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(57) **Abrégé/Abstract:**

Embodiments of the invention provide method and devices for predicting the likelihood of acute appendicitis without invasive exploratory medical procedures. Several protein biomarkers: leucine-rich α -2-glycoprotein (LRG); S100-A8 (calgranulin); α -1-acid glycoprotein 1 (ORM); plasminogen (PLG); mannan-binding lectin serine protease 2 (MASP2); zinc- α -2-glycoprotein (AZGP1); Apolipoprotein D (ApoD); and α -1-antichymotrypsin (SERPINA3); are increased in the urine of patients with appendicitis. The method and devices comprise detecting the levels of these biomarkers and comparing with reference levels found in healthy individuals.

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(57) Abstract: Embodiments of the invention provide method and devices for predicting the likelihood of acute appendicitis without invasive exploratory medical procedures. Several protein biomarkers: leucine-rich α -2-glycoprotein (LRG); S100-A8 (calgranulin); α -1-acid glycoprotein 1 (ORM); plasminogen (PLG); mannan-binding lectin serine protease 2 (MASP2); zinc- α -2-glycoprotein (AZGP1); Apolipoprotein D (ApoD); and α -1-antichymotrypsin (SERPINA3); are increased in the urine of patients with appendicitis. The method and devices comprise detecting the levels of these biomarkers and comparing with reference levels found in healthy individuals.



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METHOD OF PREDICTING ACUTE APPENDICITIS

BACKGROUND

[0001] Appendicitis is a condition characterized by inflammation of the appendix. All cases require removal of the inflamed appendix, either by laparotomy or laparoscopy. Untreated, mortality is high, mainly because of peritonitis and shock.

[0002] Appendicitis is among many human diseases, for which the diagnosis is complicated by the heterogeneity of its clinical presentation. Patients with many other disorders can present with symptoms similar to those of appendicitis. Examples include the following: pelvic inflammatory disease (PID) or tubo-ovarian abscess, Endometriosis, ovarian cyst or torsion, ureterolithiasis and renal colic, degenerating uterine leiomyomata, diverticulitis, Crohn's disease, colonic carcinoma, rectus sheath hematoma, cholecystitis, bacterial enteritis, mesenteric adenitis, and omental torsion.

[0003] It remains the most common surgical emergency of children, with initial diagnosis accuracy additionally challenged because of non-specific but similar symptoms of many other childhood conditions. Delays in accurate diagnosis lead to increased mortality, morbidity, and costs associated with the complications of appendicitis.

[0004] The use of high resolution computed tomography (CT) to identify appendiceal inflammation was hoped to improve both the diagnosis and treatment of acute appendicitis. Though variable, these improvements have been modest at best, with rates of unnecessary appendectomies and ruptures of 3-30 % and 30-45 %, respectively. In addition, availability of and experience with CT limit the usefulness of this approach. Furthermore, recently its use has been re-evaluated due to concerns of cancer risk.

[0005] Development of non invasive diagnostics are therefore needed and desirable.

SUMMARY OF THE INVENTION

[0006] The present invention generally relates to devices, kits and methods to determine acute appendicitis in a subject, such as a human subject. In particular, the inventors have discovered a set of appendicitis biomarkers which are present in a urine sample obtained from a

subject with acute appendicitis. As such, one aspect of the present invention provides devices, kits and methods to detect the presence of such appendicitis biomarkers in a urine sample from a subject, such as a human subject. In some embodiments, the device is in the format of a dipstick test, in particular, a lateral flow immunoassay.

[0007] In some embodiments, an appendicitis biomarker is leucine α -2 glycoprotein (LRG). In some embodiments, an appendicitis biomarker is mannan-binding lectin serine protease 2 (MASP2). In some embodiments, an appendicitis biomarker is α -1-acid glycoprotein 1 (ORM). In some embodiments, an appendicitis biomarker is selected from the groups selected from leucine-rich α -2-glycoprotein (LRG); S100-A8 (calgranulin); α -1-acid glycoprotein 1 (ORM); plasminogen (PLG); mannan-binding lectin serine protease 2 (MASP2); zinc- α -2-glycoprotein (AZGP1); apolipoprotein D (ApoD); and α -1-antichymotrypsin (SERPINA3). In some embodiments, an appendicitis biomarker is selected from at least 1, or at least about 2, or at least about 3, or at least about 4, or at least about 5, or more than 5 of any and all combinations of appendicitis biomarkers disclosed in Table 1.

[0008] One aspect of the present invention relates to a device for detecting at least one protein biomarker in a urine sample from a subject to identify if the subject is likely to have acute appendicitis, the device comprising: (a) at least one protein-binding agent which specifically binds to at least one biomarker protein selected from the group of: leucine α -2 glycoprotein (LRG), mannan-binding lectin serine protease 2 (MASP2), α -1-acid glycoprotein 1 (ORM); and (b) at least one solid support for the at least one protein binding-agent in (a), wherein the protein-binding agent is deposited on the solid support. In some embodiments, a protein-binding agent deposited on the solid support specifically binds the leucine α -2 glycoprotein (LRG) of SEQ ID NO: 1. In another embodiment, a protein-binding agent deposited on the solid support specifically binds to the polypeptide of α -1-acid glycoprotein 1 (ORM) of SEQ ID NO: 3. In another embodiment, a protein-binding agent deposited on the solid support specifically binds to the polypeptide of mannan-binding lectin serine protease 2 (MASP2) of SEQ ID NO: 5.

[0009] In some embodiment, the device is useful for detecting multiple appendicitis biomarkers, for example where the device further comprises at least one additional different protein-binding agent deposited on the solid support, wherein the additional protein-binding agent specifically binds to a biomarker protein selected from the group consisting of: leucine-rich α -2-glycoprotein (LRG); S100-A8 (calgranulin); α -1-acid glycoprotein 1 (ORM); plasminogen (PLG); mannan-binding lectin serine protease 2 (MASP2); zinc- α -2-glycoprotein (AZGP1); Apolipoprotein D (ApoD); and α -1-antichymotrypsin (SERPINA3).

[0010] In some embodiment, the device is useful for detecting multiple appendicitis biomarkers, for example where the device further comprises at least one additional different protein-binding agent deposited on the solid support, wherein the additional protein-binding agent specifically binds to a biomarker protein selected from the group consisting of: adipocyte specific adhesion molecule; AMBP; amyloid-like protein 2; angiotensin converting enzyme 2; BAZ1B; carbonic anhydrase 1; CD14; chromogranin A; FBLN7; FXR2; hemoglobin α ; hemoglobin β ; interleukin-1 receptor antagonist protein; inter- α -trypsin inhibitor; lipopolysaccharide binding protein; lymphatic vessel endothelial hyaluronan acid receptor 1; MLKL; nicastrin; novel protein (Accession No: IPI00550644); PDZK1 interacting protein 1; PRIC285; prostaglandin-H2 D-isomerase; Rcl; S100-A9; serum amyloid A protein; SLC13A3; SLC2A1; SLC2A2; SLC4A1; SLC9A3; SORBS1; SPRX2; supervillin; TGFbeta2R; TTYH3; VA0D1; vascular adhesion molecule 1; versican; VIP36; α -1-acid glycoprotein 2; β -1,3-galactosyltransferase, also disclosed in Table 1.

[0011] In some embodiments, the solid support of the device is in the format of a dipstick, a microfluidic chip or a cartridge. In some embodiments, the dipstick is a lateral flow immunoassay test strip. In some embodiments, a single test strip tests for one appendicitis biomarker, such as LRG or ORM or S100-A8. In other embodiments, a single test strip test for several appendicitis biomarkers, for example, a single test strip test for all three appendicitis biomarkers: LRG, ORM and S100-A8; or a single test strip test for two appendicitis biomarkers: LRG and ORM; LRG and S100-A8; or ORM and S100-A8.

[0012] In some embodiments, a protein-binding agent is an antibody, antibody fragment, aptamer, small molecule or variant or fragment thereof. In some embodiments, a subject is a mammalian subject such as a human subject. In some embodiments, a subject with at least one symptom of appendicitis, as disclosed herein.

[0013] In some embodiments, a protein-binding agent deposited on the device specifically binds to the specific appendicitis biomarker protein when the level of the appendicitis biomarker protein is at least 2-fold above a reference level for that appendicitis biomarker protein. Typically, a reference level for a particular appendicitis biomarker is an average level of the appendicitis biomarker protein in a plurality of urine samples from a population of healthy humans not having acute appendicitis.

[0014] Another aspect of the present invention relates to the use of a device as disclosed herein to identify if a subject has acute appendicitis, wherein if at least one biomarker specifically binds to at least one protein-binding agent, the subject is likely to have acute appendicitis.

[0015] Another aspect of the present invention provides a kit, where the kit comprises (a) a device as disclosed herein, and (b) a first agent, wherein the first agent produces a detectable signal in the presence of a protein-binding agent which deposited on the device is specifically bound to a biomarker protein. In some embodiments, a kit optionally further comprises a second agent, wherein the second agent produces a different detectable signal in the presence of a second protein-binding agent deposited on the device which is specifically bound to a second biomarker protein.

[0016] Another aspect of the present invention relates to a method to identify the likelihood of a subject to have acute appendicitis comprising: (a) measuring the level of at least one appendicitis biomarker protein selected from the group listed in Table 1 in a urine sample from the human subject; (b) comparing the level of the at least one biomarker protein measured in step (a) to a reference level for the measured appendicitis biomarker, where if the level of a measured appendicitis biomarker is at least 2-fold increased than the reference level for the particular appendicitis biomarker measured, it identifies that the subject is likely to have acute appendicitis. In some embodiments, the method can be used to guide a clinician to direct an appropriate therapy to a subject which is identified to have acute appendicitis.

[0017] In some embodiments, the method further comprises determining the level of albumin in the urine sample from the human subject. In some embodiments, the subject is a human subject and the human subject has exhibited at least one symptom of acute appendicitis.

[0018] In some embodiments, the method comprises measuring an appendicitis biomarker level by any method known by one of ordinary skill in the art, such as for example with the use of an immunoassay or an automated immunoassay, or a dipstick test, as disclosed herein. In some embodiments, the method comprises measuring the level of the appendicitis biomarker leucine α -2 glycoprotein (LRG). In some embodiments, the method comprises measuring the level of the appendicitis biomarker α -1-acid glycoprotein 1 (ORM). In some embodiments, the method comprises measuring the level of the appendicitis biomarker mannan-binding lectin serine protease 2 (MASP2).

[0019] In some embodiments, the method comprises measuring the level of at least one the appendicitis biomarker selected from a group consisting of leucine α -2 glycoprotein (LRG), calgranulin A (S100-A8), α -1-acid glycoprotein 1 (ORM), plasminogen (PLG), mannan-binding lectin serine protease 2 (MASP2), zinc- α -2-glycoprotein (AZGP1), α -1-antichymotrypsin (SERPINA3) and apolipoprotein D (ApoD).

[0020] In some embodiments, the reference level in the method is a level of the particular appendicitis biomarker measured in a urine sample of a healthy human not having

acute appendicitis. In some embodiments, the reference level is an average level of the appendicitis biomarker in a plurality of urine samples from a population of healthy humans not having acute appendicitis. In some embodiments, the reference level is a normalized level of the appendicitis biomarker in a urine sample of a healthy human not having acute appendicitis, wherein the normalization is performed against the level of albumin in the urine sample of a healthy human not having acute appendicitis.

[0021] In some embodiments, the method comprises measuring the level of at least one the appendicitis biomarker in a urine sample is collected in mid-stream. In some embodiments, the method comprises measuring the level of at least one the appendicitis biomarker by depositing the urine sample from the subject on a device, such as a test strip or dipstick device, as disclosed herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] Figure 1 is a representative SDS-PAGE separation of 17,000 g, 210,000 g, and TCA fractions of three urine specimens (1, 2, 3) demonstrating small differences in total protein abundance among different urine specimens, and preferential fractionation of albumin (●) and uromodulin (►) in the 17,000 g fraction, enabling improved detection of the remaining urinary proteins. The majority of albumin and uromodulin appears to sediment at 17,000 g, demonstrating that they exist in high molecular weight complexes, consistent with uromodulin's ability to polymerize in urine.

[0023] Figures 2A-2B show representative mass spectra. Fig 2A is the relative ion intensity as a function of m/z values of precursor ions (MS), with the doubly charged peptide LDITAEILAVR from plunc labeled by arrow, and Fig 2B is the fragmentation spectrum with fragment ions labeled as y- and b-series fragment ions (MS/MS).

[0024] Figures 3A-3B shows the apparent mass accuracy error of the LTQ-Orbitrap. Fig 3A is a cumulative probability graph of the mass accuracy error, and Fig 3B is the histogram of the LTQ-Orbitrap mass accuracy error, as assessed by comparison of observed masses of the trypsin autolysis peptide VATVSLPR, as compared to its expected monoisotopic mass, indicating that most peptides have apparent mass errors of less than 2 ppm.

[0025] Figure 4 is a venn diagram showing the comparisons of the observed aggregate urine proteome with those published by Adachi *et al* [13], and Pisitkun *et al* [10], demonstrating high concordance with the previous studies of human urine, as well as discovery of not previously observed proteins.

[0026] Figure 5 is a histogram showing the variability in the composition of individual urine proteomes, as assessed by the coefficients of variation of their proteins' spectral counts, demonstrating a broad distribution, including proteins that are relatively invariant (A: Albumin, cubilin, megalin), and those that appear to vary among individual proteomes (B: α 1-anti-trypsin, fibrinogen, α 2-macroglobulin).

[0027] Figure 6 is a scatter plot showing the relative enrichment of appendicitis protein biomarkers as a function of appendicitis tissue overexpression of the corresponding genes, demonstrating that more than 50 % of markers with tissue overexpression exhibit urine enrichment ($\square$), but that only 3 of these ($\blacksquare$) were identified as markers by urine proteome profiling.

[0028] Figure 7 is a flow diagram showing an experimental scheme, outlining methods used for protein capture and fractionation, of the identification and discovery of appendicitis biomarkers using urine proteomics, and the validation of appendicitis diagnostic biomarkers.

[0029] Figure 8 is a boxplot showing the relative urine protein abundance (logarithm normalized ion current units) of the validated diagnostic markers for the non-appendicitis (open) and appendicitis (hatched) patient groups. Normalized value of 1 corresponds to the apparent abundance of internal reference standard. Boxes contain the 25-75 % interquartile range, with the dividing bars representing means, whiskers representing 10-90 % range, and crosses representing 1-99 % range. Square symbols represent medians. Abundance of LRG in patients with pyelonephritis (solid dot, $\bullet$) and those who underwent appendectomies with findings of histologically normal appendices (open dot, $\circ$).

[0030] Figures 9A-9B show validation of selected appendicitis biomarkers. Fig 9A shows receiver operating characteristics of appendicitis protein biomarkers from urine validated by target mass spectrometry, demonstrating the relative diagnostic performance of leucine-rich α -2-glycoprotein (LRG), calgranulin A (S100-A8), α -1-acid glycoprotein 1 (ORM), and apolipoprotein D (ApoD). Fig 9B shows the enrichment of LRG in a random sample of urine of patients with histologically proven appendicitis (+) as compared to those without (-) by using Western immunoblotting. LRG signal was observed in 5/5 patients with appendicitis and no signal was observed in 5/6 patients without appendicitis.

[0031] Figures 10A-10B show clinical validation of selected appendicitis biomarkers. Fig 10A is a boxplot showing the relative appendicitis protein biomarker abundance (normalized ion current units) of leucine-rich α -2-glycoprotein (LRG) (top panel) and calgranulin A (S100-A8) (bottom panel) as a function of appendicitis severity, as assessed using histologic classification. Note that the group with histologically normal appendices includes both patients who underwent appendectomies and patients without clinical diagnosis of appendicitis. Figure 10B shows

representative micrographs of appendectomy specimens and immunohistochemistry staining against LRG, demonstrating increased LRG signal in appendectomy specimens with more severe grade of appendicitis.

[0032] Figure 11A (top view) and 11B (side view) shows the schematic diagrams of an exemplary lateral flow immunoassay (LFIA) dipstick test strip for determining that the level of an appendicitis biomarker protein in urine is greater than (or increased as compared to) a predetermined reference level.

[0033] Figure 12A-D are schematic diagrams of the top views of exemplary LFIA dipstick test strips shown in Fig 11, showing the different results that can be obtained using the simple test strip shown in Figure 11.

[0034] Figure 13 shows a schematic diagram of how the levels of three biomarker proteins can be determined simultaneously using three independent LFIA test strips, one test strip for a different biomarker protein. A diagnostic kit can comprise several LFIA test strips, one strip for a different biomarker protein.

[0035] Figure 14 shows a schematic diagram of how the levels of three biomarker proteins are determined simultaneously on the same LFIA test strip. A diagnostic kit can comprise a single composite or multiplex LFIA test strip for determining the levels of several biomarker proteins simultaneously. The single composite test strip has three distinct protein binding agent specific respectively for three appendicitis biomarker proteins.

[0036] Figure 15A-D are schematic diagrams of an alternative embodiment of an exemplary LFIA dipstick test strip shown in Fig 11 for determining whether the level of a biomarker protein in a fluid sample is above or below a reference/control value for that biomarker and the interpretation of the results obtained. Two different anti-biomarker antibodies are used on the test strip.

[0037] Figure 16A (top view) and 16B (side view) shows a schematic diagram of an alternative embodiment of a LFIA test strip for determining the level of a biomarker protein in a fluid sample and comparing the determined level with a reference value. S, T, C definition are as in Figure 11.

[0038] Figure 17A-F are schematic diagrams showing the different results that can be obtained using the LFIA test strip shown in Figure 16.

[0039] Figure 18 shows a schematic diagram of an alternative version on how the levels of four biomarker proteins can be determined simultaneously using four separate LFIA test strips, one test strip for a different biomarker protein. A diagnostic kit can comprise multiple LFIA test strips, one strip for a different biomarker protein.

[0040] Figure 19 shows a schematic diagram of an alternative version how the levels of three biomarker proteins are determined simultaneously on the same LFIA test strip. A diagnostic kit can comprise a single composite LFIA test strip for determining the levels of several biomarker proteins.

DETAILED DESCRIPTION OF THE INVENTION

[0041] Embodiments of the present invention are based on the discovery of eight biomarkers whose increase in urinary concentration correlate accurately with acute appendicitis. These eight biomarkers are leucine-rich α 2-glycoprotein (LRG), calgranulin A (S100-A8), α -1-acid glycoprotein 1 (orosomucoid) (ORM), plasminogen (PLG), mannan-binding lectin serine protease 2 (MASP2), zinc- α -2-glycoprotein (AZGP1), α -1-antichymotrypsin (SERPINA3) and apolipoprotein D (ApoD). These appendicitis biomarker proteins have been confirmed by Western immunoblotting (Example 2, Fig. 9 and 10) and further validated by target mass spectrometry (Example 2).

[0042] Accordingly, in some embodiments, these biomarkers can be used as indicators of acute appendicitis. By simply measuring the levels of these biomarkers in a urine sample from an individual having some symptoms of acute appendicitis or that is suspected of having acute appendicitis, a physician can quickly make a diagnosis and administer appropriate medical treatment in a timely manner. When the levels of these biomarkers in an individual is greater than the reference level or reference value of the respective biomarkers, at least one order of magnitude greater than that found in healthy individual not having acute appendicitis, it is indicative that the individual is indeed having acute appendicitis.

[0043] In one embodiment, a subject or individual is a mammalian subject, such as a human.

[0044] Non-limiting symptoms of acute appendicitis include pain starting centrally (periumbilical) before localizing to the right iliac fossa (the lower right side of the abdomen); loss of appetite and fever; nausea or vomiting; the feeling of drowsiness; the feeling of general bad health; pain beginning and staying in the right iliac fossa, diarrhea and a more prolonged, smoldering course; increased frequency of urination; marked retching; tenesmus or "downward urge" (the feeling that a bowel movement will relieve discomfort); positive Rovsing's sign, Psoas sign, and/or Obturator sign.

[0045] In one embodiment, the invention provides a kit for predicting acute appendicitis in a human comprising an indicator or device that is responsive to a level of at least one biomarker in a sample of urine from a human upon contact with the sample of urine, wherein the

appendicitis biomarker protein in a sample of urine is selected from a group consisting of leucine α -2 glycoprotein (LRG), calgranulin A (S100-A8), α -1-acid glycoprotein 1 (ORM), plasminogen (PLG), mannan-binding lectin serine protease 2 (MASP2), zinc- α -2-glycoprotein (AZGP1), α -1-antichymotrypsin (SERPINA3) and apolipoprotein D (ApoD), and wherein the indicator provides a positive test result when the appendicitis biomarker level exceeds a reference value.

[0046] In some embodiments, the present invention provides a kit or device for predicting acute appendicitis in a subject, (e.g. a human subject) that are responsive to at least one marker selected from the list of appendicitis biomarkers listed in Table 1. In one embodiment, the kit or device for predicting acute appendicitis in a subject is responsive to leucine α -2 glycoprotein (LRG). In one embodiment, the kit or device for predicting acute appendicitis in a subject, is responsive to leucine α -2 glycoprotein (LRG) and at least one marker selected from α -1-acid glycoprotein 1 (ORM), and/or mannan-binding lectin serine protease 2 (MASP2). In some embodiments, the kit or device for predicting acute appendicitis in a subject, is responsive to leucine α -2 glycoprotein (LRG) and at least one marker selected from the group consisting of calgranulin A (S100-A8), α -1-acid glycoprotein 1 (ORM), plasminogen (PLG), mannan-binding lectin serine protease 2 (MASP2), zinc- α -2-glycoprotein (AZGP1), α -1-antichymotrypsin (SERPINA3) and apolipoprotein D (ApoD). As used herein, the term “responsive” refers to the ability to detect the level of an appendicitis biomarkers of interest in a urine sample.

[0047] In another embodiment, the kit or device for predicting acute appendicitis in a subject, is responsive to leucine α -2 glycoprotein (LRG) and at least 1, or at least 2 or at least 3, or at least 4 or at least 5, or at least 6, or at least 7, or at least 8, or at least 9, or at least 10 other marker(s), in all and any combination, selected from the group consisting of the list of biomarkers listed in Table 1. In another embodiment, the kit or device for predicting acute appendicitis in a subject, is responsive to leucine α -2 glycoprotein (LRG) and at least one marker selected from the group consisting of adipocyte specific adhesion molecule; AMBP; amyloid-like protein 2; angiotensin converting enzyme 2; BAZ1B; carbonic anhydrase 1; CD14; chromogranin A; FBLN7; FXR2; hemoglobin α ; hemoglobin β ; interleukin-1 receptor antagonist protein; inter- α -trypsin inhibitor; lipopolysaccharide binding protein; lymphatic vessel endothelial hyaluronan acid receptor 1; MLKL; nicastrin; novel protein (Accession No: IPI00550644); PDZK1 interacting protein 1; PRIC285; prostaglandin-H2 D-isomerase; Rcl; S100-A9; serum amyloid A protein; SLC13A3; SLC2A1; SLC2A2; SLC4A1; SLC9A3;

SORBS1; SPRX2; supervillin; TGFbeta2R; TTYH3; VA0D1; vascular adhesion molecule 1; versican; VIP36; α -1-acid glycoprotein 2; and β -1,3-galactosyltransferase.

[0048] In one embodiment, the indicator is in the form of a test strip such as a dipstick. In one embodiment, the test strip is a lateral flow immunoassay (LFIA). In one embodiment, the test strip is a double sandwich LFIA. In another embodiment, test strip is a competitive LFIA.

[0049] In one embodiment, the reference value is an average level of the appendicitis biomarker in urine samples from a population of healthy humans not having acute appendicitis. In some embodiments, healthy humans not having acute appendicitis do not exhibit any symptom associated with acute appendicitis as disclosed herein.

[0050] In one embodiment, the responsiveness of the indicator of the kit is by way of an immunoassay. In one embodiment, the immunoassay is a lateral flow immunoassay test, also known as the immunochromatographic assay, or strip test.

[0051] In one embodiment, the invention provides a method of predicting acute appendicitis in a human comprising the steps of: (a) determining the level of at least one biomarker protein in a sample of urine from the human; and comparing the level of step (a) to a reference value to determine whether the human is suffering from acute appendicitis.

[0052] In one embodiment, the invention further comprises determining the level of albumin in the sample of urine from the human.

[0053] In one embodiment, the sample of urine is collected by the human.

[0054] In one embodiment, the human exhibits at least one symptom of acute appendicitis described herein.

[0055] In one embodiment, the human had an inconclusive CT to determine inflammation of the appendix.

[0056] In one embodiment, the human did not have a CT to determine inflammation of the appendix.

[0057] In one embodiment, the determination of the appendicitis biomarker level is completed with the use of an immunoassay. In some embodiments, the immunoassay is a lateral flow immunoassay test, also known as the immunochromatographic assay, or strip test. In some embodiments, the lateral flow immunoassay is a double antibody sandwich assay, a competitive assay, a quantitative assay or variations thereof.

[0058] In one embodiment, the appendicitis biomarker protein is leucine α -2 glycoprotein (LRG). In one embodiment, the appendicitis biomarker protein is selected from a group consisting of leucine α -2 glycoprotein (LRG), calgranulin A (S100-A8), α -1-acid glycoprotein 1 (ORM), plasminogen (PLG), mannan-binding lectin serine protease 2 (MASP2), zinc- α -2-glycoprotein (AZGP1), α -1-antichymotrypsin (SERPINA3) and apolipoprotein D

(ApoD). In another embodiment, the appendicitis biomarker is selected from the group of biomarkers selected from any of those listed in Table 1.

[0059] In other embodiments, for the method and kit or devices, various combinations of appendicitis biomarkers can be selected. For examples: LRG and S100-8A; LRG and ORM; ORM and S100-A8, LRG and PLG; LRG and MASP2; LRG and AZGP1; LRG and SERPINA3; LRG and ApoD; LRG, MASP2 and ORM; ORM and MASP2, LRG, S100-A8 and ORM; LRG, ORM and PLG; LRG, ORM and ApoD; LRG, S100-A8, and PLG; LRG, S100-A8, and ApoD; LRG, S100-A8, ORM and SERPINA3; LRG, S100-8A and SERPINA3; LRG, SERPINA3 and AZGP1; LRG, SERPINA3 and Apo D and so forth.

[0060] In one embodiment, the method of predicting acute appendicitis in a human comprises the step of determining the level of leucine-rich α -2-glycoprotein (LRG) in a sample of urine from the human.

[0061] In one embodiment, the method of predicting acute appendicitis in a human comprises the step of determining the levels of LRG and S100-A8 (calgranulin) in a sample of urine from the human.

[0062] In one embodiment, the method of predicting acute appendicitis in a human comprises the step of determining the levels of LRG and α -1-acid glycoprotein 1 (ORM) in a sample of urine from the human.

[0063] In one embodiment, the method of predicting acute appendicitis in a human comprises the step of determining the levels of LRG and plasminogen (PLG) in a sample of urine from the human.

[0064] In one embodiment, the method of predicting acute appendicitis in a human comprises the step of determining the levels of LRG and mannan-binding lectin serine protease 2 (MASP2) in a sample of urine from the human.

[0065] In one embodiment, the method of predicting acute appendicitis in a human comprises the step of determining the levels of LRG and zinc- α -2-glycoprotein (AZGP1) in a sample of urine from the human.

[0066] In one embodiment, the method of predicting acute appendicitis in a human comprises the step of determining the levels of LRG and apolipoprotein D (ApoD) in a sample of urine from the human.

[0067] In one embodiment, the method of predicting acute appendicitis in a human comprises the step of determining the levels of ORM and S100-A8 in a sample of urine from the human.

