prepared through the use of polymers to complex or adsorb the antibody, antibody fragment or fusion protein. For example, biocompatible polymers include matrices of poly(ethylene-co-vinyl acetate) and matrices of a polyanhydride copolymer of a stearic acid dimer and sebacic acid. Sherwood et al., Bio/Technology 10: 1446 (1992). The rate of release of an antibody, antibody fragment or fusion protein from such a matrix depends upon the molecular weight of the antibody, antibody fragment or fusion protein, the amount of antibody within the matrix, and the size of dispersed particles. Saltzman et al., Biophys. J. 55: 163 (1989); Sherwood et al., supra. Other solid dosage forms are described in Ansel et al., PHARMACEUTICAL DOSAGE FORMS AND DRUG DELIVERY SYSTEMS, 5th Edition (Lea & Febiger 1990), and Gennaro (ed.), REMINGTON'S PHARMACEUTICAL SCIENCES, 18th Edition (Mack Publishing Company 1990), and revised editions thereof.

[0192] The antibodies, fragments thereof or fusion proteins to be delivered to a subject can comprise one or more pharmaceutically suitable excipients, one or more additional ingredients, or some combination of these. The antibody can be formulated according to known methods to prepare pharmaceutically useful compositions, whereby the immunoconjugate or naked antibody is combined in a mixture with a pharmaceutically

suitable excipient. Sterile phosphate-buffered saline is one example of a pharmaceutically suitable excipient. Other suitable excipients are well-known to those in the art. See, for example, Ansel et al., PHARMACEUTICAL DOSAGE FORMS AND DRUG DELIVERY SYSTEMS, 5th Edition (Lea & Febiger 1990), and Gennaro (ed.), REMINGTON'S PHARMACEUTICAL SCIENCES, 18th Edition (Mack Publishing Company 1990), and revised editions thereof.

[0193] The immunoconjugate or naked antibody can be formulated for intravenous administration via, for example, bolus injection or continuous infusion. Formulations for injection can be presented in unit dosage form, e.g., in ampules or in multi-dose containers, with an added preservative. The compositions can take such forms as suspensions, solutions or emulsions in oily or aqueous vehicles, and can contain formulatory agents such as suspending, stabilizing and/or dispersing agents. Alternatively, the active ingredient can be in powder form for constitution with a suitable vehicle, e.g., sterile pyrogen-free water, before use.

[0194] The immunoconjugate, naked antibody, fragment thereof or fusion protein may also be administered to a mammal subcutaneously or by other parenteral routes. In a preferred embodiment, the antibody or fragment thereof is administered in a dosage of 20 to 2000 milligrams protein per dose. Moreover, the administration may be by continuous infusion or by single or multiple boluses. In general, the dosage of an administered immunoconjugate, fusion protein or naked antibody for humans will vary depending upon such factors as the patient's age, weight, height, sex, general medical condition and previous medical history. Typically, it is desirable to provide the recipient with a dosage of immunoconjugate, antibody fusion protein or naked antibody that is in the range of from about 1 mg/kg to 20 mg/kg as a single intravenous or infusion, although a lower or higher dosage also may be administered as circumstances dictate. This dosage may be repeated as needed, for example, once per week for four to ten weeks, preferably once per week for eight weeks, and more preferably, once per week for four weeks. It may also be given less frequently, such as every other week for several months, or more frequently, such as two- or three-time weekly. The dosage may be given through various parenteral routes, with appropriate adjustment of the dose and schedule.

Kits

[0195] Various embodiments may concern kits containing components suitable for treating or diagnosing diseased tissue in a patient. Exemplary kits may contain at least one antibody, antigen binding fragment or fusion protein as described herein. If the composition containing components for administration is not formulated for delivery via the alimentary canal, such as by oral delivery, a device capable of delivering the kit components through some other route may be included. One type of device, for applications such as parenteral delivery, is a syringe that is used to inject the composition into the body of a subject. Inhalation devices may also be used. In certain embodiments, an anti-pancreatic cancer antibody or antigen binding fragment thereof may be provided in the form of a prefilled syringe or autoinjection pen containing a sterile, liquid formulation or lyophilized preparation of antibody (e.g., Kivitz et al., Clin. Ther. 2006, 28:1619-29).

[0196] The kit components may be packaged together or separated into two or more containers. In some embodiments, the containers may be vials that contain sterile, lyophilized formulations of a composition that are suitable for reconstitution. A kit may also contain one or more buffers suitable for reconstitution and/or dilution of other reagents. Other containers that may be used include, but are not limited to, a pouch, tray, box, tube, or the like. Kit components may be packaged and maintained sterilely within the containers. Another component that can be included is instructions for use of the kit.

EXAMPLES

[0197] The examples below are illustrative of embodiments of the current invention. The examples discuss studies employing an exemplary anti-pancreatic cancer monoclonal antibody (PAM4). Clinical studies with the PAM4 MAb have shown that a majority of pancreatic cancer lesions were targeted in patients and there was no indication of uptake in normal tissues. Dosimetry indicated that it was possible to deliver 10 to 20 cGy/mCi to tumors, with a tumor to red marrow dose ratio of 3:1 to 10:1. The data show that PAM4 is useful for the treatment of pancreatic cancer.

Example 1. Humanized PAM4 Mab

[0198] In preferred embodiments, the claimed methods and compositions utilize the antibody hPAM4 which is a humanized IgG of the murine PAM4 MAb raised against

pancreatic cancer mucin. Humanization of the murine PAM4 sequences was utilized to reduce the human antimouse antibody (HAMA) response. To produce the humanized PAM4, murine complementarity determining regions (CDR) were transferred from heavy and light variable chains of the mouse immunoglobulin into human framework region (FR) antibody sequences, followed by the replacement of some human FR residues with their murine counterparts. Humanized monoclonal antibodies are suitable for use in *in vitro* and *in vivo* diagnostic and therapeutic methods.

[0199] Comparison of the variable region framework sequences of the murine PAM4 MAb (**FIGS. 1A** and **1B**) to known human antibodies in the Kabat database showed that the FRs of PAM4 Vκ and VH exhibited the highest degree of sequence homology to that of the human antibodies Walker Vκ and Wil2 VH, respectively. Therefore, the Walker Vκ and Wil2 VH FRs were selected as the human frameworks into which the murine CDRs for PAM4 Vκ and VH were grafted, respectively (**FIG. 3**). The FR4 sequence of the human antibody, NEWM, however, was used to replace the Wil2 FR4 sequence for the humanization of the PAM4 heavy chain (**FIG. 3B**). A few amino acid residues in PAM4 FRs that flank the putative CDRs were maintained in hPAM4 based on the consideration that these residues have more impact on Ag binding than other FR residues. These residues were 21M, 47W, 59P, 60A, 85S, 87F, and 100G of Vκ and 27Y, 30P, 38K, 48I, 66K, 67A, and 69L of VH. The DNA and amino acid sequences of hPAM4 Vκ (SEQ ID NO:16) and VH (SEQ ID NO:19) are shown in **FIGS. 3A** and **3B**, respectively.

[0200] A modified strategy as described by Leung et al. (Leung et al., 1994)) was used to construct the designed Vκ and VH genes (**FIG. 4**) for hPAM4 using a combination of long oligonucleotide syntheses and PCR. For the construction of the hPAM4 VH domain, two long oligonucleotides, hPAM4VHA (173-mer) and hPAM4VHB (173-mer) were synthesized on an automated DNA synthesizer (Applied Biosystem).

[0201] hPAM4VHA represents nt 17 to 189 of the hPAM4 VH domain.

5'- AGTCTGGGGC TGAGGTGAAG AAGCCTGGGG CCTCAGTGAA GGTCTCCTGC GAGGCTTCTG GATACACATT CCCTAGCTAT GTTTTGCACT GGGTGAAGCA GGCCCCTGGA CAAGGGCTTG AGTGGATTGG ATATATTAAT CCTTACAATG ATGGTACTCA GTACAATGAG AAG-3' (SEQ ID NO:20)

[0202] hPAM4VHB represents the minus strand of the hPAM4 VH domain complementary to nt 169 to 341.
5'- AGGGTTCCCT GGCCCCAGTA AGCAAATCCG TAGCTACCAC CGAAGCCTCT TGCACAGTAA TACACGGCCG TGTCGTCAGA TCTCAGCCTG CTCAGCTCCA TGTAGGCTGT GTTGATGGAC GTGTCCCTGG TCAGTGTGGC CTTGCCTTTG AACTTCTCAT TGTACTGAGT ACC-3' (SEQ ID NO:21)

[0203] The 3'-terminal sequences (21 nt residues) of hPAM4VHA and VHB are complementary to each other. Under defined PCR condition, the 3'-ends of hPAM4VHA and VHB anneal to form a short double stranded DNA flanked by the rest of the long oligonucleotides. Each annealed end serves as a primer for the transcription of the single stranded DNA, resulting in a double strand DNA composed of the nt 17 to 341 of hPAM4 VH. This DNA was further amplified in the presence of two short oligonucleotides, hPAM4VHBACK and hPAM4VHFOR to form the full-length hPAM4 VH. The underlined portions are restriction sites for subcloning as shown in **FIG. 4B**.

hPAM4VHBACK 5'-CAG GTG CAG CTG CAG CAG TCT GGG GCT GAG GTG A-3' (SEQ ID NO:22)
hPAM4VHFOR 5'-TGA GGA GAC GGT GAC CAG GGT TCC CTG GCC CCA-3' (SEQ ID NO:23)

[0204] A minimal amount of hPAM4VHA and VHB (determined empirically) was amplified in the presence of 10 μL of 10X PCR Buffer (500 mM KCl, 100 mM Tris HCl buffer, pH 8.3, 15 mM $MgCl_2$), 2 μmol of hPAM4VHBACK and hPAM4VKFOR, and 2.5 units of Taq DNA polymerase (Perkin Elmer Cetus, Norwalk, Conn.). This reaction mixture was subjected to three cycles of polymerase chain reaction (PCR) consisting of denaturation at 94°C for 1 minute, annealing at 45°C for 1 minute, and polymerization at 72°C for 1.5 minutes. This procedure was followed by 27 cycles of PCR reaction consisting of denaturation at 94°C for 1 minute, annealing at 55°C for 1 minute, and polymerization at 72°C for 1 minute. Double-stranded PCR-amplified product for hPAM4 VH was gel-purified, restriction-digested with PstI and BstEII restriction sites and cloned into the complementary PstI/BstEII restriction sites of the heavy chain staging vector, VHpBS2, in which the VH sequence was fully assembled with the DNA sequence

encoding the translation initiation codon and a secretion signal peptide in-frame ligated at the 5'-end and an intron sequence at the 3'-end. VHpBS2 is a modified staging vector of VHpBS (Leung et al., Hybridoma, 13:469, 1994), into which a XhoI restriction site was introduced at sixteen bases upstream of the translation initiation codon to facilitate the next subcloning step. The assembled VH gene was subcloned as a XhoI-BamHI restriction fragment into the expression vector, pdHL2, which contains the expression cassettes for both human IgG heavy and light chains under the control of IgH enhancer and MT1 promoter, as well as a mouse d/fr gene as a marker for selection and amplification. Since the heavy chain region of pdHL2 lacks a BamHI restriction site, this ligation requires use of a linker to provide a bridge between the BamHI site of the variable chain and the HindIII site present in the pdHL2 vector. The resulting expression vectors were designated as hPAM4VHpdHL2.

[0205] For constructing the full length DNA of the humanized Vκ sequence, hPAM4VKA (157-mer) and hPAM4VKB (156-mer) were synthesized as described above. hPAM4VKA and VKB were amplified by two short oligonucleotides hPAM4VKBACK and hPAM4VKFOR as described above.

[0206] hPAM4VKA represents nt 16 to 172 of the hPAM4 Vκ domain.
5'-CAGTCTCCAT CCTCCCTGTC TGCATCTGTA GGAGACAGAG TCACCATGAC CTGCAGTGCC AGCTCAAGTG TAAGTTCCAG CTACTTGTAC TGGTACCAAC AGAAACCAGG GAAAGCCCCC AAACTCTGGA TTTATAGCAC ATCCAACCTG GCTTCTG-3' (SEQ ID NO:24)

[0207] hPAM4VKB represents the minus strand of the hPAM4 Vκ domain complementary to nt 153 to 308.
5'-GTCCCCCCTC CGAACGTGTA CGGGTACCTA TTCCACTGAT GGCAGAAATA AGAGGCAGAA TCTTCAGGTT GCAGACTGCT GATGGTGAGA GTGAAGTCTG TCCCAGATCC ACTGCCACTG AAGCGAGCAG GGACTCCAGA AGCCAGGTTG GATGTG-3' (SEQ ID NO:25)

[0208] The 3'-terminal sequences (20 nt residues) of hPAM4VKA and VKB are complementary to each other. Under defined PCR condition, the 3'-ends of hPAM4VKA and VKB anneal to form a short double-stranded DNA flanked by the rest of the long

oligonucleotides. Each annealed end served as a primer for the transcription of the single stranded DNA, resulting in a double strand DNA composed of nt 16 to 308 of hPAM4 Vκ. This DNA was further amplified in the presence of two short oligonucleotides, hPAM4VKBACK and hPAM4VKFOR to form the full-length hPAM4 Vκ. The underlined portions are restriction sites for subcloning as described below.

hPAM4VKBACK 5'-GAC ATC CAG CTG ACC CAG TCT CCA TCC TCC CTG-3' (SEQ ID NO:26)
hPAM4VKFOR 5'- TTA GAT CTC CAG TCG TGT CCC CCC TCC GAA CGT-3' (SEQ ID NO:27)

[0209] Gel-purified PCR products for hPAM4 Vκ were restriction-digested with PvuII and BglII and cloned into the complementary PvuII/BclI sites of the light chain staging vector, VKpBR2. VKpBR2 is a modified staging vector of VKpBR (Leung et al., Hybridoma, 13:469, 1994), into which a XbaI restriction site was introduced at sixteen bases upstream of the translation initiation codon. The assembled Vκ genes were subcloned as XbaI-BamHI restriction fragments into the expression vector containing the VH sequence, hPAM4VHpdHL2. The resulting expression vectors were designated as hPAM4pdHL2.

[0210] Approximately 30 μg of hPAM4pdHL2 was linearized by digestion with SalI and transfected into Sp2/0-Ag14 cells by electroporation at 450 V and 25 μF. The transfected cells were plated into 96-well plates and incubated in a CO_2 cell culture incubator for two days and then selected for MTX resistance. Colonies surviving selection emerged in two to three weeks and were screened for human antibody secretion by ELISA assay. Briefly, supernatants (~100 ul) from the surviving colonies were added into the wells of an ELISA microplate precoated with goat anti-human IgG $F(ab')_2$ fragment-specific Ab. The plate was incubated for one hour at room temperature. Unbound proteins were removed by washing three times with wash buffer (PBS containing 0.05% Tween-20). Horseradish peroxidase-conjugated goat anti-human IgG Fc fragment-specific Ab was added to the wells. Following incubation for one hour, a substrate solution (100 μL/well) containing 4 mM o-phenylenediamine dihydrochloride (OPD) and 0.04% H_2O_2 in PBS was added to the wells after washing. Color was allowed to develop in the dark for 30 minutes and the reaction was stopped by the addition of 50 μL of 4 N H_2SO_4 solution. The bound human

IgG was measured by reading the absorbance at 490 nm on an ELISA reader. Positive cell clones were expanded and hPAM4 was purified from cell culture supernatant by affinity chromatography on a Protein A column.

[0211] The Ag-binding activity of hPAM4 was confirmed by ELISA assay in a microtiter plate coated with pancreas cancer cell extracts. An ELISA competitive binding assay using PAM4-antigen coated plates was developed to assess the Ag-binding affinity of hPAM4 in comparison with that of a chimeric PAM4 composed of murine V and human C domains. Constant amounts of the HRP-conjugated cPAM4 mixed with varying concentrations of cPAM4 or hPAM4 were added to the coated wells and incubated at room temperature for 1-2 h. The amount of HRP-conjugated cPAM4 bound to the CaPan1 Ag was revealed by reading the absorbance at 490 nm after the addition of a substrate solution containing 4 mM o-phenylenediamine dihydrochloride and 0.04% H_2O_2. As shown by the competition assays in FIG. 4, hPAM4 and cPAM4 antibodies exhibited similar binding activities.

Example 2. Immunohistochemistry Staining Studies

[0212] Immunohistochemistry on normal adult tissues showed that the PAM4 reactive epitope was restricted to the gastrointestinal tract where staining was weak, yet positive (**Table 1**). Normal pancreatic tissue, including ducts, ductules, acini, and islet cells, were negative for staining. A PAM4 based enzyme immunoassay with tissue homogenates as antigens generally supported the immunohistology data (**Table 2**). The PAM4 epitope was absent from normal pancreas and other non-gastrointestinal tissues. In neoplastic tissues, PAM4 was reactive with twenty one out of twenty five (85%) pancreatic cancers (**Table 3** and **Table 4**) and ten out of twenty six colon cancers, but only limited reactivity with tumors of the stomach, lung, breast, ovary, prostate, liver or kidney (**Table 4**). PAM4 reactivity appeared to correlate with the stage of tumor differentiation, with a greater percentage of staining observed in well differentiated pancreatic cancers than in moderately differentiated or poorly differentiated tumors. Generally, poorly differentiated tumors represent less than 10% of all pancreatic cancers.

[0213] These studies have shown the PAM4 reactivity and tissue distribution (both normal and cancer) to be unlike that reported for the CA19.9, DUPAN2, SPAN1, Nd2 and B72.3 antibodies and antibodies against the Lewis antigens. Together with crossblocking studies performed with certain of these MAbs, the data suggests that the PAM4 MAb

recognizes a unique and novel epitope. When compared to the antigens recognized by the CA19.9, DUPAN2, and anti-Le[a] antibodies, the PAM4 antigen appears to be more restricted in its tissue distribution and is reactive with a higher percentage of pancreatic tumors. Moreover, it gives a greater overall intensity of reaction at equivalent concentrations and is reactive with a higher percentage of cells within the pancreatic tumors. Finally, PAM4 was found to be only weakly reactive with three out of twelve chronic pancreatitis specimens, whereas CA19.9 and DUPAN2 were strongly reactive with all twelve specimens. Although it is recognized that specificity is dependent in part upon the type of assay employed and the range and number of tissues examined, the ability of PAM4 to discriminate between normal and neoplastic pancreatic tissue, its ability to react with a large percentage of the cancer specimens, the high intensity of the reactions, and the ability to distinguish between early stage pancreatic cancer and benign conditions such as pancreatitis are important characteristics of this exemplary anti-pancreatic cancer antibody.

TABLE 1 Immunoperoxidase Staining of Normal Adult Tissues with MAb PAM4

Tissue	**Staining**
	Reaction
Pancreas (22)[a]	-
Ducts	-
Acini	-
Islets	-
Submaxillary gland (2)	-
Esophagus (2)	-
Stomach (3)	+ mucus secreting cells
Duodenum (3)	+ goblet cells
Jejunum (3)	+ goblet cells
Ileum (3)	+ goblet cells
Colon (5)	+ goblet cells
Liver (3)	-
Gallbladder (2)	-
Bronchus (3)	-

Lung (3)	-
Heart (3)	-
Spleen (3)	-
Kidney (3)	-
Bladder (3)	-
Prostate (2)	-
Testes (2)	-
Uterus (2)	-
Ovary (2)	-

[a] – number of individual specimens examined in parentheses

TABLE 2 Monoclonal Antibody PAM4 Reactivity with Normal Adult Tissue Homogenates by EIA

Tissue	µg/g tissue[a]
Pancreas	6.4
Esophagus	8.1
Stomach	61.3
Duodenum	44.7
Jejunum	60.6
Colon	74.5
Liver	0.0
Gallbladder	5.6
Heart	3.7
Spleen	3.4
Kidney	6.6
Bladder	4.9
Thyroid	3.5
Adrenal	1.3
Ureter	2.6
Testes	3.9
CaPan1 Pancreatic Tumor	569

a – values are mean from two autopsy specimens

TABLE 3 Immunohistochemical Reactivity of Several Monoclonal Antibodies with Pancreatic Tumors

	Differentiation	PAM4	CA19.9	Le^a	DUPAN2
1	W	+++	-	-	+++
2	M	++	+++	+++	+
3	M	+	-	+	+
4	M	+++	+++	+++	+
5	M	++	+	-	-
6	M	+	ND	ND	ND
7	M*	+++	+++	+++	+++
8	M	+	-	-	+++
9	M	++	+	++	-
10	M*	++	++	++	+++
11	M	++	+++	+++	+
12	M	++	+	+	+++
13	M	+	+++	+++	+
14	M	++	+	+	++
15	M	+++	+	+	++
16	M	+	+	++	-
17	M	-	+	+	-
18	M	++	++	++	++
19	M	+++	+	+++	++
20	M	+	-	-	-
21	M	+++	+++	+	++
22	P	+	+	+	+++
23	P	-	-	-	-
24	P	-	-	-	-
25	P	-	-	+	-
TOTAL		21/25	17/24	18/24	16/24

- : Negative; + : 5-20% of tissue is stained; ++ : 21-50% of tissue is stained;
+++ : >50% of tissue is stained; W,M,P : Well, moderate, or poor differentiation;
* : Metastatic tissue; ND : Not Done

TABLE 4 Immunoperoxidase Staining of Neoplastic Tissues with MAb PAM4

Cancer Tissue	Positive/Total
Pancreas	21/25
Colon	10/26
Stomach	1/5
Lung	1/15
Breast	0/30
Ovarian	0/10
Prostate	0/4
Liver	0/10
Kidney	0/4

Example 3. *In Vivo* Biodistribution and Tumor Targeting of Radiolabeled PAM4

[0214] Initial biodistribution studies of PAM4 were carried out in a series of four different xenografted human pancreatic tumors covering the range of expected differentiation. Each of the four tumor lines employed, AsPc1, BxPc3, Hs766T and CaPan1, exhibited concentrations of ^{131}I-PAM4 within the tumors (range: 21%-48% ID/g on day three) that were significantly (P<0.01-0.001) higher than concomitantly administered nonspecific, isotype-matched Ag8 antibody (range: 3.6%-9.3% ID/g on day three). The biodistribution data were used to estimate potential radiation doses to the tumor of 12,230; 10,684; 6,835; and 15,843 cGy/mCi of injected dose to AsPc1, BxPc3, Hs766T and CaPan1, respectively. With an actual maximum tolerated dose (MTD) of 0.7 mCi, PAM4 could provide substantial rad dose to each of the xenografted tumor models. In each tumor line the blood levels of radiolabeled PAM4 were significantly (P<0.01-0.001) lower than the nonspecific Ag8. Potential radiation doses to the blood from PAM4 were 1.4-4.4 fold lower than from Ag8. When radiation doses to the tumor from PAM4 were normalized to the blood doses from PAM4, the tumors received doses that were 2.2; 3.3; 3.4; and 13.1-fold higher than blood, respectively. Importantly, potential radiation doses to non-tumor tissues were minimal.