[0068] In one embodiment, the method of predicting acute appendicitis in a human comprises the step of determining the levels of LRG, ORM and S100-A8 in a sample of urine from the human.

[0069] In one embodiment, the method of predicting acute appendicitis in a human comprises the step of determining the levels of LRG and α -1-antichymotrypsin (SERPINA3) in a sample of urine from the human.

[0070] *Table 1.* List of appendicitis biomarkers for use in the kits, devices and methods as disclosed herein for predicting acute appendicitis in the subject, for example a human subject. The SEQ ID NO refers to the amino acid sequence encoding the protein biomarker, and are incorporated herein by reference.

Protein biomarker	Accession no	SEQ ID
Leucine-rich α-2-glycoprotein (LRG)	IPI00022417	1
S100-A8 (calgranulin)	IPI00007047	2
α-1-acid glycoprotein 1 (ORM)	IPI00022429	3
Plasminogen	IPI00019580	4
Mannan-binding lectin serine protease 2 (MASP2)	IPI00306378	5
Zinc- α-2-glycoprotein (AZGP1)	IPI00166729	6
Apolipoprotein D (ApoD)	IPI00006662	7
α-1-antichymotrypsin (SERPINA3)	IPI00550991	8
Adipocyte specific adhesion molecule	IPI00024929	9
AMBP	IPI00022426	10
Amyloid-like protein 2	IPI00031030	11
Angiotensin converting enzyme 2	IPI00465187	12
BAZ1B	IPI00216695	13
Carbonic anhydrase 1	IPI00215983	14
CD14	IPI00029260	15
chromogranin A	IPI00383975	16
FBLN7	IPI00167710	17
FXR2	IPI00016250	18
Hemoglobin α	IPI00410714	19
Hemoglobin β	IPI00654755	20
Interleukin-1 receptor antagonist protein	IPI00000045	21
Inter- α -trypsin inhibitor	IPI00218192	22
Lipopolysaccharide binding protein	IPI00032311	23
Lymphatic vessel endothelial hyaluronan acid receptor 1	IPI00290856	24
MLKL	IPI00180781	25
Nicastrin	IPI00021983	26
Novel protein	IPI00550644	27
PDZK1 interacting protein 1	IPI00011858	28
PRIC285	IPI00249305	29
Prostaglandin-H2 D-isomerase	IPI00013179	30
Rcl	IPI00007926	31
S100-A9	IPI00027462	32
Serum amyloid A protein	IPI00552578	33

Protein biomarker	Accession no	SEQ ID
SLC13A3	IPI00103426	34
SLC2A1	IPI00220194	35
SLC2A2	IPI00003905	36
SLC4A1	IPI00022361	37
SLC9A3	IPI00011184	38
SORBS1	IPI00002491	39
SPRX2	IPI00004446	40
Supervillin	IPI00412650	41
TGFbeta2R	IPI00383479	42
TTYH3	IPI00749429	43
VA0D1	IPI00034159	44
Vascular adhesion molecule 1	IPI00018136	45
Versican	IPI00009802	46
VIP36	IPI00009950	47
α -1-acid glycoprotein 2	IPI00020091	48
β -1,3-galactosyltransferase	IPI00032034	49

[0071] In one embodiment, the reference level or reference value is a level of a appendicitis biomarker in a urine sample of a healthy human not having acute appendicitis, or not having been diagnosed with acute appendicitis. A healthy human is any person who exhibits no symptom which commonly known to be associated with acute appendicitis as described herein. In another embodiment, the reference value is an average level of the appendicitis biomarker in a plurality of urine samples from a population of healthy humans not having acute appendicitis or not having been diagnosed with acute appendicitis. A population of healthy subjects that have not been diagnosed with acute appendicitis is at least five healthy humans, at least 10 healthy humans, preferably 20 or more healthy humans. The average urine level of an appendicitis biomarker can be obtained by taking the sum of the level of an appendicitis biomarker from a number of humans divided by the number of humans.

[0072] In one embodiment, the reference level or reference value is a normalized level of the appendicitis biomarker in a urine sample of a healthy human not having acute appendicitis, wherein the normalization is performed against the level of albumin in the urine sample of a healthy human not having acute appendicitis, or not having been diagnosed with acute appendicitis. The normalized reference value for leucine α -2 glycoprotein (LRG), calgranulin A (S100-A8), α -1-acid glycoprotein 1 (ORM), plasminogen (PLG), mannan-binding lectin serine protease 2 (MASP2), Zinc- α -2-glycoprotein (AZGP1), α -1-antichymotrypsin (SERPINA3) and apolipoprotein D (ApoD) is 0.001. When the normalized value for any of the described biomarker from a human is at least one order of magnitude greater than the normalized reference value, i. e. 0.01 and greater, this is indicative that the human has acute appendicitis.

[0073] In one embodiment, the urine sample is collected in mid-stream.

[0074] In one embodiment, the urine sample is obtained by depositing the urine on to a test strip. In one embodiment, the test strip is a lateral flow immunoassay test, also known as the immunochromatographic assay. In some embodiments, the lateral flow immunoassay is a double antibody sandwich assay, a competitive assay, a quantitative assay or variations thereof (See Figs. 11-19).

Appendicitis biomarker proteins

[0075] As discussed herein, in some embodiments, the present invention provides kits or devices for predicting acute appendicitis in a subject, for example, a human subject that is responsive to at least one appendicitis biomarker selected from the list of appendicitis biomarkers listed in Table 1. In one embodiment, the kit or device for predicting acute appendicitis in a subject is responsive to leucine α -2 glycoprotein (LRG). In one embodiment, the kit or device for predicting acute appendicitis in a subject, is responsive to leucine α -2 glycoprotein (LRG) and at least one marker selected from α -1-acid glycoprotein 1 (ORM), and/or mannan-binding lectin serine protease 2 (MASP2).

[0076] **LRG:** leucine-rich alpha-2-glycoprotein 1 (LRG) is also known in the art as LRG; HMFT1766; LRG1. The leucine-rich repeat (LRR) family of proteins, including LRG1, has been shown to be involved in protein-protein interaction, signal transduction, and cell adhesion and development. LRG1 is expressed during granulocyte differentiation.

[0077] In some embodiments, LRG can be detected in the methods, kits and devices using commercially available assay kits, e. g., from Immuno-Biological Laboratories, Inc., Human LRG Assay Kit, catalog number 27769. LRG can also be detected using the kits as disclosed in US patent application serial No 11/627,164 filed January 25, 2007, and provisional patent application 60/761,808 filed January 25, 2006, which are incorporated herein in their entirety by reference.

[0078] Commercial polyclonal and monoclonal antibodies against LRG are also useful as protein-binding agents to LRG and are available from a variety of companies, e. g., but not limited to Assay Designs, SIGMA-ALDRICH and Novus Biologicals.

[0079] Antibodies or protein binding agents which recognize and specifically bind the LRG1 protein of SEQ ID NO: 1, the sequence of which is reproduced below, can be readily produced by one of ordinary skill in the art and are useful for the methods, kits and devices as disclosed herein. SEQ ID NO: 1 is the polypeptide sequence for LRG (Leucine-rich alpha-2-glycoprotein) and has the amino acid sequence as follows:

MSSWSRQRPKSPGGIQPHVSRTLFLLLLLAASAWGVTLSPKDCQVFRSDHGSSISCQPPAEIPG
 YLPADTVHLAVEFFNLTHLPANLLQGASKLQELHLSSNGLESLSPEFLRPVPQLRVLDLTRNAL
 TGLPPGLFQASATLDTLVLKENQLEVLEVSWLHGLKALGHLDLSGNRLRKLPPGLLANFTLLRT
 LDLGENQLETLPPDLLRGPLQLERLHLEGNKLQVLGKDLLLPQPDRLYLFLNGNKLARVAAGAF
 QGLRQLDMLDLSNNSLASVPEGLWASLGQPNWDMRDGFDISGNPWICDQNLSDLYRWLQAQKDK
 MFSQNDTRCAGPEAVKGQTLLAVAKSQ

[0080] **S100A8:** S100A8 is also known in the art as synonyms 60B8AG; CAGA; CFAG; CGLA; CP-10; L1Ag; MA387; MIF; Migration inhibitory factor-related protein 8 (MRP8); NIF; OTTHUMP00000015329; OTTHUMP00000015330; P8; S100 calcium-binding protein A8; S100 calcium-binding protein A8 (calgranulin A); S100A8; calgranulin A; cystic fibrosis antigen.

[0081] Without wishing to be bound by theory, S100 calcium binding protein A8 (S100 A8), also known as migration inhibitory factor-related protein (MRP-8) belongs to the S-100 family of calcium binding proteins associated with myeloid cell differentiation. They are highly expressed in resting neutrophils, keratinocytes (particularly in psoriasis), in infiltrating tissue macrophages and on epithelial cells in active inflammatory disease. The heterogeneity of macrophage subpopulations in chronic or acute inflammation is reflected by different expression of MRP8 and migration inhibitory factor-related proteins-14 (MRP14). Phagocytes expressing MRP8 and MRP14 belong to the early infiltrating cells, while MRP8 alone is found in chronic inflammatory tissues. The partially antagonistic functions of MRP8, MRP14 and of the Ca^{2+} -dependent MRP8/14 heterocomplex makes them versatile mediators.

[0082] Human S100A8 (MRP8) has a molecular weight of 11.0kD, while human MRP14 exists in a 13.3kD and a truncated 12.9kD form. Ca^{2+} induces the formation of heterocomplexes of the form (MRP8)(MRP14) (abbreviated MRP8/14), (MRP8)₂(MRP14), and (MRP8/14)₂. There are two EF-hand motifs each on MRP8 and MRP14. MRP14 shows a higher affinity for calcium than MRP8, and the affinity of the C terminal EF2 is higher than that of the N-terminal EF1. The C-terminal domain also mainly determines the specificity of dimerization. The helix in EF2 undergoes a large conformational change upon calcium binding and may play a role as a trigger for Ca^{2+} induced conformational change.

[0083] In some embodiments, S100A8 can be detected in the methods, kits and devices using commercial assays, such as, but without limitation, S100A8 assay kits from R & D Systems's Human MIF QUANTIKINE[®] ELISA Kit · Catalog number: DMF00; and BMA Biomedicals, MRP8 Enzyme Immunoassay Product Code: S-1007. S100A8 can also be detected using the kits as disclosed in US Patent 7,501,256 and WO/2006/012588 which is incorporated herein in its entirety by reference.

[0084] In some embodiments, commercial polyclonal and monoclonal antibodies against S100A8 are also useful as protein-binding agents to S100A8 and are available from a variety of companies, e. g. , but not limited to commercial polyclonal and monoclonal antibodies against S100A8 are available from a variety of companies, e. g. Assay Designs, SIGMA-ALDRICH, R & D Systems, Novus Biologicals and Santa Cruz Biotechnology.

[0085] Antibodies or protein binding agents which recognize and specifically bind the S100 A8 protein of SEQ ID NO: 2, the sequence of which is reproduced below, can be readily produced by one of ordinary skill in the art and are useful for the methods, kits and devices as disclosed herein.

SEQ ID NO: 2 is the polypeptide sequence for S100 A8 and has the amino acid sequence as follows:

MLTELEKALNSIIDVYHKYSLIKGNFHAVYRDDLLKKLLETCPQYIRKKGADVWFKELD
INTDGAVNFQEFLILVIKMGVAAHKKKSHEESHKE

[0086] *ORM*: alpha-1-acid-glycoprotein 1 (ORM) is also known in the art as orosomucoid 1, AGP1; AGP-A; ORM1. This gene encodes a key acute phase plasma protein. Because of its increase due to acute inflammation, this protein is classified as an acute-phase reactant. The specific function of this protein has not yet been determined; however, it may be involved in aspects of immunosuppression.

[0087] In some embodiments, ORM can be detected in the methods, kits and devices using commercial assays, such as, but without limitation, Human Orosomucoid ELISA Quantitation Kit from GenWay Biotech, Inc. catalog No. 40-288-22927F.

[0088] In some embodiments, commercial polyclonal and monoclonal antibodies against ORM are also useful as protein-binding agents to ORM and are available from a variety of companies, e. g., but not limited to Assay Designs, SIGMA-ALDRICH, Novus Biologicals, Lifespan Biosciences, R & D Systems, and Santa Cruz Biotechnology

[0089] Antibodies or protein binding agents which recognize and specifically bind the ORM protein of SEQ ID NO: 3, the sequence of which is reproduced below, can be readily produced by one of ordinary skill in the art and are useful for the methods, kits and devices as disclosed herein.

SEQ ID NO: 3 is the polypeptide sequence for ORM and has the amino acid sequence as follows:

MALSWVLTVLSSLPLLEAQIPLCANLVPVPITNATLDQITGKWFYIASAFRNEEYNKSVQEIQ
ATFFYFTPNKTEDTIFLREYQTRQDQCIYNTTYLNVQRENGTISRIVGGQEHFAHLLILRDTKTY
MLAFDVNDEKNWGLSVYADKPETTKEQLGEFYEALDCLRIPKSDVVYTDWKKDKCEPLEKQHEK
ERKQEEGES

[0090] *Plasminogen (PLG)*: Plasminogen, is also known in the art as PLG or DKFZp779M0222 and is a circulating zymogen that is converted to the active enzyme plasmin by cleavage of the peptide bond between arg560 and val561, which is mediated by urokinase (PLAU; MIM 191840) and tissue plasminogen activator (PLAT; MIM 173370). The main function of plasmin is to dissolve fibrin (see, e.g., FGA, MIM 134820) clots. Plasmin, like trypsin, belongs to the family of serine proteinases.

[0091] In some embodiments, PLG can be detected in the methods, kits and devices using commercial assays, such as, but without limitation, commercial assay kits from Human Plasminogen ELISA Kit from Alpco Diagnostics 41-PLAHU-E01; Human Plasminogen ELISA Kit from AMERICAN DIAGNOSTICA, 640; Plasminogen Colorimetric Assay Kit from AMERICAN DIAGNOSTICA, 851; Human Plasminogen total antigen ELISA Assay Kit from Innovative Research, IHPLGKT-TOT. PLG can also be detected using the kits as disclosed in International Patent Application WO/1991/005257 and European Patent Application EP1990914430 which is incorporated herein in its entirety by reference.

[0092] In some embodiments, commercial polyclonal and monoclonal antibodies against PLG are also useful as protein-binding agents to PLG and are available from a variety of companies, e. g. , but not limited to Rockland, Abcam, Assay Designs, EMD Biosciences, SIGMA-ALDRICH, Novus Biologicals, Lifespan Biosciences, R & D Systems, and Santa Cruz Biotechnology.

[0093] Antibodies or protein binding agents which recognize and specifically bind the PLG protein of SEQ ID NO: 4, the sequence of which is reproduced below, can be readily produced by one of ordinary skill in the art and are useful for the methods, kits and devices as disclosed herein.

SEQ ID NO: 4 is the polypeptide sequence for PLG and has the amino acid sequence as follows:

MEHKEVVL L L L L L F L K S G Q G E P L D D Y V N T Q G A S L F S V T K K Q L G A G S I E E C A A K C E E D E E F T C R A F
Q Y H S K E Q Q C V I M A E N R K S S I I I R M R D V V L F E K K V Y L S E C K T G N G K N Y R G T M S K T K N G I T C Q K W S
S T S P H R P R F S P A T H P S E G L E E N Y C R N P D N D P Q G P W C Y T T D P E K R Y D Y C D I L E C E E E C M H C S G E N
Y D G K I S K T M S G L E C Q A W D S Q S P H A H G Y I P S K F P N K N L K K N Y C R N P D R E L R P W C F T T D P N K R W E L
C D I P R C T T P P P S S G P T Y Q C L K G T G E N Y R G N V A V T V S G H T C Q H W S A Q T P H T H N R T P E N F P C K N L D
E N Y C R N P D G K R A P W C H T T N S Q V R W E Y C K I P S C D S S P V S T E Q L A P T A P P E L T P V V Q D C Y H G D G Q S
Y R G T S S T T T T G K K C Q S W S S M T P H R H Q K T P E N Y P N A G L T M N Y C R N P D A D K G P W C F T T D P S V R W E Y
C N L K K C S G T E A S V V A P P P V V L L P D V E T P S E E D C M F G N G K G Y R G K R A T T V T G T P C Q D W A A Q E P H R
H S I F T P E T N P R A G L E K N Y C R N P D G D V G G P W C Y T T N P R K L Y D Y C D V P Q C A A P S F D C G K P Q V E P K K
C P G R V V G G C V A H P H S W P W Q V S L R T R F G M H F C G G T L I S P E W V L T A A H C L E K S P R P S S Y K V I L G A H
Q E V N L E P H V Q E I E V S R L F L E P T R K D I A L L K L S S P A V I T D K V I P A C L P S P N Y V V A D R T E C F I T G W

GETQGTFGAGLLKEAQLPVIENKVCNRYEFLNGRVQSTELCAGHLAGGTDSCQGDSSGGPLVCFE
KDKYIILQGVTSWGLGCARPKNKPGVYVRVSRFVTWIEGVMRNN

[0094] *MASP2*: mannan-binding lectin serine peptidase 2 (MASP2) is also known in the art as aliases sMAP; MAP19; MASP-2; MASP2 and is a Ra-reactive factor (RARF) which is a complement-dependent bactericidal factor that binds to the Ra and R2 polysaccharides expressed by certain enterobacteria. Alternate splicing of this gene results in two transcript variants encoding two RARF components that are involved in the mannan-binding lectin pathway of complement activation. The longer isoform is cleaved into two chains which form a heterodimer linked by a disulfide bond. The encoded proteins are members of the trypsin family of peptidases.

[0095] In some embodiments, MASP2 can be detected in the methods, kits and devices using commercial assays, such as, but without limitation, commercial assay kits such as Human MASP-2 ELISA Kit from Cell Sciences, HK326. MASP2 can also be detected using the kits as disclosed in International Patent Application WO/2007/028795 which is incorporated herein in its entirety by reference.

[0096] In some embodiments, commercial polyclonal and monoclonal antibodies against MASP2 are also useful as protein-binding agents to MASP2 and are available from a variety of companies, e. g. , but not limited to Cell Sciences, USBIO, and Santa Cruz Biotechnology.

[0097] Antibodies or protein binding agents which recognize and specifically bind the MASP2 protein of SEQ ID NO: 5, the sequence of which is reproduced below, can be readily produced by one of ordinary skill in the art and are useful for the methods, kits and devices as disclosed herein.

SEQ ID NO: 5 is the polypeptide sequence for MASP5 and has the amino acid sequence as follows:

MRLLTLLGLLCGSVATPLGPKWPEPVFGRLASPGFPGYANDQERRWTLTAPPGYRLRLYFTHF
DLELSHLCEYDFVKLSSGAKVLATLCGQESTDTERAPGKDTFYSLGSSLDITFRSDYSNEKPFT
GFEAFYAAEDIDECQVAPGEAPTCDHHCHNHLGGFYCSCRAGYVLHRNKRTCSEQSL

[0098] *AZGP1*: alpha-2-glycoprotein 1 (AZGP1) is also known in the art as aliases zinc-alpha-2-glycoprotein (ZAG); ZA2G; AZGP1, Azgp1, ZNGP1 and lipid-Mobilizing Factor (LMF). AZGP1 is a soluble 41 kDa glycoprotein belonging to the immunoglobuline protein family and consisting of a single polypeptide chain. Human ZAG shares 59% sequence identity with the murine homolog. AZGP1 is closely related to antigens of the class I major histocompatibility complex (MHC I) and shares 30–40 % sequence identity with the heavy chain of MHC I. Most MHC-I members heterodimerize with beta-2-microglobuline (b2m) and bind peptides derived from intracellular proteins to present them to cytotoxic T cells. In contrast,

AZGP1 is a soluble protein rather than being anchored to plasma membranes that acts independently on b2m and binds the hydrophobic ligand which may relate to its function in lipid metabolism.

[0099] AZGP1 is widespread in body fluids and is also found in various human tissues such as adipose tissue, prostate, breast, skin, salivary gland, trachea, broncheus, lung, gastrointestinal tract, pancreas, liver and kidney. AZGP1 acts as a lipid mobilizing factor to induce lipolysis in adipocytes and plays an important role in lipid utilization and loss of adipose tissue, especially during cachexia, which occurs in patient suffering from cancer, AIDS and other chronic illnesses. The role of AZGP1 in cancer cachexia is also connected with its ability to directly influence expression of uncoupling proteins (UCPs) which are implicated in the regulation of energy balance. In human adipocytes, AZGP1 expression is regulated particularly through TNF-alpha and the PPAR gamma nuclear receptor. AZGP1 expression is also upregulated by glucocorticoides and attenuated by eicosapentaenoic acid (EPA) and beta-3-adrenoreceptor antagonists.

[0100] AZGP1 is overexpressed in certain human malignant tumors such as prostate, breast, lung or bladder cancer and can relate to tumor differentiation. Additionally, AZGP1 plays a role in obesity, diabetic kidney disorders, frontotemporal dementia and regulation of melanin production by melanocytes. AZGP1 is proposed to have a therapeutic use in obesity and cachexia. It can be used as a marker for clinical analysis of diabetic nephropathy and as a marker for certain tumors.

[0101] In some embodiments, AZGP1 can be detected in the methods, kits and devices using commercial assays, such as, but without limitation, Human Zinc-Alpha-2-Glycoprotein (ZA2G, ZAG) ELISA Kit, HRP Detection, from BioVendor Laboratory Medicine, Inc., RD191093100R, The assay is intended for the determination of human Zinc-alpha-2-glycoprotein in serum, plasma, cerebrospinal fluid, urine and cell lysate.; Human / Mouse / Rat ZAG EIA Kit from Raybiotech, Inc or Biovendor lab medicine Inc., EIA-ZAG-1.

[0102] In some embodiments, commercial polyclonal and monoclonal antibodies against AZGP1 are also useful as protein-binding agents to AZGP1 and are available from a variety of companies, e. g. , but not limited to Abcam (Zinc Alpha 2 Glycoprotein antibody, catalog # ab47116) and Novus Biologicals (AZGP1 Antibody, catalog # H00000563-B01). Cell Sciences, USBIO, and Santa Cruz Biotechnology.

[0103] Antibodies or protein binding agents which recognize and specifically bind the AZGP1 protein of SEQ ID NO: 6, the sequence of which is reproduced below, can be readily produced by one of ordinary skill in the art and are useful for the methods, kits and devices as disclosed herein.

SEQ ID NO: 6 is the polypeptide sequence for AZGP1 and has the amino acid sequence as follows:

MVRMVPVLLSLLLLLGPVAVPQENQDGRYSLTYIYTGLSKHVEDVPAFQALGSLNDLQFFRYNSK
DRKSQPMGLWRQVEGMEDWKQDSQLQKAREDIFMETLKDIVEYYNDSNGSHVLQGRFGCEIENN
RSSGAFWKYYYDGDYIEFNKEIPAWVPFDPAAQITKQKWEAEPVYVQRAKAYLEEECPATLRK
YLKYSKNILDRQDPPSVVVTSHQAPGEKKKLKCLAYDFYPGKIDVHWTRAGEVQEPELRGDVLH
NGNGTYQSWVVAVPPQDTAPYSCHVQHSSLAQPLVVPWEAS

[0104] APOD: Apolipoprotein D (ApoD or APOD) is a polypeptide which is a high density lipoprotein that has no marked similarity to other apolipoprotein sequences. It has a high degree of homology to plasma retinol-binding protein and other members of the alpha 2 microglobulin protein superfamily of carrier proteins, also known as lipocalins. This glycoprotein is closely associated with the enzyme lecithin:cholesterol acyltransferase - an enzyme involved in lipoprotein metabolism.

[0105] In some embodiments, ApoD can be detected in the methods, kits and devices using as disclosed in International Patent Application WO/1996/019500 or U.S. Patents 5,804,368 or 5,804,368 or European Patent EP0301667 which are incorporated herein in their entirety by reference.

[0106] Antibodies or protein binding agents which recognize and specifically bind the ApoD protein of SEQ ID NO: 7, the sequence of which is reproduced below, can be readily produced by one of ordinary skill in the art and are useful for the methods, kits and devices as disclosed herein.

SEQ ID NO: 7 is the polypeptide sequence for ApoD and has the amino acid sequence as follows:

MVMLLLLLSALAGLFGAAEGQAFHLGKCPNPPVQENFDVNKYLGRWYEIEKIPTTFENGRCIQA
NYSLMENGKIKVLNQELRADGTVNQIEGEATPVNLTEPAKLEVKFSWFMPSPYWILATDYENY
ALVYSCTCIQFLHVDFAWILARNPNLPPETVDSLKNILTSNNIDVKKMTVTDQVNCPLS

[0107] **SERPINA3:** α -1-antichymotrypsin (SERPINA3) is also known in the art as aliases serpin peptidase inhibitor, clade A (alpha-1 antiproteinase, antitrypsin), member 3, ACT; AACT; GIG24; GIG25 and MGC88254. The SERPINA3 polypeptide is a plasma protease inhibitor and member of the serine protease inhibitor class. Polymorphisms in this protein appear to be tissue specific and influence protease targeting. Variations in this protein's sequence have been implicated in Alzheimer's disease, and deficiency of this protein has been associated with liver disease. Mutations have been identified in patients with Parkinson disease and chronic obstructive pulmonary disease.

[0108] In some embodiments, SERPINA3 can be detected in the methods, kits and devices using as disclosed in International Patent Application WO/2005/039588 which is incorporated herein in its entirety by reference.

[0109] In some embodiments, commercial polyclonal and monoclonal antibodies against SERPINA3 are also useful as protein-binding agents to SERPINA3 and are available from a variety of companies, e. g. , but not limited to Proteintech Group, Lifespan Biosciences, and Santa Cruz Biotechnology.

[0110] Antibodies or protein binding agents which recognize and specifically bind the SERPINA3 protein of SEQ ID NO: 8, the sequence of which is reproduced below, can be readily produced by one of ordinary skill in the art and are useful for the methods, kits and devices as disclosed herein.

SEQ ID NO: 8 is the polypeptide sequence for SERPINA3 and has the amino acid sequence as follows:

MKIHYSRQTALESTSYIQLPEAELRMERMLPLLLALGLLAAGFCPAVLCHPNSPLDEENLTQENQ
DRGTHVDLGLASANVDFAFSLYKQLVLKAPDKNVIFSPLSISTALAFSLSLGAHNTTLTEILKGL
KFNLTTETSEAEIHQSFQHLLRTLNQSSDELQLSMGNAMFVKEQLSLDDRFTEDAKRLYGSEAF
TDFQDSAAAKKLINDYVKNNGTRGKITDLIKDLDSQTMMLVNYIFFKAKWEMPFDPDQDTHQSRF
YLSKKKWVMPMMSLHHLTIPYFRDEELSCTVVELKYTGNASALFILPDQDKMEEVEAMLLPET
LKRWRDSLEFREIGELYLPKFSISRDNLDILLQLGIEEAFTSKADLSGITGARNLAVSQVVH
KAVLDVFEEGTEASAATAVKITLLSALVETRITIVRFNRPFMIIVPTDTQNIFFMASKVTNPKQA

Measuring levels of appendicitis biomarker proteins

[0111] In embodiments of the invention, the level of appendicitis biomarker proteins, such as those disclosed in Table 1, and in particular, the following appendicitis biomarker: leucine α -2 glycoprotein (LRG), calgranulin A (S100-A8), α -1-acid glycoprotein 1 (ORM), plasminogen (PLG), mannan-binding lectin serine protease 2 (MASP2), zinc- α -2-glycoprotein (AZGP1), α -1-antichymotrypsin (SERPINA3) or apolipoprotein D (ApoD), is measured to obtain a determination of whether a human patient has acute appendicitis. A urinary biomarker protein level can be measured using any assay known to those of ordinary skilled in the art, including, but not limited to, Enzyme-Linked Immunosorbent Assay (ELISA), immunoprecipitation assays, radioimmunoassay, mass spectrometry, Western Blotting, and via dipsticks using conventional technology.

[0112] For purposes of comparison, the levels of an appendicitis biomarker protein in a urine sample from the patient should be measured in the same manner as the reference value is measured. For example, the levels of appendicitis biomarker proteins can be represented in arbitrary units dependent upon the assay used to measure the levels of appendicitis biomarker proteins, e.g., the intensity of the signal from the detectable label can correspond to the amount of appendicitis biomarker proteins present (e.g. as determined by eye, densitometry, an ELISA plate reader, a luminometer, or a scintillation counter).

[0113] The levels of an appendicitis biomarker protein present in a urine sample can be determined using any protein-binding agent. In some embodiments, a protein-binding agent is a ligand that specifically binds to an appendicitis biomarker protein, and can be for example, a synthetic peptide, chemical, small molecule, or antibody or antibody fragment or variants thereof. In some embodiments, a protein-binding agent is a ligand or antibody or antibody fragment, and in some embodiments, a protein-binding agent is preferably detectably labeled.

[0114] In one embodiment of the invention, immunoassays using antibodies are used to measure the levels of biomarker proteins in urine. As used herein, the term “antibody” is intended to include immunoglobulin molecules and immunologically active determinants of immunoglobulin molecules, e.g., molecules that contain an antigen binding site which specifically binds (immunoreacts with) to the appendicitis biomarker to be measured. The term “antibody” is intended to include whole antibodies, e.g., of any isotype (IgG, IgA, IgM, IgE, etc), and includes fragments thereof which are also specifically reactive with the appendicitis biomarker proteins to be measured, e.g. leucine α -2 glycoprotein (LRG), calgranulin A (S100-A8), α -1-acid glycoprotein 1 (ORM), plasminogen (PLG), mannan-binding lectin serine protease 2 (MASP2), zinc- α -2-glycoprotein (AZGP1), α -1-antichymotrypsin (SERPINA3) or apolipoprotein D (ApoD). Antibodies can be fragmented using conventional techniques. Thus, the term “antibody” includes segments of proteolytically-cleaved or recombinantly-prepared portions of an antibody molecule that are capable of selectively reacting with a certain protein. Non limiting examples of such proteolytic and/or recombinant fragments include Fab, F(ab')₂, Fab', Fv, dAbs and single chain antibodies (scFv) containing a VL and VH domain joined by a peptide linker. The scFv's can be covalently or non-covalently linked to form antibodies having two or more binding sites. Thus, “antibody” includes polyclonal, monoclonal, or other purified preparations of antibodies and recombinant antibodies. The term “antibody” is further intended to include humanized antibodies, bispecific antibodies, and chimeric molecules having at least one antigen binding determinant derived from an antibody molecule. In one embodiment, the antibody is detectably labeled.

[0115] Antibodies to the appendicitis biomarker proteins can be generated using methods known to those skilled in the art. Alternatively, commercially available antibodies can be used. Antibodies to LRG, S100-A8, ORM1, PLG, MASP2, AZGP1, ApoD and SERPINA3 are commercially available.

[0116] As used herein “detectably labeled”, includes antibodies that are labeled by a measurable means and include, but are not limited to, antibodies that are enzymatically, radioactively, fluorescently, and chemiluminescently labeled. Antibodies can also be labeled with a detectable tag, such as c-Myc, HA, VSV-G, HSV, FLAG, V5, HIS, or biotin.

[0117] In the diagnostic methods of the invention that use an antibody for the detection of biomarker proteins levels, the level of biomarker proteins present in the urine samples correlates to the intensity of the signal emitted from the detectably labeled antibody.

[0118] In one embodiment, the antibody is detectably labeled by linking the antibody to an enzyme. The enzyme, in turn, when exposed to its substrate, will react with the substrate in such a manner as to produce a chemical moiety which can be detected, for example, by spectrophotometric, fluorometric, or by visual means. Enzymes which can be used to detectably label the antibodies of the present invention include, but are not limited to, 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-VI-phosphate dehydrogenase, glucoamylase and acetylcholinesterase. Chemiluminescence is another method that can be used to detect an antibody.

[0119] Detection can also be accomplished using any of a variety of other immunoassays. For example, by radioactively labeling an antibody, it is possible to detect the antibody through the use of radioimmune assays. The radioactive isotope can be detected by such means as the use of a gamma counter or a scintillation counter or by autoradiography. Isotopes which are particularly useful for the purpose of the present invention are ^3H , ^{131}I , ^{35}S , ^{14}C , and preferably ^{125}I .

[0120] It is also possible to label an antibody with a fluorescent compound. When the fluorescently labeled antibody is exposed to light of the proper wave length, its presence can then be detected due to fluorescence. Among the most commonly used fluorescent labeling compounds are CYE dyes, fluorescein isothiocyanate, rhodamine, phycoerytherin, phycocyanin, allophycocyanin, o-phthaldehyde and fluorescamine.

[0121] An antibody can also be detectably labeled using fluorescence emitting metals such as ^{152}Eu , or others of the lanthanide series. These metals can be attached to the antibody

using such metal chelating groups as diethylenetriaminepentaacetic acid (DTPA) or ethylenediaminetetraacetic acid (EDTA).

[0122] An antibody also can be detectably labeled by coupling it to a chemiluminescent compound. The presence of the chemiluminescent-antibody is then determined by detecting the presence of luminescence that arises during the course of a chemical reaction. Examples of particularly useful chemiluminescent labeling compounds are luminol, luciferin, isoluminol, theromatic acridinium ester, imidazole, acridinium salt and oxalate ester.

[0123] In one embodiment, the levels of biomarker proteins in urine are detected by an immunoassay. Immunoassays include but are not limited to enzyme immunoassay (EIA), also called enzyme-linked immunosorbant assay (ELISA), radioimmunoassay (RIA), diffusion immunoassay (DIA), fluoroimmunoassay (FIA), chemiluminescent immunoassay (CLIA), counting immunoassay (CIA), lateral flow tests or immunoassay (LFIA), also known as lateral flow immunochromatographic assays, and magnetic immunoassay (MIA).

[0124] An immunoassay is a biochemical test that measures the concentration of a substance in a biological sample, typically serum or urine, using the reaction of an antibody or antibodies to its antigen. The assay takes advantage of the specific binding of an antibody to its antigen. Monoclonal antibodies are often used as they only usually bind to one site of a particular molecule, and therefore provide a more specific and accurate test, which is less easily confused by the presence of other molecules. The antibodies picked must have a high affinity for the antigen (if there is antigen available, a very high proportion of it must bind to the antibody).

[0125] For numerical results, the response of the biological sample being measured must be compared to standards of a known concentration. This is usually done through the plotting of a standard curve on a graph, the position of the curve at response of the unknown is then examined, and so the quantity of the unknown found. Alternatively, a defined amount of antibody is used in the assay where the defined amount of antibody binds completely to a fixed amount of antigen. This fixed amount of antigen is the reference level of biomarker in the urine. Thus, this defined amount of antibody is used to indicate whether the amount of antigen in the biological sample is at least at, below or above the reference level of biomarker (See Figs. 11-12).

[0126] Detecting the quantity of antigen in the biological sample can be achieved by a variety of methods. One of the most common is to label either the antigen or the antibody. The label can consist of an enzyme (see enzyme immunoassay (EIA)), colloidal gold (lateral flow assays), radioisotopes such as I-¹²⁵ Radioimmunoassay (RIA), magnetic labels (magnetic immunoassay - MIA) or fluorescence. Other techniques include agglutination, nephelometry, turbidimetry and Western Blot.

[0127] In one embodiment, the immunoassay is a competitive immunoassay. In another embodiment, the immunoassay is a noncompetitive immunoassay.

[0128] Immunoassays can be divided into those that involve labeled reagents and those which involve non-labeled reagents. Those which involve labeled reagents are divided into homogenous and heterogeneous (which require an extra step to remove unbound antibody or antigen from the site, usually using a solid phase reagent) immunoassays. Heterogeneous immunoassays can be competitive or non-competitive.

[0129] In a competitive immunoassay, the antigen in the unknown sample competes with labeled antigen to bind with antibodies. The amount of labeled antigen bound to the antibody site is then measured. In this method, the response will be inversely proportional to the concentration of antigen in the unknown. This is because the greater the response, the less antigen in the unknown was available to compete with the labeled antigen.

[0130] In noncompetitive immunoassays, also referred to as the "sandwich assay," antigen in the unknown, e. g. urine sample, is bound to a first antibody site, then second antibody that is labeled is bound to the antigen, forming a sandwich. The amount of labeled antibody on the site is then measured. Unlike the competitive method, the results of the noncompetitive method will be directly proportional to the concentration of the antigen. This is because labeled antibody will not bind if the antigen is not present in the unknown sample, e. g. urine sample.

[0131] In one embodiment, the levels of biomarker proteins in urine are detected by ELISA assay. There are different forms of ELISA which are well known to those skilled in the art, e.g. standard ELISA, competitive ELISA, and sandwich ELISA. The standard techniques for ELISA are described in "Methods in Immunodiagnosis", 2nd Edition, Rose and Bigazzi, eds. John Wiley & Sons, 1980; Campbell et al., "Methods and Immunology", W. A. Benjamin, Inc., 1964; and Oellerich, M. 1984, J. Clin. Chem. Clin. Biochem., 22:895-904.

[0132] Enzyme-linked immunosorbent assay, also called ELISA, enzyme immunoAssay or EIA, is a biochemical technique used mainly in immunology to detect the presence of an antibody or an antigen in a sample. The ELISA has been used as a diagnostic tool in medicine and plant pathology, as well as a quality control check in various industries. For the methods described herein, in the ELISA a known amount of anti-biomarker antibody is affixed to a solid surface, and then the sample, e. g. urine, containing the biomarker of interest is washed over the surface so that the antigen biomarker can bind to the immobilized antibodies (a first antibody). The surface is washed to remove any unbound biomarker and also any non-biomarker proteins present in the urine sample. A detection antibody (a second antibody) is applied to the surface. The detection antibody is specific to antibodies from the subject. For example, if the subject is a

human, the detection antibody should be an anti-human IgG antibody. If the subject is a dog, the detection antibody then should be an anti-dog IgG antibody. This detection antibody can be linked to an enzyme, and in the final step a substance is added that the enzyme can convert to some detectable signal. For example, in the case of fluorescence ELISA, when light is shone upon the sample, any antigen/antibody complexes will fluoresce so that the amount of antibodies in the sample can be measured.

[0133] The following is a general standard protocol for setting up and performing an indirect enzyme-linked immunosorbent assay. Using 96-well microtiter plates (Falcon Pro-Bind assay plate 3915; Becton Dickinson, Paramus, N.J.), test wells are coated with anti-biomarker antibody by incubation with 100 μ l of purified anti-LRG antibody (3 μ g/ml in PBS) per well overnight at room temperature, with PBS substituted for the antibody in control wells. After the plates have been washed three times with PBS-Tween, 250 μ l of 2% BSA in PBS is added to each well, and the plates are incubated for 1 h at room temperature. The plates are washed three times with PBS-Tween and incubated for 1 h at room temperature with test urine sample and control urine sample from healthy individuals diluted 1:100 in PBS-Tween-BSA; each urine sample is tested in triplicate in anti-LRG antibody-coated wells as well as in PBS control wells. The plate is then assayed (with appropriate controls) for the presence and/or the level of LRG by incubation for 1 h at room temperature with 100 μ l of goat anti-LRG IgG conjugated with horseradish peroxidase (Bio-Rad, Richmond, Calif.) per well diluted 1:2,000 in PBS-Tween-BSA. After three washes in PBS-Tween, the substrate solution (o-phenylenediamine dihydrochloride; Sigma) is added to each well. The plates are then incubated for 30 min at room temperature in darkness, and the reaction is terminated by the addition of 2N sulfuric acid. The optical density values at 490 nm (OD₄₉₀) are measured in a micro plate ELISA reader. For each urine sample, mean OD₄₉₀ readings are calculated for the test wells and for the antigen control wells, the latter being subtracted from the former to obtain the net ELISA value.

[0134] Performing an ELISA involves at least one antibody with specificity for a particular biomarker. A known amount of anti-biomarker antibody is immobilized on a solid support (usually a polystyrene micro titer plate) either non-specifically (via adsorption to the surface) or specifically (via capture by another antibody specific to the anti-biomarker antibody, in a "sandwich" ELISA). After the antigen is immobilized, the detection antibody is added, forming a complex with the antigen. The detection antibody can be covalently linked to an enzyme, or can itself be detected by a secondary antibody which is linked to an enzyme through bio-conjugation. Between each step the plate is typically washed with a mild detergent solution to remove any proteins or antibodies that are not specifically bound. After the final wash step the

plate is developed by adding an enzymatic substrate to produce a visible signal, which indicates the quantity of antigen in the sample. Older ELISAs utilize chromogenic substrates, though newer assays employ fluorogenic substrates with much higher sensitivity.

[0135] In another embodiment, a competitive ELISA is used. Purified anti-biomarker antibody is coated on the solid phase of multi-wells. Urine sample, a defined amount of purified biomarker and horseradish peroxidase labeled with anti-biomarker antibody (secondary detection conjugated antibody) are added to coated wells to form competitive combination. After incubation, if the biomarker level in the urine sample is high, a complex of biomarker- anti-biomarker antibody- anti-biomarker antibody labeled with HRP will form. Washing the wells will remove the complex. Incubation with TMB (3,3', 5,5'-tetramethylbenzidine) will result in color development substrate for the localization of horseradish peroxidase-conjugated antibodies in the wells. There will be no color change or little color change. If the biomarker level in the urine sample is low, there will be much color change. Such a competitive ELISA test is specific, sensitive, reproducible and easy to operate.

[0136] In one embodiment, the levels of appendicitis biomarker proteins are determined by contacting a urine sample with a first antibody that specifically binds to a biomarker protein to be measured under conditions permitting formation of a complex between the antibody and the appendicitis biomarker proteins (e.g. LRG, S100- A8, ORM1, PLG, MASP2, AZGP1, ApoD and SERPINA3). The amount of complex formed is then measured as a measure of the level of the appendicitis biomarker protein, and the amount of complex formed is compared to the amount of complex formed between the first antibody and a predetermined reference amount of the appendicitis biomarker protein. This predetermined reference level amount of the appendicitis biomarker protein is the amount found in the urine of healthy humans. A level above the reference level amount of an appendicitis biomarker protein indicates that the human has acute appendicitis.

[0137] In one embodiment, the first antibody is detectably labeled. Detectably labeling the first antibody is appropriate for use, for example, in standard ELISA assays where biomarker protein is absorbed to an ELISA plate, or in Western Blot analysis, or certain LFIA dipstick analyses.

[0138] In one embodiment, the first antibody is immobilized on a solid support, for example, when using a "Sandwich ELISA" or a dipstick analysis, then the amount of complex formed can be measured by detecting binding of a second antibody that specifically binds to the appendicitis biomarker protein (e.g. LRG, S100- A8, ORM1, PLG, MASP2, AZGP1, ApoD and SERPINA3) under conditions permitting formation of a complex between the second antibody

and the appendicitis biomarker protein, wherein the second antibody does not substantially cross-react with the first antibody, and wherein the second antibody is detectably labeled.

[0139] Any solid support can be used, including but not limited to, nitrocellulose, solid organic polymers, such as polystyrene, or laminated dipsticks such as described in U.S. patent 5,550,375 and 5,656,448, which is specifically incorporated herein by reference in their entirety.

[0140] In one embodiment, the levels of two appendicitis biomarker proteins defining a first and a second appendicitis biomarker protein, are measured using at least two antibodies specific to each appendicitis biomarker protein to be measured. Each antibody specifically reacts either the first appendicitis biomarker protein or the second appendicitis biomarker protein to be measured while not substantially cross-reacting with the other appendicitis biomarker proteins to be measured.

[0141] In one embodiment, the levels of three biomarker proteins defining a first biomarker protein, a second biomarker protein, and a third biomarker protein, are measured using at least three antibodies specific to each biomarker protein to be measured, wherein each antibody specifically reacts either the first biomarker protein, the second biomarker protein, or the third biomarker protein to be measured while not substantially cross-reacting with the other biomarker proteins to be measured.

[0142] In one embodiment, the levels of four biomarker proteins defining a first, a second, a third and a fourth biomarker protein, are measured using at least four antibodies specific to each biomarker protein to be measured, wherein each antibody specifically reacts either the first biomarker protein, the second biomarker protein, the third biomarker protein, or the fourth biomarker protein to be measured while not substantially cross-reacting with the other biomarker proteins to be measured.

[0143] In one embodiment, the appendicitis biomarker proteins are selected from the group consisting of LRG, S100- A8, ORM1, PLG, MASP2, AZGP1, ApoD and SERPINA3.

[0144] In one embodiment, the levels of biomarker proteins in urine are detected by a lateral flow immunoassay test (LFIA), also known as the immunochromatographic assay, or strip test. LFIAs are a simple device intended to detect the presence (or absence) of a target antigen in a fluid sample. There are currently many LFIA tests are used for medical diagnostics either for home testing, point of care testing, or laboratory use. LFIA tests are a form of immunoassay in which the test sample flows along a solid substrate via capillary action. After the sample is applied to the test it encounters a coloured reagent which mixes with the sample and transits the substrate encountering lines or zones which have been pretreated with an antibody or antigen. Depending upon the antigens present in the sample the coloured reagent can become bound at the test line or zone. LFIAs are essentially immunoassays adapted to operate

along a single axis to suit the test strip format or a dipstick format. Strip tests are extremely versatile and can be easily modified by one skilled in the art for detecting an enormous range of antigens from fluid samples such as urine, blood, water samples etc. Strip tests are also known as dip stick test, the name bearing from the literal action of “dipping” the test strip into a fluid sample to be tested. LFIA strip test are easy to use, require minimum training and can easily be included as components of point-of-care test (POCT) diagnostics to be use on site in the field.

[0145] LFIA tests can be operated as either competitive or sandwich assays. Sandwich LFIAs are similar to sandwich ELISA. The sample first encounters coloured particles which are labeled with antibodies raised to the target antigen. The test line will also contain antibodies to the same target, although it may bind to a different epitope on the antigen. The test line will show as a coloured band in positive samples. Example 5 illustrates a sandwich LFIA in the test strip format. Competitive LFIAs are similar to competitive ELISA. The sample first encounters coloured particles which are labeled with the target antigen or an analogue. The test line contains antibodies to the target/its analogue. Unlabelled antigen in the sample will block the binding sites on the antibodies preventing uptake of the coloured particles. The test line will show as a coloured band in negative samples.

[0146] A typical test strip consists of the following components: (1) sample application area comprising an absorbent pad (i. e. the matrix or material) onto which the test sample is applied; (2) conjugate or reagent pad– this contains antibodies specific to the target antigen conjugated to coloured particles (usually colloidal gold particles, or latex microspheres); test results area comprising a reaction membrane – typically a hydrophobic nitrocellulose or cellulose acetate membrane onto which anti-antigen antibodies are immobilized in a line across the membrane as a capture zone or test line (a control zone may also be present, containing antibodies specific for the conjugate antibodies); and (4) optional wick or waste reservoir – a further absorbent pad designed to draw the sample across the reaction membrane by capillary action and collect it. The components of the strip are usually fixed to an inert backing material and may be presented in a simple dipstick format or within a plastic casing with a sample port and reaction window showing the capture and control zones. While not strictly necessary, most tests will incorporate a second line which contains an antibody that picks up free latex/gold in order to confirm the test has operated correctly. Figs. 11 -19 show the various components and embodiments of several test strips.

[0147] In some embodiments, the lateral flow immunoassay is a double antibody sandwich assay, a competitive assay, a quantitative assay or variations thereof. Figs. 15, 16, 17, Example 5 and Example 6 exemplify double antibody sandwich LFIA in a test strip format.

[0148] There are a number of variations on lateral flow technology. It is also possible to apply multiple capture zones to create a multiplex test. Fig. 14 and 19 exemplify a multiplex LFIA in a test strip format. In one embodiment, a diagnostic kit can comprise multiple LFIA test strips, one strip for a different biomarker protein. In another embodiment, a diagnostic kit can comprise a single composite LFIA test strip for determining the levels of several biomarker proteins. Such diagnostic kits and LFIA test strips can be used as POCT in the field.

[0149] The use of “dip sticks” or LFIA test strips and other solid supports have been described in the art in the context of an immunoassay for a number of antigens. U.S. Pat. Nos. 4,943,522; 6,485,982; 6,187,598; 5,770,460; 5,622,871; 6,565,808, U. S. patent applications Ser. No. 10/278,676; U.S. Ser. No. 09/579,673 and U.S. Ser. No. 10/717,082,

are non-limiting examples of such lateral flow test devices. Three U.S. patents (U.S. Pat. No. 4,444,880, issued to H. Tom; U.S. Pat. No. 4,305,924, issued to R. N. Piasio; and U.S. Pat. No. 4,135,884, issued to J. T. Shen) describe the use of “dip stick” technology to detect soluble antigens via immunochemical assays. The apparatuses and methods of these three patents broadly describe a first component fixed to a solid surface on a “dip stick” which is exposed to a solution containing a soluble antigen that binds to the component fixed upon the “dip stick,” prior to detection of the component-antigen complex upon the stick.

[0150] A urine dipstick is a colorimetric chemical assay that can be used to determine the pH, specific gravity, protein, glucose, ketone, bilirubin, urobilinogen, blood, leukocyte, and nitrite levels of an individual's urine. It consists of a reagent stick-pad, which is immersed in a fresh urine specimen and then withdrawn. After predetermined times the colors of the reagent pad are compared to standardized reference charts.

[0151] The urine dipstick offers an inexpensive and fast method to perform screening urinalyses, which help in identifying the presence of various diseases or health problems. A urine dipstick provides a simple and clear diagnostic guideline and can be used in the methods and kits as described herein. Accordingly, one aspect of the presents invention relates to a method for detecting acute appendicitis using a device, such as a dipstick, to test for the presence of appendicitis biomarkers as described herein. Dipsticks useful in the present invention can be used to test for at least one appendicitis biomarker, for example LRG or multiple biomarkers, such as any combination selected from the group of leucine-rich α -2-glycoprotein (LRG); S100-A8 (calgranulin); α -1-acid glycoprotein 1 (ORM); plasminogen (PLG); mannan-binding lectin serine protease 2 (MASP2); zinc- α -2-glycoprotein (AZGP1); apolipoprotein D (ApoD); α -1-antichymotrypsin (SERPINA3), or alternatively, multiple biomarkers selected from any combination listed in Table 1. Combination dipsticks can be used to test for at least two

appendicitis biomarkers selected from the group of leucine-rich α -2-glycoprotein (LRG); S100-A8 (calgranulin); α -1-acid glycoprotein 1 (ORM); plasminogen (PLG); mannan-binding lectin serine protease 2 (MASP2); zinc- α -2-glycoprotein (AZGP1); apolipoprotein D (ApoD); α -1-antichymotrypsin (SERPINA3), or alternatively, multiple biomarkers selected from any combination listed in Table 1. Examples of combinations of two appendicitis biomarkers are LRG and ORM; LRG and S100-A8; LRG and PLG; LRG and MASP2; LRG and AZGP1; LRG and ApoD; LRG and SERPINA3; ORM and S100-A8; ORM and PLG; ORM and MASP2; ORM and ApoD; ORM and SERPINA3; S100-A8 and PLG; S100-A8 and MASP2; S100-A8 and ApoD; S100-A8 and SERPINA3; PLG and MASP2; PLG and ApoD; PLG and SERPINA3; MASP2 and ApoD; MASP2 and SERPINA3; and Apo and SERPINA3.

Combination dipsticks can be used to test for at least three appendicitis biomarkers, at least four appendicitis biomarkers, at least five appendicitis biomarkers, or at least six appendicitis biomarkers selected from the group of leucine-rich α -2-glycoprotein (LRG); S100-A8 (calgranulin); α -1-acid glycoprotein 1 (ORM); plasminogen (PLG); mannan-binding lectin serine protease 2 (MASP2); zinc- α -2-glycoprotein (AZGP1); apolipoprotein D (ApoD); α -1-antichymotrypsin (SERPINA3), or alternatively, multiple biomarkers selected from any combination listed in Table 1. Combination dipsticks can be used to test for at least seven appendicitis biomarkers selected from the group of leucine-rich α -2-glycoprotein (LRG); S100-A8 (calgranulin); α -1-acid glycoprotein 1 (ORM); plasminogen (PLG); mannan-binding lectin serine protease 2 (MASP2); zinc- α -2-glycoprotein (AZGP1); apolipoprotein D (ApoD); α -1-antichymotrypsin (SERPINA3), or alternatively, multiple biomarkers selected from any combination listed in Table 1. An example of a combination of seven appendicitis biomarkers is LRG, ORM, S100-A8, PLG, MASP2, ApoD, and SERPINA3. Uses of dipsticks are commonly known in the art, and are described in U.S. Pat. No. 5,972,594 to Heine,

which is used to detect the presence of neutrophil defensins to diagnose reproductive tract inflammation and preeclampsia.

[0152] Other dipsticks and related components are well known in the art, for example dipsticks to detect leukocytes and leukocyte enzymes in body fluids have been patented. For example, U.S. Patent No: 5,656,448 to Kang et al, discloses a dipstick encompassed for use in the present invention. Additionally, U.S. Pat. No.4,758,508 to Schnabel, et al. describes an agent and a method for detecting esterolytic and/or proteolytic enzymes in body fluids. U.S. Pat. No. 4,637,979 to Skjold, et al. describes a composition and test device for determining the presence of leukocytes in test samples including body fluids such as urine. U.S. Pat. No. 4,645,842 describes pyrrole compounds, and U.S. Pat.

No. 4,704,460 (both to Corey) describes novel compounds for detecting the presence of hydrolytic analytes including leukocytes, esterase, and protease, in a test sample, including urine. U.S. Pat. No. 4,774,340 to Corey describes a method for preparing 3-hydroxy pyrroles and esters thereof, which are used to test samples including urine. A composition and test device for determining the presence of leukocytes, esterase, and protease in a body fluid including urine is described in U.S. Pat. No. 4,657,855 to Corey, et al. A method for determining the concentration of white blood cells in urine or other biological fluid is described in U.S. Pat. No. 5,663,044 to Noffsinger, et al. A method for preparing an ester used to detect leukocyte cells, esterase, and protease in body fluids such as urine is described in U.S. Pat. No. 4,716,236 to Ward, et al. All of these patents, which are incorporated herein in their entirety by reference, identify an abnormally high level of leukocytes in a patient's urine and produce a signal to identify likelihood that the subject from which the urine was obtained has a pathological condition such as kidney or urogenital tract infection or other dysfunction.

[0153] In some embodiments, the present invention provides a LFIA device such as a dipstick to identify appendicitis biomarkers in a urine test sample. In one embodiment is a method for detecting acute appendicitis using a LFIA device, such as a dipstick, having diagnostic test reagents to detect acute appendicitis. The diagnostic test reagents react with the test sample, such as urine test sample to produce a change upon contact with the test sample, such as urine. Another embodiment of the invention is a device, such as a dipstick, that has (1) a positive indication for the presence of acute appendicitis and (2) a negative indication for the absence of acute appendicitis. The difference between the positive indication and the negative indication is pre-determined.