[0215] The biodistribution of PAM4 was compared with an anti-CEA antibody, MN-14, using the CaPan1 tumor model. The concentration of PAM4 within the tumor was much

greater than MN-14 at early timepoints, yielding tumor:blood ratios at day three of 12.7 ± 2.3 for PAM4 compared to 2.7 ± 1.9 for MN-14. Although PAM4 uptake within the tumor was significantly higher than for MN-14 at early timepoints (day one--$P<0.001$; day three--$P<0.01$), dosimetry analyses indicated only a 3.2-fold higher dose to the tumor from PAM4 as compared to MN-14 over the fourteen day study period. This was due to a rapid clearance of PAM4 from the tumor, such that at later timepoints similar concentrations of the two antibodies were present within the tumors. A rapid clearance of PAM4 from the tumor was also noted in the BxPc3 and Hs766T but not AsPc1 tumor models. These observations were unlike those reported for other anti-mucin antibodies, as for example G9 and B72.3 in colorectal cancer, where each exhibited longer retention times as compared to the MN-14 antibody. Results from studies on the metabolism of PAM4, indicate that after initial binding to the tumor cell, antibody is rapidly released, possibly being catabolized or being shed as an antigen:antibody complex. The blood clearance is also very rapid. These data suggest that ^{131}I may not be the appropriate choice of isotope for therapeutic applications. A short-lived isotope, such as ^{90}Y or ^{188}Re, that can be administered frequently may be a more effective reagent.

[0216] PAM4 showed no evidence of targeting to normal tissues, except in the CaPan1 tumor model, where a small but statistically significant splenic uptake was observed (range 3.1-7.5% ID/g on day-3). This type of splenic targeting has been observed in the clinical application of the anti-mucin antibodies B72.3 and CC49. Importantly, these studies also reported that splenic targeting did not affect tumor uptake of antibody nor did it interfere with interpretation of the nuclear scans. These studies suggested that splenic targeting was not due to crossreactive antigens in the spleen, nor to binding by Fc receptors, but rather to one or more of the following possibilities: direct targeting of antigen trapped in the spleen, or indirect uptake of antigen:antibody complexes formed either in the blood or released from the tumor site. The latter would require the presence of immune complexes in the blood. However, these were not observed when specimens as early as five minutes and as late as seven days were examined by gel filtration (HPLC, GF-250 column); radiolabeled antibody eluted as native material. The former explanation seems more likely in view of the fact that the CaPan1 tumor produced large quantities of PAM4-reactive antigen, 100- to 1000-fold higher than for the other tumor cell lines examined. The lack of splenic targeting by PAM4 in these other tumor lines suggests that this phenomenon was related to excessive antigen production. Splenic targeting can be

overcome by increasing the protein dose to 10 μg from the original 2 μg dose. A greater amount of the splenic entrapped antigen presumably was complexed with unlabeled PAM4 rather than radiolabeled antibody. Increasing the protein dose had no adverse effect upon targeting of PAM4 to the tumor or nontumor tissues. In fact, an increase of the protein dose to 100 μg more than doubled the concentration of radiolabeled PAM4 within the CaPan1 tumor.

Example 4. Development of Orthotopic Pancreatic Tumor Model in Athymic Nude Mice.

[0217] In order to resemble the clinical presentation of pancreatic cancer in an animal model more closely, we developed an orthotopic model by injecting tumor cells directly into the head of the pancreas. Orthotopic CaPan1 tumors grew progressively without overt symptoms until the development of ascites and death at ten to fourteen weeks. By three to four weeks post-implantation, animals developed a palpable tumor of approximately 0.2 g. Within eight weeks of growth, primary tumors of approximately 1.2 g along with metastases to the liver and spleen were observed (1-3 metastatic tumors/animal; each tumor <0.1 g). At ten to fourteen weeks seeding of the diaphragm with development of ascites were evident. Ascites formation and occasional jaundice were usually the first overt indications of tumor growth. At this time tumors were quite large, 1 to 2 g, and animals had at most only three to four weeks until death occurred.

[0218] Radiolabeled ^{131}I-PAM4, administered to animals bearing four week old orthotopic tumors (approximately 0.2 g) showed specific targeting to the primary tumor with localization indices of 7.9 ± 3.0 at day one increasing to 22.8 ± 15.3 at day fourteen. No evidence of specific targeting to other tissues was noted. In one case where tumor metastases to the liver and spleen were observed, both metastases were targeted, and had high concentrations of radiolabeled antibody. In addition, approximately half of the animals developed a subcutaneous tumor at the incision site. No significant differences were noted in the targeting of orthotopic and subcutaneous tumors within the same animal, and no significant differences were observed in the targeting of orthotopic tumor whether or not the animal had an additional subcutaneous tumor. The estimated radiation doses from PAM4 were 6,704 and 1,655 cGy/mCi to the primary tumor and blood, respectively.

Example 5. Experimental Radioimmunotherapy of Pancreatic Cancer

[0219] The initial studies on the use of ^{131}I-PAM4 for therapy were carried out with the CaPan1 tumor, which was grown as a subcutaneous xenograft in athymic mice. Animals bearing a 0.25 g tumor were administered 350 μCi, ^{131}I-PAM4 in an experiment that also compared the therapeutic effects of a similar dose of nonspecific Ag8. The MTD for administration of ^{131}I-PAM4 to animals bearing 1 cm^3 tumors is 700 μCi. By weeks five and six, the PAM4 treated animals showed a dramatic regression of tumor, and even at week twenty seven, five out of eight remained tumor free. The untreated, as well as Ag8-treated animals, showed rapid progression of tumor growth although a significant difference was noted between these two control groups. At seven weeks, tumors from the untreated group had grown 20.0 ± 14.6-fold from the initial timepoint whereas the ^{131}I-Ag8-treated tumors had grown only 4.9 ± 1.8-fold. At this time point, the PAM4 tumors had regressed to 0.1 ± 0.1-fold of their original size, a significant difference from both untreated (P<0.001) and nonspecific Ag8-treated (P<0.01) animals.

[0220] These data show that CaPan1 tumors were sensitive to treatment with ^{131}I-PAM4. The outcome, that is, regression or progression of the tumor, was dependent upon several factors including initial tumor size. Thus, groups of animals bearing CaPan1 tumor burdens of 0.25 g, 0.5 g, 1.0 g, or 2.0 g were treated with a single dose of the 350 μCi ^{131}I-PAM4. The majority of animals having tumors of initial size 0.25 g and 0.5 g (nine of ten animals in each group) showed tumor regression or growth inhibition for at least sixteen weeks post treatment. In the 1.0 g tumor group five out of seven showed no tumor growth for the sixteen week period and in the 2.0 g tumor group six out of nine showed no tumor growth for a period of six weeks before progression occurred. Although a single 350 μCi dose was not as effective against larger tumors, a single dose may not be the appropriate regimen for large tumors.

[0221] Toxicity studies indicate the ability to give multiple cycles of radioimunotherapy, which may be more effective with a larger tumor burden. Animals bearing CaPan1 tumors averaging 1.0 g, were given either a single dose of 350 μCi ^{131}I-PAM4, two doses given at times zero and four weeks or were left untreated. The untreated group had a mean survival time of 3.7 ± 1.0 weeks (survival defined as time for tumor to reach 5 cm^3). Animals died as early as three weeks, with no animal surviving past six weeks. A single dose of 350 μCi ^{131}I-PAM4 produced a significant increase in the survival time to 18.8 ± 4.2 weeks (P<0.0001). The range of animal deaths extended from weeks thirteen to

twenty five. None of the animals were alive at the end of the study period of twenty six weeks.

[0222] A significant increase in survival time was observed for the two dose group as compared to the single dose group. Half of the animals were alive at the twenty six week timepoint with tumor sizes from 1.0-2.8 cm^3, and a mean tumor growth rate of 1.6 ± 0.7 fold from initial tumor size. For those animals that were non-survivors at twenty six weeks, the mean survival time (17.7 ± 5.3 weeks) was similar to the single dose group.

[0223] Therapy studies with PAM4 were also conducted using the orthotopic tumor model. Groups of animals bearing four week old orthotopic tumors (estimated tumor weight of 0.25 g) were either left untreated or treated with a single dose of either 350 μCi ^{131}I-PAM4 or 350 μCi of ^{131}I-nonspecific Ag8. The untreated animals had a 50% death rate by week ten with no survivors at week fifteen. Animals administered nonspecific ^{131}I-Ag8 at four weeks of tumor growth, showed a 50% death rate at week seven with no survivors at week fourteen. Although statistically (logrank analysis) there were no differences between these two groups, it is possible that radiation toxicity had occurred in the Ag8 treated animals. Radiolabeled PAM4 provided a significant survival advantage ($P<0.001$) as compared to the untreated or Ag8 treated animals, with 70% survival at sixteen weeks, the end of the experiment. At this time the surviving animals were sacrificed to determine tumor size. All animals had tumor with an average weight of 1.2 g, as well as one or two small (<0.1 g) metastases evident in four of the seven animals. At sixteen weeks of growth, these tumors were more representative of an eight-week-old tumor.

Example 6. Combined Modality GEMZAR® Chemotherapy and ^{131}I-PAM4 Experimental Radioimmunotherapy

[0224] Initial studies into the combined use of gemcitabine (GEMZAR®) with ^{131}I-PAM4 radioimmunotherapy were performed as a checkerboard array; a single dose of gemcitabine (0, 100, 200, 500 mg/kg) versus a single dose of ^{131}I-PAM4 ([MTD=700 μCi] 100%, 75%, 50%, 0% of the MTD). The combined MTD was found to be 500 mg/kg gemcitabine with 350 μCi ^{131}I-PAM4 (50% MTD). Toxicity, as measured by loss of body weight, went to the maximum considered as nontoxic; that is 20% loss in body weight. Although the combined treatment protocol was significantly more effective than gemcitabine alone, the treatment was no more effective than radioimmunotherapy alone.

The next studies were performed at a low dose of gemcitabine and radioimmunotherapy to examine if a true synergistic therapeutic effect would be observed. Athymic nude mice bearing tumors of approximately 1 cm^3 (approximately 5% of body weight) were administered gemcitabine, 100 mg/kg on days zero, three, six, nine, and twelve, with 100 μCi of ^{131}I-PAM4 given on day zero. A therapeutic effect was observed with statistically significant ($P<0.0001$) regression (two of five tumors less than 0.1 cm^3) and/or growth inhibition of the tumors compared to gemcitabine alone. Thus, at lower dosages of therapeutic agent, there surprisingly appears to be a synergistic effect of the combination of gemcitabine and radioimmunotherapy. Of additional note, in terms of body weight, toxicity was not observed. The combination treatment protocol can, if necessary, be delivered in multiple cycles, with the second treatment cycle beginning in week-four, as was done with the radioimmunotherapy-alone studies described above.

Example 7. Pretargeting with Bispecific cPAM4 x 734 and ^{99m}Tc- or ^{111}In-Labeled Peptide Haptens

[0225] For imaging of pancreatic cancer using a pretargeted approach we prepared a bispecific F(ab')$_2$ antibody (bsMAb) consisting of a chimeric PAM4 (cPAM4) Fab' and a murine 734 (m734) Fab'. The murine 734 antibody recognizes an In-DTPA complex. This bsMAb was labeled with ^{125}I (7 μCi) and injected into athymic nude mice bearing a human pancreatic cancer xenograft (CaPan1). A non-targeting F(ab')$_2$ bsMAb made from chimeric rituximab (anti-CD20 monoclonal antibody) and m734, was labeled with ^{131}I and co-injected as a control. At various time-points (4, 24, 36, 48, and 72-hours post-injection) mice were necropsied, the tissues removed and counted to determine percent-injected dose per gram (% ID/g). There was significantly greater tumor uptake of bsPAM4 at each time-point in comparison to the control bs-rituximab ($P<0.032$ or better). Our past experience with this type of pre-targeting system suggested that a blood level of less than 1% ID/g was necessary to obtain good tumor:non-tumor ratios. At 36-hours post-administration of the bsPAM4 there was 1.10 ± 0.40% ID/g in the blood which fell to 0.56 ± 0.08% ID/g at 48 hours post-injection. Tumor uptake at these two time-points was 6.43 ± 1.50% ID/g and 5.37 ± 2.38% ID/g, respectively. These values were significantly higher than the control bs-rituximab which had 0.65 ± 0.33% ID/g and 0.47 ± 0.19% ID/g in the tumor at 36 and 48 hours, respectively ($P<0.018$ and $P<0.0098$). Blood clearance rates, however, were very similar and were not significantly different.

[0226] Based on these data, a pre-targeting experiment was carried out in CaPan1 tumor-bearing mice in which radiolabeled peptide-haptens were injected 40-hours post-bsMAb administration. Two peptides, IMP-192 and IMP-156, were used, each containing divalent DTPA for recognition by the 734 MAb, but one had an additional group specific for binding ^{99m}Tc stably (IMP-192). Tumor-bearing mice (tumor volume about 0.30 cm^3) were administered ^{125}I-bsPAM4 (6 μCi) followed 40 hours later by a radiolabeled peptide-hapten (34.5 μCi; 1.5 x 10^{-11} moles; bsMAb:peptide=10:1). One group of mice received ^{99m}Tc-labeled IMP192 while a second group of mice received ^{111}In-labeled IMP156. Controls for non-specific targeting included two groups that received ^{125}I-bs-rituximab prior to administration of radiolabeled peptide and two other groups that received ^{111}In- or ^{99m}Tc-labeled peptide alone.

[0227] Mice were sacrificed at 3 and 24 hours after the administration of peptides and the% ID/g determined for the tumor and various tissues. Consistent with our previous findings, there was significantly greater bsPAM4 in the tumors in comparison to the non-targeting control bsRituximab, 8.2 ± 3.4% and 0.3 ± 0.08% ID/g, respectively (P<0.0001). This translated into a significantly greatly tumor uptake of ^{111}In-IMP156 (20.2 ± 5.5% ID/g vs. 0.9 ± 0.1% ID/g, P<0.0001). There was also significantly greater tumor uptake of ^{99m}Tc-IMP192 in the mice pre-targeted with bsPAM4 than in those pre-targeted with bs-rituximab (16.8 ± 4.8% ID/g vs. 1.1 ± 0.2% ID/g, P<0.0005). Tumor uptake of each peptide, when administered alone, was significantly less than in those mice that received the bsPAM4 (0.2 ± .05% ID/g and 0.1 ± 0.03% ID/g for ^{99m}Tc-IMP 192 and ^{111}In-IMP156, P<0.0004 and P<0.0001, respectively).

[0228] As with the 3-hour time-point, there was significantly more bsPAM4 in the tumors at 24 hours post-injection of peptide (64 hours post bsMAb administration) than bs-rituximab (6.4 ± 2.2% ID/g vs. 0.2 ± 0.09% ID/g, respectively; P<0.0001). At this time-point there was 11.1 ± 3.5% ID/g ^{111}In-IMP156 and 12.9 ± 4.2% ID/g ^{99m}Tc-IMP192 in the tumors of mice pre-targeted with bsPAM4 versus 0.5 ± 0.2% ID/g and 0.4 ± 0.03% ID/g in bs-rituximab pre-targeted tumors (P<0.0008 and P<0.0002, respectively). In the mice that received peptide alone, there was significantly less ^{99m}Tc-IMP192 in the tumors (0.06 ± 0.02% ID/g, P<0.0007) and ^{111}In-IMP156 (0.09 ± 0.02% ID/g, P<0.0002) in comparison to the bsPAM4 pre-targeted peptides.

Table 5. Tumor:Non-Tumor Tissue Ratios at Early Time-Points

	Pre-targeted ^{111}In-Peptide (3-Hours)		Pre-targeted ^{99m}Tc-Peptide (3-Hours)		^{125}I-bsPAM4 F(ab')$_2$ (4-Hours)	
Tissue	**Mean**	**(±STD)**	**Mean**	**(±STD)**	**Mean**	**(±STD)**
Tumor	1.00	0.00	1.00	0.00	1.00	0.00
Liver	36.07	11.74	16.66	7.19	2.34	0.61
Spleen	33.40	20.62	14.62	9.12	2.15	.074
Kidney	7.79	2.81	8.13	3.33	1.10	.020
Lung	44.55	12.99	15.75	5.85	1.58	.037
Blood	36.47	8.28	9.93	5.21	0.47	0.11
Bone	123.24	40.00	---	---	---	---
W. Bone	378.00	124.57	---	---	---	---
Pancreas	155.55	30.07	73.29	32.85	4.65	1.23
Tumor						
Wt (g) (±STD)	***0.189***	***(0.070)***	***0.174***	***(0.040)***	***0.179***	***(0.139)***

[0229] **Table 5** presents the tumor:non-tumor ratios (T:NT) of various tissues for these groups, each at an early time-point post-administration of radiolabeled product. It is important to note that at 4-hours post-administration of bsPAM4 x m734 F(ab')$_2$, the tumor:blood ratio was less than 2:1. However, at 3-hours post-administration, the pre-targeted ^{111}In-IMP156 and ^{99m}Tc-IMP192 had significantly greater tumor:nontumor ratios for all tissues examined and in particular tumor:blood ratios were equal to 36:1 and 9:1, (P<0.001 and P<0.011, respectively). When we examined tumor:blood ratios at the 24-hour time-point, the pre-targeted ^{111}In-IMP156 and ^{99m}Tc-IMP192 had significantly higher values, 274:1 and 80:1, respectively, versus 4:1 for ^{125}I-bsPAM4 alone (P<0.0002). These data strongly support the ability to utilize this pretargeted bsPAM4 approach with short half-life, high energy radioisotopes that would then deliver high radiation dose to tumor with minimal radiation dose to non-tumor tissues.

Example 8. Binding of PAM4 Antibodies to Transfected Cell Lines

Transfected Pancreatic Cells

[0230] PanC1 human pancreatic adenocarinoma cells that do not express the MUC-1 mucin were transfected with MUC-1 encoding cDNA as disclosed in Hudson et al. (Amer. J. Pathol. 148, 3:951-60, 1996) and obtained from Dr. M.A. Hollingsworth (Univ. of Nebraska Medical Center, Omaha, NE). The MUC-1 cDNAs encoded either 30 tandem repeat (30TR) or 42 tandem repeat (42TR) versions of MUC-1 (Hudson et al., 1996; Lidell et al, FEBS J. 275:481-89, 2008). The MUC-1 sequences were identical other than in the number of tandem repeat sequences encoded.

[0231] PanC1 cells transfected with either 30TR or 42TR MUC-1 or control vectors (no insert or reversed insert) or untransfected PanC1 cells were examined for reactivity with PAM4 antibody by enzyme immunoassay of the supernatants from cell culture. Neither the untransfected PanC1 cells nor the control transfected PanC1 cells produced detectable levels of PAM4-reactive mucins by immunoassay (not shown). However, both the 30TR and 42TR MUC-1 transfected cells were highly reactive with PAM4 antibody (not shown).

[0232] The transfected PanC1 cells were reexamined using a more sensitive immunoassay. Briefly, cells were grown in T75 flasks until they reached approximately 80%-90% confluency (~4-5 days from initial seeding). At this time, the spent-media were collected, centrifuged at high speed, and used for quantitation of PAM4-reactive mucin by enzyme immunoassay. The cells were also collected and counted. Both the Panc1 parent cell line originating from Dr. Hollingsworth and a separate Panc1 cell line obtained from the American Type Culture Collection (Manassas, VA), as well as the vector control, produced low, but detectable quantities of PAM4-reactive mucin (0.87 ± 0.17, 0.54 ± 0.17 and 0.02 ± 0.02 $\mu g/mL/10^6$ cells, respectively), whereas the 30TR-MUC-1 gene transfected cells produced 14.17 ± 2.22 $\mu g/mL/10^6$ cells ($P < 0.0003$ or better for comparison of 30TR-MUC-1 gene transfected media compared to all other samples).

[0233] It has been reported that transfection of PanC1 cells with MUC-1 cDNA, in addition to increasing expression of MUC-1 by the transfected PanC1 cells, also has secondary effects on cell protein expression, such as increasing levels of cytokeratins 8 and 18 in the transfected cells (Hudson et al., 1996, Abstract), but only in cells transfected with the larger (42TR) MUC-1 cDNA (Hudson et al. 1996, pg. 956, col. 1, 3rd paragraph).

Transfected Kidney Cells

[0234] MUC-1 gene-transfected HEK-293 (human embryonic kidney cells) produced MUC-1 that was reactive with the MA5 monoclonal antibody, but that was not reactive with PAM4 (not shown). However, as discussed above, MUC-1-transfected PanC1 cells that express very low levels of endogenous MUC-1 synthesized MUC-1 that was strongly reactive with PAM4 and non-reactive with MAb-MA5. Heterologous sandwich immunoassays (PAM4→MA5 and MA5→PAM4 capture/probe) did not function to produce a signal with supernatants from several cell lines. Use of a polyclonal anti-mucin antiserum as probe with the PAM4 or MA5 MAbs as capture reagents did provide effective immunoassays. Cross-blocking of these two MAbs within their respective immunoassays using the polyclonal as the probe suggested these MAbs were reactive with independent epitopes.

[0235] The data suggest that the PAM4 and MA5 epitopes are not co-expressed within the same antigenic molecule, and that while the PanC1 cell line may possess biosynthetic processes that create the PAM4-epitope, the HEK-293 cells do not. Differences in post-translational modification of the MUC-1 protein core (expression/activity of specific glycosyltransferases) may be responsible for these findings.

Example 9. Effects of Reagent Treatment on Immunoreactivity of PAM4 Antigen

[0236] Treatment of pancreatic mucin PAM4 antigen with DTT (15 min at room temp), completely abolished reactivity with PAM4 (DTT-EC_{50}, 0.60 $\pm$ 0.00 μM). The only cysteines (cystine bridges) within MUC-1 are present within the transmembrane domain and should not be accessible to DTT. The secreted form of MUC-1 does not contain the transmembrane domain and therefore has no intramolecular cystine bridges. Data from periodate oxidation treatment of PAM4 antigen with 0.05 M sodium periodate for 2 hrs at room temperature yielded 40% loss of immunoreactivity with PAM4 antibody (not shown). Further periodate studies have shown as high as a 60% loss of immunoreactivity with PAM4 antibody (not shown). The results of periodate and DTT studies suggest that the PAM4 epitope is conformationally dependent upon some minimal form of glycosylation, and may be affected by intermolecular disulfide bond formation.