[0154] In some embodiments, the present invention also provides a method for determining if a subject has a likelihood of acute appendicitis. In some embodiments, the method begins with obtaining a urine sample from a subject, such as a symptomatic patient for appendicitis. Symptomatic patients for appendicitis are described herein. Once the sample is obtained, a device having diagnostic test reagents that detect the presence of at least one appendicitis biomarker, such as leucine-rich α -2-glycoprotein (LRG); S100-A8 (calgranulin); α -1-acid glycoprotein 1 (ORM); plasminogen (PLG); mannan-binding lectin serine protease 2 (MASP2); zinc- α -2-glycoprotein (AZGP1); apolipoprotein D (ApoD); α -1-antichymotrypsin (SERPINA3) or any listed from Table 1 is contacted with the urine sample. Depending on the type of device used, a certain amount of time might have to pass before the device is read. For example, as a general guideline but not as a limitation, when using a MULTISTIX-2 by Bayer Aktiengesellschaft (Fed. Rep. Germany) two minutes pass between the time that the device is contacted with the sample and when it is read to produce an experimental test result. The

MULTISTIX-2 dipstick is sold to test urine. The experimental test result is then compared to pre-determined test results that indicate either the presence or absence of acute appendicitis.

[0155] In some embodiments, the method to diagnose acute appendicitis in a subject uses a quantitative device (such as, for example, the MULTISTIX-2, MULTISTIX-10, URISTIX-4, or any appendicitis biomarker-detecting device as disclosed herein) or the subject inventive device that has two indications, one for a positive result and one for a negative result. When using such a quantitative device, it produces a range of results. For example, the MULTISTIX-2 produces quantitative results of 0, trace, +1, +2 and +3. Quantitative results also include "Between +1 and +2" and "Between +2 and +3." A test result of 0, trace, and +1 corresponds to the absence of acute appendicitis). A test result of "Between +1 and +2", "Moderate (+2)", "Between +2 and +3", and "Large (+3)" corresponds to the presence of acute appendicitis). The pre-determination is done using a study where the range of the urine marker presence is determined based on the range in urine from confirmed appendicitis subjects as compared to the range of urine marker in the urine from healthy (i.e. confirmed non-appendicitis) subjects.

[0156] In some embodiments, a device, such as a dipstick immunological device as disclosed herein can include (1) a matrix (preferably filter paper) with diagnostic test reagents and (2) a mounting substrate (preferably polystyrene film), which typically does not absorb the test (e.g. urine) sample, such that the user can hold onto the substrate without contacting the sample. The device produces a visual change in the matrix upon contact with the urine sample. In some embodiments, the matrix has two indicators-a first that indicates the presence of acute appendicitis and a second that indicates the absence of appendicitis. The first indicator produces a positive test result and the second indicator produces a negative result. The test result is positive when the test result is pre-determined to correspond with a level of the appendicitis biomarker which is indicative of acute appendicitis. Conversely, a test result is negative when the test result is pre-determined to be below the level of an appendicitis biomarker which indicates the absence of acute appendicitis. The device, such as a dipstick device determines the presence of acute appendicitis with the positive test result, and the absence of acute appendicitis with the negative test result.

[0157] In some embodiments, the diagnostic test reagents may be associated with the matrix by any physical or chemical means, including, for example impregnation, coating, linking, and covalent attachment. The matrix may take any convenient physical form, such as a card, pad, strip, or dipstick. Such diagnostic test reagents include the compositions of the above-referenced patents, including an ester (preferably a chromogenic ester) and a diazonium salt such as those described in U.S. Pat. No. 4,637,979. Another preferred reagent is a derivatized pyrrole

amino acid ester, a diazonium salt, a buffer, and non-reactive ingredients as described in U.S. Pat. Nos. 4,645,842; 4,637,979; 4,657,855; 4,704,460; 4,758,508; and 4,774,340. The preferred amounts of these ingredients is based on dry weight at the time of impregnation and is as follows: about 0.4% w/w derivatized pyrrole amino acid ester, about 0.2% w/w diazonium salt, about 40.9% w/w buffer, and about 58.5% w/w non-reactive ingredients.

[0158] In one embodiment, the test reagent, e. g. the anti-antigen antibody of the immunoassay is detectably labeled. In some embodiments, the detectable label is selected from a group consisting of enzyme, fluorescent, biotin, gold, latex, hapten and radioisotope labeling. A detectable-hapten includes but is not limited to biotin, fluorescein, digoxigenin, dinitrophenyl (DNP). Other labels include but are not limited to colloidal gold and latex beads. The latex beads can also be colored. Methods of labeling antibodies, antibody-based moiety, or proteins are known in the art, for example, as described in "Colloidal Gold. Principles. Methods and Applications", Hayat MA (ed) (1989-91). Vols 1-3, Academic press, London; in "Techniques in Immunocytochemistry", Bullock GR and Petrusz P (eds) (1982-90) Vols 1, 2, 3, and 4, Academic Press, London; in "Principles of Biological Microtechnique", Baker JR (1970), Methuen, London; Lillie RD (1965), Histopathologic Technique and practical Histochemistry, 3rd ed, McGraw Hill, New York; Berryman MA, et al (1992), J. Histochem Cytochem 40, 6, 845-857.

[0159] In one embodiment, the detectable label is a dye. A "dye" refers to a substance, compound or particle that can be detected, particularly by visual, fluorescent or instrumental means. A dye can be, for example, but not limited to, a pigment produced as a coloring agent or ink, such as Brilliant Blue, 3132 Fast Red 2R and 4230 Malachite Blue Lake, all available from Hangzhou Hongyan Pigment Chemical Company, China. The "dye" can also be a particulate label, such as, but not limited to, blue latex beads or gold particles. The particulate labels may or may not be bound to a protein, depending upon if it is desired for the particles to move in the test strip or not. If the particles are to be immobilized in the test strip, the particles may be conjugated to a protein, e. g. the anti-antigen antibody, which in turn is bound to the test strip by either physical or chemical means.

[0160] In colloidal gold labeling technique, the unique red color of the accumulated gold label, when observed by lateral or transverse flow along a membrane on which an antigen is captured by an immobilized antibody, or by observation of the red color intensity in solution, provides an extremely sensitive method for detecting sub nanogram quantities of proteins in solution. A colloidal gold conjugate consists of a suspension of gold particles coated with a selected protein or macromolecule (such as an antibody or antibody-based moiety). The gold particles may be manufactured to any chosen size from 1-250 nm. This gold probe detection

system, when incubated with a specific target, such as in a tissue section, will reveal the target through the visibility of the gold particles themselves. For detection by eye, gold particles will also reveal immobilized antigen on a solid phase such as a blotting membrane through the accumulated red color of the gold sol. Silver enhancement of this gold precipitate also gives further sensitivity of detection. Suppliers of colloidal gold reagents for labeling are available from SPI-MARK™. Polystyrene latex Bead size 200 nm colored latex bead coated with antibody SIGMA ALDRICH®, Molecular Probes, Bangs Laboratory Inc., and AGILENT® Technologies.

[0161] Other detection systems can also be used, for example, a biotin-streptavidin system. In this system, the antibodies immunoreactive (i. e. specific for) with the biomarker of interest is biotinylated. Quantity of biotinylated antibody bound to the biomarker is determined using a streptavidin-peroxidase conjugate and a chromagenic substrate. Such streptavidin peroxidase detection kits are commercially available, e. g. from DAKO; Carpinteria, CA.

[0162] Protein binding agents described herein such as antibodies and antibody-based moiety can alternatively be labeled with any of a number of fluorescent compounds such as fluorescein isothiocyanate, europium, lucifer yellow, rhodamine B isothiocyanate (Wood, P. In: Principles and Practice of Immunoassay, Stockton Press, New York, pages 365-392 (1991)) for use in immunoassays. In conjunction with the known techniques for separation of antibody-antigen complexes, these fluorophores can be used to quantify the biomarker of interest. The same applies to chemiluminescent immunoassay in which case antibody or biomarker of interest can be labeled with isoluminol or acridinium esters (Krodel, E. et al., In: Bioluminescence and Chemiluminescence: Current Status. John Wiley and Sons Inc. New York, pp 107-110 (1991); Weeks, I. et al., Clin. Chem. 29:1480-1483 (1983)). Radioimmunoassay (Kashyap, M. L. et al., J. Clin. Invest, 60:171-180 (1977)) is another technique in which antibody can be used after labeling with a radioactive isotope such as ¹²⁵I. Some of these immunoassays can be easily automated by the use of appropriate instruments such as the IMX™ (Abbott, Irving, Tex.) for a fluorescent immunoassay and Ciba Coming ACS 180™ (Ciba Corning, Medfield, Mass.) for a chemiluminescent immunoassay.

[0163] A “LFIA test strip” or “dip stick” can include one or more bibulous or non-bibulous materials or matrices. In reference to a “LFIA test strip” or “dip stick”, the terms “material” and “matrix” are used interchangeably. If a test strip comprises more than one material, the one or more materials are preferably in fluid communication. One material of a test strip may be overlaid on another material of the test strip, such as for example, filter paper overlaid on nitrocellulose membrane. Alternatively or in addition, a test strip can include a region comprising one or more materials followed by a region comprising one or more different

materials. In this case, the regions are in fluid communication and may or may not partially overlap one another. Suitable materials for test strips include, but are not limited to, materials derived from cellulose, such as filter paper, chromatographic paper, nitrocellulose, and cellulose acetate, as well as materials made of glass fibers, nylon, dacron, PVC, polyacrylamide, cross-linked dextran, agarose, polyacrylate, ceramic materials, and the like. The material or materials of the test strip may optionally be treated to modify their capillary flow characteristics or the characteristics of the applied sample. For example, the sample application region of the test strip may be treated with buffers to correct the pH or specific gravity of an applied urine sample, to ensure optimal test conditions.

[0164] The material or materials can be a single structure such as a sheet cut into strips or it can be several strips or particulate material bound to a support or solid surface such as found, for example, in thin-layer chromatography and may have an absorbent pad either as an integral part or in liquid contact. The material can also be a sheet having lanes thereon, capable of spotting to induce lane formation, wherein a separate assay can be conducted in each lane. The material can have a rectangular, circular, oval, triangular or other shape provided that there is at least one direction of traversal of a test solution by capillary migration. Other directions of traversal may occur such as in an oval or circular piece contacted in the center with the test solution. However, the main consideration is that there be at least one direction of flow to a predetermined site.

[0165] The support for the test strip, where a support is desired or necessary, will normally be water insoluble, frequently non-porous and rigid but may be elastic, usually hydrophobic, and porous and usually will be of the same length and width as the strip but may be larger or smaller. The support material can be transparent, and, when a test device is assembled, a transparent support material can be on the side of the test strip that can be viewed by the user, such that the transparent support material forms a protective layer over the test strip where it may be exposed to the external environment, such as by an aperture in the front of a test device. A wide variety of materials, both natural and synthetic, and combinations thereof, may be employed provided only that the support does not interfere with the capillary action of the material or materials, or non-specifically bind assay components, or interfere with the signal producing system. Illustrative polymers include polyethylene, polypropylene, poly(4-methylbutene), polystyrene, polymethacrylate, poly(ethylene terephthalate), nylon, poly(vinyl butyrate), glass, ceramics, metals, and the like. Elastic supports may be made of polyurethane, neoprene, latex, silicone rubber and the like.

[0166] In some embodiments, a dipstick device has one indication of the presence of acute appendicitis and a second indication for the absence of acute appendicitis. The two

indications preferably are a negative (-) symbol and a positive (+) symbol, but could be any two indications. In one embodiment, the device has the negative indication (e.g., the "-" portion of a possible "+" symbol) containing reagents that reacts with all samples. That is, the diagnostic test reagents react to some constituent analyte, such as urea which is present in all urine samples. Alternatively, the diagnostic test reagents test an aspect of the sample, such as pH, that every sample has. The positive indication (e.g., the "+" portion of a "+" symbol) contains a reagent that reacts only with a sample containing the presence of a test appendicitis biomarker which is above a certain pre-defined level, such that it reacts in urine samples which only contain the presence of the appendicitis biomarker (i.e. of a LRG biomarker) above a certain level, i.e. above a pre-defined level of the appendicitis biomarker. Another embodiment has the negative indicator (e.g., the "-" portion of a possible "+" symbol) which contains reagents that reacts with the sample which either has the absence of the test appendicitis biomarker (i.e. absence of a LRG biomarker) or the level of the test appendicitis biomarker (i.e. the LRG biomarker) below a certain pre-defined or threshold level. The positive indication (e.g., the "+" part of the "+" symbol) has a lower sensitivity to the presence of a test appendicitis biomarker (i.e. LRG biomarker) and thus such the reagents react only with urine samples containing level of the urine marker (i.e. LRG biomarker) above a pre-defined level.

[0167] In some embodiments, a test device, such as a dipstick device has text on the device in two places. In one place the text indicates a positive result (i.e. the likelihood the subject has acute appendicitis). In another, it indicates a negative result (i.e. the likelihood the subject does not have acute appendicitis). Next to the indications are matrices having the appropriate diagnostic test reagents. For example, next to the negative indication is a matrix having diagnostic test reagents that react with all urine samples, regardless of the content of appendicitis biomarkers as disclosed herein. Next to the positive indication is a matrix having diagnostic test reagents that react only with samples that have the presence of the test appendicitis biomarker, (e.g. LRG, or any or any combination of appendicitis biomarkers listed in Table 1) above a pre-defined level. In some embodiments, such a device such as one discussed in Figure 12, does not require a chart, such as a coloration chart, to interpret the results. In some embodiments of this aspect of the invention, this enables the detection device, such as a dipstick device (and the corresponding method) to be used easily by one without special training and provides a more rapid diagnostic (and method) for determining if a subject is likely to have acute appendicitis. In some embodiments of this aspect of the invention, such a device is ideal for point-of-care testing application.

[0168] Production and manufacturer of dipsticks are well known by ordinary skill in the art. Dipsticks are commercially available from Bayer Corporation of Elkhart, Ind., as well as

other commercial sources. The dipstick is dipped into a well mixed urine sample, and after a time period, for example between about thirty seconds (30s) to about two minutes (2 mins) or more, the various reagent bands are visually or optically examined for color changes. The bands can be visually compared to a preprinted color chart in order to determine the amount of each of the constituents or parameters being measured. It is also possible to optically scan using a machine or optical scanner the dipstick and thereby obtain instrument readings of color intensity or wave length through the use of a particular instrument adapted for reading the reagents and color of the dipstick. Examples of such instruments or machines are manufactured by Ames. Examples of useful machines or instruments for optically scanning the dipstick bands are able to distinguish between positive and negative reaction or reagent bands, as well as differences in color distribution of the reagent bands in the presence (i.e. above a certain threshold level) or absence (or below a certain threshold level) of the test appendicitis biomarker(s). In some embodiments, the instrument is capable of quantify a number of reagent bands as well as quantify the overall color intensity sensed on the band.

[0169] In some embodiments, the immunoassays operate on a purely qualitative basis. However it is possible to measure the intensity of the test line to determine the quantity of antigen in the sample when using an immunoassay such as a LFIA. Implementing a magnetic immunoassay (MIA) in the lateral flow test form also allows for getting a quantified result.

[0170] Instruments have been developed which both determine the chemical constituents of the urine and also assist in the microscopic analysis, for example the instrument disclosed in US Patent 6,004,821.

Such an instrument is the Yellow IRIS, which automatically places the sample on the urine dipstick and then reads the chemical results. FIG. 8 of US Patent 6,004,821 shows a schematic depiction of such an automated calorimetric microscopical instrument assembly (which is denoted generally by the numeral 54), and which can be used to scan a urine sample, and can, without significant human intervention, colorimetrically analyze the wavelengths of the colors imparted to the dipstick by the urine in the chamber 14, either colorimetrically and/or morphometrically. Accordingly, such an instrument, which is specifically adapted to scan the reaction of the dipstick after contact with a urine sample for the presence of the appendicitis biomarkers (such as at least one selected from Table 1) is encompassed for use in the present invention.

[0171] In some embodiments, the dipstick uses reagents such as copper-creatinine and iron-creatinine complexes have peroxidase activity. Other dipstick reagents can use reagents such as 3, 3', 5, 5'-tetramethylbenzidine (TMB), and diisopropyl benzene dihydroperoxide (DBDH) which are used with peroxidase. In some embodiments, a dipstick for use to detect the presence of appendicitis biomarkers is based upon the first-generation devices which relied on

the same colorimetric reaction used for assessing the presence of glucose test strips for urine. Besides glucose oxidase, a test kit for use herein can contain a benzidine derivative, which is oxidized to a blue polymer by the hydrogen peroxide formed in the oxidation reaction. Care must be taken if such a dipstick is generated to ensure the test strip is developed after a precise interval after contact with the urine test sample as well as frequent calibration of the meter to read the test result. The same principle is used in test strips that have been commercialized for the detection Diabetic ketoacidosis (DKA). These test strips use a beta-hydroxybutyrate-dehydrogenase enzyme instead of a glucose oxidizing enzyme and have been used to detect and help treat some of the complications that can result from prolonged hyperglycaemia. Blood alcohol sensors using the same approach but with alcohol dehydrogenase enzymes have been developed.

[0172] In another embodiment, the device, such as a dipstick device uses an electrochemical method. Test strips contain a capillary that sucks up a reproducible amount of urine. The presence of an appendicitis biomarker such as any or a combination of those listed in Table 1 in the urine reacts with an enzyme electrode containing protein-binding agents with the test appendicitis biomarker. The coulometric method is a technique where the total amount of charge generated by the specific binding of the appendicitis biomarker to the specific protein-binding agent reaction is measured over a period of time. This is analogous to throwing a ball and measuring the distance it has covered so as to determine how hard it was thrown. The amperometric method is used by some meters and measures the electrical current generated at a specific point in time. This is analogous to throwing a ball and using the speed at which it is travelling at a point in time to estimate how hard it was thrown. The coulometric method can allow for variable test times, whereas the test time on a meter using the amperometric method is always fixed. Both methods give an estimation of the concentration of the appendicitis biomarker in the urine sample.

[0173] In one embodiment, the levels of appendicitis biomarker proteins in urine are detected by a magnetic immunoassay (MIA). MIA is a type of diagnostic immunoassay using magnetic beads as labels in lieu of conventional enzymes (ELISA), radioisotopes (RIA) or fluorescent moieties (fluorescent immunoassays). This assay involves the specific binding of a protein binding agent to an appendicitis biomarker protein, such as an antibody binding to its antigen, where a magnetic label is conjugated to one element of the pair. The presence of magnetic beads is then detected by a magnetic reader (magnetometer) which measures the magnetic field change induced by the beads. The signal measured by the magnetometer is proportional to the antigen or biomarker quantity in the initial sample.

[0174] Magnetic beads are made of nanometric-sized iron oxide particles encapsulated or glued together with polymers. These magnetic beads can range from 35nm up to 4.5µm. The component magnetic nanoparticles range from 5 to 50nm and exhibit a unique quality referred to as superparamagnetism in the presence of an externally applied magnetic field. Magnetic labels exhibit several features very well adapted for such applications: they are not affected by reagent chemistry or photo-bleaching and are therefore stable over time; the magnetic background in a biomolecular sample is usually insignificant; sample turbidity or staining have no impact on magnetic properties; and magnetic beads can be manipulated remotely by magnetism.

[0175] The use of MIA is well known in the art, for example, Dittmer WU and colleagues (J Immunol Methods. 2008, 338:40-6) described a sensitive and rapid immunoassay for detection and measurement parathyroid hormone using magnetic particle labels and magnetic actuation. The assay involves a 1-step sandwich immunoassay with no fluid replacement steps. The detection limit is the 10 pM range and the assay took only 15 minutes; Kuma H and colleagues (Rinsho Byori. 2007, 55:351-7) developed a sensitive immunoassay system using magnetic nanoparticles made from Fe₃O₄; and Kuramitz H. reviews the current state of concerning electrochemical immunoassays using magnetic microbeads as a solid phase in Anal Bioanal Chem. 2009, 394:61-9. U. S. Patent No. 5,252,493; 5,238,811; 5,236,824; 7,604,956; U. S. Patent Application No. 20090216082; 20090181359; and 20090263834 all describe various improvements and versions of MIA.

[0176] Magnetometers are instruments that can detect the presence and measure the total magnetic signal of a sample. An effective MIA is one that is capable of separating naturally occurring magnetic background (noise) from the weak magnetically labeled target (signal). Various approaches and devices have been employed to achieve a meaningful signal-to-noise ratio (SNR) for bio-sensing applications: giant magneto-resistive sensors and spin valves, piezo-resistive cantilevers, inductive sensors, superconducting quantum interference devices, anisotropic magneto-resistive rings, and miniature Hall sensors. MIA that exploits the non-linear magnetic properties of magnetic labels can effectively use the intrinsic ability of a magnetic field to pass through plastic, water, nitrocellulose, and other materials, thus allowing for true volumetric measurements in various immunoassay formats. Unlike conventional methods that measure the susceptibility of superparamagnetic materials, a MIA based on non-linear magnetization eliminates the impact of linear dia- or paramagnetic materials such as sample matrix, consumable plastics and/or nitrocellulose. Although the intrinsic magnetism of these materials is very weak, with typical susceptibility values of -10^{-5} (dia) or $+10^{-3}$ (para), when one is investigating very small quantities of superparamagnetic materials, such as nanograms per

test, the background signal generated by ancillary materials cannot be ignored. In MIA based on non-linear magnetic properties of magnetic labels the beads are exposed to an alternating magnetic field at two frequencies, f_1 and f_2 . In the presence of non-linear materials such as superparamagnetic labels, a signal can be recorded at combinatorial frequencies, for example, at $f = f_1 \pm 2 \times f_2$. This signal is exactly proportional to the amount of magnetic material inside the reading coil. Ultrasensitive magnetic biosensor for homogeneous immunoassay have been described by Y. R. Chemla, et al., Proc Natl Acad Sci U S A. 2000, 97:14268–14272.

[0177] In one embodiment, the levels of biomarker proteins in urine are detected by a diffusion immunoassay (DIA). In this assay, the transport of molecules perpendicular to flow in a microchannel, e. g. in a microfluidic chip, is affected by binding between antigens and antibodies. By imaging the steady-state position of labeled components in a flowing stream, the concentration of very dilute analytes, in this invention, the urine biomarkers, can be measured in a few microliters of sample in seconds. Microfluidics is the manipulation of microliter volumes in channels with sub-millimeter dimensions. Microfluidic diffusion immunoassays for the detection of analytes or biomarkers in fluid samples have been described in the art, for example, in U. S. Patent No. 6,541,213; 6,949 377; 7,271,007; U. S. Patent Application No. 20090194707; 20090181411; in Hatch et al., 2001, Nature Biotechnology 19(5): 461-465; K. Scott Phillips and Quan Cheng, Anal. Chem., 2005, 77:327–334; J. Hsieh, et al., Nanotech 2007 Vol. 3, Technical Proceedings of the 2007 NSTI Nanotechnology Conference and Trade Show, Chapter 4: Micro and Nano Fluidics, pp292 – 295; Frank Y. H. Lin et al., Clinical and Diagnostic Laboratory Immunology, 2005, 12:418-425; and A. Bhattacharyya and C. M. Klapperich, 2007, Biomedical Microdevices, 9: 245-251.

U. S. Patent No. 6,541,213 describes the use of a credit-card sized microfluidic device to perform competitive immunoassays. The ability to perform assays in this microscale dimension affords an extremely rapid, homogenous, and cost effective alternative to current methods used commercially today. The credit-card sized microfluidic device can be integrated into the development of point-of-use systems that allow real-time answers to health questions while at the physician's office, home, workplace, school, shopping mall and other public places. These systems include portable and handheld instruments with integrated laboratory-tests-on-a-card ("lab cards"), as well as stand alone, single use lab cards being developed to provide rapid on-site results in infectious diseases testing, nucleic acid testing, blood type analysis, cancer testing, and respiratory disease testing.

[0178] In one embodiment, the levels of biomarker proteins in urine are detected by an on-the-spot assay also known as point-of-care assay. Point-of-care testing (POCT) is defined as

diagnostic testing at or near the site of patient care. Currently majority of the detection and diagnostic testing for analytes, toxin, pathogen toxins and antigens in samples are largely restricted to centralized laboratories because of the need for long assay times, complex and expensive equipment, and highly trained technicians. POCT brings the test conveniently and immediately to the patient. This increases the likelihood that the patient will receive the results in a timely manner. POCT is accomplished through the use of transportable, portable, and handheld instruments (e.g., blood glucose meter, nerve conduction study device) and test kits (e.g., CRP, HBA1C, Homocystein, HIV salivary assay, etc.). POCTs are well known in the art, especially immunoassays. For example, the LFIA test strip or dip sticks can easily be integrated into a POCT diagnostic kit. One skilled in the art would be able to modify immunoassays for POCT using different format, e. g. ELISA in a microfluidic device format or a test strip format. For example, U. S. Patent Application No.2009/0181411 describes a microfluidic device-based point-of-care immunoassay for biomarker molecules associated with pathology in a vertebrate host, man or animal. The microfluidic devices such as chips are formatted to either hand-held cartridges (also termed “cards”), or cartridges for automated or semi-automated, machine-aided testing. Microfluidic device-based assays enable small-volume sampling, with point-of-care results from a broad variety of biological fluids and samples in real time. In addition, the assay cartridges can be single use reagent packs, or be fully self-contained and operable entirely by hand.

[0179] Embodiments of the invention further provide for diagnostic kits and products of manufacture comprising the diagnostic kits. The kits can comprise a means for predicting acute appendicitis in a human.

[0180] In one embodiment, the kit comprises an indicator responsive to the level of biomarker protein in a sample of urine, wherein the appendicitis biomarker protein is selected from the group consisting of LRG, S100- A8, ORM1, PLG, MASP2, AZGP1, ApoD and SERPINA3. In some embodiments, the indicator is in the form of a LFIA test strip or a microfluidic device. In one embodiment, a diagnostic kit can comprise multiple LFIA test strips, one strip for a different biomarker protein. In another embodiment, a diagnostic kit can comprise a single composite LFIA test strip for determining the levels of several biomarker proteins. In one embodiment, a diagnostic kit can comprise a single multichannel microfluidic device for determining the levels of several biomarker proteins. In another embodiment, a diagnostic kit can comprise several microfluidic devices for determining the levels of several biomarker proteins, one microfluidic device for a different biomarker protein.

[0181] The kits can further comprise cups or tubes, or any other collection device for sample collection of urine.

[0182] In one embodiment, the kit can optionally further comprise at least one diagram and/or instructions describing the interpretation of test results.

Protein-binding agents, antibodies or antisera against biomarker proteins

[0183] In one embodiment, the methods disclosed herein uses antibodies or anti-sera for detecting, quantifying, and/or labeling LRG, S100- A8, ORM1, PLG, MASP2, AZGP1, ApoD and SERPINA3 described herein. The antibodies can be obtained from a commercial source. These commercial antibodies can also be conjugated with labels, e.g. Cy 3 or FITC.

[0184] Antibodies for use in the methods described herein can also be produced using standard methods to produce antibodies, for example, by monoclonal antibody production (Campbell, A.M., Monoclonal Antibodies Technology: Laboratory Techniques in Biochemistry and Molecular Biology, Elsevier Science Publishers, Amsterdam, the Netherlands (1984); St. Groth et al., J. Immunology, (1990) 35: 1-21; and Kozbor et al., Immunology Today (1983) 4:72). Antibodies can also be readily obtained by using antigenic portions of the protein to screen an antibody library, such as a phage display library by methods well known in the art. For example, U.S. patent 5,702,892 (U.S.A. Health & Human Services) and WO 01/18058 (Novopharm Biotech Inc.) disclose bacteriophage display libraries and selection methods for producing antibody binding domain fragments.

[0185] Methods for the production of antibodies are disclosed in PCT publication WO 97/40072 or U.S. Application. No. 2002/0182702.

The processes of immunization to elicit antibody production in a mammal, the generation of hybridomas to produce monoclonal antibodies, and the purification of antibodies may be performed by described in "Current Protocols in Immunology" (CPI) (John Wiley and Sons, Inc.) and Antibodies: A Laboratory Manual (Ed Harlow and David Lane editors, Cold Spring Harbor Laboratory Press 1988);

-----Brown, "Clinical Use of Monoclonal Antibodies, " in BIOTECHNOLOGY AND PHARMACY 227-49, Pezzuto et al. (eds.) (Chapman & Hall 1993).

[0186] For example, to generate a polyclonal antibody against human LRG, S100- A8, ORM1, PLG, MASP2, AZGP1, ApoD or SERPINA3. Methods of making recombinant proteins are well known in the art. For example, full-length cDNAs of LRG, S100- A8, ORM1, PLG, MASP2, AZGP1, ApoD and SERPINA3 (Genbank Accession Nos. NM_052972.2, NM_002964.3, NM_000607.2, NM_000301.2, NM_006610.2, NM_001185.2, NM_001647.3, and NM_001085.4 respectively) can be cloned into the pQE30 vector containing an N-terminal hexa-histidine tag (QIAGEN, GmbH, Hilden, Germany), and then transformed into *E. coli* strain

JM109 cells. Recombinant proteins is expressed and purified by affinity chromatography using Ni-nitriloacetic acid agarose (QIAGEN) according to the manufacturer's instructions. The final preparation yielded a single calculated molecular weight of 89707 kDa band on SDS-PAGE and is used for the immunization of rabbits.

[0187] Detection of anti-antibodies to the appendicitis biomarkers can be achieved by direct labeling of the antibodies themselves, with labels including a radioactive label such as ^3H , ^{14}C , ^{35}S , ^{125}I , or ^{131}I , a fluorescent label (e. g. Cy3, Cy5, FITC), a hapten label such as biotin, heavy metal such as gold, or an enzyme such as horse radish peroxidase or alkaline phosphatase. Such methods are well known in the art. Alternatively, unlabeled primary antibody is used in conjunction with labeled secondary antibody, comprising antisera, polyclonal antisera or a monoclonal antibody specific for the primary antibody. In another embodiment, the primary antibody or antisera is unlabeled, the secondary antisera or antibody is conjugated with biotin and enzyme-linked streptavidin is used to produce visible staining for histochemical analysis.

[0188] In one embodiment, the levels of the appendicitis biomarker proteins described herein in a sample can be determined by mass spectrometry such as MALDI/TOF (time-of-flight), SELDI/TOF, liquid chromatography-mass spectrometry (LC-MS), gas chromatography-mass spectrometry (GC-MS), high performance liquid chromatography-mass spectrometry (HPLC-MS), capillary electrophoresis-mass spectrometry, nuclear magnetic resonance spectrometry, or tandem mass spectrometry (e.g., MS/MS, MS/MS/MS, ESI-MS/MS, etc.). See for example, U.S. Patent Application Nos: 20030199001, 20030134304, 20030077616.

[0189] Mass spectrometry methods are well known in the art and have been used to quantify and/or identify biomolecules, such as proteins (see, e.g., Li et al. (2000) *Tibtech* 18:151-160; Rowley et al. (2000) *Methods* 20: 383-397; and Kuster and Mann (1998) *Curr. Opin. Structural Biol.* 8: 393-400). Further, mass spectrometric techniques have been developed that permit at least partial de novo sequencing of isolated proteins. Chait et al., *Science* 262:89-92 (1993); Keough et al., *Proc. Natl. Acad. Sci. USA.* 96:7131-6 (1999); reviewed in Bergman, *EXS* 88:133-44 (2000).

[0190] In certain embodiments, a gas phase ion spectrophotometer is used. In other embodiments, laser-desorption/ionization mass spectrometry is used to analyze the sample. Modern laser desorption/ionization mass spectrometry ("LDI-MS") can be practiced in two main variations: matrix assisted laser desorption/ionization ("MALDI") mass spectrometry and surface-enhanced laser desorption/ionization ("SELDI"). In MALDI, the analyte is mixed with a solution containing a matrix, and a drop of the liquid is placed on the surface of a substrate. The matrix solution then co-crystallizes with the biological molecules. The substrate is inserted into

the mass spectrometer. Laser energy is directed to the substrate surface where it desorbs and ionizes the biological molecules without significantly fragmenting them. See, e.g., U.S. Pat. No. 5,118,937 (Hillenkamp et al.), and U.S. Pat. No. 5,045,694 (Beavis & Chait).

[0191] In SELDI, the substrate surface is modified so that it is an active participant in the desorption process. In one variant, the surface is derivatized with adsorbent and/or capture reagents that selectively bind the protein of interest. In another variant, the surface is derivatized with energy absorbing molecules that are not desorbed when struck with the laser. In another variant, the surface is derivatized with molecules that bind the protein of interest and that contain a photolytic bond that is broken upon application of the laser. In each of these methods, the derivatizing agent generally is localized to a specific location on the substrate surface where the sample is applied. See, e.g., U.S. Pat. No. 5,719,060 and WO 98/59361. The two methods can be combined by, for example, using a SELDI affinity surface to capture an analyte and adding matrix-containing liquid to the captured analyte to provide the energy absorbing material.

[0192] For additional information regarding mass spectrometers, see, e.g., Principles of Instrumental Analysis, 3rd edition., Skoog, Saunders College Publishing, Philadelphia, 1985; and Kirk-Othmer Encyclopedia of Chemical Technology, 4.sup.th ed. Vol. 15 (John Wiley & Sons, New York 1995), pp. 1071-1094.

[0193] Detection and quantification of the appendicitis biomarker proteins will typically depend on the detection of signal intensity. This, in turn, can reflect the quantity and character of a polypeptide bound to the substrate. For example, in certain embodiments, the signal strength of peak values from spectra of a first sample and a second sample can be compared (e.g., visually, by computer analysis etc.), to determine the relative amounts of particular biomolecules. Software programs such as the appendicitis biomarker WIZARD program (CIPHERGEN Biosystems, Inc., Fremont, Calif.) can be used to aid in analyzing mass spectra. The mass spectrometers and their techniques are well known to those of skill in the art.

Diagnostic imaging of acute appendicitis

[0194] In some embodiments, described herein is a method of diagnosing likelihood of acute appendicitis in a subject by *in situ* histochemical imaging of an appendix using at least a protein binding agent that bind specifically to a biomarker selected from the group consisting of leucine-rich α -2-glycoprotein (LRG); S100-A8 (calgranulin); α -1-acid glycoprotein 1 (ORM); plasminogen (PLG); mannan-binding lectin serine protease 2 (MASP2); zinc- α -2-glycoprotein (AZGP1); apolipoprotein D (ApoD); and α -1-antichymotrypsin (SERPINA3).

[0195] In other embodiments, the method further comprises at least one additional different protein-binding agent that bind specifically to a biomarker selected from the group consisting AMBP; amyloid-like protein 2; angiotensin converting enzyme 2; BAZ1B; carbonic anhydrase 1; CD14; chromogranin A; FBLN7; FXR2; hemoglobin α ; hemoglobin β ; interleukin-1 receptor antagonist protein; inter- α -trypsin inhibitor; lipopolysaccharide binding protein; lymphatic vessel endothelial hyaluronan acid receptor 1; MLKL; nicastrin; novel protein (Accession No: IPI00550644); PDZK1 interacting protein 1; PRIC285; prostaglandin-H2 D-isomerase; Rcl; S100-A9; serum amyloid A protein; SLC13A3; SLC2A1; SLC2A2; SLC4A1; SLC9A3; SORBS1; SPRX2; supervillin; TGFbeta2R; TTYH3; VA0D1; vascular adhesion molecule 1; versican; VIP36; α -1-acid glycoprotein 2; and β -1,3-galactosyltransferase. In other embodiments, the method further comprises at least one additional different protein-binding agent that bind specifically to a biomarker selected from Table 1.

[0196] In one embodiment, the method for diagnosing likelihood of acute appendicitis in a subject comprise (a) introducing a protein-binding agent into the subject via a physiologically compatible vehicle in an amount effective for detection, wherein the protein binding agent is detectably labeled; (b) detecting the location of the protein-binding agent at the appendix with an extracorporeal detection means capable of detecting the labeling means; and (c) quantifying the protein-binding agent concentration in order to determine the presence and extent of inflammation in the appendix. In one embodiment, the intensity of the label is directly proportional to the concentration of the protein-binding agent that binds specifically to an appendicitis biomarker protein.

[0197] In some embodiment, the protein-binding agent concentration measured by extracorporeal detection means in a patient is compared to the protein-binding agent concentration in a healthy individual, wherein in the detectable label and the imaging method are the same for both the patient and the healthy individuals. In some embodiments, the patient has at least one symptom associated with acute appendicitis as disclosed herein or as known to one skilled in the art such as a physician. In some embodiments, the protein-binding agent concentration at the appendix of a patient is compared to the protein-binding agent concentration that is the average obtained for a population, i. e. more than two individuals, preferably ten or more, of healthy individuals, wherein in the detectable label and the imaging method are the same for both the patient and the healthy individual.

[0198] In one embodiment, the protein-binding agent is introduced into the vascular system of the subject, for example, intravenously. In one embodiment, the protein-binding agent is introduced into the abdomen cavity of the subject, preferably within the vicinity of the

appendix at the lower right abdomen. In one embodiment, the protein-binding agent is introduced into the peritoneal cavity, preferably within the vicinity of the appendix at the lower right abdomen.

[0199] In one embodiment, a fixed amount of time is allowed to lapse before imaging is performed.

[0200] In one embodiment, the protein-binding agent is an antibody or fragment thereof. In one embodiment, the protein-binding agent is a monoclonal antibody or active fragment thereof. In one embodiment, the protein-binding agent is a polyclonal antibody or active fragment thereof. For example, the protein-binding agent is an anti-LRG antibody or fragments thereof. In some embodiments, the protein-binding agent is an antibody that is specifically immunoreactive (i. e. binds specifically to) to a biomarker protein selected from the group consisting of leucine-rich α -2-glycoprotein (LRG); S100-A8 (calgranulin); α -1-acid glycoprotein 1 (ORM); plasminogen (PLG); mannan-binding lectin serine protease 2 (MASP2); zinc- α -2-glycoprotein (AZGP1); apolipoprotein D (ApoD); α -1-antichymotrypsin (SERPINA3); AMBP; amyloid-like protein 2; angiotensin converting enzyme 2; BAZ1B; carbonic anhydrase 1; CD14; chromogranin A; FBLN7; FXR2; hemoglobin α ; hemoglobin β ; interleukin-1 receptor antagonist protein; inter- α -trypsin inhibitor; lipopolysaccharide binding protein; lymphatic vessel endothelial hyaluronan acid receptor 1; MLKL; nicastrin; novel protein (Accession No: IPI00550644); PDZK1 interacting protein 1; PRIC285; prostaglandin-H2 D-isomerase; Rcl; S100-A9; serum amyloid A protein; SLC13A3; SLC2A1; SLC2A2; SLC4A1; SLC9A3; SORBS1; SPRX2; supervillin; TGFbeta2R; TTYH3; VA0D1; vascular adhesion molecule 1; versican; VIP36; α -1-acid glycoprotein 2; β -1,3-galactosyltransferase and a biomarker selected from Table 1.

[0201] In one embodiment, the protein-binding agent is conjugated to a label for extracorporeal detection of the protein binding agent located in the body of the subject.

[0202] In some embodiments, the detectable label on the protein-binding agent is selected from the group comprising of radioisotopes, paramagnetic labels, echogenic liposomes, biotin, and fluorescence.

[0203] In some embodiments, the extracorporeal detection method is selected from the group comprising magnetic resonance imaging (MRI), computer axial tomography (CAT) scan, positron emission tomography (PET) scan, electron beam, computed tomography (CT) scan, single photon emission computed tomography (SPECT) imaging, gamma imaging, angiography, abdominal ultrasound, and abdominal radioactive and fluorescent detection.

[0204] In one embodiment, radionuclide is used as the labeling means and the step of detecting the location of the protein binding agent within the subject further includes detecting radiation therefrom with a radiation detector. In one embodiment, a radionuclide is the detectable label conjugated to the protein binding agent.

[0205] In one embodiment, step of detecting radiation further includes employing a gamma camera to detect and make an image of gamma radiation emitted by the labeling means of the protein binding reagent.

[0206] Suitable radionuclides include Co-57, Cu-67, Ga-67, Ga-68, Ru-97, Tc-99m, In-111, In-113m, I-123, I-125, I-131, Hg-197, Au-198, and Pb-203. The radionuclides can be linked by direct labeling (e.g., by acidic buffered reactions or oxidative procedures) or by ligand exchange or chelation. The radionuclides are preferably imaged with a radiation detection means capable of detecting gamma radiation, such as a gamma camera or the like. Methods of radiolabeling of proteins for imaging are well known to one skilled in the art, for examples, D. Hnatowich, et al., 1983, Science 220:613-615; M. R. McDevitt, et al., 2000, Cancer Res. 60:6095-6100; DA Scheinberg, et al., 1982, Science, 215:1511-1513; and W. J. McBride, et al., 2009, J. Nucl. Med. 50, 991-998; and R. Macklis, B. et al., 1988, Science 240:1024-1026; U. S. Patent Nos. 4,472,509; 4,454,106; 4,634,586; 4,994,560; 5,286,850; U. S. Patent Application Nos. 2008/0241967 and 20090297620.

[0207] Typically, radiation imaging cameras employ a conversion medium (wherein the high energy gamma ray is absorbed, displacing an electron which emits a photon upon its return to the orbital state), photoelectric detectors arranged in a spatial detection chamber (to determine the position of the emitted photons), and circuitry to analyze the photons detected in the chamber and produce an image.

[0208] The invention can also be practiced with non-radioactive labeling means, such as magnetic contrast agents capable of detection in magnetic resonance imaging (MRI) systems. In such systems, a strong magnetic field is used to align the nuclear spin vectors of the atoms in a patient's body. The field is then disturbed and an image of the patient is read as the nuclei return to their equilibrium alignments. In the present invention, the protein binding agent can be linked to diamagnetic contrast agents, such as gadolinium, cobalt, nickel, manganese or copper complexes, to form conjugate diagnostic reagents that are imaged extracorporeally with an MRI system. Other imaging techniques include plethysmography, thermography and ultrasonic scanning.

[0209] In one embodiment, the protein binding agent such as an antibody can be genetically or chemically engineered to contain ^{99m}Tc binding sites for nuclear scintigraphy

imaging. *In vivo* localized quantitative imaging is performed (SPECT imaging) can be carried out on the subject.

[0210] In one embodiment, the protein binding agent can be labeled with gadolinium or echogenic liposomes for magnetic resonance and abdomen ultrasound imaging, respectively.

[0211] Methods and reagents such as detectably labeled antibodies for *in situ* imaging are been described and are well known in the art, for example, U. S. Patent Nos. 3,899,675; 4,660,563; 4,877,599; 4,647,445; 5,605,831; 6,716,410; U. S. Patent Application Nos. 2009/0016965 and 20070059775. Additional methods and reagents for *in situ* imaging are described in JH Tseng, 2001, Abdominal Imaging, 26: 171-177; Liu, Qing-Yu, 2009, Abdominal Imaging, in press; DA Scheinberg, et al., 1982, Science, 215:1511-1513; and W. J. McBride, et al., 2009, J. Nucl. Med. 50, 991-998.

Conjugation of protein binding agent, e.g. antibody to echogenic liposomes for ultrasound imaging

[0212] Antibody-conjugated echogenic liposomes have been developed for site-specific intravascular (30 MHz) and transvascular (15 MHz) image enhancement. As examples, anti-fibrinogen and anti-intercellular adhesion molecule-1 (anti-ICAM-1) antibodies have been conjugated to acoustically reflective liposomes and images obtained in animal models of thrombi and atherosclerotic lesions. These acoustic liposomes consist of a 60:8:2:30 molar mixture of phosphatidylcholine:phosphatidyl-ethanolamine:phosphatidylglycerol: cholesterol and are prepared by a dehydration/rehydration mixture. They are multilamellar with well separated lipid bilayers and internal vesicles which confers echogenicity. Their mean size is ~800 nm as measured by quasielastic light scattering. These liposomes are stable in circulation, do not trap gas, pass through pulmonary capillaries and retain their properties at 37°C., even after conjugation with antibodies. Antibodies are modified by the addition of cysteines to the C- or N-terminus of the protein and conjugated to liposomes. A 12 MHz imaging catheter (Acuson) is used for imaging (resolution <1 mm). The antibodies are thiolated with N-succinimidyl-3-(2-pyridyldithio) propionate, reduced, and conjugated with the liposomes by creating a thioether linkage between the antibody and phospholipid. The conjugated antibodies are stable and have a long shelf half-life. Imaging is by ultrasound.

Gadolinium(Gd³⁺)-labeled protein binding agent, e.g. scFv antibodies (MAbs)

[0213] An alternative imaging method that provides enhanced resolution (<0.5 mm), magnetic resonance imaging (MRI) is using Gd³⁺ -labeling protein binding agent as a contrast agent. MRI has the advantages of rapid acquisition, increased resolution, and absence of radioactivity. However, because free Gd³⁺ as a contrast agent is toxic, it is used in clinical MRI imaging bound to diethylenetriaminepentaacetic acid (DTPA). Precedent exists for conjugating Gd³⁺ to MAbs by reacting cyclic-diaminetriaminepentaacetic acid anhydride (c-DTPA) with the MAb. Polylysine-DTPA-Gd³⁺ -coupled antibodies have been used for tumour imaging with up to 30 Gd³⁺ ions conjugated without significantly affecting antigen affinity. Previous studies using Gd³⁺ -labeled MAbs have either directly bound Gd³⁺ to available NH₂ groups or chemically conjugated polylysine. The natural site for coupling DTPA is limited in scFv (single chain antibody) molecules. Therefore, genetic fusion of several clusters of polylysine groups (6-30 in length) to the N-terminal or C-terminal of scFv MAb can be used and this fusion can be reacted with c-DTPA. Although other amino groups may potentially react, the availability of polylysine in the tail of the molecule should allow preferential site-directed labeling. The bioengineering of the polylysine site was done by PCR using primers encoding six lysine residues and restriction site for cloning at both 5' and 3' ends.

Imaging With ^{99m}Tc-labeled protein binding agent, e.g. antibody

[0214] ^{99m}Tc-labeling of oxidation specific antibodies has been previously described (Tsimikas et al., 1999, J Nucl Cardiol. 1999;6:41-53). ^{99m}Tc-protein binding agent specific for the biomarkers described herein can be intravenously injected into the patient and is analyzed for the pharmacokinetics, organ distribution and appendix uptake. For *in vivo* imaging, 1-5 mCi are intravenously injected in the patient and imaging can be performed with a dual detector ADAC vertex model gamma camera set to a 20% window for ^{99m}Tc (VXUR collimator) equipped with ADAC Pegasys™ computer software. *In vivo* images planar (anterior, posterior and 45° oblique positions) and SPECT can be acquired on a 256×256×12 matrix for a minimum of 1×10⁶ counts at 10 minutes post injection. Repeat imaging can be performed for 3-500,000 counts at various time points based on the optimal target to background ratio derived from *in vivo* uptake data. Previous imaging studies using whole monoclonal antibody have shown that whole monoclonal antibody often give a low signal to noise ratio due to the prolonged half-life of the ^{99m}Tc-MAb in the circulation. The use of Fab, scFv, or smaller fragments can abrogate this problem under certain imaging conditions as the Fabs and scFvs have a very short half lives (<30 minutes). When the signal to noise ratio is not favorable, injections of MDA-LDL, Cu-OxLDL, or other appropriate antigen can be injected to clear the background signal.

Imaging With Gd3 -labeled protein binding agent, e.g. antibody

[0215] Labeling of Gd3 to an antibody-DTPA complex has been previously described (Lister-James, et al, 1996, J Nucl Med. 1996;40:221-233; Wu et al, 1995, Arterioscler Thromb Vasc Biol. 1995; 15:529-533). Initial testing by *in vivo* uptake assays can be carried out with ¹⁵³Gd-antibody in mice and rabbits and the pharmacokinetics, biodistribution and aortic plaque uptake of antibody is determined. *In vivo* imaging can be performed in rabbits with a 1.5 T GE MRI scanner with a small surface coil.

Computer systems and computer readable media to assay appendicitis biomarkers in urine samples.

[0216] One aspect of the present invention relates to a system for analyzing a urine biological sample from a subject, where the system comprises: (a) a determination module configured to receive a urine biological sample and to determine an appendicitis biomarker level information, wherein the appendicitis biomarker level information comprises determination of at least one appendicitis biomarker level, i.e. at the level or amount of an appendicitis biomarker, such as LRG, or any or a combination of appendicitis biomarkers listed in Table 1; (b) a connection from the determination module to transmit the appendicitis biomarker level information to an electronic computer, wherein the computer comprises a storage device, a comparison module and a display module; (c) the storage device configured to store appendicitis biomarker level information from the determination module; (d) the comparison module adapted to compare the appendicitis biomarker level information stored on the storage device with reference data, and to provide a comparison result, wherein the comparison result comprises; (i) a comparison of the appendicitis biomarker level in the urine biological sample with the reference appendicitis biomarker level, and (ii) a determination of the appendicitis biomarker level in the biological sample above or below a threshold level relative to the reference appendicitis biomarker level, wherein a appendicitis biomarker level above the threshold level for that biomarker is indicative of acute appendicitis (i.e. a positive test result); and wherein a appendicitis biomarker level below the threshold level is indicative of absence of acute appendicitis (i.e. a negative test result); and (e) the display module for displaying a content based in part on the comparison result for the user, wherein the content is a signal indicative of the likelihood of a subject having acute appendicitis (i.e. a positive test result) or unlikely to have acute appendicitis (i.e. a negative test result).

[0217] Another aspect of the present invention relates to a computer readable medium having computer readable instructions recorded thereon to define software modules including a

comparison module and a display module for implementing a method on a computer, the method comprising: (a) comparing with the comparison module the data stored on a storage device with reference data to provide a comparison result, wherein the comparison result is the appendicitis biomarker level information in the urine biological above a threshold level relative to a reference appendicitis biomarker level for that biomarker tested which is indicative of acute appendicitis; and (b) displaying a content based in part on the comparison result for the user, wherein the content is a signal indicative of acute appendicitis.

[0218] In some embodiments, the appendicitis biomarker threshold level which is used in the system, computer-readable medium and methods as disclosed herein that is indicative of acute appendicitis is at a level of at least about two-fold (2x) above the control or reference appendicitis biomarker level for that biomarker. For example, if the appendicitis biomarker is LRG, if the level of LRG in the test urine sample from the subject is at least about 2-fold above the reference LRG biomarker level, it is indicative of a subject likely to have or be at risk of acute appendicitis. In some embodiments a threshold level is at least about 3-fold, or at least about 4-fold, or at least about 5-fold, or at least about 6-fold, or at least about 7-fold, or at least about 8-fold, or at least about 9-fold, or at least about 10-fold or more than 10-fold above the reference level for that biomarker, and thus a the level of the appendicitis biomarker in the test urine sample above the threshold level it is indicative of a subject likely to have or be at risk of acute appendicitis.

[0219] In some embodiments, the system, computer-readable media and methods as disclosed herein is used to measure an appendicitis biomarker level in a biological sample, where the appendicitis biomarker level is the level of a polypeptide biomarker, for example any biomarker of Table 1 or of any SEQ ID NOs 1-49. In some embodiments, the level of at least one biomarker protein is measured by immuno assay, for example western blot analysis or ELISA, or a highthrough-put protein detection method, for example but are not limited to automated immunohistochemistry apparatus, for example, robotically automated immunohistochemistry apparatus which in an automated system section the tissue or biological sample specimen, prepare slides, perform immunohistochemistry procedure and detect intensity of immunostaining, such as intensity of an antibody binding to a biomarker protein in the urine sample and produce output data. Examples of such automated immunohistochemistry apparatus are commercially available, for example such Autostainers 360, 480, 720 and Labvision PT module machines from LabVision Corporation, which are disclosed in U.S. Patents 7,435,383; 6,998,270; 6,746,851, 6,735,531; 6,349,264; and 5,839,091.

Other commercially available automated immunohistochemistry instruments are also encompassed for use in the present invention, for example, but not are

limited BOND™ Automated Immunohistochemistry & *In Situ* Hybridization System, Automate slide loader from GTI vision. Automated analysis of immunohistochemistry can be performed by commercially available systems such as, for example, IHC Scorer and Path EX, which can be combined with the Applied spectral Images (ASI) CytoLab view, also available from GTI vision or Applied Spectral Imaging (ASI) which can all be integrated into data sharing systems such as, for example, Laboratory Information System (LIS), which incorporates Picture Archive Communication System (PACS), also available from Applied Spectral Imaging (ASI) (see world-wide-web: spectral-imaging.com). Other a determination module can be an automated immunohistochemistry systems such as NexES® automated immunohistochemistry (IHC) slide staining system or BenchMark® LT automated IHC instrument from Ventana Discovery SA, which can be combined with VIAS™ image analysis system also available Ventana Discovery. BioGenex Super Sensitive MultiLink® Detection Systems, in either manual or automated protocols can also be used as the detection module, preferably using the BioGenex Automated Staining Systems. Such systems can be combined with a BioGenex automated staining systems, the i6000™ (and its predecessor, the OptiMax® Plus), which is geared for the Clinical Diagnostics lab, and the GenoMx 6000™, for Drug Discovery labs. Both systems BioGenex systems perform "All-in-One, All-at-Once" functions for cell and tissue testing, such as Immunohistochemistry (IHC) and In Situ Hybridization (ISH).

[0220] As an example, a determination module used in the system, computer-readable media and methods as disclosed herein for determining appendicitis biomarker level measures the level of at least one appendicitis biomarker polypeptide, for instance the determination module is configured to detect the total level (i.e. amount) of at least one appendicitis biomarker polypeptide of Table 1 using any known systems for automated protein expression analysis, including for example, but not limited Mass Spectrometry systems including MALDI-TOF, or Matrix Assisted Laser Desorption Ionization – Time of Flight systems; SELDI-TOF-MS ProteinChip array profiling systems, e.g. Machines with Ciphergen Protein Biology System II™ software; systems for analyzing gene expression data (see for example U.S. 2003/0194711); systems for array based expression analysis, for example HT array systems and cartridge array systems available from Affymetrix (Santa Clara, CA 95051) AutoLoader, Complete GeneChip® Instrument System, Fluidics Station 450, Hybridization Oven 645, QC Toolbox Software Kit , Scanner 3000 7G, Scanner 3000 7G plus Targeted Genotyping System, Scanner 3000 7G Whole-Genome Association System, GeneTitan™ Instrument, GeneChip® Array Station, HT Array; an automated ELISA system (e.g. DSX® or DS2® form Dynax, Chantilly, VA or the ENEASYSTEM III®, Triturus®, The Mago® Plus); Densitometers (e.g. X-Rite-508-Spectro Densitometer®, The HYRYS™ 2 densitometer); automated Fluorescence in situ hybridization

systems (see for example, United States Patent 6,136,540); 2D gel imaging systems coupled with 2-D imaging software; microplate readers; Fluorescence activated cell sorters (FACS) (e.g. Flow Cytometer FACSVantage SE, Becton Dickinson); and radio isotope analyzers (e.g. scintillation counters).

[0221] In some embodiments, the appendicitis biomarker level is the appendicitis biomarker polypeptide level of any biomarker listed in Table 1. In some embodiments, the appendicitis biomarker level is LRG polypeptide (SEQ ID NO:1). In some embodiments, the appendicitis biomarker level is ORM (SEQ ID NO:3) or MASP2 (SEQ ID NO:5).