Example 10. Distribution and Cross-Reactivity of the PAM4 Antigen

[0237] The expression of the PAM4-epitope within PanINs is atypical for MUC-1. It is similar to the expression reported for MUC-5ac as detected by the commercially available

MAb-CLH2-2. However, an attempted sandwich immunoassay with PAM4 capture and MAb-CLH2-2 as probe gave negative results. Although this possibly suggests the PAM4 and CLH2-2 epitopes may overlap and thus block each other, the CLH2-2 was reported to be reactive with 42/66 (64%) gastric carcinomas whereas the PAM4 MAb showed reactivity with only 6/40 (15%) of gastric carcinomas and, of these, only in focal reactivity.

[0238] Use of the commercially available 45M1, an anti-MUC-5ac MAb, as a probe reagent in EIA (with PAM4 as capture) provided positive results, indicating that the two epitopes may be present on the same antigenic molecule. Blocking studies (either direction) indicated that the epitopes bound by 45M1 and PAM4 are in fact two distinct epitopes, as no blocking was observed. Labeling of tissue microarrays consisting of cores from invasive pancreatic carcinoma has demonstrated significant differences for expression of the 45M1 and PAM4 epitopes in individual patient specimens. Of 28 specimens, concordance was observed in only 17 cases (61%). PAM4 was reactive with 24/28 cases (86%) while 45M1 was reactive with 13/28 (46%) cases (not shown).

[0239] It is possible that in the studies above (Example 8) regarding MUC-1 gene transfection, expression of MUC-1 may have upregulated expression of another mucin, or affected exposure of the PAM4-epitope in some other manner. The results of periodate studies are consistent with glycosylation as a factor in PAM4 antigen immunoreactivity with the PAM4 antibody. Thus, results of studies with apomucins may not be definitive for antigen determination.

[0240] Although based on EIA capture, the PAM4 antibody appears to bind to the same antigenic protein as the 45M1 anti-MUC-5ac MAb, it is noted that MUC-5ac is not specific to pancreas cancer and it is found in a number of normal tissues (other than the gastric mucosa with which PAM4 is reactive). For example, MUC-5ac is found in normal lung, colon and other tissues. PAM4 antibody does not bind to normal lung tissues, except as indicated above in few samples and to a limited or minimal amount.

[0241] With respect to the effects of DTT and periodate, it is probable that the peptide core disulfide bridges are identical no matter what tissue produces the protein. A specific amino acid sequence should fold in a specific manner, independent of the tissue source. However, glycosylation patterns may differ dependent upon tissue source.

Example 11. Phage Display Peptide Binding of PAM4 Antibody

[0242] PAM4 antibody binding was examined with two different phage display peptide libraries. The first was a linear peptide library consisting of 12 amino acid sequences and the second was a cyclic peptide consisting of 7 amino acid sequences cyclized by a disulfide bridge. We panned the individual libraries alternately against hPAM4 and hLL2 (negative selection with anti-CD22 antibody) for a combined total of 4 rounds, and then screened the phage displayed peptide for reactivity with both hPAM4 and mPAM4 with little to no reactivity against hLL2. Phage binding in a non-specific manner (i.e., binding to epratuzumab [hLL2]) were discarded.

[0243] For the linear phage-displayed peptide, the sequence WTWNITKAYPLP (SEQ ID NO:29) was identified 30 times (in 35 sequenced phage), each of which were shown to have reactivity with PAM4 antibodies. A mutational analysis was conducted in which a library based on this sequence and having 7.5% degeneracy at each position, was constructed, panned and screened as before. Variability was noted in the 19 obtained peptide sequences that were positive for PAM4 binding with 7 being identical to the parental sequence, 5 having the sequence WTWNITKEYPQP (SEQ ID NO:31) and the rest being uniquely present. **Table 6** shows the results of this mutational analysis. The upper row lists the sequences identified and the lower row lists the frequency with which each of the amino acids was identified in that position. The parent sequence is most frequent (bold) with the next highest variation a substitution of E for A at position 8 and a substitution of Q for L at position 11. It does not appear that these substitutions had any great effect upon immunoreactivity.

Table 6. Phage Display Amino Acid Sequence Variation with Linear Peptide Binding to PAM4 Antibody (SEQ ID NO: 60)

	W	**T**	**W**	**N** D	**I**	**T** R	**K** R T N G	**A** **E** T R F C	**Y** T	**P** R	**L** **Q** I M C	**P**
number of occurrences	**19**	**19**	**19**	**18** 1	**19**	**17** 2	**14** 1	**10** **5**	**18** 1	**17** 2	**11** **5**	**19**

(out of 19 sequences analyzed)							2 1 1	1 1 1 1			1 1 1	

[0244] Results with the phage displayed cyclic library were significantly different from the linear library (**Table 7**). The sequence ACPEWWGTTC (SEQ ID NO:30) was present in 33 of 35 peptide sequences examined. Analysis of the cyclic library presented the following results (positions with an asterick were invariant and not subject to selective pressure in the library).

Table 7. Phage Display Amino Acid Sequence Variation with Linear Peptide Binding to PAM4 Antibody (SEQ ID NO: 61)

	A	**C**	**P** Y	**E**	**W**	**W**	**G** S	**T** G S	**T** M S Q P	**C**
number of occurrences (out of 19 sequences analyzed)	*	*	**33** 2	**35**	**35**	**35**	**34** 1	**29** 5 1	**28** 4 1 1 1	*

[0245] The two cysteines (at positions 2 and 10) formed a disulfide bridge. Substitution of T at position 9 with any amino acid greatly affected immunoreactivity. The sequence GTTGTTC (SEQ ID NO:32) is present within the MUC-5ac protein towards the amino terminus as compared to the cyclic peptide sequence shown above, which shows homology at the C-terminal end of the consensus peptide sequence. However, the cyclic peptide only showed approximately 10% of the immunoreactivity of the linear sequence with the PAM4 antibody. Both linear and cyclic consensus sequences are associated with

a cysteine, which may or may not relate to the effect of DTT on PAM4 antigen immunoreactivity.

[0246] The results reported herein indicate that the PAM4 epitope is dependent upon a specific conformation which may be produced by disulfide bridges, as well as a specific glycosylation pattern.

Example 12. Immunohistology of Pancreatic Cancer in a Pancreatitis Specimen

[0231] Several pathologic conditions predispose patients to the development of pancreatic carcinoma, such as pancreatitis, diabetes, smoking and others. Within this pre-selected group of patients, screening measures are particularly important for the early detection of pancreatic neoplasia. We examined 9 specimens of chronic pancreatitis tissue from patients having primary diagnosis of this disease. We employed an anti-CD74 MAb, LL1, as an indicator of inflammatory infiltrate, and MAb-MA5 as a positive control for pancreatic ductal and acinar cells. Whereas the two control MAbs provided immunohistologic evidence consistent with pancreatitis, in no instance did PAM4 react with inflamed pancreatic tissue. However, in one case, a moderately differentiated pancreatic adenocarcinoma was also present within the tissue specimen. PAM4 gave an intense stain of the neoplastic cells within this tumor. In a second case, while the inflamed tissue was negative with PAM4, a small PanIN precursor lesion was identified that was labeled with PAM4. Labeling of the PanIN within this latter specimen is consistent with early detection of pancreatic neoplasia in a patient diagnosed with a non-malignant disease. These results show that detection and/or diagnosis using the PAM4 antibody may be performed with high sensitivity and selectivity for pancreatic neoplasia against a background of benign pancreatic tissues.

Example 13. Therapy of a Patient With Inoperable and Metastatic Pancreatic Carcinoma

[0232] Patient 118-001, CWG, is a 63-year-old man with Stage-IV pancreatic adenocarcinoma with multiple liver metastases, diagnosed in November of 2007. He agreed to undertake combined radioimmunotherapy and gemcitabine chemotherapy as a first treatment strategy, and was then given a first therapy cycle of 6.5 mCi/m^2 of ^{90}Y-hPAM4, combined with 200 mg/m^2 gemcitabine, whereby the gemcitabine was given once weekly on weeks 1-4 and ^{90}Y-hPAM4 was given once-weeky on weeks 2-4 (3 doses).

Two months later, the same therapy cycle was repeated, because no major toxicities were noted after the first cycle. Already 4 weeks after the first therapy cycle, CT evidence of a reduction in the diameters of the primary tumor and 2 of the 3 liver metastases surprisingly was noted, and this was consistent with significant decreases in the SUV values of FDG-PET scans, with 3 of the 4 tumors returning to normal background SUV levels at this time (**FIG. 6** and **FIG. 7**). The patient's pre-therapy CA-19.9 level of 1,297 dropped to a low level of 77, further supportive of the therapy being effective. **Table 8** shows the effects of combined radioimmunotherapy with ^{90}Y-hPAM4 and gemcitabine chemotherapy in this patient. It was surprising and unexpected that such low doses of the radionuclide conjugated to the antibody combined with such low, nontoxic, doses of gemcitabine showed such antitumor activity even after only a single course of this therapy.

Table 8. Effects of Combined Radioimmunotherapy with ^{90}Y-hPAM4 and Gemcitabine Chemotherapy in Metastatic Pancreatic Carcinoma

Tumor Location	**Baseline Longest Diameter (cm)**	**4 wk post-Tx Longest Diameter (cm)**	**Baseline PET (SUV)**	**4 wk post-Tx PET (SUV)**
Pancreatic tail (primary)	4.5	4.3	9.2	4.2
L hepatic met	1.9	1.9	4.1	background
R post hepatic met	1.7	1.6	3.7	background
R central hepatic met	1.9	1.2	3.2	background

Example 14. Therapy of a Patient with Inoperable Metastatic Pancreatic Carcinoma

[0233] A 56-year-old male with extensive, inoperable adenocarcinoma of the pancreas, with several liver metastases ranging from 1 to 4 cm in diameter, substantial weight loss (30 lbs of weight or more), mild jaundice, lethargy and weakness, as well as abdominal pains requiring medication, is given 4 weekly infusions of gemcitabine at doses of 200 mg/m^2 each. On the last three gemcitabine infusions, ^{90}Y-DOTA-hPAM4 radiolabeled humanized antibody is administered at a dose of 10 mCi/m^2 of ^{90}Y and 20 mg antibody protein, in a two-hour i.v. infusion. Two weeks later, the patient is given a course of

gemcitabine chemotherapy consisting of 3 weekly doses of 600 mg/m^2 by i.v. infusion. The patient is then evaluated 4 weeks later, and has a mild leukopenia (grade-2), no other major blood or enzyme changes over baseline, but shows an improvement in the blood CA19.9 titer from 5,700 to 1,200 and a decrease in jaundice, with an overall subjective improvement. This follows 3 weeks later with a repeat of the cycle of lower-dose gemcitabine (weekly x 4), with 3 doses of ^{90}Y-DOTA-hPAM4. Four weeks later, the patient is reevaluated, and the CT and PET scans confirm an approximately 40% reduction of total tumor mass (primary cancer and metastases), with a further reduction of the CA19.9 titer to 870. The patient regains appetite and activity, and is able to return to more usual daily activities without the need for pain medication. He gains 12 lbs after beginning this experimental therapy. A repeat of the scans and blood values indicates that this response is maintained 6 weeks later.

Example 15. Preparation of Dock-and-Lock (DNL) Constructs for Pretargeting

DDD and AD Fusion Proteins

[0247] The DNL technique can be used to make dimers, trimers, tetramers, hexamers, etc. comprising virtually any antibodies or fragments thereof or other effector moieties. For certain preferred embodiments, IgG antibodies or Fab antibody fragments may be produced as fusion proteins containing either a dimerization and docking domain (DDD) or anchoring domain (AD) sequence. Although in preferred embodiments the DDD and AD moieties are produced as fusion proteins, the skilled artisan will realize that other methods of conjugation, such as chemical cross-linking, may be utilized within the scope of the claimed methods and compositions.

[0248] Bispecific antibodies may be formed by combining a Fab-DDD fusion protein of a first antibody with a Fab-AD fusion protein of a second antibody. Alternatively, constructs may be made that combine IgG-AD fusion proteins with Fab-DDD fusion proteins. The technique is not limiting and any protein or peptide of use may be produced as an AD or DDD fusion protein for incorporation into a DNL construct. Where chemical cross-linking is utilized, the AD and DDD conjugates are not limited to proteins or peptides and may comprise any molecule that may be cross-linked to an AD or DDD sequence using any cross-linking technique known in the art. In certain exemplary embodiments, a polyethylene glycol (PEG) or other polymeric moiety may be incorporated into a DNL construct, as described in further detail below.

[0249] For pretargeting applications, an antibody or fragment containing a binding site for an antigen associated with a diseased tissue, such as a tumor-associated antigen (TAA), may be combined with a second antibody or fragment that binds a hapten on a targetable construct, to which a therapeutic and/or diagnostic agent is attached. The DNL-based bispecific antibody is administered to a subject, circulating antibody is allowed to clear from the blood and localize to target tissue, and the conjugated targetable construct is added and binds to the localized antibody for diagnosis or therapy.

[0250] Independent transgenic cell lines may be developed for each Fab or IgG fusion protein. Once produced, the modules can be purified if desired or maintained in the cell culture supernatant fluid. Following production, any DDD-fusion protein module can be combined with any AD-fusion protein module to generate a bispecific DNL construct. For different types of constructs, different AD or DDD sequences may be utilized. Exemplary DDD and AD sequences are provided below.

DDD1: SHIQIPPGLTELLQGYTVEVLRQQPPDLVEFAVEYFTRLREARA (SEQ ID NO:33)

DDD2: CGHIQIPPGLTELLQGYTVEVLRQQPPDLVEFAVEYFTRLREARA (SEQ ID NO:34)

AD1: QIEYLAKQIVDNAIQQA (SEQ ID NO:35)

AD2: CGQIEYLAKQIVDNAIQQAGC (SEQ ID NO:36)

Expression Vectors

[0251] The plasmid vector pdHL2 has been used to produce a number of antibodies and antibody-based constructs. See Gillies et al., J Immunol Methods (1989), 125:191-202; Losman et al., Cancer (Phila) (1997), 80:2660-6. The di-cistronic mammalian expression vector directs the synthesis of the heavy and light chains of IgG. The vector sequences are mostly identical for many different IgG-pdHL2 constructs, with the only differences existing in the variable domain (VH and VL) sequences. Using molecular biology tools known to those skilled in the art, these IgG expression vectors can be converted into Fab-DDD or Fab-AD expression vectors. To generate Fab-DDD expression vectors, the coding sequences for the hinge, CH2 and CH3 domains of the heavy chain are replaced with a sequence encoding the first 4 residues of the hinge, a 14 residue Gly-Ser linker and

the first 44 residues of human RIIα (referred to as DDD1). To generate Fab-AD expression vectors, the sequences for the hinge, CH2 and CH3 domains of IgG are replaced with a sequence encoding the first 4 residues of the hinge, a 15 residue Gly-Ser linker and a 17 residue synthetic AD called AKAP-*IS* (referred to as AD1), which was generated using bioinformatics and peptide array technology and shown to bind RIIα dimers with a very high affinity (0.4 nM). See Alto, et al. Proc. Natl. Acad. Sci., U.S.A (2003), 100:4445-50.

[0252] Two shuttle vectors were designed to facilitate the conversion of IgG-pdHL2 vectors to either Fab-DDD1 or Fab-AD1 expression vectors, as described below.

Preparation of CH1

[0253] The CH1 domain was amplified by PCR using the pdHL2 plasmid vector as a template. The left PCR primer consisted of the upstream (5') end of the CH1 domain and a SacII restriction endonuclease site, which is 5' of the CH1 coding sequence. The right primer consisted of the sequence coding for the first 4 residues of the hinge (PKSC) followed by four glycines and a serine, with the final two codons (GS) comprising a Bam HI restriction site. The 410 bp PCR amplimer was cloned into the PGEMT® PCR cloning vector (PROMEGA®, Inc.) and clones were screened for inserts in the T7 (5') orientation.

Construction of $(G_4S)_2$DDD1 ($(G_4S)_2$ disclosed as SEQ ID NO:37)

[0254] A duplex oligonucleotide, designated $(G_4S)_2$DDD1 ($(G_4S)_2$ disclosed as SEQ ID NO:37), was synthesized by Sigma GENOSYS® (Haverhill, UK) to code for the amino acid sequence of DDD1 preceded by 11 residues of the linker peptide, with the first two codons comprising a BamHI restriction site. A stop codon and an EagI restriction site are appended to the 3'end. The encoded polypeptide sequence is shown below.

GSGGGGSGGGGSHIQIPPGLTELLQGYTVEVLRQQPPDLVEFAVEYFTRLREARA (SEQ ID NO:38)

[0255] Two oligonucleotides, designated RIIA1-44 top and RIIA1-44 bottom, that overlap by 30 base pairs on their 3' ends, were synthesized (Sigma GENOSYS®) and combined to comprise the central 154 base pairs of the 174 bp DDD1 sequence. The oligonucleotides were annealed and subjected to a primer extension reaction with Taq polymerase. Following primer extension, the duplex was amplified by PCR. The amplimer was cloned into PGEMT® and screened for inserts in the T7 (5') orientation.

Construction of $(G_4S)_2$-AD1 ($(G_4S)_2$ disclosed as SEQ ID NO:37)

[0256] A duplex oligonucleotide, designated $(G_4S)_2$-AD1 ($(G_4S)_2$ disclosed as SEQ ID NO:37), was synthesized (Sigma GENOSYS®) to code for the amino acid sequence of AD1 preceded by 11 residues of the linker peptide with the first two codons comprising a BamHI restriction site. A stop codon and an EagI restriction site are appended to the 3'end. The encoded polypeptide sequence is shown below.

GSGGGGSGGGGSQIEYLAKQIVDNAIQQA (SEQ ID NO:39)

[0257] Two complimentary overlapping oligonucleotides encoding the above peptide sequence, designated AKAP-IS Top and AKAP-IS Bottom, were synthesized and annealed. The duplex was amplified by PCR. The amplimer was cloned into the PGEMT® vector and screened for inserts in the T7 (5') orientation.

Ligating DDD1 with CH1

[0258] A 190 bp fragment encoding the DDD1 sequence was excised from PGEMT® with BamHI and NotI restriction enzymes and then ligated into the same sites in CH1-PGEMT® to generate the shuttle vector CH1-DDD1-PGEMT®.

Ligating AD1 with CH1

[0259] A 110 bp fragment containing the AD1 sequence was excised from PGEMT® with BamHI and NotI and then ligated into the same sites in CH1-PGEMT® to generate the shuttle vector CH1-AD1-PGEMT®.

Cloning CH1-DDD1 or CH1-AD1 into pdHL2-based vectors

[0260] With this modular design either CH1-DDD1 or CH1-AD1 can be incorporated into any IgG construct in the pdHL2 vector. The entire heavy chain constant domain is replaced with one of the above constructs by removing the SacII/EagI restriction fragment (CH1-CH3) from pdHL2 and replacing it with the SacII/EagI fragment of CH1-DDD1 or CH1-AD1, which is excised from the respective pGemT shuttle vector.

Construction of h679-Fd-AD1-pdHL2

[0261] h679-Fd-AD1-pdHL2 is an expression vector for production of h679 Fab with AD1 coupled to the carboxyl terminal end of the CH1 domain of the Fd via a flexible Gly/Ser peptide spacer composed of 14 amino acid residues. A pdHL2-based vector containing the variable domains of h679 was converted to h679-Fd-AD1-pdHL2 by

replacement of the SacII/EagI fragment with the CH1-AD1 fragment, which was excised from the CH1-AD1-SV3 shuttle vector with SacII and EagI.

Construction of C-DDD1-Fd-hMN-14-pdHL2

[0262] C-DDD1-Fd-hMN-14-pdHL2 is an expression vector for production of a stable dimer that comprises two copies of a fusion protein C-DDD1-Fab-hMN-14, in which DDD1 is linked to hMN-14 Fab at the carboxyl terminus of CH1 via a flexible peptide spacer. The plasmid vector hMN-14(I)-pdHL2, which has been used to produce hMN-14 IgG, was converted to C-DDD1-Fd-hMN-14-pdHL2 by digestion with SacII and EagI restriction endonucleases to remove the CH1-CH3 domains and insertion of the CH1-DDD1 fragment, which was excised from the CH1-DDD1-SV3 shuttle vector with SacII and EagI.

[0263] The same technique has been utilized to produce plasmids for Fab expression of a wide variety of known antibodies, such as hLL1, hLL2, hPAM4, hR1, hRS7, hMN-14, hMN-15, hA19, hA20 and many others. Generally, the antibody variable region coding sequences were present in a pdHL2 expression vector and the expression vector was converted for production of an AD- or DDD-fusion protein as described above. The AD- and DDD-fusion proteins comprising a Fab fragment of any of such antibodies may be combined, in an approximate ratio of two DDD-fusion proteins per one AD-fusion protein, to generate a trimeric DNL construct comprising two Fab fragments of a first antibody and one Fab fragment of a second antibody.

C-DDD2-Fd-hMN-14-pdHL2

[0264] C-DDD2-Fd-hMN-14-pdHL2 is an expression vector for production of C-DDD2-Fab-hMN-14, which possesses a dimerization and docking domain sequence of DDD2 appended to the carboxyl terminus of the Fd of hMN-14 via a 14 amino acid residue Gly/Ser peptide linker. The fusion protein secreted is composed of two identical copies of hMN-14 Fab held together by non-covalent interaction of the DDD2 domains.

[0265] The expression vector was engineered as follows. Two overlapping, complimentary oligonucleotides, which comprise the coding sequence for part of the linker peptide (GGGGSGGGCG, SEQ ID NO:40) and residues 1-13 of DDD2, were made synthetically. The oligonucleotides were annealed and phosphorylated with T4 PNK,

resulting in overhangs on the 5' and 3' ends that are compatible for ligation with DNA digested with the restriction endonucleases BamHI and PstI, respectively.

[0266] The duplex DNA was ligated with the shuttle vector CH1-DDD1-PGEMT®, which was prepared by digestion with BamHI and PstI, to generate the shuttle vector CH1-DDD2-PGEMT®. A 507 bp fragment was excised from CH1-DDD2-PGEMT® with SacII and EagI and ligated with the IgG expression vector hMN-14(I)-pdHL2, which was prepared by digestion with SacII and EagI. The final expression construct was designated C-DDD2-Fd-hMN-14-pdHL2. Similar techniques have been utilized to generated DDD2-fusion proteins of the Fab fragments of a number of different humanized antibodies.

h679-Fd-AD2-pdHL2

[0267] h679-Fab-AD2, was designed to pair as **B** to C-DDD2-Fab-hMN-14 as **A**. h679-Fd-AD2-pdHL2 is an expression vector for the production of h679-Fab-AD2, which possesses an anchoring domain sequence of AD2 appended to the carboxyl terminal end of the CH1 domain via a 14 amino acid residue Gly/Ser peptide linker. AD2 has one cysteine residue preceding and another one following the anchor domain sequence of AD1.