[0222] In some embodiments, the system, computer-readable media and methods as disclosed herein is used to measure at least one appendicitis biomarker level in the biological sample such as a urine sample.

[0223] In some embodiments, the system, computer-readable media and methods as disclosed herein is used to measure at least one appendicitis biomarker level in urine biological sample which is obtained from a mammalian subject, for example a human subject. In some embodiments, the subject has at least one symptom of appendicitis as discussed herein.

[0224] In some embodiments, the system, computer-readable media and methods as disclosed herein is used to measure at least one appendicitis biomarker level in biological sample obtained from a subject who has experienced one or more symptoms of acute appendicitis include pain starting centrally (periumbilical) before localizing to the right iliac fossa (the lower right side of the abdomen); loss of appetite and fever; nausea or vomiting; the feeling of drowsiness; the feeling of general bad health; pain beginning and staying in the right iliac fossa, diarrhea and a more prolonged, smoldering course; increased frequency of urination; marked retching; tenesmus or "downward urge" (the feeling that a bowel movement will relieve discomfort); positive Rovsing's sign, Psoas sign, and/or Obturator sign.

[0225] In some embodiments, the system, computer-readable media and methods as disclosed herein comprises a determination module which has been configured to determine the level of an additional agent in the biological sample, for example, albumin.

[0226] In some embodiments, the system, computer-readable media and methods as disclosed herein is used to measure at least one appendicitis biomarker level in a urine biological sample to indicate if a subject has, or is at risk of acute appendicitis. Accordingly, in some embodiments, the system, computer-readable media and methods as disclosed herein is used to identify if a subject is has acute appendicitis.

[0227] In some embodiments, the system, computer-readable media and methods as disclosed herein is used to measure at least one appendicitis biomarker level in a urine biological sample obtained from a subject.

[0228] Another aspect of the present invention relates to a method of treating a subject identified to have acute appendicitis comprising; (a) determining if the subject has, or is likely to have or is at risk of having acute appendicitis by measuring at least one appendicitis biomarker level in a urine sample obtained from the subject, and if high levels (e.g. at least about 2-fold above a reference level for the measured biomarker) of the appendicitis biomarker protein exists in the urine biological sample from the subject, it indicates that the subject is likely to have acute appendicitis, and (b) administering an appropriate treatment to a subject determined to likely have acute appendicitis, where an appropriate treatment can be determined by an ordinary physician, for example by surgical resection of the appendix (i.e. appendectomy) if the appendicitis is severe, or antibiotics if the appendicitis is not severe.

[0229] In one embodiment, the method is performed on a subject who has experienced or exhibited symptoms of acute appendicitis or one or more of the following symptoms or risk factors: pain starting centrally (periumbilical) before localizing to the right iliac fossa (the lower right side of the abdomen); loss of appetite and fever; nausea or vomiting; the feeling of drowsiness; the feeling of general bad health; pain beginning and staying in the right iliac fossa, diarrhea and a more prolonged, smoldering course; increased frequency of urination; marked retching; tenesmus or "downward urge" (the feeling that a bowel movement will relieve discomfort); positive Rovsing's sign, Psoas sign, and/or Obturator sign.

[0230] In one embodiment, the diagnostic tool or device is used to test a urine sample from a subject who has experienced or exhibited symptoms of acute appendicitis or one or more of the following symptoms or risk factors: pain starting centrally (periumbilical) before localizing to the right iliac fossa (the lower right side of the abdomen); loss of appetite and fever; nausea or vomiting; the feeling of drowsiness; the feeling of general bad health; pain beginning and staying in the right iliac fossa, diarrhea and a more prolonged, smoldering course; increased frequency of urination; marked retching; tenesmus or "downward urge" (the feeling that a bowel movement will relieve discomfort); positive Rovsing's sign, Psoas sign, and/or Obturator sign.

[0231] The device or methods as disclosed herein can be used to assess the urine sample from a subject at one or more indicated times following specific experienced symptoms of the subject, such as initial symptoms (e.g., at about 1 hour, 2-5 hours, 10 hours, 12 hours, 24 hours, 36 hours, 48 hours, and/ or 72 hours).

[0232] It should be understood that this invention is not limited to the particular methodology, protocols, and reagents, etc., described herein and as such may vary. The terminology used herein is for the purpose of describing particular embodiments only, and is not intended to limit the scope of the present invention, which is defined solely by the claims.

Definitions of terms

[0233] Unless otherwise explained, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. Definitions of common terms in urology, endocrinology, biochemistry and molecular biology can be found in The Merck Manual of Diagnosis and Therapy, 18th Edition, published by Merck Research Laboratories, 2006 (ISBN 0-911910-18-2); Robert S. Porter et al. (eds.), The Encyclopedia of Molecular Biology, published by Blackwell Science Ltd., 1994 (ISBN 0-632-02182-9); and Robert A. Meyers (ed.), Molecular Biology and Biotechnology: a Comprehensive Desk Reference, published by VCH Publishers, Inc., 1995 (ISBN 1-56081-569-8); The ELISA guidebook (Methods in Molecular Biology 149) by Crowther J. R. (2000); Fundamentals of RIA and Other Ligand Assays by Jeffrey Travis, 1979, Scientific Newsletters; and Immunology by Werner Luttmann, published by Elsevier, 2006.

[0234] Unless otherwise stated, the present invention was performed using standard procedures, as described, for example in Maniatis et al., Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y., USA (1982); Sambrook et al., Molecular Cloning: A Laboratory Manual (2 ed.), Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y., USA (1989); Davis et al., Basic Methods in Molecular Biology, Elsevier Science Publishing, Inc., New York, USA (1986); A. R. Kimmerl Eds., Academic Press Inc., San Diego, USA (1987)) and Current Protocols in Immunology (CPI) (John E. Coligan, et. al., ed. John Wiley and Sons, Inc.).

[0235] As used herein, the term “biomarker” is a biological characteristic that is measured and evaluated objectively as an indicator of normal biological or pathogenic processes (a diagnostic biomarker), or a pharmacological response to therapeutic intervention (a therapeutic biomarker). A “biomarker” can be any patient parameter that can be measured, for example, mRNA expression profiles, proteomic signatures, protein, hormone or lipid levels, imaging methods or electrical signals. Typically, the term “biomarker” as used herein refers to a protein, polypeptide or peptide in the sample.

[0236] The term “protein binding agent” is used interchangeably herein with “protein binding molecule” or “protein binding moiety” and refers to any entity which has specific affinity for a protein. The term “protein-binding molecule” also includes antibody-based binding moieties and antibodies and includes immunoglobulin molecules and immunologically active determinants of immunoglobulin molecules, e.g., molecules that contain an antigen binding site which specifically binds (immunoreacts with) to the Psap proteins. The term “antibody-based

binding moiety” is intended to include whole antibodies, e.g., of any isotype (IgG, IgA, IgM, IgE, etc), and includes fragments thereof which are also specifically reactive with the Psap proteins. Antibodies can be fragmented using conventional techniques. Thus, the term includes segments of proteolytically-cleaved or recombinantly-prepared portions of an antibody molecule that are capable of selectively reacting with a certain protein. Non limiting examples of such proteolytic and/or recombinant fragments include Fab, F(ab')₂, Fab' , Fv, dAbs and single chain antibodies (scFv) containing a VL and VH domain joined by a peptide linker. The scFv's can be covalently or non-covalently linked to form antibodies having two or more binding sites. Thus, "antibody-base binding moiety" includes polyclonal, monoclonal, or other purified preparations of antibodies and recombinant antibodies. The term "antibody-base binding moiety" is further intended to include humanized antibodies, bispecific antibodies, and chimeric molecules having at least one antigen binding determinant derived from an antibody molecule. In a preferred embodiment, the antibody-based binding moiety detectably labeled. In some embodiments, a “protein-binding agent” is a co-factor or binding protein that interacts with the appendicitis biomarker protein to be measured, for example a co-factor or binding protein or ligand to the appendicitis biomarker protein.

[0237] The term "labeled antibody", as used herein, includes antibodies that are labeled by a detectable means and include, but are not limited to, antibodies that are enzymatically, radioactively, fluorescently, and chemiluminescently labeled. Antibodies can also be labeled with a detectable tag, such as c-Myc, HA, VSV-G, HSV, FLAG, V5, or HIS. The detection and quantification of a appendicitis biomarker protein present in a urine samples correlate to the intensity of the signal emitted from the detectably labeled antibody.

[0238] The term “specific affinity” or “specifically binds” or “specific binding” are used interchangeably herein refers to an entity such as a protein-binding molecule or antibody that recognizes and binds a desired polypeptide (e.g. a specific appendicitis biomarker protein) but that does not substantially recognize and bind other molecules in the sample, i.e. a urine sample. In some embodiments, the term "specifically binds" refers to binding with a K_d of 10 micromolar or less, preferably 1 micromolar or less, more preferably 100 nM or less, 10 nM or less, or 1 nM or less.

[0239] The term “antibody” is meant to be an immunoglobulin protein that is capable of binding an antigen. Antibody as used herein is meant to include antibody fragments, e.g. F(ab')₂, Fab', Fab, capable of binding the antigen or antigenic fragment of interest.

[0240] The term “humanized antibody” is used herein to describe complete antibody molecules, i.e. composed of two complete light chains and two complete heavy chains, as well as antibodies consisting only of antibody fragments, e.g. Fab, Fab', F(ab')₂, and Fv, wherein the

CDRs are derived from a non-human source and the remaining portion of the Ig molecule or fragment thereof is derived from a human antibody, preferably produced from a nucleic acid sequence encoding a human antibody.

[0241] The terms “human antibody” and “humanized antibody” are used herein to describe an antibody of which all portions or majority (at least 80%) of the antibody molecule are derived from a nucleic acid sequence encoding a human antibody. Such human antibodies are most desirable for use in antibody therapies; as such antibodies would elicit little or no immune response in the human subject.

[0242] The term “chimeric antibody” is used herein to describe an antibody molecule as well as antibody fragments, as described above in the definition of the term “humanized antibody.” The term “chimeric antibody” encompasses humanized antibodies. Chimeric antibodies have at least one portion of a heavy or light chain amino acid sequence derived from a first mammalian species and another portion of the heavy or light chain amino acid sequence derived from a second, different mammalian species. In some embodiments, a variable region is derived from a non-human mammalian species and the constant region is derived from a human species. Specifically, the chimeric antibody is preferably produced from a nucleotide sequence from a non-human mammal encoding a variable region and a nucleotide sequence from a human encoding a constant region of an antibody.

[0243] In the context of this invention, the term “probe” refers to a molecule which can detectably distinguish between target molecules differing in structure. Detection can be accomplished in a variety of different ways depending on the type of probe used and the type of target molecule, thus, for example, detection may be based on discrimination of activity levels of the target molecule, but preferably is based on detection of specific binding. Examples of such specific binding include antibody binding and nucleic acid probe hybridization. Thus, for example, probes can include enzyme substrates, antibodies and antibody fragments, and preferably nucleic acid hybridization probes.

[0244] The term “label” refers to a composition capable of producing a detectable signal indicative of the presence of the target polynucleotide in an assay sample. Suitable labels include radioisotopes, nucleotide chromophores, enzymes, substrates, fluorescent molecules, chemiluminescent moieties, magnetic particles, bioluminescent moieties, and the like. As such, a label is any composition detectable by spectroscopic, photochemical, biochemical, immunochemical, electrical, optical or chemical means.

[0245] The term “agent” as used herein refers to a chemical entity or biological product, or combination of chemical entities or biological products. The chemical entity or biological product is preferably, but not necessarily a low molecular weight compound, but may also be a

larger compound, for example, an oligomer of nucleic acids, amino acids, or carbohydrates including without limitation proteins, oligonucleotides, ribozymes, DNazymes, glycoproteins, siRNAs, lipoproteins, aptamers, and modifications and combinations thereof. The term “agent” refers to any entity selected from a group comprising; chemicals; small molecules; nucleic acid sequences; nucleic acid analogues; proteins; peptides; aptamers; antibodies; or fragments thereof. A nucleic acid sequence may be RNA or DNA, and may be single or double stranded, and can be selected from a group comprising; nucleic acid encoding a protein of interest, oligonucleotides, nucleic acid analogues, for example peptide-nucleic acid (PNA), pseudo-complementary PNA (pc-PNA), locked nucleic acid (LNA), etc. Such nucleic acid sequences include, for example, but not limited to, nucleic acid sequence encoding proteins, for example that act as transcriptional repressors, antisense molecules, ribozymes, small inhibitory nucleic acid sequences, for example but not limited to RNAi, shRNAi, siRNA, micro RNAi (mRNAi), antisense oligonucleotides etc. A protein and/or peptide agent can be any protein of interest, for example, but not limited to; mutated proteins; therapeutic proteins; truncated proteins, wherein the protein is normally absent or expressed at lower levels in the cell. Proteins can also be selected from a group comprising; mutated proteins, genetically engineered proteins, peptides, synthetic peptides, recombinant proteins, chimeric proteins, antibodies, midibodies, tribodies, humanized proteins, humanized antibodies, chimeric antibodies, modified proteins and fragments thereof. In some embodiments, the agent is any chemical, entity or moiety, including without limitation synthetic and naturally-occurring non-proteinaceous entities. In certain embodiments the agent is a small molecule having a chemical moiety. For example, chemical moieties included unsubstituted or substituted alkyl, aromatic, or heterocyclyl moieties including macrolides, leptomycins and related natural products or analogues thereof. Agents can be known to have a desired activity and/or property, or can be selected from a library of diverse compounds.

[0246] The term “support” refers to conventional supports such as beads, particles, dipsticks, fibers, filters, membranes and silane or silicate supports such as glass slides.

[0247] The terms “reduced” or “reduce” or “decrease” as used herein generally means a decrease by a statistically significant amount relative to a reference. However, for avoidance of doubt, “reduced” means statistically significant decrease of at least 10% as compared to a reference level, for example a decrease by at least 20%, at least 30%, at least 40%, at least 50%, or least 60%, or least 70%, or least 80%, at least 90% or more, up to and including a 100% decrease (i.e. absent level as compared to a reference sample), or any decrease between 10-100% as compared to a reference level, as that term is defined herein.

[0248] The term “low” as used herein generally means lower by a statically significant amount; for the avoidance of doubt, “low” means a statistically significant value at least 10% lower than a reference level, for example a value at least 20% lower than a reference level, at least 30% lower than a reference level, at least 40% lower than a reference level, at least 50% lower than a reference level, at least 60% lower than a reference level, at least 70% lower than a reference level, at least 80% lower than a reference level, at least 90% lower than a reference level, up to and including 100% lower than a reference level (i.e. absent level as compared to a reference sample).

[0249] The terms “increased” or “increase” as used herein generally mean an increase by a statically significant amount; for the avoidance of doubt, “increased” means a statistically significant increase of at least 10% as compared to a reference level, including an increase of at least 20%, at least 30%, at least 40%, at least 50%, at least 60%, at least 70%, at least 80%, at least 90%, at least 100% or more, including, for example at least 2-fold, at least 3-fold, at least 4-fold, at least 5-fold, at least 10-fold increase or greater as compared to a reference level, as that term is defined herein.

[0250] The term “high” as used herein generally means a higher by a statically significant amount relative to a reference; for the avoidance of doubt, “high” means a statistically significant value at least 10% higher than a reference level, for example at least 20% higher, at least 30% higher, at least 40% higher, at least 50% higher, at least 60% higher, at least 70% higher, at least 80% higher, at least 90% higher, at least 100% higher, at least 2-fold higher, at least 3-fold higher, at least 4-fold higher, at least 5-fold higher, at least 10-fold higher or more, as compared to a reference level.

[0251] As used herein, the terms “treat,” “treating,” and “treatment” refer to the alleviation or measurable lessening of one or more symptoms or measurable markers of a disease or disorder; while not intending to be limited to such, disease or disorders of particular interest include ischemic or ischemia/reperfusion injury and diabetes. Measurable lessening includes any statistically significant decline in a measurable marker or symptom.

[0252] As used herein, the terms “prevent,” “preventing” and “prevention” refer to the avoidance or delay in manifestation of one or more symptoms or measurable markers of a disease or disorder. A delay in the manifestation of a symptom or marker is a delay relative to the time at which such symptom or marker manifests in a control or untreated subject with a similar likelihood or susceptibility of developing the disease or disorder. The terms “prevent,” “preventing” and “prevention” include not only the complete avoidance or prevention of symptoms or markers, but also a reduced severity or degree of any one of those symptoms or markers, relative to those symptoms or markers arising in a control or non-treated individual

with a similar likelihood or susceptibility of developing the disease or disorder, or relative to symptoms or markers likely to arise based on historical or statistical measures of populations affected by the disease or disorder. By “reduced severity” is meant at least a 10% reduction in the severity or degree of a symptom or measurable disease marker, relative to a control or reference, e.g., at least 15%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 95%, 99% or even 100% (i.e., no symptoms or measurable markers).

[0253] As used herein the term "reference level" is used interchangeably herein with “reference value” and refers to a level in a particular appendicitis biomarker which provides a baseline against which to compare the measured appendicitis biomarker protein level from the test urine biological sample. As an illustrative example, the reference level for a particular appendicitis biomarker protein can be calculated as the average level of that appendicitis biomarker protein level from a plurality of urine biological samples obtained from a plurality of subjects with similar demographics (i.e. age, gender, weight, ethnicity and the like) which do not have appendicitis. As another illustrative example only, a reference level for a particular appendicitis biomarker protein can be from a plurality of subjects that do not have appendicitis. As another illustrative example only, a reference level for a particular appendicitis biomarker protein can be from the same subject taken at an earlier timepoint. Typically, a reference level is normalized to "0" value, and an increase, for example at least about a 2-fold increase in the particular appendicitis biomarker protein measured by the determination module or in the system and methods as disclosed herein relative to the reference level would indicate a subject would likely have appendicitis (i.e. a positive appendicitis test result). A reference appendicitis biomarker level can be from an individual not affected by a given pathology (i.e. not affected with appendicitis or having a symptom of appendicitis), or, alternatively, from the same individual being tested, where the urine for the reference appendicitis biomarker level was taken at an at least one earlier time point (i.e. t_0 , t_1 , t_2 etc) when the subject did not exhibit a symptom of appendicitis. A reference appendicitis biomarker level can also be a pooled sample, taken from a plurality of individuals not affected by appendicitis. Where appropriate, a reference appendicitis biomarker level can also be a fixed reference level of an appendicitis biomarker level, where a test appendicitis biomarker level above the fixed reference level (i.e. at least about 2-fold above the fixed reference level) identifies a subject likely to have appendicitis. It is preferred that a reference sample be from an individual or group of individuals of similar characteristics to the tested individual, e.g., that the reference be taken from individuals of similar age, gender, race or ethnic background, etc. In some embodiments, other reference levels can also be used, for example a positive reference appendicitis biomarker level can be used as a positive control for a subject having a risk of acute appendicitis. Typically, where a

positive reference level is used, if the appendicitis biomarker level in the test urine biological sample is substantially the same or close in the value of the positive reference appendicitis biomarker level, it would indicate a positive test result for acute appendicitis.

[0254] The term "computer" can refer to any non-human apparatus that is capable of accepting a structured input, processing the structured input according to prescribed rules, and producing results of the processing as output. Examples of a computer include: a computer; a general purpose computer; a supercomputer; a mainframe; a super mini-computer; a mini-computer; a workstation; a micro-computer; a server; an interactive television; a hybrid combination of a computer and an interactive television; and application-specific hardware to emulate a computer and/or software. A computer can have a single processor or multiple processors, which can operate in parallel and/or not in parallel. A computer also refers to two or more computers connected together via a network for transmitting or receiving information between the computers. An example of such a computer includes a distributed computer system for processing information via computers linked by a network.

[0255] The term "computer-readable medium" may refer to any storage device used for storing data accessible by a computer, as well as any other means for providing access to data by a computer. Examples of a storage-device-type computer-readable medium include: a magnetic hard disk; a floppy disk; an optical disk, such as a CD-ROM and a DVD; a magnetic tape; a memory chip.

[0256] The term "software" can refer to prescribed rules to operate a computer. Examples of software include: software; code segments; instructions; computer programs; and programmed logic.

[0257] The term a "computer system" may refer to a system having a computer, where the computer comprises a computer-readable medium embodying software to operate the computer.

[0258] The term "proteomics" may refer to the study of the expression, structure, and function of proteins within cells, including the way they work and interact with each other, providing different information than genomic analysis of gene expression.

[0259] As used herein the term "consisting essentially of" refers to those elements required for a given embodiment. The term permits the presence of elements that do not materially affect the basic and novel or functional characteristic(s) of that embodiment of the invention.

[0260] Other than in the operating examples, or where otherwise indicated, all numbers expressing quantities of ingredients or reaction conditions used herein should be understood as

modified in all instances by the term "about." The term "about" when used in connection with percentages may mean $\pm 1\%$.

[0261] The singular terms "a," "an," and "the" include plural referents unless context clearly indicates otherwise. Similarly, the word "or" is intended to include "and" unless the context clearly indicates otherwise. It is further to be understood that all base sizes or amino acid sizes, and all molecular weight or molecular mass values, given for nucleic acids or polypeptides are approximate, and are provided for description. Although methods and materials similar or equivalent to those described herein can be used in the practice or testing of this disclosure, suitable methods and materials are described below. The abbreviation, "e.g." is derived from the Latin *exempli gratia*, and is used herein to indicate a non-limiting example. Thus, the abbreviation "e.g." is synonymous with the term "for example."

[0262] As used herein, the term "comprising" means that other elements can also be present in addition to the defined elements presented, whether essential or not. The use of "comprising" indicates inclusion rather than limitation.

[0263] As used herein the term "consisting essentially of" refers to those elements required for a given embodiment. The term permits the presence of elements that do not materially affect the basic and novel or functional characteristic(s) of that embodiment of the invention.

[0264] The term "consisting of" refers to kits and methods thereof as described herein, which are exclusive of any element not recited in that description of the embodiment.

[0265] All patents and other publications identified are expressly incorporated herein by reference for the purpose of describing and disclosing, for example, the methodologies described in such publications that might be used in connection with the present invention. These publications are provided solely for their disclosure prior to the filing date of the present application. Nothing in this regard should be construed as an admission that the inventors are not entitled to antedate such disclosure by virtue of prior invention or for any other reason. All statements as to the date or representation as to the contents of these documents is based on the information available to the applicants and does not constitute any admission as to the correctness of the dates or contents of these documents.

[0266] The present invention can be defined by any of the following alphabetized paragraphs:

[A] A device for detecting at least one appendicitis biomarker protein in a urine sample from a subject to identify if the subject is likely to have acute appendicitis, the device comprising: (a) at least one protein-binding agent which specifically binds to at least one appendicitis biomarker protein selected from the group of: leucine α -2

glycoprotein (LRG), mannan-binding lectin serine protease 2 (MASP2), α -1-acid glycoprotein 1 (ORM); and (b) at least one solid support for the at least one protein binding-agent in (a), wherein the protein-binding agent is deposited on the solid support.

[B] The device of paragraph [A], wherein the protein-binding agent deposited on the solid support specifically binds the polypeptide of leucine α -2 glycoprotein (LRG) of SEQ ID NO: 1.

[C] The device of paragraph [A], wherein the protein-binding agent deposited on the solid support specifically binds to the polypeptide of α -1-acid glycoprotein 1 (ORM) of SEQ ID NO: 3.

[D] The device of paragraph [A], wherein the protein-binding agent deposited on the solid support specifically binds to the polypeptide of mannan-binding lectin serine protease 2 (MASP2) of SEQ ID NO: 5.

[E] The device of paragraph [A], wherein the device further comprises at least one additional different protein-binding agent deposited on the solid support, wherein the additional protein-binding agent specifically binds to an appendicitis biomarker protein selected from the group consisting of: leucine-rich α -2-glycoprotein (LRG); S100-A8 (calgranulin); α -1-acid glycoprotein 1 (ORM); plasminogen (PLG); mannan-binding lectin serine protease 2 (MASP2); zinc- α -2-glycoprotein (AZGP1); apolipoprotein D (ApoD); α -1-antichymotrypsin (SERPINA3).

[F] The device of paragraph [A], wherein the device further comprises at least one additional different protein-binding agent deposited on the solid support, wherein the additional protein-binding agent specifically binds to an appendicitis biomarker protein selected from the group consisting of: Adipocyte specific adhesion molecule; AMBP; Amyloid-like protein 2; Angiotensin converting enzyme 2; BAZ1B; Carbonic anhydrase 1; CD14; chromogranin A; FBLN7; FXR2; Hemoglobin α ; Hemoglobin β ; Interleukin-1 receptor antagonist protein; Inter- α -trypsin inhibitor; Lipopolysaccharide binding protein; Lymphatic vessel endothelial hyaluronan acid receptor 1; MLKL; Nicastrin; Novel protein (Accession No: IPI00550644); PDZK1 interacting protein 1; PRIC285; Prostaglandin-H2 D-isomerase; Rcl; S100-A9; Serum amyloid A protein; SLC13A3; SLC2A1; SLC2A2; SLC4A1; SLC9A3; SORBS1; SPRX2; Supervillin; TGFbeta2R; TTYH3; VA0D1; Vascular adhesion molecule 1; Versican; VIP36; α -1-acid glycoprotein 2; and β -1,3-galactosyltransferase.

[G] The device of paragraph [A], wherein the solid support is in the format of a dipstick, microfluidic chip or a cartridge.

[H] The device of any of paragraphs [A] to [G], wherein the protein-binding agent is an antibody, antibody fragment, aptamer, small molecule or variant thereof.

[I] The device of any of paragraphs [A] to [H], wherein the subject is a human subject.

[J] The device of any of paragraphs [A] to [I], wherein the subject is a subject with at least one symptom of appendicitis.

[K] The device of any of the paragraphs [A] to [J], wherein the protein-binding agent deposited on the device specifically binds to the appendicitis biomarker protein when the level of the appendicitis biomarker protein is at least 2-fold above a reference level for that biomarker protein.

[L] A device of paragraph [K], wherein the reference level is an average level of the appendicitis biomarker protein in a plurality of urine samples from a population of healthy humans not having acute appendicitis.

[M] Use of the device of any of paragraphs [A] to [L] to identify if a subject to have acute appendicitis, wherein if at least one appendicitis biomarker protein specifically binds to at least one protein-binding agent, the subject is likely to have acute appendicitis.

[N] A kit comprising: (a) a device according to any of paragraphs [A] to [L]; and (b) a first agent, wherein the first agent produces a detectable signal in the presence of a protein-binding agent which deposited on the device is specifically bound to an appendicitis biomarker protein.

[O] The kit of paragraph [N], further comprising a second agent, wherein the second agent produces a different detectable signal in the presence of a second protein-binding agent deposited on the device which is specifically bound to a second appendicitis biomarker protein.

[P] A method to identify the likelihood of a subject to have acute appendicitis comprising: (a) measuring the level of at least one appendicitis biomarker protein selected from the group listed in Table 1 in a urine sample from the human subject; (b) comparing the level of the at least one appendicitis biomarker protein measured in step (a) to a reference level for the measured biomarker; wherein if the level of the measured appendicitis biomarker protein is at least 2-fold increased than the reference level for the appendicitis biomarker protein, it identifies the subject is likely to have acute appendicitis.

[Q] The method of paragraph [P], further comprising determining the level of albumin in the urine sample from the human subject.

[R] The method of any of paragraphs [P]-[Q], wherein the human exhibits at least one symptom of acute appendicitis.

[S] The method of any of paragraphs [P]-[R], wherein the measuring is completed with the use of an immunoassay or an automated immunoassay.

[T] The method of any of paragraphs [P]-[S], wherein the appendicitis biomarker protein is leucine α -2 glycoprotein (LRG).

[U] The method of any of paragraph [P]-[T], wherein the appendicitis biomarker is α -1-acid glycoprotein 1 (ORM).

[V] The method of any of paragraphs [P]-[U], wherein the appendicitis biomarker protein is mannan-binding lectin serine protease 2 (MASP2)

[W] The method of any of paragraphs [P]-[S], wherein the appendicitis biomarker protein is selected from a group consisting of leucine α -2 glycoprotein (LRG), calgranulin A (S100-A8), α -1-acid glycoprotein 1 (ORM), plasminogen (PLG), mannan-binding lectin serine protease 2 (MASP2), Zinc- α -2-glycoprotein (AZGP1), α -1-antichymotrypsin (SERPINA3) and apolipoprotein D (ApoD).

[X] The method of any of paragraphs [P]-[W], wherein the reference level is a level of the appendicitis biomarker protein in a urine sample of a healthy human not having acute appendicitis.

[Y] The method of any of paragraphs [P]-[W], wherein the reference level is an average level of the appendicitis biomarker protein in a plurality of urine samples from a population of healthy humans not having acute appendicitis.

[Z] The method of any of paragraphs [P]-[W], wherein the reference level is a normalized level of the appendicitis biomarker protein in a urine sample of a healthy human not having acute appendicitis, wherein the normalization is performed against the level of albumin in the urine sample of a healthy human not having acute appendicitis.

[AA] The method of any of paragraphs [P]-[Z], wherein the urine sample is collected in mid-stream.

[BB] The method of any of paragraph [P]-[Z], wherein the urine sample is obtained by depositing the urine on to a test strip.

[0267] This invention is further illustrated by the following examples which should not be construed as limiting. The contents of all references, patents, and patent applications cited throughout this application, as well as the figures and table are incorporated herein by reference.

EXAMPLE 1

Urine proteomics for profiling of human disease using high accuracy mass spectrometry

[0268] Knowledge of the biologically relevant components of human tissues has enabled the invention of numerous clinically useful diagnostic tests, as well as non-invasive ways of monitoring disease and its response to treatment. By virtue of tissue perfusion, blood serum is the most useful material for the discovery of such biomarkers in general. However, the relatively high concentration of serum proteins, as well as their wide range of concentrations, spanning at least 9 orders of magnitude, often limit the study of serum biomarkers [1], though several recent approaches are promising [2-4].

[0269] On the other hand, of the biological fluids amenable to routine clinical evaluation, urine has the advantage of being frequently and non-invasively available, abundant, and as a result of being a filtrate of serum, relatively simple in its composition. Consequently, detection of urinary proteins has been used to identify markers of disease affecting the kidney and the urogenital tract [5, 6], as well as distal organs such as the brain and the intestine [7, 8]. However, the current understanding of the human urinary proteome is incomplete, specifically with respect to its overall composition and dynamics, not to mention the identity of variable components that may dependent on physiologic state and disease.

[0270] Several approaches have been used to characterize the human urinary proteome. Initial studies using electrophoresis and immunoblotting were able to identify tens of abundant and rare urinary proteins [9]. Recently, Pisitkun and colleagues applied ultracentrifugation and liquid chromatography (LC)-tandem mass spectrometry (MS/MS) to identify 295 highly abundant unique proteins isolated from urinary exosomes [10]. Sun and colleagues identified 226 soluble proteins by using multidimensional LC-MS/MS [11]. For an overview, see Pisitkun et al [12]. And most recently, Adachi and colleagues identified more than 1,500 unique proteins from ultrafiltered urine with a high degree of accuracy by using a hybrid linear ion trap-Orbitrap (LTQ-Orbitrap) mass spectrometer [13].

[0271] The inventors herein extend the current characterization of the human urinary proteome by extensively fractionating urine using ultracentrifugation, gel electrophoresis, ion exchange and reverse phase chromatography, effectively reducing mixture complexity while minimizing loss of material. By using high accuracy mass measurements of the LTQ-Orbitrap mass spectrometer and LC-MS/MS of peptides generated from such extensively fractionated specimens, the inventors identified over 2,000 unique proteins in routinely collected individual urine specimens. The inventors provide assessments of the physical and tissue origins of the urinary proteome, as well as dependence of its detection on instrumental and individual variables. Finally, by using text mining and machine learning the inventors annotate the urinary

proteome with respect to 27 common and more than 500 rare human diseases, thereby establishing a widely useful resource for the study of human pathophysiology and biomarker discovery.

Materials and Methods for Example 1

[0272] *Sample collection.* Urine was collected as clean catch, mid stream specimens as part of routine evaluation of 12 children and young adults (ages 1-18 years, median 11) presenting with acute abdominal pain in the Children's Hospital Boston's Emergency Department. Upon obtaining informed consent, urine was frozen at -80°C in 12 ml aliquots in polyethylene tubes. All samples were frozen within 6 hours of collection.

[0273] *Reagents.* All reagents were of highest purity available and purchased from Sigma Aldrich unless specified otherwise. HPLC-grade solvents were purchased from Burdick and Jackson.

[0274] *Urine sedimentation.* Aliquots were thawed and centrifuged at 17,000 g for 15 minutes at 10°C to sediment cellular debris. Absence of intact cells in the sediment was confirmed by light microscopy (data not shown). Subsequently, supernatant was centrifuged at 210,000 g for 60 minutes at 4°C to sediment vesicles and high molecular weight complexes. Resultant pellets were resuspended in 0.5 ml of 0.1× Laemmli buffer, concentrated 10-fold to 0.05 ml by vacuum centrifugation and stored at -80°C.

[0275] *Cation exchange chromatography.* Supernatant remaining after ultracentrifugation was diluted 5-fold with 0.1 M acetic acid, 10 % (v/v) methanol, pH 2.7 (Buffer A) and incubated with 1 ml 50 % (v/v) slurry of SP Sephadex (40-120 μ m beads, Amersham) for 30 minutes at 4°C to adsorb peptides that are < 30 kDa molecular weight. Upon washing the beads twice with Buffer A, peptides were eluted by incubating the beads in 5 ml of 0.5 M ammonium acetate, 10% (v/v) methanol, pH 7 for 30 minutes at 4°C. Eluted peptides were purified by reverse phase chromatography by using PepClean C-18 spin columns, according to manufacturer's instructions (Pierce). Residual purification solvents were removed by vacuum centrifugation and small proteins and peptides were resuspended in aqueous 50 mM ammonium bicarbonate buffer (pH 8.5).

[0276] *Protein precipitation.* Proteins remaining in solution after cation exchange were precipitated by adding trichloroacetic acid to 20 % (w/v), with deoxycholate to 0.02 % (w/v) and Triton X-100 to 2.5 % (v/v) as carriers, and incubating the samples for 16 hours at 4 °C. Precipitates were sedimented at 10,000 g for 15 minutes at 4 °C and pellets were washed twice

with neat acetone at 4°C with residual acetone removed by air drying. Dried pellets were resuspended in 0.1 ml of 1× Laemmli buffer.

[0277] *Gel electrophoresis.* Laemmli buffer suspended fractions (from 17,000 g and 210,000 g centrifugation, and from protein precipitation) were incubated at 70°C for 15 min and separated by using NuPage 10% polyacrylamide Bis-Tris gels according to manufacturer's instructions (Invitrogen). Gels were washed three times with distilled water, fixed with 5% (v/v) acetic acid in 50% (v/v) aqueous methanol for 15 minutes at room temperature, and stained with Coomassie. Each gel lane was cut into 6 fragments and each fragment was cut into roughly 1 mm³ particles, which were subsequently washed 3 times with water and once with acetonitrile.

[0278] *Protein reduction, alkylation and trypsinization.* Protein containing gel particles and cation exchange purified proteins were reduced with 10 mM dithiothreitol in 50 mM ammonium bicarbonate (pH 8.5) at 56°C for 45 minutes. They were subsequently alkylated with 55 mM iodoacetamide in 50 mM ammonium bicarbonate (pH 8.5) at room temperature in darkness for 30 minutes. Gel particles were washed 3 times with 50 mM ammonium bicarbonate (pH 8.5) prior to digestion. Alkylated peptides were purified by using PepClean C-18 spin columns as described above to remove residual iodoacetamide from the cation exchange fraction. They were then digested with 12.5 ng/μl sequencing grade bovine trypsin in 50 mM ammonium bicarbonate (pH 8.5) at 37°C for 16 hours. Tryptic products were purified by using PepClean C-18 spin columns as described above, vacuum centrifuged and stored at -80 °C.

[0279] *Mass spectrometry and liquid chromatography.* Fractions containing tryptic peptides dissolved in aqueous 5% (v/v) acetonitrile and 0.1% (v/v) formic acid were resolved and ionized by using nanoflow high performance liquid chromatography (nanoLC, Eksigent) coupled to the LTQ-Orbitrap hybrid mass spectrometer (Thermo Scientific). Nanoflow chromatography and electrospray ionization were accomplished by using a 15 cm fused silica capillary with 100 μm inner diameter, in-house packed with Magic C18 resin (200 Å, 5 μm, Michrom Bioresources). Peptide mixtures were injected onto the column at a flow rate of 1000 nl/min and resolved at 400 nl/min using 45 min linear acetonitrile gradients from 5 to 40 % (v/v) aqueous acetonitrile in 0.1 % (v/v) formic acid. Mass spectrometer was operated in data dependent acquisition mode, recording high accuracy and high resolution survey Orbitrap spectra using the lock mass for internal mass calibration, with the resolution of 60,000 and m/z range of 350-2000. Six most intense multiply charged ions were sequentially fragmented by using collision induced dissociation, and spectra of their fragments were recorded in the linear ion trap, with the dynamic exclusion of precursor ions already selected for MS/MS of 60 sec.

[0280] *Spectral processing and peptide identification.* Custom written software was used to extract the 200 most intense peaks from each MS/MS spectrum and to generate mascot

generic format files. Peak lists were searched against the human International Protein Index database (version 3.36) by using Mascot (version 2.1.04; Matrix Science), allowing for variable formation of N-pyroglutamate, Asn and Gln deamidation, N-acetylation, and methionine oxidation, requiring full trypsin cleavage of identified peptides with 2 possible miscleavages, and mass tolerances of 5 ppm and 0.8 Da for the precursor and fragment ions, respectively. Searches allowing semi-tryptic peptides did not affect overall search yields (data not shown). Spectral counts were calculated by summing the number of fragment ion spectra assigned to each unique precursor peptide.

[0281] *Data analysis.* Assessment of identification accuracy was carried out by searching a decoy database composed of reversed protein sequences of the target IPI database. Frequency of apparent false positive identifications was calculated by merging individual target and decoy searches for each sample. An initial estimate of the apparent false positive rate was obtained by dividing the number of peptide identifications with a Mascot score greater than the identity score obtained from the target search by the number of peptide identifications with a score higher than the identity score threshold extracted from the decoy search [37]. Only proteins identified on the basis of more than 2 peptides were included in the comparison. Parsimonious protein grouping was performed by remapping all peptide identifications onto their corresponding proteins as listed in the IPI. This step was necessary to generate a minimal, non-redundant list of proteins that explain all of the identified peptides, while excluding proteins that could not be unambiguously unidentified. This parsimonious list of proteins was used for comparisons of various samples at the protein level. For Gene Ontology annotation, the inventors used GO slim terms version 1.8, accessed by using GOfact. For annotation of tissue expression of detected proteins, the inventors used version 2 of the GNF gene expression atlas, accessed by using BioMart.

[0282] *Disease annotations.* The inventors linked proteins found in the urine proteome to published articles that associate a protein with a human disease, as well articles that associate a disease with a protein. For the former, the inventors derived sets of diseases from OMIM [38], MeSH, and a short list of common diseases of interest not described in OMIM or MeSH.

The inventors extracted disease names from MeSH by selecting MeSH concepts with DescriptorRecord DescriptorClass = 1, and marked by SemanticTypeName 'Disease or Syndrome'. Synonym disease names were obtained from the content of Term or TermList elements for the main concept. For OMIM, documents

matching an OMIM entry were obtained by searching Medline with a query of the form (Term1 OR Term2 ... Termk), where Termk include the 100 lowest frequency terms in a given OMIM entry. These OMIM disease queries were executed by using Twease with the BM25EC scorer against abstracts in Medline [39], accessed July 7, 2008. Documents that matched the query with a BM25EC score above a Z-score of 10 were considered matching the OMIM disease [40]. Each MeSH disease name and synonyms were expressed as a query of the form (“disease name” | “alias 1” | “alias 2” | ...). Common disease names were expressed as a single phrase query.

[0283] To determine diseases that are associated with a given protein, the inventors queried BioMart by using IPI identifiers for proteins in the urine proteome to obtain corresponding protein descriptions and gene names. Queries of the form (IPI-id | “description” | GeneName) were generated for each protein, where IPI-id is the IPI identifier, and description is the description phrase retrieved from BioMart. These queries were run against Medline by using Twease with the slider parameter set to 0. Lists of documents matching protein names were stored and overlapped with lists of documents matching diseases. Pairs of disease associated proteins that matched less than 5 documents were discarded (manual examination indicated that this level of overlap frequently happens as an artifact of the search procedure). To further increase stringency of the protein disease literature associations, the inventors estimated the odds that the number of overlapping documents found between a given disease and protein could occur by chance, considering the number of documents matching either the disease or the proteins in Medline. Only protein name/disease name pairs with odds ratio greater than 2,000 were reported. Lists of overlapping documents were formatted in HTML files organized in hierarchies of diseases or proteins.

[0284] *List of abbreviations.* Liquid chromatography-tandem mass spectrometry (LC-MS/MS), linear ion trap (LTQ).

Results

Exhaustive protein capture from routinely collected human urine

[0285] In order to identify medically useful urinary proteins, the inventors obtained urine as routinely collected clean catch, mid stream urine specimens, collected at the time of clinical evaluation. The inventors examined urine samples from 12 children and young adults evaluated for abdominal pain in our Emergency Department, all of whom were previously healthy. Also examined were the urine samples from asymptomatic patients evaluated 6-8 weeks after they underwent appendectomies. All urines exhibited normal profiles without evidence of renal disease or infection, as assessed by using clinical urinalysis (data not shown). All urine

specimens were frozen within 6 hours of collection, consistent with earlier temporal analysis of whole urine specimens which indicated that no detectable degradation occurred for as long as 24 hours of 4 °C refrigerated storage with subsequent freezing at -80 °C [14-16]. This is expected given the fact that urine is stored *in situ* for many hours in the bladder, reaching a physiologic equilibrium prior to collection.

[0286] Urine is a complex mixture with abundant proteins such as albumin and uromodulin obscuring the identification of less concentrated, biologically more informative proteins such as secreted cytokines and hormones for example. Thus, the inventors adopted a fractionation method that reduced mixture complexity while minimizing loss of material by first ultracentrifuging to fractionate urinary exosomes and other high molecular weight complexes from soluble peptides and proteins, subsequently capturing the latter by using size excluded cation exchange chromatography and trichloroacetic acid precipitation, respectively, which has been shown to capture more than 95% of proteins under similar conditions [17, 18].

[0287] Secondary and tertiary fractionations of thus captured proteins and peptides were achieved by using one dimensional SDS-PAGE of the ultracentrifugation and precipitation fractions, and liquid chromatography of the tryptic peptides of SDS-PAGE resolved proteins, respectively. As a result, high abundance proteins such as albumin and uromodulin, which would otherwise comprise more than 99 % of the mixture, can be separated effectively from the bulk of the proteome (Fig. 1). Though the composition and concentration of urine varies with physiologic state, there was less than 10 ± 10 % (mean $\pm$ standard deviation) difference in total protein abundance among individual specimens, as ascertained by using gel image densitometry (Fig. 1), similar to earlier studies of urine of children [19-21].

Accurate and comprehensive identification of urinary proteomes

[0288] In order to maximize detection sensitivity while minimizing identification errors, the inventors used the recently developed hybrid LTQ-Orbitrap mass spectrometer for tryptic peptide sequencing of the above fractionated proteomes. A representative set of tandem mass spectra is shown in Fig. 2, achieving mass errors of less than 2 ppm for the majority of the LC/MS runs as judged from analysis of trypsin autolysis peptides (Fig. 3). Peptide sequences were identified from tandem mass spectra by using probability based Mascot searches of the human IPI database (Methods). By carrying out simultaneous searches of the data against a decoy database containing reversed protein sequences, and rejecting (false) identifications of spectra that matched decoy sequences, as well as excluding proteins identified on the basis of single peptides, the inventors were able to achieve an apparent false positive protein

identification frequency of less than 1 %. The median number of unique peptides per identified protein was 10.

[0289] As a result, the inventors identified with high degree of accuracy [12], 126 unique peptides, corresponding to 2,362 proteins. These proteins include 891 proteins identified in an earlier high accuracy study of the human urine proteome [13], and more than 1,000 additional proteins identified for the first time (Fig. 4). These data are provided as Additional Files, and can be accessed publicly from the inventors' server (at the World Wide Website of "childrenshospital.org/research/steenlab").

Origin of the human urinary proteome

[0290] The composition of the identified proteomes was characterized with respect to Gene Ontology (GO) annotated biological function, apparent physical origin, and predicted tissue expression. As compared with the entire list of IPI entries, analysis of GO annotated biological function revealed saturation of cellular components such as the cytoplasm, endoplasmic reticulum, golgi, lysosome, and the plasma membrane. Proteins from the nucleus were relatively under-represented, consistent with the general absence of intact cells in human urine. Similar to [13], the inventors observed a relative enrichment of hydrolases, peptidases, carbohydrate and lipid binding proteins, and a relative under-representation of nucleic acid binding proteins.

[0291] By comparing whether identified proteins sedimented in the 17,000 g versus 210,000 g ultracentrifugation fractions, were adsorbed onto size exclusion ion exchange resin or were TCA precipitated, the inventors defined them as large or small complexes, and soluble peptides or proteins, respectively. The fractions of proteins identified uniquely from these physical states were 14, 20, 3 and 9 %, respectively, demonstrating that individual proteins or their variants exist in multiple physical states. For example, components of the urinary exosomes including the endosomal sorting complex (ESCRT-I), BRO1/ALIX, and VPS4, were detected as both small complexes and soluble proteins. Similarly, insulin-like growth factor binding proteins (IGFBPs) which are low molecular weight circulating hormones were detected as soluble proteins, peptides, and in small complexes. Though the size excluded ion exchange fraction contributed only 3 % to the total unique protein identifications, it was substantially enriched for biomedically significant molecules which would not be detected otherwise, including circulating hormones such as hepcidin and chromogranin [22, 23], and shed cell surface molecules such as Ly-6 and platelet glycoproteins [24, 25].

[0292] The inventors assessed the probable tissue origin of the identified proteome by comparing it to published tissue expression atlases. As expected, 90 % of the proteins detected in the urinary proteome have tissue expression profiles that include organs of the urogenital tract, such as the kidneys and the bladder, from which they likely originate. In addition to these proximal organs, the urinary proteome contains a substantial number of proteins that appear to originate from distal tissues. Among them are 336 proteins that are uniquely expressed in distal tissues such as the nervous system, heart and vasculature, lung, blood and bone marrow, intestine, liver and other intra-abdominal viscera, suggesting that a substantial portion of the urinary proteome is formed as a result of their systemic circulation and serum filtration. For instance, the urinary proteome includes Nogo/reticulon which is involved in the regulation of neurite growth and is expressed in the nervous system but not the urogenital tract [26]. Similarly, the urinary proteome includes angiopoietin-2, involved in angiogenesis and vascular homeostasis, and is expressed by the vascular endothelium [27].

Individual urinary proteomes

[0293] By virtue of studying individual urinary proteomes, the inventors assessed the extent of similarities and differences among them. For the 12 specimens studied in this example, the inventors detected $1,124 \pm 292$ (mean $\pm$ standard deviation) proteins per individual proteome, with the average concordance of 68 %, as calculated over all binary comparisons. Highly abundant proteins common to all individual proteomes include molecules involved in renotubular trafficking (uromodulin, cubilin, and megalin (LRP2)), serum filtered enzymes and carriers (bikunin (AMBP), aminopeptidase N, ceruloplasmin, apolipoproteins, and immunoglobulins), extracellular structural components (perlecan, glial fibrillary acidic proteins), as well as a variety of other secreted molecules such as CD44, tetraspanin, and lysosomal associated membrane proteins (LAMPs). Many of these have been detected in human urine previously, and many were identified for the first time. Examples of the latter include claudin, a regulator of tight junctions involved in the maintenance of glomerular and tubular integrity [28], collectrin, a novel homolog of the angiotensin converting enzyme related carboxypeptidase implicated in renal failure and the pathogenesis of polycystic kidney disease [29], SLC5A2, a tubular sodium-glucose transporter which causes autosomal recessive renal glucosuria when defective [30], and numerous other proteins with poorly understood functions such as peflin and trefoil factor 2.

[0294] In large part, the variability observed among individual proteomes appears to be multifactorial in origin, as suggested by the multimodal distribution of the coefficients of

variation of proteins' apparent detectability, as measured by using spectral counting [31] (Fig. 5; representative proteins are labeled). Proteins with high degree of apparent variability included complement factors, α 1-anti-trypsin, protein C inhibitor, galectin (LGALS3BP), CD59, CD14, α -enolase, α 2-macroglobulin, gelsolin, haptoglobin, hemopexin, intelectin, fibrinogen, arylsulfatase, serum amyloid A2, cystatin C, angiotensin, and resistin, among others. Many of these proteins are components of the acute phase response [32], consistent with the collection of some of the studied specimens from patients with acute abdominal pain. Other differences among proteomes included components of seminal fluid and other sex specific proteins such as semenogelin.

Urine proteomics for profiling of human disease

[0295] The inventors annotated the identified urinary proteins with respect to possible associations with human disease by using machine learning and text mining of Medline abstracts. Annotations identified for the 26 common and more than 200 rare examined diseases are available in hypertext documents (Additional Files, <http://www.childrenshospital.org/research/steenlab>), with links to information about the identified proteins and original studies about their role in disease. They include common kidney diseases such as nephrotic syndrome (72 proteins) and nephritis (139), systemic illnesses such as sepsis (42), diseases of distal organs such as pneumonia (34), meningitis (22), and colitis (45). In addition, the proteome was annotated with respect to more than 500 rare diseases, including storage diseases such as Niemann-Pick disease, immune system disorders such as Wiskott-Aldrich syndrome, and diseases of the nervous system such as spinocerebellar ataxia. These associations may be used to develop diagnostic tests or new approaches for the study and monitoring of disease progression.

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EXAMPLE 2

[0296] Appendicitis is among many human diseases, for which the diagnosis is complicated by the heterogeneity of its clinical presentation and shortage of diagnostic markers. As such, it remains the most common surgical emergency of children, with initial diagnosis accuracy additionally challenged because of non-specific but similar symptoms of many other childhood conditions (1). Delays in accurate diagnosis lead to increased mortality, morbidity, and costs associated with the complications of appendicitis.

[0297] The use of high resolution computed tomography (CT) to identify appendiceal inflammation was hoped to improve both the diagnosis and treatment of acute appendicitis. Though variable, these improvements have been modest at best, with rates of unnecessary appendectomies and ruptures of 3-30 % and 30-45 %, respectively (2-4). In addition, availability of and experience with CT limit the usefulness of this approach. Furthermore, recently its use has been re-evaluated due to concerns of cancer risk (5).

[0298] Thus, several studies sought to identify laboratory markers of acute appendicitis, by studying both markers of the acute phase response, as well as specific inflammatory mediators. The performance of both appeared to be limited (6-11), likely because of the non-

specific and unrelated mechanisms of their elevation during acute appendicitis which is characterized specifically by the infiltration of neutrophils and release of distinct cytokines (12, 13).

[0299] As disclosed herein, the inventors using an unbiased approach, have profiled the molecular alterations on a proteomic scale, including molecules that are being secreted locally by the diseased tissues themselves or produced systemically in response to local disease. The inventors have identified various urinary markers for appendicitis. Because urine is abundant, obtained frequently and non-invasively, and as a result of being a serum filtrate, is relatively simple in its composition, the inventors have discovered urinary markers for the use in a simple and rapid method to identify a subject with appendicitis.

[0300] Recently, advanced mass spectrometry (MS) has been used effectively to discover the protein composition of human urine, (14-16) and to identify markers of diseases affecting the kidney (17) and the urogenital tract (18). Similarly, MS studies of urine have been used to study proteins produced by distal organs such as the brain (19) and the intestine, (20) and to relate them to brain injury and inflammatory bowel disease, respectively.

[0301] Here, the inventors demonstrate the use of urine proteome profiling and have discovered urinary markers of acute appendicitis. By using high accuracy mass spectrometry, the inventors identified more than 2,000 unique proteins in urine specimens routinely collected from children and young adults evaluated for acute abdominal pain in the emergency department (ED). Statistical comparisons of individual urine proteomes, pattern recognition class prediction, and gene expression profiling of diseased appendices were used to discover diagnostic markers. By carrying out a blinded, prospective study of these markers, the inventors assessed their diagnostic performance.

Methods use in Example 2

[0302] *Study population.* The inventors studied 67 children and young adults who presented to the ED suspected of having acute appendicitis. Patients were excluded if they had pre-existing autoimmune, neoplastic, renal or urologic disease or were pregnant. Urine was collected as clean catch, mid stream samples as part of routine ED evaluation of abdominal pain. Additional intra-individual control specimens were collected from selected patients with appendicitis after undergoing appendectomies. Informed consent was obtained prior to knowledge of final diagnosis and the urine remaining in the laboratory was retrieved and stored at -80°C within 6 hours of collection. The expected number of patients was estimated by using the Pearson 2 test to detect a difference at a two-sided statistical significance level of 5% and

power of 90% that requires 6 patients in each group, assuming that 80% of the positive samples (5 patients) will contain at least one protein unique to the appendicitis as compared to the non-appendicitis group (21). This study was approved by the Children's Hospital Boston Committee on Clinical Investigation, began in November of 2006, and ended in May of 2008.

[0303] *Discovery urine proteome profiling and validation target mass spectrometry.* For the discovery of markers, thawed 10 ml urine aliquots were fractionated by using ultracentrifugation, cation exchange chromatography, protein precipitation, polyacrylamide gel electrophoresis, and reverse phase liquid chromatography. Their protein composition was discovered by using liquid chromatography tandem mass spectrometry (LC-MS/MS) using a nanoflow HPLC system (Eksigent) coupled to a hybrid linear ion trap-Orbitrap (LTQ-Orbitrap) mass spectrometer (Thermo Scientific). The LTQ-Orbitrap enables an unprecedented combination of high detection sensitivity in the attomolar (10-18 M) range, and high mass accuracy of less than 2 parts per million (0.001 Da for a typical 500 Da peptide), as described in detail in the accompanying manuscript (22). Validation of markers was performed using 1 ml aliquots of coded specimens that were blinded to the final outcome. The entire experimental procedure is schematized in Figure 7.

[0304] *Analysis.* Urine markers were ranked by calculating relative enrichment ratios (RER) of detection in appendicitis versus non-appendicitis groups by summing individual protein spectral counts normalized to the spectral counts of albumin to account for small differences in total protein abundance, (23) where $RER = (\text{appendicitis}) \sum C_p / C_a / (\text{non-appendicitis}) \sum C_p / C_a$, with C_p and C_a denoting spectral counts of protein markers and albumin, respectively. Urinary markers were additionally ranked by assessing the prevalence of their detection among different specimens by using a uniformity parameter (U), calculated by dividing the number of appendicitis cases in which they were detected by the total number of appendicitis cases. Urinary markers were filtered to have $U > 0.7$ and $RER > 5$ to identify those that were variably detected or insufficiently enriched, respectively. Support vector machine analysis and comparison of urine protein markers with tissue gene expression profiles of diseased appendices were carried as described herein. The latter was based on a previous study (24). Receiver operating characteristics were calculated using standard methods.