[0268] The expression vector was engineered as follows. Two overlapping, complimentary oligonucleotides (AD2 Top and AD2 Bottom), which comprise the coding sequence for AD2 and part of the linker sequence, were made synthetically. The oligonucleotides were annealed and phosphorylated with T4 PNK, resulting in overhangs on the 5' and 3' ends that are compatible for ligation with DNA digested with the restriction endonucleases BamHI and SpeI, respectively.

[0269] The duplex DNA was ligated into the shuttle vector CH1-AD1-PGEMT®, which was prepared by digestion with BamHI and SpeI, to generate the shuttle vector CH1-AD2-PGEMT®. A 429 base pair fragment containing CH1 and AD2 coding sequences was excised from the shuttle vector with SacII and EagI restriction enzymes and ligated into h679-pdHL2 vector that prepared by digestion with those same enzymes. The final expression vector is h679-Fd-AD2-pdHL2.

Generation of TF2 DNL Pretargeting Construct

[0270] A trimeric DNL construct designated TF2 was obtained by reacting C-DDD2-Fab-hMN-14 with h679-Fab-AD2. A pilot batch of TF2 was generated with >90% yield as follows. Protein L-purified C-DDD2-Fab-hMN-14 (200 mg) was mixed with h679-Fab-

AD2 (60 mg) at a 1.4:1 molar ratio. The total protein concentration was 1.5 mg/ml in PBS containing 1 mM EDTA. Subsequent steps involved TCEP reduction, HIC chromatography, DMSO oxidation, and IMP 291 affinity chromatography. Before the addition of TCEP, SE-HPLC did not show any evidence of **a_2b** formation. Addition of 5 mM TCEP rapidly resulted in the formation of **a_2b** complex consistent with a 157 kDa protein expected for the binary structure. TF2 was purified to near homogeneity by IMP 291 affinity chromatography (not shown). IMP 291 is a synthetic peptide containing the HSG hapten to which the 679 Fab binds (Rossi et al., 2005, Clin Cancer Res 11:7122s-29s). SE-HPLC analysis of the IMP 291 unbound fraction demonstrated the removal of a_4, a_2 and free kappa chains from the product (not shown).

[0271] Non-reducing SDS-PAGE analysis demonstrated that the majority of TF2 exists as a large, covalent structure with a relative mobility near that of IgG (not shown). The additional bands suggest that disulfide formation is incomplete under the experimental conditions (not shown). Reducing SDS-PAGE shows that any additional bands apparent in the non-reducing gel are product-related (not shown), as only bands representing the constituent polypeptides of TF2 were evident (not shown). However, the relative mobilities of each of the four polypeptides were too close to be resolved. MALDI-TOF mass spectrometry (not shown) revealed a single peak of 156,434 Da, which is within 99.5% of the calculated mass (157,319 Da) of TF2.

[0272] The functionality of TF2 was determined by BIACORE® assay. TF2, C-DDD1-hMN-14+h679-AD1 (used as a control sample of noncovalent **a_2b** complex), or C-DDD2-hMN-14+h679-AD2 (used as a control sample of unreduced a_2 and b components) were diluted to 1 μg/ml (total protein) and passed over a sensorchip immobilized with HSG. The response for TF2 was approximately two-fold that of the two control samples, indicating that only the h679-Fab-AD component in the control samples would bind to and remain on the sensorchip. Subsequent injections of WI2 IgG, an anti-idiotype antibody for hMN-14, demonstrated that only TF2 had a DDD-Fab-hMN-14 component that was tightly associated with h679-Fab-AD as indicated by an additional signal response. The additional increase of response units resulting from the binding of WI2 to TF2 immobilized on the sensorchip corresponded to two fully functional binding sites, each contributed by one subunit of C-DDD2-Fab-hMN-14. This was confirmed by the ability of TF2 to bind two Fab fragments of WI2 (not shown).

Production of TF10 Bispecific Antibody for Pretargeting

[0273] A similar protocol was used to generate a trimeric TF10 DNL construct, comprising two copies of a C-DDD2-Fab-hPAM4 and one copy of C-AD2-Fab-679. The cancer-targeting antibody component in TF10 was derived from hPAM4, a humanized anti-pancreatic cancer mucin MAb that has been studied in detail as a radiolabeled MAb (*e.g.*, Gold et al., *Clin. Cancer Res.* 13: 7380-7387, 2007). The hapten-binding component was derived from h679, a humanized anti-histaminyl-succinyl-glycine (HSG) MAb. The TF10 bispecific ([hPAM4]$_2$ x h679) antibody was produced using the method disclosed for production of the (anti CEA)$_2$ x anti HSG bsAb TF2, as described above. The TF10 construct bears two humanized PAM4 Fabs and one humanized 679 Fab.

[0274] The two fusion proteins (hPAM4-DDD and h679-AD2) were expressed independently in stably transfected myeloma cells. The tissue culture supernatant fluids were combined, resulting in a two-fold molar excess of hPAM4-DDD. The reaction mixture was incubated at room temperature for 24 hours under mild reducing conditions using 1 mM reduced glutathione. Following reduction, the DNL reaction was completed by mild oxidation using 2 mM oxidized glutathione. TF10 was isolated by affinity chromatography using IMP 291-affigel resin, which binds with high specificity to the h679 Fab.

[0275] A full tissue histology and blood cell binding panel has been examined for hPAM4 IgG and for an anti-CEA x anti-HSG bsMAb that is entering clinical trials. hPAM4 binding was restricted to very weak binding to the urinary bladder and stomach in 1/3 specimens (no binding was seen *in vivo*), and no binding to normal tissues was attributed to the anti-CEA x anti-HSG bsMAb. Furthermore, *in vitro* studies against cell lines bearing the H1 and H2 histamine receptors showed no antagonistic or agonistic activity with the IMP 288 di-HSG peptide, and animal studies in 2 different species showed no pharmacologic activity of the peptide related to the histamine component at doses 20,000 times higher than that used for imaging. Thus, the HSG-histamine derivative does not have pharmacologic activity.

Example 16. Imaging Studies Using Pretargeting With TF10 Bispecific Antibody and ^{111}In-Labeled Peptides

[0276] The following study demonstrates the feasibility of *in vivo* imaging using the pretargeting technique with bispecific antibodies incorporating hPAM4 and labeled peptides. The TF10 bispecific antibody, comprising two copies of a C-DDD2-Fab-

hPAM4 and one copy of C-AD2-Fab-679, was prepared as described in the preceding Example. Nude mice bearing 0.2 to 0.3 g human pancreatic cancer xenografts were imaged, using pretargeting with TF10 and ^{111}In-IMP-288 peptide. The results, shown in **FIG. 8,** demonstrate how clearly delineated tumors can be detected in animal models using a bsMAb pretargeting method, with ^{111}In-labeled di-HSG peptide, IMP-288. The six animals in the top of **FIG. 8** received 2 different doses of TF10 (10:1 and 20:1 mole ratio to the moles of peptide given), and the next day they were given an ^{111}In-labeled diHSG peptide (IMP 288). The 3 other animals on the bottom of **FIG. 8** received only the ^{111}In-IMP-288 (no pretargeting). The images were taken 3 h after the injection of the labeled peptide and show clear localization of 0.2 – 0.3 g tumors in the pretargeted animals, with no localization in the animals given the ^{111}In-peptide alone. Tumor uptake averaged 20-25% ID/g with tumor/blood ratios exceeding 2000:1, tumor/liver ratios of 170:1, and tumor/kidney ratios of 18/1.

Example 17. Production of Targeting Peptides for Use in Pretargeting and ^{18}F Labeling

[0277] In a variety of embodiments, ^{18}F-labeled proteins or peptides are prepared by a novel technique and used for diagnostic and/or imaging studies, such as PET imaging. The novel technique for ^{18}F labeling involves preparation of an ^{18}F-metal complex, preferably an ^{18}F-aluminum complex, which is chelated to a chelating moiety, such as DOTA, NOTA or NETA or derivatives thereof. Chelating moieties may be attached to proteins, peptides or any other molecule using conjugation techniques well known in the art. In certain preferred embodiments, the ^{18}F-Al complex is formed in solution first and then attached to a chelating moiety that is already conjugated to a protein or peptide. However, in alternative embodiments the aluminum may be first attached to the chelating moiety and the ^{18}F added later.

Peptide Synthesis

[0278] Peptides were synthesized by solid phase peptide synthesis using the Fmoc strategy. Groups were added to the side chains of diamino amino acids by using Fmoc/Aloc protecting groups to allow differential deprotection. The Aloc groups were removed by the method of Dangles et. al. (*J. Org. Chem.* 1987, 52:4984-4993) except that piperidine was added in a 1:1 ratio to the acetic acid used. The unsymmetrical tetra-t-butyl

DTPA was made as described in McBride et al. (US Patent Application Pub. No.US 2005/0002945).

[0279] The tri-*t*-butyl DOTA, symmetrical tetra-*t*-butyl DTPA, ITC-benzyl DTPA, *p*-SCN-Bn-NOTA and TACN were obtained from MACROCYCLICS® (Dallas, TX). The DiBocTACN, NODA-GA(tBu)$_3$ and the NO2AtBu were purchased from CheMatech (Dijon, France). The Aloc/Fmoc Lysine and Dap (diaminopropionic acid derivatives (also Dpr)) were obtained from CREOSALUS® (Louisville, KY) or BACHEM® (Torrance, CA). The Sieber Amide resin was obtained from NOVABIOCHEM® (San Diego, CA). The remaining Fmoc amino acids were obtained from CREOSALUS®, BACHEM®, PEPTECH® (Burlington, MA), EMD BIOSCIENCES® (San Diego, CA), CHEM IMPEX® (Wood Dale, IL) or NOVABIOCHEM®. The aluminum chloride hexahydrate was purchased from SIGMA-ALDRICH® (Milwaukee, WI). The remaining solvents and reagents were purchased from FISHER SCIENTIFIC® (Pittsburgh, PA) or SIGMA-ALDRICH® (Milwaukee, WI). ^{18}F was supplied by IBA MOLECULAR® (Somerset, NJ)

^{18}F-Labeling of IMP 272

[0280] The first peptide that was prepared and ^{18}F-labeled was IMP 272:

DTPA-Gln-Ala-Lys(HSG)-D-Tyr-Lys(HSG)-NH_2 MH^+ 1512

[0281] IMP 272 was synthesized as described (McBride et al., US Patent Application Publ. No. 20040241158).

[0282] Acetate buffer solution - Acetic acid, 1.509 g was diluted in ~ 160 mL water and the pH was adjusted by the addition of 1 M NaOH then diluted to 250 mL to make a 0.1 M solution at pH 4.03.

[0283] Aluminum acetate buffer solution - A solution of aluminum was prepared by dissolving 0.1028 g of $AlCl_3$ hexahydrate in 42.6 mL DI water. A 4 mL aliquot of the aluminum solution was mixed with 16 mL of a 0.1 M NaOAc solution at pH 4 to provide a 2 mM Al stock solution.

[0284] IMP 272 acetate buffer solution - Peptide, 0.0011 g, 7.28×10^{-7} mol IMP 272 was dissolved in 364 µL of the 0.1 M pH 4 acetate buffer solution to obtain a 2 mM stock solution of the peptide.

[0285] F-18 Labeling of IMP 272 - A 3 μL aliquot of the aluminum stock solution was placed in a REACTI-VIAL™ and mixed with 50 μL ^{18}F (as received) and 3 μL of the IMP 272 solution. The solution was heated in a heating block at 110°C for 15 min and analyzed by reverse phase HPLC. HPLC analysis (not shown) showed 93% free ^{18}F and 7% bound to the peptide. An additional 10 μL of the IMP 272 solution was added to the reaction and it was heated again and analyzed by reverse phase HPLC (not shown). The HPLC trace showed 8% ^{18}F at the void volume and 92% of the activity attached to the peptide. The remainder of the peptide solution was incubated at room temperature with 150 μL PBS for ~ 1hr and then examined by reverse phase HPLC. The HPLC (not shown) showed 58% ^{18}F unbound and 42% still attached to the peptide. The data indicate that ^{18}F-Al-DTPA complex may be unstable when mixed with phosphate.

[0286] The labeled peptide was purified by applying the labeled peptide solution onto a 1 cc (30 mg) WATERS® HLB column (Part # 186001879) and washing with 300 μL water to remove unbound F-18. The peptide was eluted by washing the column with 2 x 100 μL 1:1 EtOH/H_2O. The purified peptide was incubated in water at 25 °C and analyzed by reverse phase HPLC (not shown). The HPLC analysis showed that the ^{18}F-labeled IMP 272 was not stable in water. After 40 min incubation in water about 17% of the ^{18}F was released from the peptide, while 83% was retained (not shown).

[0287] The peptide (16 μL 2 mM IMP 272, 48 μg) was labeled with ^{18}F and analyzed for antibody binding by size exclusion HPLC. The size exclusion HPLC showed that the peptide bound hMN-14 x 679 but did not bind to the irrelevant bispecific antibody hMN-14 x 734 (not shown).

IMP 272 ^{18}F Labeling with Other Metals

[0288] A ~3 μL aliquot of the metal stock solution (6 x 10^{-9} mol) was placed in a polypropylene cone vial and mixed with 75 μL ^{18}F (as received), incubated at room temperature for ~ 2 min and then mixed with 20 μL of a 2 mM (4 x 10^{-8} mol) IMP 272 solution in 0.1 M NaOAc pH 4 buffer. The solution was heated in a heating block at 100°C for 15 min and analyzed by reverse phase HPLC. IMP 272 was labeled with indium (24%), gallium (36%), zirconium (15%), lutetium (37%) and yttrium (2%) (not shown). These results demonstrate that the ^{18}F metal labeling technique is not limited to an aluminum ligand, but can also utilize other metals as well. With different metal ligands,

different chelating moieties may be utilized to optimize binding of an F-18-metal conjugate.

Production and Use of a Serum-Stable ^{18}F-Labeled Peptide IMP 449

[0289] The peptide, IMP 448 D-Ala-D-Lys(HSG)-D-Tyr-D-Lys(HSG)-NH_2 MH^+ 1009 was made on Sieber Amide resin by adding the following amino acids to the resin in the order shown: Aloc-D-Lys(Fmoc)-OH, Trt-HSG-OH, the Aloc was cleaved, Fmoc-D-Tyr(But)-OH, Aloc-D-Lys(Fmoc)-OH, Trt-HSG-OH, the Aloc was cleaved, Fmoc-D-Ala-OH with final Fmoc cleavage to make the desired peptide. The peptide was then cleaved from the resin and purified by HPLC to produce IMP 448, which was then coupled to ITC-benzyl NOTA. The peptide, IMP 448, 0.0757g (7.5×10^{-5} mol) was mixed with 0.0509 g (9.09×10^{-5} mol) ITC benzyl NOTA and dissolved in 1 mL water. Potassium carbonate anhydrous (0.2171 g) was then slowly added to the stirred peptide/NOTA solution. The reaction solution was pH 10.6 after the addition of all the carbonate. The reaction was allowed to stir at room temperature overnight. The reaction was carefully quenched with 1 M HCl after 14 hr and purified by HPLC to obtain 48 mg of IMP 449.

^{18}F Labeling of IMP 449

[0290] The peptide IMP 449 (0.002 g, 1.37×10^{-6} mol) was dissolved in 686 µL (2 mM peptide solution) 0.1 M NaOAc pH 4.02. Three microliters of a 2 mM solution of Al in a pH 4 acetate buffer was mixed with 15 µL, 1.3 mCi of ^{18}F. The solution was then mixed with 20 µL of the 2 mM IMP 449 solution and heated at 105 °C for 15 min. Reverse Phase HPLC analysis showed 35% ($t_R \sim 10$ min) of the activity was attached to the peptide and 65% of the activity was eluted at the void volume of the column (3.1 min, not shown) indicating that the majority of activity was not associated with the peptide. The crude labeled mixture (5 µL) was mixed with pooled human serum and incubated at 37 °C. An aliquot was removed after 15 min and analyzed by HPLC. The HPLC showed 9.8% of the activity was still attached to the peptide (down from 35%). Another aliquot was removed after 1 hr and analyzed by HPLC. The HPLC showed 7.6% of the activity was still attached to the peptide (down from 35%), which was essentially the same as the 15 min trace (data not shown).

High Dose ^{18}F Labeling

[0291] Further studies with purified IMP 449 demonstrated that the ^{18}F-labeled peptide was highly stable (91%, not shown) in human serum at 37 °C for at least one hour and was partially stable (76%, not shown) in human serum at 37 °C for at least four hours. Additional studies were performed in which the IMP 449 was prepared in the presence of ascorbic acid as a stabilizing agent. In those studies (not shown), the metal-^{18}F-peptide complex showed no detectable decomposition in serum after 4 hr at 37 °C. The mouse urine 30 min after injection of ^{18}F-labeled peptide was found to contain ^{18}F bound to the peptide (not shown). These results demonstrate that the ^{18}F-labeled peptides disclosed herein exhibit sufficient stability under approximated *in vivo* conditions to be used for ^{18}F imaging studies.

[0292] For studies in the absence of ascorbic acid, ^{18}F ~ 21 mCi in ~ 400 μL of water was mixed with 9 μL of 2 mM $AlCl_3$ in 0.1 M pH 4 NaOAc. The peptide, IMP 449, 60 μL (0.01 M, 6 x 10^{-7} mol in 0.5 NaOH pH 4.13) was added and the solution was heated to 110 °C for 15 min. The crude labeled peptide was then purified by placing the reaction solution in the barrel of a 1 cc WATERS® HLB column and eluting with water to remove unbound ^{18}F followed by 1:1 EtOH/H_20 to elute the ^{18}F-labeled peptide. The crude reaction solution was pulled through the column into a waste vial and the column was washed with 3 x 1 mL fractions of water (18.97 mCi). The HLB column was then placed on a new vial and eluted with 2 x 200 μL 1:1 EtOH/H_2O to collect the labeled peptide (1.83 mCi). The column retained 0.1 mCi of activity after all of the elutions were complete. An aliquot of the purified ^{18}F-labeled peptide (20 μL) was mixed with 200 μL of pooled human serum and heated at 37 °C. Aliquots were analyzed by reverse phase HPLC. The results showed the relative stability of ^{18}F-labeled purified IMP 449 at 37 °C at time zero, one hour (91% labeled peptide), two hours (77% labeled peptide) and four hours (76% labeled peptide) of incubation in human serum (not shown). It was also observed that ^{18}F-labeled IMP 449 was stable in TFA solution, which is occasionally used during reverse phase HPLC chromatography. There appears to be a general correlation between stability in TFA and stability in human serum observed for the exemplary ^{18}F-labeled molecules described herein. These results demonstrate that ^{18}F-labeled peptide, produced according to the methods disclosed herein, shows sufficient stability in human serum to be successfully used for *in vivo* labeling and imaging studies, for example using PET scanning to detect labeled cells or tissues. Finally, since IMP 449 peptide contains a thiourea linkage, which is sensitive to radiolysis, several products are observed by RP-HPLC. However, when

ascorbic acid is added to the reaction mixture, the side products generated were markedly reduced.

Example 18. *In Vivo* Studies With Pretargeting TF10 DNL Construct and ^{18}F-Labeled Peptide

[0293] ^{18}F-labeled IMP 449 was prepared as follows. The ^{18}F, 54.7 mCi in ~ 0.5 mL was mixed with 3 µL 2 mM Al in 0.1 M NaOAc pH 4 buffer. After 3 min 10 µL of 0.05 M IMP 449 in 0.5 M pH 4 NaOAc buffer was added and the reaction was heated in a 96 °C heating block for 15 min. The contents of the reaction were removed with a syringe. The crude labeled peptide was then purified by HPLC on a C_{18} column. The flow rate was 3 mL/min. Buffer A was 0.1% TFA in water and Buffer B was 90% acetonitrile in water with 0.1% TFA. The gradient went from 100% A to 75/25 A:B over 15 min. There was about 1 min difference in retention time (t_R) between the labeled peptide, which eluted first and the unlabeled peptide. The HPLC eluent was collected in 0.5 min (mL) fractions. The labeled peptide had a t_R between 6 to 9 min depending on the column used. The HPLC purified peptide sample was further processed by diluting the fractions of interest two fold in water and placing the solution in the barrel of a 1 cc WATERS® HLB column. The cartridge was eluted with 3 x 1 mL water to remove acetonitrile and TFA followed by 400 µL 1:1 EtOH/H_20 to elute the ^{18}F-labeled peptide. The purified [Al^{18}F] IMP 449 eluted as a single peak on an analytical HPLC C_{18} column (not shown).

[0294] TACONIC® nude mice bearing the four slow-growing sc CaPan1 xenografts were used for *in vivo* studies. Three of the mice were injected with TF10 (162 µg) followed with [Al^{18}F] IMP 449 18 h later. TF10 is a humanized bispecific antibody of use for tumor imaging studies, with divalent binding to the PAM-4 defined tumor antigen and monovalent binding to HSG (see, e.g., Gold et al., 2007, J. Clin. Oncol. 25(18S):4564). One mouse was injected with peptide alone. All of the mice were necropsied at 1 h post peptide injection. Tissues were counted immediately. Animal #2 showed high counts in the femur. The femur was transferred into a new vial and was recounted along with the old empty vial. Recounting indicated that the counts were on the tissue. This femur was broken and had a large piece of muscle attached to it. Comparison of mean distributions showed substantially higher levels of ^{18}F-labeled peptide localized in the tumor than in any normal tissues in the presence of tumor-targeting bispecific antibody.

[0295] Tissue uptake was similar in animals given the [Al^{18}F] IMP 449 alone or in a pretargeting setting (**Table 9**). Uptake in the human pancreatic cancer xenograft, CaPan1, at 1 h was increased 5-fold in the pretargeted animals as compared to the peptide alone (4.6 ± 0.9% ID/g vs. 0.89% ID/g). Exceptional tumor/nontumor ratios were achieved at this time (e.g., tumor/blood and liver ratios were 23.4 ± 2.0 and 23.5 ± 2.8, respectively).

Table 9. Tissue uptake at 1 h post peptide injection, mean and the individual animals:

	TF10 (162μg) -→18 h → [Al^{18}F] IMP 449 **(10 :1)**						[Al^{18}F] IMP 449 **alone**
Tissue	n	Mean	SD	Animal 1	Animal 2	Animal 3	Animal 1
Tumor *(mass)*	3	4.591	0.854	**4.330** ***(0.675 g)***	**5.546** ***(0.306g)***	**3.898** ***(0.353g)***	0.893 *(0.721g)*
Liver	3	0.197	0.041	0.163	0.242	0.186	0.253
Spleen	3	0.202	0.022	0.180	0.224	0.200	0.226
Kidney	3	5.624	0.531	5.513	6.202	5.158	5.744
Lung	3	0.421	0.197	0.352	0.643	0.268	0.474
Blood	3	0.196	0.028	0.204	0.219	0.165	0.360
Stomach	3	0.123	0.046	0.080	0.172	0.118	0.329
Small Int.	3	0.248	0.042	0.218	0.295	0.230	0.392
Large Int.	3	0.141	0.094	0.065	0.247	0.112	0.113
Pancreas	3	0.185	0.078	0.259	0.194	0.103	0.174
Spine	3	0.394	0.427	0.140	0.888	0.155	0.239
Femur	3	3.899	4.098	2.577	8.494	0.625	0.237
Brain	3	0.064	0.041	0.020	0.072	0.100	0.075
Muscle	3	0.696	0.761	0.077	1.545	0.465	0.162

[0296] The results demonstrate that ^{18}F labeled peptide used in conjunction with a PAM4 containing antibody construct, such as the TF10 DNL construct, provide suitable targeting of the ^{18}F label to perform *in vivo* imaging, such as PET imaging analysis.

Example 19. Further Imaging Studies with TF10

Summary

[0297] Preclinical and clinical studies have demonstrated the application of radiolabeled mAb-PAM4 for nuclear imaging and radioimmunotherapy of pancreatic carcinoma. We have examined herein the ability of the novel PAM4-based, bispecific monoclonal antibody (mAb) construct, TF10, to pretarget a radiolabeled peptide for improved imaging and therapy. TF10 is a humanized, bispecific mAb, divalent for mAb-PAM4 and monovalent for mAb-679, reactive against the histamine-succinyl-glycine hapten. Biodistribution studies and nuclear imaging of the radiolabeled TF10 and/or TF10-pretargeted hapten-peptide (IMP-288) were conducted in nude mice bearing CaPan1 human pancreatic cancer xenografts. ^{125}I-TF10 cleared rapidly from the blood, with levels decreasing to <1% injected dose per gram (ID/g) by 16 hours. Tumor uptake was 3.47 ± 0.66% ID/g at this time point with no accumulation in any normal tissue. To show the utility of the pretargeting approach, ^{111}In-IMP-288 was administered 16 hours after TF10. At 3 hours postadministration of radiolabeled peptide, imaging showed intense uptake within the tumors and no evidence of accretion in any normal tissue (Example 16). No targeting was observed in animals given only the ^{111}In-peptide (Example 16). Tumor uptake of the TF10-pretargeted ^{111}In-IMP-288 was 24.3 ± 1.7% ID/g, whereas for ^{111}In-IMP-288 alone it was only 0.12 ± 0.002% ID/g at 16 hours. Tumor/blood ratios were significantly greater for the pretargeting group (~1,000:1 at 3 hours) compared with ^{111}In-PAM4-IgG (~5:1 at 24 hours; $P < 0.0003$). Radiation dose estimates suggested that TF10/^{90}Y-peptide pretargeting would provide a greater antitumor effect than ^{90}Y-PAM4-IgG. Thus, the results support that TF10 pretargeting may provide improved imaging for early detection, diagnosis, and treatment of pancreatic cancer as compared with directly radiolabeled PAM4-IgG. (Gold et al., Cancer Res 2008, 68(12):4819–26)

[0298] We have identified a unique biomarker present on mucin expressed by >85% of invasive pancreatic adenocarcinomas, including early stage I disease and the precursor lesions, pancreatic intraepithelial neoplasia and intraductal papillary mucinous neoplasia (Gold et al., Clin Cancer Res 2007, 13:7380-87). The specific epitope, as detected by mAb-PAM4 (Gold et al., Int J Cancer 1994, 57:204-10), is absent from normal and inflamed pancreatic tissues, as well as most other malignant tissues. Thus, detection of the epitope provides a high diagnostic likelihood for the presence of pancreatic neoplasia.

Early clinical studies using ^{131}I- and ^{99m}Tc-labeled, murine PAM4 IgG or Fab', respectively, showed specific targeting in 8 of 10 patients with invasive pancreatic adenocarcinoma (Mariani et al., Cancer Res 1995, 55:5911s-15s; Gold et al., Crit Rev Oncol Hematol 2001, 39:147-54). Of the two negative patients, one had a poorly differentiated pancreatic carcinoma that did not express the PAM4-epitope, whereas the other patient was later found to have pancreatitis rather than a malignant lesion.

[0299] Accordingly, the high specificity of PAM4 for pancreatic cancer is of use for the detection and diagnosis of early disease. In addition to improved detection, ^{90}Y-PAM4 IgG was found to be effective in treating large human pancreatic cancer xenografts in nude mice (Cardillo et al., Clin Cancer Res 2001, 7:3186–92), and when combined with gemcitabine, further improvements in therapeutic response were observed (Gold et al., Clin Cancer Res 2004, 10:3552–61; Gold et al., Int J Cancer 2004, 109:618–26). A Phase I therapy trial in patients who failed gemcitabine treatment was recently completed, finding the maximum tolerated dose of ^{90}Y-humanized PAM4 IgG to be 20 mCi/m^2 (Gulec et al., Proc Amer Soc Clin Onc, 43rd Annual Meeting, J Clin Oncol 2007, 25(18S):636s). Although all patients showed disease progression at or after week 8, initial shrinkage of tumor was observed in several cases. Clinical studies are now underway to evaluate a fractionated dosing regimen of ^{90}Y-hPAM4 IgG in combination with a radiosensitizing dose of gemcitabine.

[0300] We report herein the development of a novel recombinant, humanized bispecific monoclonal antibody (mAb), TF10, based on the targeting specificity of PAM4 to pancreatic cancer. This construct also binds to the unique synthetic hapten, histamine-succinyl-glycine (HSG), which has been incorporated in a number of small peptides that can be radiolabeled with a wide range of radionuclides suitable for single-photon emission computed tomography (SPECT) and positron emission tomography (PET) imaging, as well as for therapeutic purposes (Karacay et al., Clin Cancer Res 2005, 11:7879–85; Sharkey et al., Leukemia 2005, 19:1064–9; Rossi et al., Proc Natl Acad Sci U S A 2006, 103:6841–6; McBride et al., J Nucl Med 2006, 47:1678–88). These studies illustrate the potential of this new construct to target pancreatic adenocarcinoma for imaging or therapeutic applications.

Methods and Materials

[0301] The TF2 and TF10 bispecific DNL constructs and the IMP 288 targeting peptide were prepared as described above. Sodium iodide (^{125}I) and indium chloride (^{111}In) were

obtained from PERKIN-ELMER®. TF10 was routinely labeled with ^{125}I by the iodogen method, with purification by use of size-exclusion spin columns. Radiolabeling of DOTA-peptide and DOTA-PAM4-IgG with $^{111}InCl$ was done as previously described (Rossi et al., Proc Natl Acad Sci U S A 2006, 103:6841–6; McBride et al., J Nucl Med 2006, 47:1678–88). Purity of the radiolabeled products was examined by size-exclusion high-performance liquid chromatography with the amount of free, unbound isotope determined by instant TLC.

[0302] For TF10 distribution studies, female athymic nude mice ~20 g (TACONIC® Farms), bearing s.c. CaPan1 human pancreatic cancer xenografts, were injected with ^{125}I-TF10 (10 μCi; 40 μg, 2.50×10^{-10} mol). At various time points, groups of mice ($n = 5$) were necropsied, with tumor and nontumor tissues removed and counted in a gamma counter to determine the percentage of injected dose per gram of tissue (%ID/g), with these values used to calculate blood clearance rates and tumor/nontumor ratios.

[0303] For pretargeting biodistribution studies, a bispecific mAb/radiolabeled peptide molar ratio of 10:1 was used. For example, a group of athymic nude mice bearing s.c. CaPan1 human pancreatic cancer xenografts was administered TF10 (80 μg, 5.07×10^{-10} mol), whereas a second group was left untreated. At 16 h postinjection of TF10, ^{111}In-IMP-288 hapten-peptide (30 μCi, 5.07×10^{-11} mol) was administered. Mice were necropsied at several time points, with tumor and nontumor tissues removed and counted in a gamma counter to determine the %ID/g. Tumor/nontumor ratios were calculated from these data. In a separate study, groups of mice were given ^{111}In-DOTA-PAM4-IgG (20 μC, 50 μg, 3.13×10^{-10} mol) for the purpose of comparing biodistribution, nuclear imaging, and potential therapeutic activity. Radiation dose estimates were calculated from the time-activity curves with the assumption of no activity at zero time. Student's *t* test was used to assess significant differences.

[0304] To perform nuclear immuoscintigraphy, at 3 h postinjection of radiolabeled peptide or 24 h postinjection of radiolabeled hPAM4-IgG, tumor-bearing mice were imaged with a dual-head Solus gamma camera fitted with medium energy collimator for ^{111}In (ADAC Laboratories). Mice were imaged for a total of 100,000 cpm or 10 min, whichever came first.

Results

[0305] *In vitro* characterization of the bispecific mAb TF10. The binding of TF10 to the target mucin antigen was analyzed by ELISA (**FIG. 9**). The results showed nearly identical

binding curves for the divalent TF10, PAM4-IgG, and PAM4-F(ab')$_2$ (half-maximal binding was calculated as 1.42 ± 0.10, 1.31 ± 0.12, and 1.83 ± 0.16 nmol/L, respectively; P > 0.05 for all), whereas the monovalent bsPAM4 chemical conjugate (PAM4-Fab' x anti-DTPA-Fab') had a significantly lower avidity (half-maximal binding, 30.61 ± 2.05 nmol/L; P = 0.0379, compared with TF10), suggesting that TF10 binds in a divalent manner. The immunoreactive fraction of ^{125}I-TF10 bound to the mucin was 87%, with 9% found as unbound TF10 and 3% as free iodide (not shown). Ninety percent of the ^{111}In-IMP-288 bound to TF10 (not shown). Of the total ^{111}In-IMP-288 bound to TF10, 92% eluted at higher molecular weight when excess mucin (200 μg) was added, with only 3% eluting with the non–mucin-reactive TF10 fraction. An additional 5% of the radiolabeled peptide eluted in the free peptide volume. None of the radiolabeled peptide bound to the mucin antigen in the absence of TF10 (not shown).

[0306] Biodistribution of ^{125}I-TF10 in CaPan1 tumor–bearing nude mice. TF10 showed a rapid clearance from the blood, starting with 21.03 ± 1.93 %ID/g at 1 hour and decreasing to just 0.13 ± 0.02 %ID/g at 16 hours. The biological half-life was calculated to be 2.19 hours [95% confidence interval (95% CI), 2.11–2.27 hours]. Tissue uptake revealed enhanced activity in the liver, spleen, and kidneys at 1 hour, which cleared just as quickly by 16 hours [$T_{1/2}$ = 2.09 hours (95% CI, 2.08–2.10), 2.84 hours (95% CI, 2.49–3.29), and 2.44 hours (95% CI, 2.28–2.63) for liver, spleen, and kidney, respectively]. Activity in the stomach most likely reflects the accretion and excretion of radioiodine, suggesting that the radioiodinated TF10 was actively catabolized, presumably in the liver and spleen, thereby explaining its rapid clearance from the blood. Nevertheless, by 16 hours, the concentration of radioiodine within the stomach was below 1% ID/g. A group of five non–tumor-bearing nude mice given ^{125}I-TF10 and necropsied at 16 hours showed similar tissue distribution, suggesting that the tumor had not affected the bispecific mAb distribution and clearance from normal tissues (data not shown). Of course, it is possible that differences occurred before the initial time point examined. Tumor uptake of TF10 peaked at 6 hours postinjection (7.16 ± 1.10 %ID/g) and had decreased to half maximum binding (3.47 ± 0.66 %ID/g) at 16 hours. Tumor uptake again decreased nearly 2-fold over the next 32 hours, but then was stable over the following 24 hours.

[0307] Biodistribution of TF10-pretargeted, ^{111}In-labeled peptide. Although maximum tumor uptake of TF10 occurred at 6 hours, previous experience indicated that the radiolabeled peptide would need to be given at a time point when blood levels of TF10 had

cleared to <1% ID/g (i.e., 16 hours). Higher levels of TF10 in the blood would lead to unacceptably high binding of the radiolabeled peptide within the blood (i.e., low tumor/blood ratios), whereas administering the peptide at a later time would mean the concentration of TF10 in the tumor would be decreased with consequently reduced concentration of radiolabeled peptide within the tumor. Thus, an initial pretargeting study was done using a 16-hour interval. With the amount of the ^{111}In-IMP-288 held constant (30 μCi, 5.07 x 10^{-11} mol), increasing amounts of TF10 were given so that the administered dose of TF10 and IMP-288 expressed as mole ratio varied from 5:1 to 20:1 (**Table 10**).

Table 10. Biodistribution of ^{111}In-IMP-288 alone (no TF10) or pretargeted with varying amounts of TF10

	%ID/g at 3 h (mean ± SD)			
	5:1	10:1	20:1	No TF10
Tumor	19.0 ± 3.49	24.3 ± 1.71	28.6 ± 0.73	0.12 ± 0.00
Liver	0.09 ± 0.01	0.21 ± 0.12	0.17 ± 0.01	0.07 ± 0.00
Spleen	0.12 ± 0.04	0.16 ± 0.07	0.26 ± 0.10	0.04 ± 0.01
Kidneys	1.59 ± 0.11	1.72 ± 0.24	1.53 ± 0.14	1.71 ± 0.22
Lungs	0.19 ± 0.06	0.26 ± 0.00	0.29 ± 0.04	0.03 ± 0.00
Blood	0.01 ± 0.00	0.01 ± 0.01	0.01 ± 0.00	0.00 ± 0.00
Stomach	0.03 ± 0.02	0.02 ± 0.02	0.01 ± 0.00	0.02 ± 0.01
Small intestine	0.12 ± 0.08	0.08 ± 0.03	0.04 ± 0.01	0.06 ± 0.02
Large intestine	0.23 ± 0.10	0.39 ± 0.08	0.25 ± 0.08	0.33 ± 0.02
Pancreas	0.02 ± 0.00	0.02 ± 0.01	0.02 ± 0.00	0.02 ± 0.00
Tumor weight (g)	0.12 ± 0.03	0.32 ± 0.09	0.27 ± 0.01	0.35 ± 0.03

[0308] At 3 hours the amount of ^{111}In-IMP-288 in the blood was barely detectable (0.01%). Tumor uptake increased from 19.0 ± 3.49% ID/g to 28.55 ± 0.73% ID/g as the amount of bispecific mAb administered was increased 4-fold (statistically significant

differences were observed for comparison of each TF10/peptide ratio, one group to another; $P < 0.03$ or better), but without any appreciable increase in normal tissue uptake. Tumor uptake in the animals given TF10 was >100-fold higher than when ^{111}In-IMP-288 was given alone. Comparison of ^{111}In activity in the normal tissues of the animals that either received or did not receive prior administration of TF10 indicated similar absolute values, which in most instances were not significantly different. This suggests that the bispecific mAb had cleared sufficiently from all normal tissues by 16 hours to avoid appreciable peptide uptake in these tissues. Tumor/blood ratios were >2,000:1, with other tissue ratios exceeding 100:1. Even tumor/kidney ratios exceeded 10:1. The highest tumor uptake of radioisotope with minimal targeting to nontumor tissues resulted from the 20:1 ratio; however, either of the TF10/peptide ratios could be used to achieve exceptional targeting to tumor, both in terms of signal intensity and contrast ratios. The 10:1 ratio was chosen for further study because the absolute difference in tumor uptake of radiolabeled peptide was not substantially different between the 10:1 (24.3 ± 1.71% ID/g) and 20:1 (28.6 ± 0.73% ID/g) ratios.

[0309] Images of the animals given TF10-pretargeted ^{111}In-IMP-288 at a bispecific mAb/peptide ratio of 10:1, or the ^{111}In-IMP-288 peptide alone, are shown in **FIG. 10**. The majority of these tumors were ≤0.5 cm in diameter, weighing ~0.25 g. The images show highly intense uptake in the tumor of the TF10-pretargeted animals (**FIG. 10A**). The intensity of the image background for the TF10-pretargeted animals was increased to match the intensity of the image taken of the animals given the ^{111}In-IMP-288 alone (**FIG. 10B**). However, when the images were optimized for the TF10-pretargeted mice, the signal intensity and contrast were so high that no additional activity was observed in the body. No tumor localization was seen in the animals given the ^{111}In-IMP-288 alone, even when image intensity was enhanced (**FIG. 10C**).

[0310] An additional experiment was done to assess the kinetics of targeting ^{111}In-hPAM4 whole-IgG compared with that of the TF10-pretargeted ^{111}In-IMP-288 peptide. Tumor uptake of the ^{111}In-peptide was highest at the initial time point examined, 3 hours (15.99 ± 4.11% ID/g), whereas the blood concentration of radiolabeled peptide was only 0.02 ± 0.01% ID/g, providing a mean tumor/blood ratio of 946.3 ± 383.0. Over time, radiolabeled peptide cleared from the tumor with a biological half-life of 76.04 hours. Among nontumor tissues, uptake was highest in the kidneys, averaging 1.89 ± 0.42% ID/g at 3 hours with a steady decrease over time (biological half-life, 33.6 hours). Liver uptake

started at 0.15 ± 0.06% ID/g and remained essentially unchanged over time. In contrast to the TF10-pretargeted ^{111}In-IMP-288, the ^{111}In-hPAM4-IgG had a slower clearance from the blood, albeit there was a substantial clearance within the first 24 hours, decreasing from 30.1% ID/g at 3 hours to just 11.5 ± 1.7% ID/g at 24 hours. Variable elevated uptake in the spleen suggested that the antibody was likely being removed from the blood by targeting of secreted mucin that had become entrapped within the spleen. Tumor uptake peaked at 48 hours with 80.4 ± 6.1% ID/g, and remained at an elevated level over the duration of the monitoring period. The high tumor uptake, paired with a more rapid than expected blood clearance for an IgG, produced tumor/blood ratios of 5.2 ± 1.0 within 24 hours. **FIG. 10C** shows the images of the animals at 24 hours postadministration of ^{111}In-PAM4-IgG, illustrating that tumors could be visualized at this early time, but there was still considerable activity within the abdomen. Tumor/nontumor ratios were mostly higher for TF10-pretargeted ^{111}In-labeled hapten-peptide as compared with ^{111}In-hPAM4-IgG, except for the kidneys, where tumor/kidney ratios with the ^{111}In-IMP-288 and ^{111}In-hPAM4-IgG were similar at later times. However, tumor/kidney ratios for the TF10-pretargeted ^{111}In-IMP-288 were high enough (e.g., ~7:1) at 3 hours to easily discern tumor from normal tissue.

[0311] FIG. 11 illustrates the potential therapeutic capability of the direct and pretargeted methods to deliver radionuclide (^{90}Y). Although the concentration (%ID/g) of radioisotope within the tumor seems to be much greater when delivered by PAM4-IgG than by pretargeted TF10 at their respective maximum tolerated dose (0.15 mCi for ^{90}Y-hPAM4 and 0.9 mCi for TF10-pretargeted ^{90}Y-IMP-288), the radiation dose to tumor would be similar (10,080 and 9,229 cGy for ^{90}Y-PAM4-IgG and TF10-pretargeted ^{90}Y-IMP-288, respectively). The advantage for the pretargeting method would be the exceptionally low activity in blood (9 cGy), almost 200-fold less than with the ^{90}Y-hPAM4 IgG (1,623 cGy). It is also important to note that the radiation dose to liver, as well as other nontumor organs, would be much lower with the TF10-pretargeted ^{90}Y-IMP-288. The exception would be the kidneys, where the radiation dose would be similar for both protocols at their respective maximum dose (612 and 784 cGy for ^{90}Y-PAM4-IgG and TF10-^{90}Y-IMP-288, respectively). The data suggest that for ^{90}Y-PAM4-IgG, as with most other radiolabeled whole-IgG mAbs, the dose-limiting toxicity would be hematologic; however, for the TF10 pretargeting protocol, the dose-limiting toxicity would be the kidneys.

Discussion

[0312] Current diagnostic modalities such as ultrasound, computerized tomography (CT), and magnetic resonance imaging (MRI) technologies, which provide anatomic images, along with PET imaging of the metabolic environment, have routinely been found to provide high sensitivity in the detection of pancreatic masses. However, these data are, for the most part, based on detection of lesions >2 cm in a population that is already presenting clinical symptoms. At this time in the progression of the pancreatic carcinoma, the prognosis is rather dismal. To improve patient outcomes, detection of small, early pancreatic neoplasms in the asymptomatic patient is necessary.

[0313] Imaging with a mAb-targeted approach, such as is described herein with mAb-PAM4, may provide for the diagnosis of these small, early cancers. Of prime importance is the specificity of the mAb. We have presented considerable data, including immunohistochemical studies of tissue specimens (Gold et al., Clin Cancer Res 2007;13:7380–7; Gold et al., Int J Cancer 1994;57:204–10) and immunoassay of patient sera (Gold et al., J Clin Oncol 2006;24:252–8), to show that mAb-PAM4 is highly reactive with a biomarker, the presence of which provides high diagnostic likelihood of pancreatic neoplasia. Furthermore, we determined that PAM4, although not reactive with normal adult pancreatic tissues nor active pancreatitis, is reactive with the earliest stages of neoplastic progression within the pancreas (pancreatic intraepithelial neoplasia 1 and intraductal papillary mucinous neoplasia) and that the biomarker remains at high levels of expression throughout the progression to invasive pancreatic adenocarcinoma (Gold et al., Clin Cancer Res 2007;13:7380–7). Preclinical studies with athymic nude mice bearing human pancreatic tumor xenografts have shown specific targeting of radiolabeled murine, chimeric, and humanized versions of PAM4.

[0314] In the current studies, we have examined a next-generation, recombinant, bispecific PAM4-based construct, TF10, which is divalent for the PAM4 arm and monovalent for the anti-HSG hapten arm. There are several important characteristics of this pretargeting system's constructs, named dock-and-lock, including its general applicability and ease of synthesis. However, for the present consideration, the major differences from the previously reported chemical construct are the valency, which provides improved binding to tumor antigen, and, importantly, its pharmacokinetics. TF10 clearance from nontumor tissues is much more rapid than was observed for the chemical conjugate. Time for blood levels of the bispecific constructs to reach less than 1% ID/g was 40 hours postinjection for the chemical construct versus 16 hours for TF10. A more rapid clearance of the

pretargeting agent has provided a vast improvement of the tumor/blood ratio, while maintaining high signal strength at the tumor site (%ID/g).

[0315] In addition to providing a means for early detection and diagnosis, the results support the use of the TF10 pretargeting system for cancer therapy. Consideration of the effective radiation dose to tumor and nontumor tissues favors the pretargeting method over directly radiolabeled PAM4-IgG. The dose estimates suggest that the two delivery systems have different dose-limiting toxicities: myelotoxicity for the directly radiolabeled PAM4 versus the kidney for the TF10 pretargeting system. This is of significance for the future clinical development of radiolabeled PAM4 as a therapeutic agent. Gemcitabine, the frontline drug of choice for pancreatic cancer, can provide significant radiosensitization of tumor cells. In previous studies, we showed that combinations of gemcitabine and directly radiolabeled PAM4-IgG provided synergistic antitumor effects compared with either arm alone (Gold et al., Clin Cancer Res 2004, 10:3552–61; Gold et al., Int J Cancer 2004, 109:618–26). The dose-limiting factor with this combination was overlapping hematologic toxicity. However, because the dose-limiting organ for TF10 pretargeting seems to be the kidney rather than hematologic tissues, combinations with gemcitabine should be less toxic, thus allowing increased administration of radioisotope with consequently greater antitumor efficacy.

[0316] The superior imaging achieved with TF10 pretargeting in preclinical models, as compared with directly radiolabeled DOTA-PAM4-IgG, provides a compelling rationale to proceed to clinical trials with this imaging system. The specificity of the tumor-targeting mAb for pancreatic neoplasms, coupled with the bispecific antibody platform technology providing the ability to conjugate various imaging compounds to the HSG-hapten-peptide for SPECT (^{111}In), PET (^{68}Ga), ultrasound (Au), or other contrast agents, or for that matter ^{90}Y or other radionuclides for therapy, provides high potential to improve overall patient outcomes (Goldenberg et al., J Nucl Med 2008, 49:158–63). In particular, we believe that a TF10-based ImmunoPET procedure will have major clinical value to screen individuals at high-risk for development of pancreatic cancer (e.g., genetic predisposition, chronic pancreatitis, smokers, etc.), as well as a means for follow-up of patients with suspicious abdominal images from conventional technologies and/or with indications due to the presence of specific biomarker(s) or abnormal biochemical findings. When used as part of an ongoing medical plan for following these patients, early detection of pancreatic cancer may be achieved. Finally, in combination with gemcitabine, TF10 pretargeting may

provide a better opportunity for control of tumor growth than directly radiolabeled PAM4-IgG.

Example 20. Therapy of Pancreatic Cancer Xenografts with Gemcitabine and ^{90}Y-Labeled Peptide Pretargeted Using TF10

Summary

[0317] ^{90}Y-hPAM4 IgG is currently being examined in Phase I/II trials in combination with gemcitabine in patients with Stage III/IV pancreatic cancer. We disclose a new approach for pretargeting radionuclides that is able to deliver a similar amount of radioactivity to pancreatic cancer xenografts, but with less hematological toxicity, which would be more amenable for combination with gemcitabine. Nude mice bearing ~0.4 cm^3 sc CaPan1 human pancreatic cancer were administered a recombinant bsMAb, TF10, followed 1 day later with a ^{90}Y-labeled hapten-peptide (IMP-288). Various doses and schedules of gemcitabine were added to this treatment, and tumor progression monitored up to 28 weeks. 0.7 mCi PT-RAIT alone produce only a transient 60% loss in blood counts, and animals given 0.9 mCi of PT-RAIT alone and 0.7 mCi PT-RAIT + 6 mg gemcitabine (human equivalent ~1000 mg/m^2) had no histological evidence of renal toxicity after 9 months. A single dose of 0.25 or 0.5 mCi PT-RAIT alone can completely ablate 20% and 80% of the tumors, respectively. Monthly fractionated PT-RAIT (0.25 mCi/dose given at the start of each gemcitabine cycle) added to a standard gemcitabine regimen (6 mg wkly x 3; 1 wk off; repeat 3 times) significantly increased the median time for tumors to reach 3.0 cm^3 over PT-RAIT alone. Other treatment plans examining non-cytotoxic radiosensitizing dose regimens of gemcitabine added to PT-RAIT also showed significant improvements in treatment response over PT-RAIT alone. The results show that PT-RAIT is a promising new approach for treating pancreatic cancer. Current data indicate combining PT-RAIT with gemcitabine will enhance therapeutic responses.

Methods

[0318] TF10 bispecific antibody was prepared as described above. For pretargeting, TF10 was given to nude mice bearing the human pancreatic adenocarcinoma cell line, CaPan1. After allowing sufficient time for TF10 to clear from the blood (16h), the radiolabeled divalent HSG-peptide was administered. The small molecular weight HSG-peptide (~1.4 kD) clears within minutes from the blood, entering the extravascular space where it can bind to anti-HSG arm of the pretargeted TF10 bsMAb. Within a few hours, >80% of the

radiolabeled HSG-peptide is excreted in the urine, leaving the tumor localized peptide and a trace amount in the normal tissues.

Results

[0319] FIG. 12 illustrates the therapeutic activity derived from a single treatment of established (~0.4 cm^3) CaPan1 tumors with 0.15 mCi of ^{90}Y-hPAM4 IgG, or 0.25 or 0.50 mCi of TF10-pretargeted ^{90}Y-IMP-288. Similar anti-tumor activity was observed for the 0.5-mCi pretargeted dose vs. 0.15-mCi dose of the directly radiolabeled IgG, but hematological toxicity was severe at this level of the direct conjugate (not shown), while the pretargeted dose was only moderately toxic (not shown). Indeed, the MTD for pretargeting using 90Y-IMP-288 is at least 0.9 mCi in nude mice.

[0320] FIG. 13 shows that the combination of gemcitabine and PT-RAIT has a synergistic effect on anti-tumor therapy. Human equivalent doses of 1000 mg/m^2 (6 mg) of gemcitabine (GEM) were given intraperitoneally to mice weekly for 3 weeks, then after resting for 1 week, this regimen was repeated 2 twice. PT-RAIT (0.25 mCi of TF10-pretargeted ^{90}Y-IMP-288) was given 1 day after the first GEM dose in each of the 3 cycles of treatment. Gem alone had no significant impact on tumor progression (survival based on time to progress to 3.0 cm^3). PT-RAIT alone improved survival compared to untreated animals, but the combined GEM with PT-RAIT regimen increased the median survival by nearly 10 weeks. Because hematological toxicity is NOT dose-limiting for PT-RAIT, but it is one of the limitations for gemcitabine therapy, these studies suggest that PT-RAIT could be added to a standard GEM therapy with the potential for enhanced responses. The significant synergistic effect of gemcitabine plus PT-RAIT was surprising and unexpected.

[0321] A further study examined the effect of the timing of administration on the potentiation of anti-tumor effect of gemcitabine plus PT-RAIT. A single 6-mg dose of GEM was given one day before or 1 day after 0.25 mCi of TF10-pretargeted ^{90}Y-IMP-288 (not shown). This study confirmed what is already well known with GEM, i.e., radiosensitization is best given in advance of the radiation. Percent survival of treated mice showed little difference in survival time between PT-RAIT alone and PT-RAIT with gemcitabine given 22 hours after the radiolabeled peptide. However, administration of gemcitabine 19 hours prior to PT-RAIT resulted in a substantial increase in survival (not shown).

[0322] Single PT-RAIT (0.25 mCi) combined with cetuximab (1 mg weekly ip; 7 weeks) or with cetuximab + GEM (6 mg weekly x 3) in animals bearing CaPan1 showed the

GEM + cetuximab combination with PT-RAIT providing a better initial response (**FIG. 14**), but the response associated with just cetuximab alone added to PT-RAIT was encouraging (**FIG. 14**), since it was as good or better than PT-RAIT + GEM. Because the overall survival in this study was excellent, with only 2 tumors in each group progressing to >2.0 cm3 after 24 weeks when the study was terminated, these results indicate a potential role for cetuximab when added to PT-RAIT.

Example 21. Effect of Fractionated Pretargeted Radioimmunotherapy (PT-RAIT) for Pancreatic Cancer Therapy

[0323] We evaluated fractionated therapy with ^{90}Y-DOTA-di-HSG peptide (IMP-288) and TF10. Studies using TF10 and radiolabeled IMP-288 were performed in nude mice bearing s.c. CaPan1 human pancreatic cancer xenografts, 0.32-0.54cm^3. For therapy, TF10-pretargeted ^{90}Y-IMP-288 was given [A] once (0.6mCi on wk 0) or [B] fractionated (0.3 mCi on wks 0 and 1), [C] (0.2 mCi on wks 0, 1 and 2) or [D] (0.2 mCi on wks 0, 1 and 4).

[0324] Tumor regression (>90%) was observed in the majority of mice, 9/10, 10/10, 9/10 and 8/10 in groups [A], [B], [C] and [D], respectively. In group [A], maximum tumor regression in 50 % of the mice was reached at 3.7 wks, compared to 6.1, 8.1 and 7.1 wks in [B], [C] and [D], respectively. Some tumors showed regrowth. At week 14, the best therapeutic response was observed in the fractionated group (2x0.3 mCi), with 6/10 mice having no tumors (NT) compared to 3/10 in the 3x0.2 mCi groups and 1/10 in the 1x 0.6mCi group. No major body weight loss was observed. Fractionated PT-RAIT provides another alternative for treating pancreatic cancer with minimum toxicity.

Example 22. ^{90}Y-hPAM4 Radioimmunotherapy (RAIT) Plus Radiosensitizing Gemcitabine (GEM) Treatment in Advanced Pancreatic Cancer (PC)

[0325] ^{90}Y-hPAM4, a humanized antibody highly specific for PC, showed transient activity in patients with advanced disease, and GEM enhanced RAIT in preclinical studies. This study evaluated repeated treatment cycles of ^{90}Y-hPAM4 plus GEM in patients with untreated, unresectable PC. The ^{90}Y-dose was escalated by cohort, with patients repeating 4-wk cycles (once weekly 200 mg/m^2 GEM, ^{90}Y-hPAM4 once-weekly wks 2-4) until progression or unacceptable toxicity. Response assessments used CT, FDG-PET, and CA19.9 serum levels.

[0326] Of 8 patients (3F/5M, 56-72 y.o.) at the 1st 2 dose levels (6.5 and 9.0 mCi/m^2 ^{90}Y-hPAM4 x 3), hematologic toxicity has been transient Grade 1-2. Two patients responded to initial treatment with FDG SUV and CA19.9 decreases, and lesion regression by CT. Both patients continue in good performance status now after 9 and 11 mo. and after a total of 3 and 4 cycles, respectively, without additional toxicity. A 3rd patient with a stable response by PET and CT and decreases in CA19.9 levels after initial treatment is now undergoing a 2nd cycle. Four other patients had early disease progression and the remaining patient is still being evaluated. Dose escalation is continuing after fractionated RAIT with ^{90}Y-hPAM4 plus low-dose gemcitabine demonstrated therapeutic activity at the initial ^{90}Y-dose levels, with minimal hematologic toxicity, even after 4 therapy cycles.

Example 23. Early Detection of Pancreatic Carcinoma Using Mab-PAM4 and *In Vitro* Immunoassay

[0327] Immunohistochemistry studies were performed with PAM4 antibody. Results obtained with stained tissue sections showed no reaction of PAM4 with normal pancreatic ducts, ductules and acinar tissues (not shown). In contrast, use of the MA5 antibody applied to the same tissue samples showed diffuse positive staining of normal pancreatic ducts and acinar tissue (not shown). In tissue sections with well differentiated or moderately differentiated pancreatic adenocarcinoma, PAM4 staining was positive, with mostly cytoplasmic staining but intensification of at the cell surface. Normal pancreatic tissue in the same tissue sections was unstained.

[0328] **Table 11** shows the results of immunohistochemical analysis with PAM4 MAb in pancreatic adenocarcinoma samples of various stages of differentiation. Overall, there

was an 87% detection rate for all pancreatic cancer samples, with 100% detection of well differentiated and almost 90% detection of moderately differentiated pancreatic cancers.

Table 11 **PAM4 Labeling Pattern**

Cancer	n	Focal	Diffuse	Total
Well Diff.	13	2	11	13 (100%)
Moderately Diff.	24	6	15	21 (88%)
Poorly Diff.	18	5	9	14 (78%)
Total	55	13	35	48 (87%)

[0329] Table 12 shows that PAM4 immunohistochemical staining also detected a very high percentage of precursor lesions of pancreatic cancer, including PanIn-1A to PanIN-3, IPMN (intraductal papillary mucinous neoplasms) and MCN (mucinous cystic neoplasms). Overall, PAM4 staining detected 89% of all pancreatic precursor lesions. These results demonstrate that PAM4 antibody-based immunodetection is capable of detecting almost 90% of pancreatic cancers and precursor lesions by *in vitro* analysis. PAM4 expression was observed in the earliest phases of PanIN development. Intense staining was observed in IPMN and MCN samples (not shown). The PAM4 epitope was present at high concentrations (intense diffuse stain) in the great majority of pancreatic adenocarcinomas. PAM4 showed diffuse, intense ractivity with the earliest stages of pancreatic carcinoma precursor lesions, including PanIN-1, IPMN and MCN, yet was non-reactive with normal pancreatic tissue. Taken together, these results show that diagnosis and/or detection with the PAM4 antibody is capable of detecting, with very high specificity, the earliest stages of pancreatic cancer development.

Table 12 **PAM4 Labeling Pattern**

	n	Focal	Diffuse	Total
PanIn-1A	27	9	15	24 (89%)
PanIn-1B	20	4	16	20 (100%)
PanIn-2	11	6	4	10 (91%)
PanIn-3	5	2	0	2 (40%)
Total PanIn	63	21	35	56 (89%)

IPMN	36	6	25	31 (86%)
MCN	27	3	22	25 (92%)

[0330] An enzyme based immunoassay for PAM4 antigen in serum samples was developed. **FIG. 15** shows the results of differential diagnosis using PAM4 immunoassay for pancreatic cancer *versus* normal tissues and other types of cancer. The results showed a sensitivity of detection of pancreatic cancer of 77.4%, with a specificity of detection of 94.3%, comparing pancreatic carcinoma (n=53) with all other specimens (n=233), including pancreatitis and breast, ovarian and colorectal cancer and lymphoma. The data of **FIG. 15** are presented in tabular form in **Table 13.**

Table 13. PAM4-Reactive Mucin in Patient Sera

	n	Mean	SD	Median	Range	# Positive (%)
Normal	**43**	**0.1**	**0.3**	**0.0**	**0-2.0**	**0 (0)**
Pancreatitis	**87**	**3.0**	**11.5**	**0.0**	**0-63.6**	**4 (5)**
Pancreatic CA	**53**	**171**	**317**	**31.7**	**0-1000**	**41 (77)**
Colorectal CA	**36**	**3.3**	**7.7**	**0.0**	**0-37.8**	**5 (14)**
Breast CA	**30**	**3.7**	**10.1**	**0.0**	**0-53.5**	**2 (7)**
Ovarian CA	**15**	**1.8**	**4.3**	**0.0**	**0-16.5**	**1 (7)**
Lymphoma	**19**	**12.3**	**44.2**	**0.0**	**0-194**	**1 (5)**

[0331] An ROC curve (not shown) was constructed with the data from **Table 13**. Examining a total of 283 patients, including 53 with pancreatic carcinoma, and comparing the presence of circulating PAM4 antigen in patients with pancreatic cancer to all other samples, the ROC curve provided an AUC of 0.88 ± 0.03 (95% ci, 0.84-0.92) with a *P* value <0.0001, a highly significant difference for discrimination of pancreatic carcinoma from non-pancreatic carcinoma samples. Comparing pancreatic CA with other tumors and normal tissue, the PAM4 based serum assay showed a sensitivity of 77% and a specificity of 95%.

[0332] A comparison was made of PAM4 antigen concentration in serum samples from normal patients, "early" (stage 1) pancreatic carcinoma and all pancreatic carcinoma samples. The specimens included 13 sera from healthy volunteers, 12 sera from stage-1,

13 sera from stage-2 and 25 sera from stage-3/4 (advanced) pancreatic carcinoma. A cutoff value of 8.8 units/ml (red line) was used, as determined by ROC curve statistical analysis. The frequency distribution of PAM4 antigen concentration is shown in **FIG. 16**, which shows that 92% of "early" stage-1 pancreatic carcinomas were above the cutoff line for diagnosis of pancreatic cancer. An ROC curve for the PAM4 based assay is shown in **FIG. 17**, which demonstrates a sensitivity of 81.6% and specificity of 84.6% for the PAM4 assay in detection of pancreatic cancer.

[0333] These results confirm that an enzyme immunoassay based on PAM4 antibody binding can detect and quantitate PAM4-reactive antigen in the serum of pancreatic carcinoma patients. The immunoassay demonstrates high specificity and sensitivity for pancreatic carcinoma. The majority of patients with stage 1 disease were detectable using the PAM4 immunoassay.

[0334] In conclusion, an immunohistology procedure employing PAM4 antibody identified approximately 90% of invasive pancreatic carcinoma and its precursor lesions, PanIN, IPMN and MCN. A PAM4 based enzyme immunoassy to quantitate PAM4 antigen in human patient sera showed high sensitivity and specificity for detection of early pancreatic carcinoma. Due to the high specificity of PAM4 for pancreatic carcinoma, the mucin biomarker can also serve as a target for *in vivo* targeting of imaging and therapeutic agents. ImmunoPET imaging for detection of "early" pancreatic carcinoma is of use for the early diagnosis of pancreatic cancer, when it can be more effectively treated. Use of radioimmunotherapy with a humanized PAM4 antibody construct, preferably in combination with a radiosensitizing agent, is of use for the treatment of pancreatic cancer.

Example 24. PEGylated DNL Constructs

[0335] In certain embodiments, it may be preferred to prepare constructs comprising PEGylated forms of antibody or immunoconjugate. Such PEGylated constructs may be prepared by the DNL technique.

[0336] In a preferred method, the effector moiety to be PEGylated, such as hPAM4 Fab, is linked to a DDD sequence to generate the DDD module. A PEG reagent of a desirable molecular size is derivatized with a complementary AD sequence and the resulting PEG-AD module is combined with the DDD module to produce the PEGylated conjugate that consists of a single PEG tethered site-specifically to two copies of the Fab or other effector moiety via the disulfide bonds formed between DDD and AD. The PEG reagents may be

capped at one end with a methoxy group (m-PEG), can be linear or branched, and may contain one of the following functional groups: propionic aldehyde, butyric aldehyde, ortho-pyridylthioester (OPTE), N-hydroxysuccinimide (NHS), thiazolidine-2-thione, succinimidyl carbonate (SC), maleimide, or ortho-pyridyldisulfide (OPPS). Among the effector moieties that may be of interest for PEGylation are enzymes, cytokines, chemokines, growth factors, peptides, aptamers, hemoglobins, antibodies and antibody fragments. The method is not limiting and a wide variety of agents may be PEGylated using the disclosed methods and compositions. PEG of various sizes and derivatized with a variety of reactive moieties may be obtained from commercial sources as discussed in more detail below.

Generation of PEG-AD2 modules

IMP350: CGQIEYLAKQIVDNAIQQAGC(SS-tbu)-NH_2 (SEQ ID NO:41)

[0337] IMP350, incorporating the sequence of AD2, was made on a 0.1 mmol scale with Sieber Amide resin using Fmoc methodology on a peptide synthesizer. Starting from the C-terminus the protected amino acids used were Fmoc-Cys(t-Buthio)-OH, Fmoc-Gly-OH, Fmoc-Ala-OH, Fmoc-Gln(Trt)-OH, Fmoc-Gln(Trt)-OH, Fmoc-Ile-OH, Fmoc-Ala-OH, Fmoc-Asn(Trt)-OH, Fmoc-Asp(OBut)-OH, Fmoc-Val-OH, Fmoc-Ile-OH, Fmoc-Gln(Trt)-OH, Fmoc-Lys(Boc)-OH, Fmoc-Ala-OH, Fmoc-Leu-OH, Fmoc-Tyr(But)-OH, Fmoc-Glu(OBut)-OH, Fmoc-Ile-OH, Fmoc-Gln(Trt)-OH, Fmoc-Gly-OH and Fmoc-Cys(Trt)-OH. The peptide was cleaved from the resin and purified by reverse phase (RP)-HPLC.

Synthesis of PEG_{20}-IMP350

[0338] IMP350 (0.0104 g) was mixed with 0.1022 g of mPEG-OPTE (20kDa, NEKTAR® Therapeutics) in 7 mL of 1 M Tris buffer at pH 7.81. Acetonitrile, 1 mL, was then added to dissolve some suspended material. The reaction was stirred at room temperature for 3 h and then 0.0527 g of TCEP was added along with 0.0549 g of cysteine. The reaction mixture was stirred for 1.5 h and then purified on a PD-10 desalting column, which was equilibrated with 20% methanol in water. The sample was eluted, frozen and lyophilized to obtain 0.0924 g of crude PEG_{20}-IMP350 (MH+ 23508 by MALDI).

Synthesis of IMP362 (PEG_{20}-IMP360)

IMP360: CGQIEYLAKQIVDNAIQQAGC(SS-tbu)G-EDANS (SEQ ID NO:42)
MH^+ 2660

[0339] IMP 360, incorporating the AD2 sequence, was synthesized on a 0.1 mmol scale with Fmoc-Gly-EDANS resin using Fmoc methodology on a peptide synthesizer. The Fmoc-Gly-OH was added to the resin manually using 0.23 g of Fmoc-Gly-OH, 0.29 g of HATU, 26 μL of DIEA, 7.5 mL of DMF and 0.57 g of EDANS resin (NOVABIOCHEM®). The reagents were mixed and added to the resin. The reaction was mixed at room temperature for 2.5 hr and the resin was washed with DMF and IPA to remove the excess reagents. Starting from the C-terminus the protected amino acids used were Fmoc-Cys(t-Buthio)-OH, Fmoc-Gly-OH, Fmoc-Ala-OH, Fmoc-Gln(Trt)-OH, Fmoc-Gln(Trt)-OH, Fmoc-Ile-OH, Fmoc-Ala-OH, Fmoc-Asn(Trt)-OH, Fmoc-Asp(OBut)-OH, Fmoc-Val-OH, Fmoc-Ile-OH, Fmoc-Gln(Trt)-OH, Fmoc-Lys(Boc)-OH, Fmoc-Ala-OH, Fmoc-Leu-OH, Fmoc-Tyr(But)-OH, Fmoc-Glu(OBut)-OH, Fmoc-Ile-OH, Fmoc-Gln(Trt)-OH, Fmoc-Gly-OH and Fmoc-Cys(Trt)-OH. The peptide was cleaved from the resin and purified by RP-HPLC.

[0340] For synthesis of IMP362, IMP360 (0.0115 g) was mixed with 0.1272 g of mPEG-OPTE (20kDa, NEKTAR® Therapeutics) in 7 mL of 1 M tris buffer, pH 7.81. Acetonitrile (1 mL) was then added to dissolve some suspended material. The reaction was stirred at room temperature for 4 h and then 0.0410 g of TCEP was added along with 0.0431 g of cysteine. The reaction mixture was stirred for 1 h and purified on a PD-10 desalting column, which was equilibrated with 20% methanol in water. The sample was eluted, frozen and lyophilized to obtain 0.1471 g of crude IMP362 (MH+ 23713).

Synthesis of IMP413 (PEG_{30}-IMP360)

[0341] For synthesis of IMP 413, IMP 360 (0.0103 g) was mixed with 0.1601 g of mPEG-OPTE (30kDa, NEKTAR® Therapeutics) in 7 mL of 1 M tris buffer at pH 7.81. Acetonitrile (1 mL) was then added to dissolve some suspended material. The reaction was stirred at room temperature for 4.5 h and then 0.0423 g of TCEP was added along with 0.0473 g of cysteine. The reaction mixture was stirred for 2 h followed by dialysis for two days. The dialyzed material was frozen and lyophilized to obtain 0.1552 g of crude IMP413 (MH^+ 34499).

Synthesis of IMP421

IMP 421 Ac-C-PEG_3-C(S-*t*Bu)GQIEYLAKQIVDNAIQQAGC(S-*t*Bu)G-NH_2 (SEQ ID NO:43)

[0342] The peptide IMP421, MH^+ 2891 was made on NOVASYN® TGR resin (487.6 mg, 0.112 mmol) by adding the following amino acids to the resin in the order shown: Fmoc-Gly-OH, Fmoc-Cys(t-Buthio)-OH, Fmoc-Gly-OH, Fmoc-Ala-OH, Fmoc-Gln(Trt)-OH, Fmoc-Gln(Trt)-OH, Fmoc-Ile-OH, Fmoc-Ala-OH, Fmoc-Asn(Trt)-OH, Fmoc-Asp(OBut)-OH, Fmoc-Val-OH, Fmoc-Ile-OH, Fmoc-Gln(Trt)-OH, Fmoc-Lys(Boc)-OH, Fmoc-Ala-OH, Fmoc-Leu-OH, Fmoc-Tyr(But)-OH, Fmoc-Glu(OBut)-OH, Fmoc-Ile-OH, Fmoc-Gln(Trt)-OH, Fmoc-Gly-OH, Fmoc-Cys(t-Buthio)-OH, Fmoc-NH-PEG_3-COOH, Fmoc-Cys(Trt)-OH. The N-terminal amino acid was protected as an acetyl derivative. The peptide was then cleaved from the resin and purified by RP-HPLC to yield 32.7 mg of a white solid.

Synthesis of IMP457

[0343] IMP 421 (SEQ ID NO:43, incorporating the sequence of AD2, was synthesized by standard chemical means. To a solution of 15.2 mg (5.26 μmol) IMP 421 (F.W. 2890.50) and 274.5 mg (6.86 μmol) mPEG2-MAL-40K in 1 mL of acetonitrile was added 7 mL 1 M Tris pH 7.8 and allowed to react at room temperature for 3 h. The excess mPEG2-MAL-40K was quenched with 49.4 mg L-cysteine, followed by S-S-*t*Bu deprotection over one hour with 59.1 mg TCEP. The reaction mixture was dialyzed overnight at 2-8 °C using two 3-12 mL capacity 10K SLIDE-A-LYZER® dialysis cassettes (4 ml into each cassette) into 5 L of 5 mM ammonium acetate, pH 5.0. Three more 5 L buffer changes of 5 mM ammonium acetate, pH 5.0 were made the next day with each dialysis lasting at least 2½ h. The purified product (19.4 mL) was transferred into two 20 mL scintillation vials, frozen and lyophilized to yield 246.7 mg of a white solid. MALDI-TOF gave results of mPEG2-MAL-40K 42,982 and IMP-457 45,500.

Example 25. Generation of PEGylated hPAM4 by DNL

[0344] A DNL structure is prepared having two copies of hPAM4 Fab coupled to a 20 kDa PEG. A DNL reaction is performed by the addition of reduced and lyophilized IMP362 in 10-fold molar excess to hPAM4 Fab-DDD2 in 250 mM imidazole, 0.02% Tween 20, 150 mM NaCl, 1 mM EDTA, 50 mM NaH_2PO_4, pH 7.5. After 6 h at room

temperature in the dark, the reaction mixture is dialyzed against CM Loading Buffer (150 mM NaCl, 20 mM NaAc, pH 4.5) at 4°C in the dark. The solution is loaded onto a 1-mL Hi-Trap CM-FF column (AMERSHAM®), which is pre-equilibrated with CM Loading buffer. After sample loading, the column is washed with CM loading buffer to baseline, followed by washing with 15 mL of 0.25 M NaCl, 20 mM NaAc, pH 4.5. The PEGylated hPAM4 is eluted with 12.5 mL of 0.5 M NaCl, 20 mM NaAc, pH 4.5.

[0345] The conjugation process is analyzed by SDS-PAGE with Coomassie blue staining. Under non-reducing conditions, the Coomassie blue-stained gel reveals the presence of a major band in the reaction mixture, which is absent in the unbound or 0.25 M NaCl wash fraction, but evident in the 0.5 M NaCl fraction. Fluorescence imaging, which is used to detect the EDANS tag on IMP362, demonstrates that the band contains IMP362 and the presence of excess IMP362 in the reaction mixture and the unbound fraction. The DNL reaction results in the site-specific and covalent conjugation of IMP362 with a dimer of hPAM4 Fab. Under reducing conditions, which breaks the disulfide linkage, the components of the DNL structures are resolved. The calculated MW of the (hPAM4 $Fab)_2$-PEG construct matches that determined by MALDI TOF. Overall, the DNL reaction results in a near quantitative yield of a homogeneous product that is > 90% pure after purification by cation-exchange chromatography.

[0346] Another DNL reaction is performed by the addition of reduced and lyophilized IMP457 in 10-fold molar excess to hPAM4 Fab-DDD2 in 250 mM imidazole, 0.02% Tween 20, 150 mM NaCl, 1 mM EDTA, 50 mM NaH_2PO_4, pH 7.5. After 60 h at room temperature, 1mM oxidized glutathione is added to the reaction mixture, which is then held for an additional 2 h. The mixture is diluted 1:20 with CM Loading Buffer (150 mM NaCl, 20 mM NaAc, pH 4.5) and titrated to pH 4.5 with acetic acid. The solution is loaded onto a 1-mL Hi-Trap CM-FF column (AMERSHAM®), which is pre-equilibrated with CM Loading Buffer. After sample loading, the column is washed with CM Loading Buffer to baseline, followed by washing with 15 mL of 0.25 M NaCl, 20 mM NaAc, pH 4.5. The PEGylated product is eluted with 20 mL of 0.5 M NaCl, 20 mM NaAc, pH 4.5. The DNL construct is concentrated to 2 mL and diafiltered into 0.4 M PBS, pH 7.4. The final PEGylated hPAM4 Fab_2 construct is approximately 90% purity as determined by SDS-PAGE.

[0347] A DNL construct having two copies of hPAM4 Fab coupled to a 30 kDa PEG is prepared as described immediately above using IMP413 instead of IMP362. The

PEGylated hPAM4 Fab_2 DNL construct is purified as described above and obtained in approximately 90% purity. The PEGylated DNL constructs may be used for therapeutic methods as described above for non-PEGylated forms of hPAM4.

Example 26. Generation of DDD module based on Interferon (IFN)-α2b

[0348] The cDNA sequence for IFN-α2b was amplified by PCR, resulting in a sequence comprising the following features, in which XbaI and BamHI are restriction sites, the signal peptide is native to IFN-α2b, and 6 His is a hexahistidine tag (SEQ ID NO: 59): XbaI---Signal peptide--- IFNα2b ---6 His---BamHI (6 His disclosed as SEQ ID NO: 59). The resulting secreted protein consists of IFN-α2b fused at its C-terminus to a polypeptide consisting of SEQ ID NO:44.

KSHHHHHHGSGGGGSGGGCGHIQIPPGLTELLQGYTVEVLRQQPPDLVEFAVEYF TRLREARA (SEQ ID NO:44)

[0349] PCR amplification was accomplished using a full length human IFNα2b cDNA clone (INVITROGEN® Ultimate ORF human clone cat# HORF01Clone ID IOH35221) as a template and the following oligonucleotides as primers:

IFNA2 Xba I Left

5'-TCTAGACACAGGACCTCATCATGGCCTTGACCTTTGCTTTACTGG-3' (SEQ ID NO:45)

IFNA2 BamHI right

5'GGATCCATGATGGTGATGATGGTGTGACTTTTCCTTACTTCTTAAACT TTCTTGC-3' (SEQ ID NO:46)

[0350] The PCR amplimer was cloned into the PGEMT® vector (PROMEGA®). A DDD2-pdHL2 mammalian expression vector was prepared for ligation with IFN-α2b by digestion with XbaI and Bam HI restriction endonucleases. The IFN-α2b amplimer was excised from PGEMT® with XbaI and Bam HI and ligated into the DDD2-pdHL2 vector to generate the expression vector IFN-α2b-DDD2-pdHL2.

[0351] IFN-α2b-DDD2-pdHL2 was linearized by digestion with SalI enzyme and stably transfected into Sp/EEE myeloma cells by electroporation (see, e.g., U.S. Patent 7,537,930). Two clones were found to have detectable levels of IFN-α2b by ELISA. One

of the two clones, designated 95, was adapted to growth in serum-free media without substantial decrease in productivity. The clone was subsequently amplified with increasing methotrexate (MTX) concentrations from 0.1 to 0.8 μM over five weeks. At this stage, it was sub-cloned by limiting dilution and the highest producing sub-clone (95-5) was expanded. The productivity of 95-5 grown in shake-flasks was estimated to be 2.5 mg/L using commercial rIFN-α2b (CHEMICON® IF007, Lot 06008039084) as a standard.

[0352] Clone 95-5 was expanded to 34 roller bottles containing a total of 20 L of serum-free Hybridoma SFM with 0.8 μM MTX and allowed to reach terminal culture. The supernatant fluid was clarified by centrifugation and filtered (0.2 μM). The filtrate was diafiltered into 1X Binding buffer (10 mM imidazole, 0.5 M NaCl, 50 mM NaH_2PO_4, pH 7.5) and concentrated to 310 mL in preparation for purification by immobilized metal affinity chromatography (IMAC). The concentrate was loaded onto a 30-mL Ni-NTA column, which was washed with 500 mL of 0.02% Tween 20 in 1X binding buffer and then 290 mL of 30 mM imidazole, 0.02% Tween 20, 0.5 M NaCl, 50 mM NaH_2PO_4, pH 7.5. The product was eluted with 110 mL of 250 mM imidazole, 0.02% Tween 20, 150 mM NaCl, 50 mM NaH_2PO_4, pH 7.5. Approximately 6 mg of IFNα2b-DDD2 was purified.

[0353] The purity of IFN-α2b-DDD2 was assessed by SDS-PAGE under reducing conditions (not shown). IFN-α2b-DDD2 was the most heavily stained band and accounted for approximately 50% of the total protein (not shown). The product resolved as a doublet with an M_r of ~26 kDa, which is consistent with the calculated MW of IFN-α2b-DDD2-SP (26 kDa). There was one major contaminant with a M_r of 34 kDa and many faint contaminating bands (not shown).

Example 27. Generation of hPAM4 Fab-(IFN-α2b)$_2$ by DNL

Creation of C-H-AD2-IgG-pdHL2 expression vectors.

[0354] The pdHL2 mammalian expression vector has been used to mediate the expression of many recombinant IgGs. A plasmid shuttle vector was produced to facilitate the conversion of any IgG-pdHL2 vector into a C-H-AD2-IgG-pdHL2 vector. The gene for the Fc (CH2 and CH3 domains) was amplified using the pdHL2 vector as a template and the oligonucleotides *Fc BglII Left* and *Fc Bam-EcoRI Right* as primers.

Fc BglII Left

5'-AGATCTGGCGCACCTGAACTCCTG-3' (SEQ ID NO:47)

Fc Bam-EcoRI Right

5'-GAATTCGGATCCTTTACCCGGAGACAGGGAGAG-3' (SEQ ID NO:48)

[0355] The amplimer was cloned in the PGEMT® PCR cloning vector. The Fc insert fragment was excised from PGEMT® and ligated with AD2-pdHL2 vector to generate the shuttle vector Fc-AD2-pdHL2.

Generation of hPAM4 IgG-AD2

[0356] To convert any IgG-pdHL2 expression vector to a C-H-AD2-IgG-pdHL2 expression vector, an 861 bp BsrGI / NdeI restriction fragment is excised from the former and replaced with a 952 bp BsrGI / NdeI restriction fragment excised from the Fc-AD2-pdHL2 vector. BsrGI cuts in the CH3 domain and NdeI cuts downstream (3') of the expression cassette. This method is used to generate a hPAM4 IgG-AD2 protein.

Generation of hPAM4 IgG-(IFN-α2b)$_2$ Construct

[0357] A DNL reaction is performed by the addition of reduced and lyophilized hPAM4 IgG-AD2 to IFN-α2b-DDD2 in 250 mM imidazole, 0.02% Tween 20, 150 mM NaCl, 1 mM EDTA, 50 mM NaH_2PO_4, pH 7.5. After 6 h at room temperature in the dark, the reaction mixture is dialyzed against CM Loading Buffer (150 mM NaCl, 20 mM NaAc, pH 4.5) at 4°C in the dark. The solution is loaded onto a 1-mL Hi-Trap CM-FF column (AMERSHAM®), which is pre-equilibrated with CM Loading buffer. After sample loading, the column is washed with CM loading buffer to baseline, followed by washing with 15 mL of 0.25 M NaCl, 20 mM NaAc, pH 4.5. The product is eluted with 12.5 mL of 0.5 M NaCl, 20 mM NaAc, pH 4.5. The DNL reaction results in the site-specific and covalent conjugation of hPAM4 IgG with a dimer of IFN-α2b. Both the IgG and IFN-α2b moieties retain their respective physiological activities in the DNL construct. This technique may be used to attach any cytokine or other physiologically active protein or peptide to hPAM4 for targeted delivery to pancreatic cancer or other cancers that express the PAM4 antigen.

Example 28. AD and DDD Sequence Variants

[0358] In certain preferred embodiments, the AD and DDD sequences incorporated into the DNL complexes comprise the amino acid sequences of AD2 (SEQ ID NO:36) and DDD2 (SEQ ID NO:34), as described above. However, in alternative embodiments sequence variants of the AD and/or DDD moieties may be utilized in construction of the

cytokine-MAb DNL complexes. The structure-function relationships of the AD and DDD domains have been the subject of investigation. (See, e.g., Burns-Hamuro et al., 2005, Protein Sci 14:2982-92; Carr et al., 2001, J Biol Chem 276:17332-38; Alto et al., 2003, Proc Natl Acad Sci USA 100:4445-50; Hundsrucker et al., 2006, Biochem J 396:297-306; Stokka et al., 2006, Biochem J 400:493-99; Gold et al., 2006, Mol Cell 24:383-95; Kinderman et al., 2006, Mol Cell 24:397-408.)

[0359] For example, Kinderman et al. (2006) examined the crystal structure of the AD-DDD binding interaction and concluded that the human DDD sequence contained a number of conserved amino acid residues that were important in either dimer formation or AKAP binding, underlined in SEQ ID NO:33 below. (See Figure 1 of Kinderman et al., 2006.) The skilled artisan will realize that in designing sequence variants of the DDD sequence, one would desirably avoid changing any of the underlined residues, while conservative amino acid substitutions might be made for residues that are less critical for dimerization and AKAP binding.

Human DDD sequence from protein kinase A

SHIQIPPGLTELLQGYTVEVLRQQPPDLVEFAVEYFTRLREARA (SEQ ID NO:33)

[0360] Alto et al. (2003) performed a bioinformatic analysis of the AD sequence of various AKAP proteins to design an RII selective AD sequence called AKAP-IS (SEQ ID NO:35), with a binding constant for DDD of 0.4 nM. The AKAP-IS sequence was designed as a peptide antagonist of AKAP binding to PKA. Residues in the AKAP-IS sequence where substitutions tended to decrease binding to DDD are underlined in SEQ ID NO:35 below.

AKAP-IS sequence

QIEYLAKQIVDNAIQQA (SEQ ID NO:35)

[0361] Similarly, Gold (2006) utilized crystallography and peptide screening to develop a SuperAKAP-IS sequence (SEQ ID NO:49), exhibiting a five order of magnitude higher selectivity for the RII isoform of PKA compared with the RI isoform. Underlined residues indicate the positions of amino acid substitutions, relative to the AKAP-IS sequence, that increased binding to the DDD moiety of RIIα. In this sequence, the N-terminal Q residue is numbered as residue number 4 and the C-terminal A residue is residue number 20. Residues where substitutions could be made to affect the affinity for RIIα were residues 8,

11, 15, 16, 18, 19 and 20 (Gold et al., 2006). It is contemplated that in certain alternative embodiments, the SuperAKAP-IS sequence may be substituted for the AKAP-IS AD moiety sequence to prepare cytokine-MAb DNL constructs. Other alternative sequences that might be substituted for the AKAP-IS AD sequence are shown in SEQ ID NO:50-52. Substitutions relative to the AKAP-IS sequence are underlined. It is anticipated that, as with the AKAP-IS sequence shown in SEQ ID NO:49, the AD moiety may also include the additional N-terminal residues cysteine and glycine and C-terminal residues glycine and cysteine.

SuperAKAP-IS

QIEYVAKQIVDYAIHQA (SEQ ID NO:49)

Alternative AKAP sequences

QIEYKAKQIVDHAIHQA (SEQ ID NO:50)

QIEYHAKQIVDHAIHQA (SEQ ID NO:51)

QIEYVAKQIVDHAIHQA (SEQ ID NO:52)

[0362] Stokka et al. (2006) also developed peptide competitors of AKAP binding to PKA, shown in SEQ ID NO:53-55. The peptide antagonists were designated as Ht31 (SEQ ID NO:53), RIAD (SEQ ID NO:54) and PV-38 (SEQ ID NO:55). The Ht-31 peptide exhibited a greater affinity for the RII isoform of PKA, while the RIAD and PV-38 showed higher affinity for RI.

Ht31

DLIEEAASRIVDAVIEQVKAAGAY (SEQ ID NO:53)

RIAD

LEQYANQLADQIIKEATE (SEQ ID NO:54)

PV-38

FEELAWKIAKMIWSDVFQQC (SEQ ID NO:55)

[0363] Hundsrucker et al. (2006) developed still other peptide competitors for AKAP binding to PKA, with a binding constant as low as 0.4 nM to the DDD of the RII form of PKA. The sequences of various AKAP antagonistic peptides is provided in Table 1 of Hundsrucker et al. Residues that were highly

conserved among the AD domains of different AKAP proteins are indicated below by underlining with reference to the AKAP IS sequence (SEQ ID NO:35). The residues are the same as observed by Alto et al. (2003), with the addition of the C-terminal alanine residue. (See FIG. 4 of Hundsrucker et al. (2006).) The sequences of peptide antagonists with particularly high affinities for the RII DDD sequence are shown in SEQ ID NO:56-58.

AKAP-IS

QIEYLAKQIVDNAIQQA (SEQ ID NO:35)

AKAP7δ-wt-pep

PEDAELVRLSKRLVENAVLKAVQQY (SEQ ID NO:56)

AKAP7δ-L304T-pep

PEDAELVRTSKRLVENAVLKAVQQY (SEQ ID NO:57)

AKAP7δ-L308D-pep

PEDAELVRLSKRDVENAVLKAVQQY (SEQ ID NO:58)

[0364] Carr et al. (2001) examined the degree of seqeunce homology between different AKAP-binding DDD sequences from human and non-human proteins and identified residues in the DDD sequences that appeared to be the most highly conserved among different DDD moieties. These are indicated below by underlining with reference to the human PKA RIIα DDD sequence of SEQ ID NO:33. Residues that were particularly conserved are further indicated by italics. The residues overlap with, but are not identical to those suggested by Kinderman et al. (2006) to be important for binding to AKAP proteins.

SHIQ*IP*P*GL*TE*LLQGYTVEVLR*Q*QP*P*DLVE*FA*VE*YF*TR*L*REA*R*A (SEQ ID NO:33)

[0365] The skilled artisan will realize that in general, those amino acid residues that are highly conserved in the DDD and AD sequences from different proteins are ones that it may be preferred to remain constant in making amino acid substitutions, while residues that are less highly conserved may be more easily varied to produce sequence variants of the AD and/or DDD sequences described herein.

[0366] The skilled artisan will realize that these and other amino acid substitutions in the antibody moiety or linker portions of the DNL constructs may be utilized to enhance the therapeutic and/or pharmacokinetic properties of the resulting DNL constructs.

Example 29. *In Vitro* Detection of PAM4 Antigen in Human Serum

[0367] In certain embodiments, it is preferred to detect the presence of PAM4 antigen and/or to diagnose the presence of pancreatic cancer in a subject by *in vitro* analysis of samples that can be obtained by non-invasive techniques, such as blood, plasma or serum samples. Such *ex vivo* analysis may be preferred, for example, in screening procedures where there is no *a priori* reason to believe that an individual has a pancreatic tumor in a specific location.

[0368] Studies were initially performed using patient serum samples that had been stored frozen for a number of years prior to analysis (Gold et al., J. Clin Oncol 2006, 24:252-58). An in vitro enzyme immunoassay was established with monoclonal antibody PAM4 as the capture reagent, and a polyclonal anti-mucin antibody as the probe. Patient sera were obtained from healthy, adult patients with acute and chronic pancreatitis, and those with pancreatic and other forms of cancer, and were measured for PAM4 antigen.

Methods

[0369] Reagents - A human pancreatic mucin preparation was isolated from CaPan1, a human pancreatic cancer grown as xenografts in athymic nude mice. Briefly, 1 g of tissue was homogenized in 10 mL of 0.1 M ammonium bicarbonate containing 0.5 M sodium chloride. The sample was then centrifuged to obtain a supernatant that was fractionated on a SEPHAROSE®-4B-CL column with the void volume material chromatographed on hydroxyapatite. The unadsorbed fraction was dialyzed extensively against deionized water and then lyophilized. A 1 mg/mL solution was prepared in 0.01 M sodium phosphate buffer (pH, 7.2) containing 0.15 M sodium chloride (phosphate-buffered saline [PBS]), and used as the stock solution for the immunoassay standards. A polyclonal, anti-mucin antiserum was prepared by immunization of rabbits, as described previously (Gold et al., Cancer Res 43:235-38, 1983). An IgG fraction was purified and assessed for purity by sodium dodecyl sulfate–polyacrylamide gel electrophoresis (SDS-PAGE) and molecular-sieve high-performance liquid chromatography. Kits for quantitation of CA19-9 were purchased from PANOMICS® Inc (Redwood City, CA).

[0370] Enzyme Immunoassay - Sera were obtained from patients enrolled in institutional review board–approved clinical trials conducted by the Garden State Cancer Center (Belleville, NJ), as well as from the Eastern Division of the Cooperative Human Tissue Network (National Cancer Institute [NCI], National Institutes of Health, Bethesda, MD). To perform the immunoassay, a 96-well polyvinyl plate was coated with 100 µL of PAM4

antibody at 20 μg/mL in PBS with incubation at 4°C overnight. On the next morning, the capture antibody was removed from the plate. The wells were then blocked by addition of 200 μL of a 1% (weight/volume [w/v]) solution of casein-sodium salt in PBS and incubated overnight at 4°C. The casein was removed from the wells and the plate washed 5 x with 250 μL of PBS containing 0.05% (volume/volume [v/v]) Tween-20. The standard, or unknown specimen, was diluted 1:2 in 1% (w/v) casein in PBS, 100 μL was added to the appropriate wells, and the plate incubated at 37°C for 1.5 hours. At this time, the plate was washed five times with PBS–Tween-20 as mentioned already. The polyclonal rabbit anti-mucin antibody, diluted to 5 μg/mL in 0.1% (w/v) casein in PBS, was added to each well, and the plate incubated for 1 hour at 37°C. The polyclonal antibody was then washed from the wells as described herein, and peroxidase-labeled donkey antirabbit IgG, at a 1:1000 dilution in 0.1% (w/v) casein in PBS, was added to the wells and incubated at 37°C for 1 hour. After washing the plate as already described, 100 μL of a solution consisting of *ortho*-phenylenediamine (0.8 mg/mL) and hydrogen peroxide (0.3% v/v in 0.1 M Tris-HCl [pH 8.0]), were added to the wells, and the plate was incubated at room temperature for 30 minutes in the dark. The reaction was stopped by the addition of 25 μL of 4.0 N sulfuric acid, and the optical density read at a wavelength of 490 nm using a SPECTRA-MAX® 250 spectrophotometer. CA19-9 determinations were performed according to the manufacturer's procedure. Standard curves were generated with regression analyses performed to determine concentrations of the unknown samples. Receiver operating characteristic (ROC) curves were generated by use of MED-CALC® statistical software package (version 7.5; MED-CALC®, Mariakerke Belgium).

Results

[0371] Development and Characterization of the PAM4-Based Immunoassay - We chose to report our results in arbitrary units/mL based on an initial reference standard of mucin purified from xenografted CaPan1 human pancreatic tumor. The lower limit of detection for the immunoassay was 1.0 unit/mL, with saturation occurring at mucin concentrations above 100 units/mL. A linear range was determined to be 1.5 units/mL to 25 units/mL of antigen (not shown). Interassay (n = 5) coefficients of variation (CV) were calculated for reference standards of 20 units/mL (CV = 8.0%) and 8 units/mL (CV = 3.8%). Mean recoveries were 17.5 ± 2.8 and 7.1 ± 1.9 for the 20 and 8 units/mL standards, respectively.

[0372] Levels of PAM4-reactive Mucin in Patient Specimens - Sera from a total of 283 patients, including 53 with pancreatic cancer, were examined for the presence of PAM4 antigen. The frequency distribution of serum mucin concentrations for the varying disease groups was determined (**FIG. 16**). The receiver operator characteristic (ROC) curve was calculated (not shown), and the area under the curve (AUC) determined to be 0.88 ± 0.03 (95% CI, 0.84 to 0.92) with $P < .0001$ (see Example 23), a highly significant difference for discrimination of pancreatic cancer from nonpancreatic cancer specimens. At a cutoff value of 10.2 units/mL, the sensitivity and specificity were calculated to be 77% and 95% (Example 23), respectively, with a positive diagnostic likelihood ratio (+DLR) of 13.7, as compared with healthy, benign, and nonpancreatic cancer groups.

[0373] The data presented in **Table 13** showed that the median and mean values for the pancreatic cancer group were more than 10-fold greater than for all of the other groups, even though the overwhelming majority of the nonpancreatic cancer cases were late-stage disease. Of 53 pancreatic cancer patients, 41 (77%) were positive at a cutoff value of 10.2 units/mL. At this same cutoff value, none of the healthy specimens were positive, and only four (5%) of 87 pancreatitis patients were positive. ROC curve analyses demonstrated high specificity with significant differences for the discrimination of pancreatic cancer from normal and pancreatitis patient groups (not shown).

[0374] Comparison of PAM4 and CA19.9 Immunonassays - Of the 53 pancreatic cancer specimens, only 41 were assessable for both PAM4-reactive mucin and CA19-9 because of insufficient volume of certain samples. Of these, 24 (59%) were considered positive for CA19-9 (at a cutoff of 35 units/mL). As with the PAM4 immunoassay, none of the healthy specimens were positive for CA19-9. However, of the 87 pancreatitis samples, CA19-9 was positive in 37% (not shown). ROC analyses for discrimination of pancreatic cancer from pancreatitis serum specimens provided an AUC of 0.67 ± 0.05 (95% CI, 0.58 to 0.75), with a specificity of 63% and a +DLR of 1.6 for the CA19-9 test (not shown). Statistical analyses for PAM4-reactive mucin in this same subset of pancreatic cancer and pancreatitis sera differed little from the group analyses discussed earlier; sensitivity for this subset was slightly reduced (71%), but specificity remained high (96%), as did the +DLR (15.4) (not shown). There was no correlation between PAM4 and CA19-9 values. Two of the four PAM4-positive pancreatitis specimens were also positive for CA19-9. A direct pair-wise comparison of the ROC curves resulted in a statistically significant difference ($P < .003$), with the PAM4 immunoassay demonstrating a superior sensitivity and specificity

for discrimination of patients with pancreatic cancer from those with pancreatitis (not shown).

[0375] The results obtained with serum samples frozen at -80°C and frozen for a period of years before analysis were not initially reproducible with fresher serum samples. Immunoassay with PAM4 antibody performed on fresh serum samples obtained from individuals with known pancreatic cancer, or fresh serum samples spiked with pancreatic cancer mucin, routinely resulted in false negative results. It was observed that the frozen and stored samples, after thawing, usually separated into lipid and aqueous components. The lipid component was removed by centrifugation before the PAM4 immunoassay was performed on the remaining aqueous component. In the initial studies with fresher serum samples, the serum did not separate and the immunoassay was run on whole serum.

[0376] To reproduce the effects of freezing and long-term storage, the fresher serum samples were subject to an organic phase extraction to remove serum lipids and other hydrophobic components. Although the phase extraction was performed with butanol, the skilled artisan will realize that the technique is not so limited and may be performed with alternative organic solvents known in the art. Exemplary organic solvents known in the art include other alcohols that are not miscible with water, chloroform, hexane, benzene, DMF (dimethyl formamide), DMSO (dimethyl sulfoxide) and ether.

[0377] To perform the organic phase extraction of serum samples, 300 μL of serum was placed in a 1.5 mL microcentrifuge tube, then 300 μL of n-Butanol was added, the tube closed tightly and vigorously vortexed several times during a 5 min extraction period. At the end of the extraction, the tubes were opened and 300 μL of choroform was added. The tubes were closed tightly, the tube was vigorously vorteed and then spun in a tabletop centrifuge at high speed for 5 min. The tubes were opened and 200 μL of the upper aqueous phase was removed to a clean tube. An equal volume of immunoassay diluent (2% casein) was added (1:2 dilution of the unknown serum) and used as antigen in the immunoassay protocol described above. Using the organic phase extraction, results for PAM4 antigen detection and pancreatic cancer diagnosis were obtained that were equivalent to those seen with samples subjected to long term freezing and storage described above (not shown).

[0378] The interference of an organic component with PAM4-based immunoassay seen with fresh serum samples was not observed with PAM4 immunohistology on formalin-fixed, paraffin-embedded tissue sections, which are typically processed with an organic

solvent extraction prior to immunoassay. The interfering component appears to be limited in distribution to serum and is not observed to interfere with PAM4 antibody binding to solid pancreatic cancer tumors *in situ*.

Example 30. Preparation and Assay of Cross-Blocking Antibodies to PAM4

[0379] Tumors of xenografted RIP1 human pancreatic carcinoma are grown in nude mice and harvested. The human pancreatic cancer mucins are extracted according to Gold et al. (Int J Cancer 1994, 15:204-10) and used to immunize mice according to standard protocols (Harlow and Lane, Antibodies: A Laboratory Manual, Ch. 5, Cold Spring Harbor Laboratory, Cold Spring Harbor, NY.) Antibody producing hybridoma cells are prepared from the immunized mice and screened for binding to human pancreatic cancer mucin extracts. Positive clones are expanded and the monoclonal antibodies are tested for cross-blocking activity against cPAM4 using competitive binding assays as described in Example 1. Cross-blocking antibodies against cPAM4 are identified by competition for binding to human pancreatic cancer mucin.

* * *

What is claimed is:

1. An antibody construct comprising at least one anti-pancreatic cancer antibody or antigen-binding fragment thereof that binds to pancreatic cancer cells and does not bind to normal pancreatic tissue or pancreatitis or benign pancreatic tissue; wherein the anti-pancreatic cancer antibody or fragment thereof binds to a linear peptide comprising the amino acid sequence WTWNITKAYPLP (SEQ ID NO:29) or to a cyclic peptide comprising the amino acid sequence ACPEWWGTTC (SEQ ID NO:30).

2. The antibody construct of claim 1, wherein the anti-pancreatic cancer antibody binds to PanIN-1A, PanIN-1B, PanIN-2, invasive pancreatic adenocarcinoma, pancreatic carcinoma, mucinous cyst neoplasms (MCN), intrapancreatic mucinous neoplasms (IPMN) and intraductal papillary mucinous neoplasia.

3. The antibody construct of claim 1, wherein the construct is a trimeric DNL (dock and lock) construct comprising two copies of a PAM4 antibody fragment moiety attached to one copy of a 679 antibody fragment moiety.

4. The antibody construct of claim 3, wherein each PAM4 antibody fragment moiety comprises a PAM4 Fab fragment attached to a DDD2 (SEQ ID NO:34) sequence and the 679 antibody fragment moiety comprises a 679 Fab fragment attached to an AD2 (SEQ ID NO:36) sequence and a dimer of the DDD2 sequence binds to the AD2 sequence to form the trimeric construct.

5. The antibody construct of claim 4, wherein the PAM4 antibody fragment is an hPAM4 Fab fragment and the 679 antibody fragment is an h679 Fab fragment.

6. The antibody construct of claim 3, wherein the PAM4 antibody fragment moiety comprises the light chain variable region CDR sequences CDR1 (SASSSVSSSYLY, (SEQ ID NO:1); CDR2 (STSNLAS, SEQ ID NO:2); and CDR3 (HQWNRYPYT, SEQ ID NO:3); and the heavy chain variable region CDR sequences CDR1 (SYVLH, SEQ ID NO:4); CDR2 (YINPYNDGTQYNEKFKG, SEQ ID NO:5)and CDR3 (GFGGSYGFAY, SEQ ID NO:6).

7. The antibody construct of claim 3, wherein the PAM4 antibody fragment moiety comprises a murine, chimeric, humanized or human antibody PAM4 fragment.

8. The antibody construct of claim 1, wherein the anti-pancreatic cancer antibody or fragment thereof binds to the PAM4 antigen.

9. The antibody construct of claim 1, wherein the anti-pancreatic cancer antibody or fragment thereof competes for binding to human pancreatic cancer mucin with a chimeric PAM4 (cPAM4) antibody, wherein the cPAM4 antibody comprises the light chain variable region CDR sequences CDR1 (SASSSVSSSYLY, (SEQ ID NO:1); CDR2 (STSNLAS, SEQ ID NO:2); and CDR3 (HQWNRYPYT, SEQ ID NO:3); and the heavy chain variable region CDR sequences CDR1 (SYVLH, SEQ ID NO:4); CDR2 (YINPYNDGTQYNEKFKG, SEQ ID NO:5)and CDR3 (GFGGSYGFAY, SEQ ID NO:6).

10. Use of an antibody construct comprising at least one anti-pancreatic cancer antibody or antigen-binding fragment thereof that binds to pancreatic cancer cells and does not bind to normal pancreatic tissue or pancreatitis or benign pancreatic tissue in the manufacture of a medicament for treating pancreatic cancer; wherein the anti-pancreatic cancer antibody or fragment thereof binds to a linear peptide comprising the amino acid sequence WTWNITKAYPLP (SEQ ID NO:29) or to a cyclic peptide comprising the amino acid sequence ACPEWWGTTC (SEQ ID NO:30).

11. The use of claim 10, wherein the anti-pancreatic cancer antibody or antigen-binding fragment thereof binds to 80% or more of human invasive pancreatic adenocarcinoma, intraductal papillary mucinous neoplasia, PanIN-1A, PanIN-1B and PanIN-2.

12. The use of claim 10, wherein the anti-pancreatic cancer antibody or antigen-binding fragment thereof binds to PanIN-1A, PanIN-1B and PanIN-2 but not to pancreatitis.

13. The use of claim 10, wherein the anti-pancreatic cancer antibody or antigen-binding fragment thereof is a naked antibody or fragment thereof.

14. The use of claim 13, wherein said medicament is to be administered with at least one therapeutic agent.

15. The use of claim 10, wherein the anti-pancreatic cancer antibody or antigen-binding fragment thereof is conjugated to at least one therapeutic agent.

16. The use of claim 15, wherein the therapeutic agent is selected from the group consisting of a radionuclide, an immunomodulator, a hormone, a hormone antagonist,

an enzyme, an anti-sense oligonucleotide, an siRNA, an enzyme inhibitor, a photoactive therapeutic agent, a cytotoxic agent, a drug, a toxin, an angiogenesis inhibitor and a pro-apoptotic agent.

17. The use of claim 16, wherein the drug is selected from the group consisting of nitrogen mustards, ethylenimine derivatives, alkyl sulfonates, nitrosoureas, gemcitabine, triazenes, folic acid analogs, anthracyclines, taxanes, COX-2 inhibitors, pyrimidine analogs, purine analogs, antibiotics, enzyme inhibitors, epipodophyllotoxins, platinum coordination complexes, vinca alkaloids, substituted ureas, methyl hydrazine derivatives, adrenocortical suppressants, hormone antagonists, endostatin, taxols, camptothecins, SN-38, doxorubicins and their analogs, antimetabolites, alkylating agents, antimitotics, anti-angiogenic agents, tyrosine kinase inhibitors, mTOR inhibitors, heat shock protein (HSP90) inhibitors, proteosome inhibitors, HDAC inhibitors, pro-apoptotic agents, methotrexate and CPT-11.

18. The use of claim 16, wherein the toxin is selected from the group consisting of ricin, abrin, alpha toxin, saporin, ribonuclease (RNase), DNase I, Staphylococcal enterotoxin-A, pokeweed antiviral protein, gelonin, diphtheria toxin, Pseudomonas exotoxin, and Pseudomonas endotoxin.

19. The use of claim 16, wherein the immunomodulator is selected from the group consisting of a cytokine, a stem cell growth factor, a lymphotoxin, a hematopoietic factor, a colony stimulating factor (CSF), an interleukin (IL), an interferon (IFN), a stem cell growth factor, erythropoietin, thrombopoietin, tumor necrosis factor (TNF), granulocyte-colony stimulating factor (G-CSF), granulocyte macrophage-colony stimulating factor (GM-CSF), interferon-α, interferon-β, interferon-γ and the stem cell growth factor designated "S1 factor".

20. The use of claim 19, wherein the cytokine is selected from the group consisting of human growth hormone, N-methionyl human growth hormone, bovine growth hormone, parathyroid hormone, thyroxine, insulin, proinsulin, relaxin, prorelaxin, glycoprotein follicle stimulating hormone (FSH), thyroid stimulating hormone (TSH), luteinizing hormone (LH), placenta growth factor (PlGF), hepatic growth factor, prostaglandin, fibroblast growth factor, prolactin, placental lactogen, OB protein, tumor necrosis factor-α, tumor necrosis factor-ß, mullerian-inhibiting substance, mouse gonadotropin-associated peptide, inhibin, activin, vascular endothelial growth

factor, integrin, thrombopoietin (TPO), NGF-ß, platelet-growth factor, TGF-α, TGF-ß, insulin-like growth factor-I, insulin-like growth factor-II, erythropoietin (EPO), osteoinductive factors, interferon-α, interferon-β, interferon-γ, macrophage-CSF (M-CSF), IL-1, IL-1α, IL-2, IL-3, IL-4, IL-5, IL-6, IL-7, IL-8, IL-9, IL-10, IL-11, IL-12, IL-13, IL-14, IL-15, IL-16, IL-17, IL-18, IL-21, IL-25, LIF, FLT-3, angiostatin, thrombospondin, endostatin, TNF-α and LT.

21. The use of claim 15, wherein the radionuclide is selected from the group consisting of ^{111}In, ^{177}Lu, ^{212}Bi, ^{213}Bi, ^{211}At, ^{62}Cu, ^{67}Cu, ^{90}Y, ^{125}I, ^{131}I, ^{32}P, ^{33}P, ^{47}Sc, ^{111}Ag, ^{67}Ga, ^{142}Pr, ^{153}Sm, ^{161}Tb, ^{152}Dy, ^{166}Dy, ^{161}Ho, ^{166}Ho, ^{186}Re, ^{188}Re, ^{189}Re, ^{212}Pb, ^{223}Ra, ^{225}Ac, ^{59}Fe, ^{75}Se, ^{77}As, ^{89}Sr, ^{99}Mo, ^{105}Rh, ^{109}Pd, ^{143}Pr, ^{149}Pm, ^{169}Er, ^{194}Ir, ^{198}Au, ^{199}Au, ^{211}Pb, ^{58}Co, ^{80m}Br, ^{99m}Tc, ^{103m}Rh, ^{109}Pt, ^{119}Sb, ^{189m}Os, ^{192}Ir, ^{219}Rn, ^{215}Po, ^{221}Fr, ^{217}At, ^{255}Fm, ^{11}C, ^{13}N, ^{15}O, ^{75}Br, ^{224}Ac, ^{126}I, ^{133}I, ^{77}Br, ^{113m}In, ^{95}Ru, ^{97}Ru, ^{103}Ru, ^{105}Ru, ^{107}Hg, ^{203}Hg, ^{121m}Te, ^{122m}Te, ^{125m}Te, ^{165}Tm, ^{167}Tm, ^{168}Tm, ^{197}Pt, ^{143}Pr, ^{57}Co, ^{51}Cr, ^{75}Se, ^{201}Tl, ^{76}Br and ^{169}Yb.

22. The use of claim 15, wherein said medicament is to be administered with a second therapeutic agent that is not conjugated to the anti-pancreatic cancer antibody or antigen-binding fragment.

23. The use of claim 22, wherein the anti-pancreatic cancer antibody or antigen-binding fragment thereof is conjugated to a radionuclide and the second therapeutic agent is a radiosensitizing agent that is to be administered to the individual before the anti-pancreatic cancer antibody or fragment is to be administered.

24. The use of claim 13, wherein the antibody construct is a bispecific or multispecific antibody comprising at least one PAM4 antibody or antigen-binding fragment thereof and at least one antibody or fragment that binds to a hapten on a targetable construct, and wherein a targetable construct attached to at least one therapeutic agent is to be further administered.

25. The use of claim 24, wherein the antibody construct is a trimeric DNL (dock and lock) construct comprising two copies of a PAM4 antibody fragment moiety attached to one copy of a 679 antibody fragment moiety and the targetable construct comprises at least one HSG hapten.

26. The use of claim 10, wherein the antibody construct comprises a second antibody or antigen-binding fragment thereof that binds to a tumor-associated antigen (TAA).

27. The use of claim 26, wherein the second antibody is selected from the group consisting of CA19.9, DUPAN2, SPAN1, Nd2, B72.3, CC49, anti-Le^a antibodies, antibodies to other Lewis antigens such as Le(y), antibodies against carcinoembryonic antigen (CEA), CEACAM6, colon-specific antigen-p (CSAp), MUC-1, MUC-2, MUC-3, MUC-4, MUC-5ac, MUC-16, MUC-17, HLA-DR, CD40, CD74, CD-80, CD138, HER2/neu, EGFR, EGP-1, EGP-2, angiogenesis factors, VEGF, PlGF, insulin-like growth factor (ILGF), carbonic anhydrase IX, tenascin, platelet-derived growth factor, IL-6, oncogene products, bcl-2, Kras, p53, HER2/neu, cMET and antibodies against tumor necrosis substances.

28. An *in vitro* method of diagnosing pancreatic cancer comprising:

a) obtaining an antibody according to claim 1, wherein the antibody is either labeled with at least one diagnostic agent or the antibody is part of a bispecific antibody that binds to a targetable construct labeled with at least one diagnostic agent;

b) detecting the presence of antibody bound to pancreatic cancer cells in a sample suspected of containing pancreatic cancer cells that has been exposed to the antibody, wherein binding of antibody to the sample indicates the presence of pancreatic cancer.

29. The *in vitro* method of claim 28, wherein binding of antibody to the sample distinguishes the presence of pancreatic cancer from normal or benign pancreatic tissue in the sample.

30. The *in vitro* method of claim 28, wherein binding of antibody to the sample distinguishes the presence of pancreatic cancer from pancreatitis in the sample.

31. The method of claim 28, wherein binding of antibody to the sample is diagnostic of the presence of early stage pancreatic cancer in the sample.

32. The *in vitro* method of claim 28, wherein the antibody has been exposed to the sample *in vitro*.

33. The *in vitro* method of claim 28, wherein the sample is a serum sample and the method further comprises performing an organic phase extraction on the serum sample before the sample is exposed to the antibody.

34. The *in vitro* method of claim 33, wherein the organic phase is butanol.