[0305] *Outcome measures.* Final diagnosis was determined by the presence or absence of appendicitis on gross and histological examination. All appendectomy specimens were reviewed by a clinical pathologist, and their disease assignments were confirmed by an independent, blinded review. One patient with perforated appendicitis underwent an interval appendectomy, and was not included in the histologic review. Assessment of the histologic severity of appendicitis was done by classifying the specimens as having: no inflammatory

changes (normal); foci of neutrophilic infiltration in mucosa or wall (focal); scattered transmural infiltration (mild); dense transmural infiltration with tissue distortion (moderate); dense transmural infiltration with tissue necrosis or wall perforation (severe). For patients who did not undergo appendectomies, the outcome was confirmed via telephone 6-8 weeks after the ED evaluation. All patients enrolled in the study received a final outcome.

[0306] *Tissue immunohistochemistry and urine immunoblotting.* Immunohistochemical staining of formalin fixed, paraffin embedded appendices was performed by using the rabbit anti-LRG polyclonal antibody at 1:750 dilution (Atlas Antibodies), OmniMap DAB anti-rabbit HRP detection kit and the Ventana Discovery XT automated slide processing platform, according to the manufacturer's instructions (Ventana Medical Systems). Staining specificity was confirmed by using liver and muscle as the positive and negative controls, respectively (data not shown).

[0307] For immunoblotting of urine, specimens were precipitated and resolved by SDS-PAGE as described for target mass spectrometry. Western blotting was done blinded to final outcome, as described previously (25), using the rabbit anti-LRG polyclonal antibody at 1:2000 dilution, and the SuperSignal West Pico chemiluminescent reagent (Thermo). Equal total protein loading was assessed by Coomassie staining (22).

Results

Study population

[0308] Over the 18 month course of this study, 67 patients were enrolled who presented to our Emergency department (ED) and underwent evaluation for possible acute appendicitis. In agreement with earlier studies of the epidemiology and presentation of acute appendicitis in pediatric EDs, the mean age of our study population was 11 years, with presenting signs and symptoms described in Table 2. Twenty five patients (37 %) received a final diagnosis of appendicitis. All patients with appendicitis underwent appendectomies, 16 % of which were found to have a perforation. One patient (4 %) who received a pre-operative diagnosis of appendicitis was found to have no gross or histologic evidence of appendicitis upon undergoing appendectomy. Twenty four percent of patients were found to have no specific cause of their abdominal pain, with the remaining patients found to have a variety of common and rare mimicking conditions (Table 3).

[0309] *Table 2:* Presenting signs, symptoms and diagnostic studies of 67 patients with acute abdominal pain. Values are reported as mean standard deviation, where appropriate. RLQ (right lower quadrant), US (ultrasound), CT (computer tomography).

	Final Diagnosis	
	Appendicitis	Non-appendicitis
Number	25	42
Gender (% male)	56	40
Age (years)	11 $\pm$ 3.5	11 $\pm$ 4.2
Duration of symptoms (days)	2.7 $\pm$ 2.0	2.2 $\pm$ 1.7
Nausea or vomiting (%)	72	52
Fever (%)	52	48
Pain migration (%)	36	14
RLQ pain or tenderness (%)	100	95
Temperature at triage (°C)	36.9 $\pm$ 0.6	36.6 $\pm$ 0.9
Peripheral white blood cell count (K cells/mm ³)	15.7 $\pm$ 5.2	11.0 $\pm$ 6.4
Absolute neutrophil count (K cells/mm ³)	12.8 $\pm$ 5.4	8.5 $\pm$ 6.6
US imaging (%)	88	74
US diagnosis of appendicitis (%)	64	0
CT imaging (%)	60	64
CT diagnosis of appendicitis (%)	93	7.4

[0310] **Table 3.** Final diagnosis of the 67 study patients

	Number of patients
Appendicitis	25
Non specific abdominal pain	16
Ovarian cyst or torsion	5
Constipation	5
Pyelonephritis or Urinary Tract Infection	5
Renal calculus	2
Mesenteric adenitis	2
Gastroenteritis or gastritis	2
Influenza or scarlet fever	2
Intussusception	1
Inflammatory bowel disease	1
Diverticulitis	1

[0311] Discovery of diagnostic markers by using urine proteomic profiling urine markers of appendicitis were identified from the analysis of 12 specimens, collected at the onset of the study, and distributed equally between patients with and without appendicitis. Table 4 lists the 32 markers, identified by ranking their relative enrichment ratios (RER). These proteins include known components of the acute phase response such as α -1-acid glycoprotein (orosomucoid), plasminogen, carbonic anhydrase, angiotensin converting enzyme, and lipopolysaccharide binding protein, consistent with the systemic inflammatory response that accompanies acute appendicitis.

[0312] **Table 4:** urine marker proteins identified using relative enrichment ratio analysis. † Values of $U = 1$ indicate markers detected in all appendicitis specimens, whereas values of relative enrichment ration (RER) = 1 indicate markers that exhibit no apparent enrichment in appendicitis as compared to non-appendicitis groups. N/A (not detected) identifies markers not detected in non-appendicitis specimens). (* International Protein Index (version 3.36, at the World Wide Website of “ebi.ac.uk/IPI”).)

Protein	Accession Number*	$U^{\dagger}$	$RER^{\dagger}$
Adipocyte specific adhesion molecule	IPI00024929	1.0	18
Leucine-rich α -2-glycoprotein	IPI00022417	1.0	9.5
Zinc- α -2-glycoprotein	IPI00 166729	1.0	7.3
α -1-acid glycoprotein 2	IPI00020091	1.0	5.8
MLKL	IPI00180781	1.0	5.5
α -1-acid glycoprotein 1	IPI00022429	1.0	5.3
Plasminogen	IPI00019580	1.0	5.1
Carbonic anhydrase 1	IPI002 15983	0.8	15
Angiotensin converting enzyme 2	IPI00465 187	0.8	12
Nicastrin	IPI00021983	0.8	12
Lipopolysaccharide binding protein	IPI00032311	0.8	11
Vascular adhesion molecule 1	IPI00018 136	0.8	10
PDZK1 interacting protein 1	IPI0001 1858	0.8	7.5
SLC9A3	IPI00011184	0.8	7.5
Lymphatic vessel endothelial hyaluronan receptor 1	IPI00290856	0.8	6.9
FXR2	IPI000 16250	0.7	N/A
SORBS1	IPI00002491	0.7	N/A
SLC4A1	IPI00022361	0.7	44
PRIC285	IPI00249305	0.7	14.9
TGFbeta2R	IPI00383479	0.7	11.3
SLC2A1	IPI00220194	0.7	10.7
Rcl	IPI00007926	0.7	9.7
VA0D1	IPI00034159	0.7	8.9
SLC13A3	IPI00103426	0.7	7.8
TTYH3	IPI00749429	0.7	7.3
SPRX2	IPI00004446	0.7	6.4
BAZ1B	IPI00216695	0.7	6.1
β -1,3-galactosyltransferase	IPI00032034	0.7	6.1
chromogranin A	IPI00383975	0.7	5.9
Novel protein	IPI00550644	0.7	5.5
SLC2A2	IPI00003905	0.7	5.2
FBLN7	IPI00167710	0.7	5.1

[0313] The markers also include a number of cell adhesion proteins such as adipocyte specific adhesion molecule, a component of the epithelial and endothelial tight junctions, leucine-rich α -2-glycoprotein (LRG), a marker of neutrophil differentiation involved in cell

trafficking, vascular adhesion molecule 1, which mediates lymphocyte-endothelial adhesion, and lymphatic vessel endothelial hyaluronan acid receptor 1 involved in cell migration, consistent with earlier findings of leukocyte trafficking and infiltration into mucosal tissue that accompanies acute appendicitis.

[0314] Remaining top ranking markers do not appear to share any known functional or structural similarities, though some of them such as β -1, 3- galactosyltransferase and VA0D1 have been shown to function specifically in the colonic epithelium, and therefore, may include components of the local and systemic appendicitis response. Additional markers were identified by using support vector machine (SVM) learning, as well as comparisons with tissue gene expression profiles of diseased appendices (Tables 6 and 7). In total, 49 markers were identified.

[0315] *Table 6.* urine marker proteins identified using SVM analysis

Protein	Accession Number
Serum amyloid A protein	IPI00552578
α -1-antichymotrypsin	IPI00550991
Supervillin	IPI00412650
Mannan-binding lectin serine protease 2	IPI00306378
Inter- α -trypsin inhibitor	IPI00218192
VIP36	IPI00009950
Prostaglandin-H2 D-isomerase	IPI00013179
α -1-acid glycoprotein 2	IPI00020091
AMBP	IPI00022426
α -1-acid glycoprotein 1	IPI00022429
CD14	IPI00029260
Hemoglobin α	IPI00410714
Apolipoprotein D	IPI00006662
Hemoglobin β	IPI00654755
Leucine-rich α -2-glycoprotein	IPI00022417
Zinc- α -2-glycoprotein	IPI00166729

[0316] *Table 7.* Urine marker proteins identified by comparisons with corresponding tissue gene overexpression. * From Murphy CG, et al. Mucosal Immunol. 2008; 1:297-308.

Protein	Accession Number	Affymetrix gene ID*	Fold gene overexpression*
S100-A8	IPI00007047	214370_at	67
S100-A9	IPI00027462	203535_at	45
Amyloid-like protein 2	IPI00031030	214456_x_at	38
Versican	IPI00009802	211571_s_at	11
SPRX2	IPI00004446	205499_at	8.1
α -1-acid glycoprotein 1	IPI00022429	205041_s_at	7.8
Interleukin-1 receptor	IPI00000045	212657_s_at	4.3

antagonist protein			
Lymphatic vessel endothelial hyaluronan acid receptor 1	IPI00290856	220037_s_at	2.0

Validation of urine protein markers by using target mass spectrometry

[0317] In order to assess their diagnostic performance, the inventors determined their concentrations in urine of all enrolled patients in a prospective fashion, with experimental measurements blinded to the patients' outcomes. Proteins detected with sufficient uniformity among the 67 specimens examined are listed in Table 5. The remaining proteins were detected in less than half of specimens, likely as a result of differences in processing of the discovery and validation specimens. Comparison of differences in urinary concentration between the appendicitis and non-appendicitis patient groups revealed LRG, S100-A8, and α -1-acid glycoprotein 1 (orosomucoid) as exhibiting substantial apparent enrichment in the urines of patients with appendicitis (Figure 8).

[0318] **Table 5:** Urine marker proteins validated by target mass spectrometry. ROC (receiver operating characteristic), AUC (area under the curve).

Protein	ROC AUC	AUC 95 % confidence interval
Leucine-rich α -2-glycoprotein (LRG)	0.97	0.93-1.0
calgranulin A (S100-A8)	0.84	0.72-0.95
α -1-acid glycoprotein 1 (ORM)	0.84	0.72-0.95
Plasminogen (PLG)	0.79	0.67-0.9 1
Mannan-binding lectin serine protease 2 (MASP2)	0.74	0.61-0.88
Zinc- α -2-glycoprotein (AZGP1)	0.74	0.60-0.88
α -1-antichymotrypsin (SERPINA3)	0.84	0.73-0.94
Apolipoprotein D (ApoD)	0.53	0.38-0.69

[0319] Indeed, receiver operating characteristic (ROC) curves for these markers exhibited excellent performance, with LRG and S 100-A8 having area under the curve (AUC) values of 0.97 and 0.84, respectively (Figure 9, Table 5). Other prospectively validated markers with apparently good performance included orosomucoid and α -1- antichymotrypsin (serpin A3); plasminogen, mannan-binding lectin serine protease 2 (MASP2), zinc- α -2-glycoprotein (AZGP) exhibited intermediate performance, and apolipoprotein D exhibited poor performance. These findings are consistent with most of these proteins being components of the general acute phase response, during which they may be upregulated by a variety of infectious and

inflammatory conditions, including some that are represented in the non-appendicitis group (Table 3).

[0320] The inventors assessed the relationship between apparent urine protein abundance of markers and the apparent severity of appendicitis by classifying appendectomy specimens with respect to the degree of neutrophil infiltration (12). As can be seen from Figure 10, LRG appears to be a marker of focal appendicitis, whereas S100-A8 appears to be a marker of progressive disease, reaching a peak level with moderate appendicitis. In addition to exhibiting excellent diagnostic performance, LRG was detected strongly in diseased as compared to normal appendices by using tissue immunohistochemistry (Figure 10), consistent with its biological function and proposed role in appendicitis. Its enrichment in urine of patients with appendicitis relative to those with other conditions was confirmed by using Western immunoblotting (Figure 9B), demonstrating that clinical diagnostic immunoassays can be used as a method to identify the urinary markers disclosed herein.

[0321] As disclosed herein, the inventors used urine proteome profiling to discover urinary markers of acute appendicitis. Usage of exhaustive protein capture and fractionation coupled with high accuracy mass spectrometry allowed the inventors to detect more than 2,000 unique proteins in routinely collected urine specimens, constituting the largest and most comprehensive characterization of protein composition of human urine to date (22). The discovered urinary diagnostic markers (Tables 4, 6, and 7) were subsequently validated in a prospective, blinded study of children suspected of having acute appendicitis, identifying several with statistically significant enrichment in the urine of children with histologically proven appendicitis as compared to those without (Table 5).

[0322] The use of high resolution CT and US has led to substantial improvements in the diagnosis of acute appendicitis, with respect to both the rates of complications and unnecessary appendectomies (2-4). However, significant diagnostic challenges remain, largely because of the non-specific nature of signs and symptoms of many conditions that can mimic acute appendicitis. Similarly, CT and US findings can often be indeterminate or equivocal (26). Finally, limited availability and experience with dedicated CT protocols for appendicitis, as well as future risk of cancer, can often limit its usefulness (5).

[0323] Numerous studies have sought to identify biomarkers to aid the diagnosis of appendicitis, with the absolute blood neutrophil count and serum C-reactive protein levels being most useful, but still limited with respect to their sensitivity and specificity (27, 28).

[0324] Recent attempts to identify new and improved diagnostic markers, such as CD44, interleukin-6, interleukin-8, and 5-hydroxy indole acetate, produced limited improvements as compared to the existing ones (6-11), likely as a result of being closely correlated with the

existing markers of the general acute phase response, or not specific for the distinct immune mechanisms that characterize acute appendicitis.

[0325] By taking advantage of the latest generation of mass spectrometers that combine high accuracy with high sensitivity, and carrying out exhaustive protein capture and fractionation of routinely collected urine specimens, the inventors developed a method that enables unbiased discovery and validation of multiple diagnostic markers, thereby overcoming the limitations of conventional approaches based on single hypothesis testing. Because of the depth of discovery achieved, identifying more than 2,000 unique proteins in total, urine proteomic profiling, like gene expression profiling, may be susceptible to noise and selection bias. In order to minimize these potential problems (12), discovery urine proteomes were compared not only between patients with histologically proven appendicitis and those without, but also with the same patients after they recovered from appendectomies, thereby minimizing individual differences due to age, gender, physiologic state or genetic variation. High stringency identification criteria were used, essentially eliminating false identifications (22). The discriminatory power of diagnostic markers was assessed by examining the level and uniformity of their enrichment in patients with appendicitis (Table 4), by using pattern recognition class prediction learning algorithms (Table 6), and by comparing discovered urine protein markers with tissue gene expression profiles of diseased appendices (Table 7) (24).

[0326] As a result, the 49 discovered urinary markers constitute an extensive characterization of the molecular response that accompanies acute appendicitis, including both systemically and locally produced molecules. Among the former are known components of the acute phase response, such as orosomucoid, plasminogen, angiotensin converting enzyme, carbonic anhydrase, TGF β , lipopolysaccharide binding protein, serum amyloid A, α -1-antichymotrypsin, AMBP (bikunin), and mannan-binding lectin serine protease (2). Numerous cell adhesion molecules that may participate in the local generation of the systemic inflammatory response or its localization to the appendiceal tissue were identified, including the vascular adhesion molecule 1, lymphatic vessel endothelial hyaluronan acid receptor 1, adipocyte specific adhesion molecule, supervillin, CD14, and leucine-rich α -2-glycoprotein. Likewise, several potential local inflammatory mediators and cytokines were identified such as chromogranin A, β -1,3- galactosyltransferase, interleukin-1 receptor antagonist protein, and S 100-A8.

[0327] The discovered urinary diagnostic markers were validated in their ability to accurately diagnose acute appendicitis by measuring their urinary concentrations in a prospective and blinded study of 67 patients who were suspected to have acute appendicitis, with the final diagnosis verified by blinded histologic examination of removed appendices.

Seven markers were successfully validated, including LRG, S100-A8, and ORM which exhibited excellent diagnostic performance (Figure 9, Table 5). The enrichment of LRG in urine of patients with appendicitis was confirmed by using Western immunoblotting (Figure 9B), and its enrichment in diseased as compared to normal appendices was demonstrated by using tissue immunohistochemistry (Figure 10).

[0328] LRG is expressed by differentiating neutrophils, liver, and high endothelial venules of the mesentery, including the meso-appendix, functioning in leukocyte activation and chemotaxis, respectively (29, 30). Its enrichment in the urine of patients with acute appendicitis demonstrates that it may be shed by locally activated neutrophils and/or local inflammatory sites such as the meso-appendix through which they likely traffic (Figure 10). As such, it is likely a specific marker of local inflammatory processes such as those that specifically characterize acute appendicitis, as opposed to general markers of systemic response such as the acute phase reactants, and macroscopic markers of local inflammation such as those observed using US and CT imaging.

[0329] LRG appears to be enriched in the urine of patients with appendicitis in the absence of macroscopic inflammatory changes, as evidenced by its accurate diagnosis of appendicitis of 2 patients who exhibited normal imaging findings but had evidence of acute appendicitis on histologic examination, as well as its accurate diagnosis of the absence of appendicitis in a patient without histologic evidence of appendicitis, but who underwent appendectomy as a result of findings of appendiceal enlargement on CT. Lastly, LRG appears to be enriched in the urine of patients with pyelonephritis, consistent with its proposed role in local inflammatory processes. Consequently, LRG will be useful to diagnose acute appendicitis following ruling out other local tissue infections, such as pyelonephritis, abscesses, and pelvic inflammatory disease (31). Importantly, LRG appears to be strongly expressed in diseased appendices, demonstrating that it may underlie a principal pathway of appendiceal inflammation by localizing or sustaining the local neutrophilic infiltration that specifically characterizes acute appendicitis (12, 13, 24).

[0330] The inventors have not tested urine protein markers of acute appendicitis in patients evaluated in settings other than the emergency department, as well as in older adult patients, who may include other causes of abdominal pain from those observed in the study cohort. The inventors' demonstration of urinary markers for appendicitis establishes a useful paradigm for the identification of other clinically useful urinary markers of human disease, including infectious, endocrine, autoimmune and neoplastic diseases.

[0331] References cited in Example 2 and disclosed in *italicized brackets* (i.e. “(#)”) are below.

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EXAMPLE 3

Discovery and validation of urine markers of acute appendicitis using high accuracy mass spectrometry

Discovery of diagnostic markers by using urine proteomic profiling

[0332] In order to identify candidate urinary markers of acute appendicitis, the inventors assembled a discovery urine proteome dataset, derived from the analysis of 12 specimens, without any clinical urinalysis abnormalities, collected at the onset of the study, and distributed equally between patients with and without appendicitis. Six of these specimens were collected from patients who were found to have histologic evidence of appendicitis (2 mild, 3 moderate, 1 severe). Three specimens were collected from patients without appendicitis (1 with non-specific abdominal pain, 1 with constipation, 1 with mesenteric adenitis). From the 3 patients with appendicitis, the inventors collected additional control specimens at their routine post-surgical evaluation 6-8 weeks after undergoing appendectomies, at which time they were asymptomatic and in their usual state of health. These specimens were included in the analysis in order to minimize the potential effect of individual variability in urinary composition that may arise due to age, gender, physiologic state or possible genetic variation.

[0333] The urine proteome composition of these 12 specimens was discovered by using protein capture and fractionation coupled with high accuracy mass spectrometry, as described in detail in the accompanying study,¹ and schematized in Figure 7. As urine is a complex mixture with abundant proteins such as albumin obscuring the detection of less concentrated, potentially diagnostic proteins such as secreted cytokines and mediators of the inflammatory response, the inventors devised a fractionation method that reduced mixture complexity while minimizing loss of material (Figure 7).

[0334] As a result, the inventors were able to identify 2,362 proteins in routinely collected urine specimens with the apparent rate of false identifications of less than 1 %, ¹ as ascertained from decoy database searching.² More than 1,200 identified proteins have not been detected in previous proteomic studies of urine, and more than 300 proteins appear to be filtered from serum and expressed in distal tissues, including the intestine. For the discovery of candidate appendicitis markers, the inventors further increased the stringency of peptide identifications to less than 0.1 % false identifications, yielding essentially no false protein identifications for proteins identified on the basis of multiple peptides. For example, proteins identified on the basis of 10 unique peptides (median for the entire dataset), have an approximate identification error frequency of 10-19.

[0335] In order to identify candidate markers of appendicitis, the inventors took advantage of the quantitative information provided by tandem mass spectrometry by recording the number of fragment ion spectra assigned to each unique precursor peptide, which are proportional to peptide abundance,³ and have been used for relative quantification of components of complex protein mixtures.⁴ Though the composition and concentration of urine varies with physiologic state, there was less than 10 ± 10 % (mean $\pm$ standard deviation) difference in total protein abundance among individual specimens, similar to earlier studies of urine of children.⁵⁻⁷ Individual protein spectral counts, calculated by summing spectral counts of unique peptides assigned to distinct proteins, were normalized relative to the spectral counts of albumin to account for these small differences in total protein abundance.⁴

[0336] In order to maximize the depth of candidate marker discovery, the inventors subjected the discovery urine proteome to support vector machine (SVM) learning in order to identify candidate urine markers that may be enriched as a group but not necessarily individually, as required by the relative expression ration (RER) analysis above. This approach is implemented in a biomarker discovery program BDVAL that uses cross-validation to identify predictive biomarkers (Fabien Campagne, unpublished results,

similar to established methods for microarray
class discovery.⁸ Because of the low number of samples, the inventors performed cross-

validation with four folds, repeated 5 times with random fold assignments (12 samples total, 6 cases, 6 controls). In this setting, 20 individual evaluation models (5 x 4) were trained. Each model was trained with a set of 50 features (normalized protein abundance levels). In each split, consisting of 9 training samples and 3 test samples, a Student t-test pre-filtering step prioritized up to 400 features whose average value differed the most between cases and controls in the training set. The 400 intermediate features were ranked by decreasing support vector machine weights and the top 50 features were used to train the evaluation model (models were implemented as a support vector machine, implemented in libSVM with linear kernel, and margin parameter C=1). At the end of the evaluation, the lists of features were inspected to determine how many times a given feature has been used in any one of the 20 evaluation models. The inventors considered features for validation only if they were found in at least 50 % of the evaluation models generated (10 models in this case).

[0337] Table 6 lists 17 proteins identified by SVM analysis, which include several proteins that were identified by RER analysis, as well as many that were not, including additional components of the acute phase response, such as serum amyloid A, α -1-antichymotrypsin, and bikunin (AMBP). Notably, exclusion of control specimens collected from asymptomatic patients after they underwent appendectomies increased the number of candidate markers to 273 by additionally including a variety of proteins unlikely to be related to the appendicitis response, such as the universal tyrosine kinase Src for example, suggesting that individually variant factors such as those that influence protein filtration and urine production may significantly affect biomarker discovery studies.

Candidate validation target mass spectrometry

[0338] Thawed 1 ml urine aliquots were precipitated by adding trichloroacetic acid to 20% (w/v), and incubating the samples for 1 hour at 4 °C. Precipitates were sedimented at 10,000 g for 15 minutes at 4 °C and pellets were washed twice with neat acetone at 4 °C, with residual acetone removed by air drying. Dried pellets were resuspended in Laemmli buffer, resolved by SDS-PAGE, alkylated and digested with trypsin as described.¹ To each sample, 0.4 μ g of single stranded binding (SSB) protein purified from *Escherichia coli* (USB) was added to serve as a reference standard. Target nanoLC-MS/MS was accomplished by using the LTQ-Orbitrap mass spectrometer, using the parameters described,¹ but operated in an inclusion list dependent acquisition mode, searching detected precursor ions against m/z values of candidate marker peptides with a tolerance of 0.05 Da, using an inclusion list of masses and charges of candidate marker peptides, derived from the analysis of the discovery proteomes. Six most

intense matched ions were sequentially fragmented by using collision induced dissociation, and spectra of their fragments were recorded in the linear ion trap, with the dynamic exclusion of precursor ions already selected for MS/MS of 60 sec. Such an approach is superior to conventional data dependent acquisition methods by minimizing the detection of non-target peptides.⁹ Differences in apparent protein abundance were normalized relative to exogenously added SSB reference standard to account for instrumental variability. Absence of SSB from urine specimens without its addition was confirmed by searching the data against database of *E. coli* proteins (data not shown).

[0339] Recorded mass spectra were processed and identified, as described.¹ The accuracy of peptide identification was assessed by decoy database searching,¹ enforcing a false peptide discovery rate of less than 1 %, which corresponds to essentially zero false protein discovery rate, given that all of the candidate diagnostic marker proteins were identified on the basis of at least 9 peptides, which corresponds to an apparent false identification frequency of less than 10-18. For example, leucine-rich α -2-glycoprotein (LRG) was identified on the basis of 55 unique peptides.

Urine markers of appendiceal inflammatory response

[0340] Because acute appendicitis is characterized by the increased expression of distinct chemoattractants in the gut mucosa,¹⁰ and specific infiltration of neutrophils,¹¹ the inventors wondered if markers of acute appendicitis identified from studies of appendiceal tissue may be detected in the urine of patients with appendicitis. To this end, the inventors compared candidate urine protein markers as identified by using urine proteome profiling (Table 4) with tissue markers identified in a different study by using microarray gene expression of diseased appendices.¹² Figure 6 plots RER values of the 40 most uniformly detected ($U > 0.7$) candidate urine markers as a function of the tissue overexpression of their respective microarray profiled genes. Of these, more than 50 % exhibit a positive correlation between tissue overexpression and urine enrichment (Figure 6) demonstrating that tissue gene expression profiles are useful to identify disease markers. However, only 3 of the genes that are overexpressed in diseased as opposed to normal appendices were also identified as candidate markers by urine proteome profiling: SPRX2, lymphatic vessel endothelial hyaluronan acid receptor 1 (LYVE1), and α -1-acid glycoprotein 1 (orosomucoid 1), demonstrating that detection of markers of local disease in the urine is not solely dependent on tissue overexpression, but likely also requires other factors, such as shedding, circulation in blood, and accumulation in urine. Table 7 lists urine protein

markers that were enriched in the urines of patients with appendicitis with corresponding genes that were overexpressed in diseased appendices.

[0341] In contrast to LRG which is expressed exclusively by the neutrophils, liver and the mesentery, S100-A8 is a cytokine expressed by diverse tissues, including a variety of endothelial and epithelial cells.^{13, 14} It is upregulated specifically in inflammatory states, including the processes of neutrophil activation and migration. Findings of its overexpression in appendiceal tissue during acute appendicitis,¹² and enrichment in the urine of appendicitis patients demonstrate that like LRG, it is also a marker of local inflammation, though its expression in a wide variety of tissues may affect its diagnostic specificity, consistent with its slightly reduced dynamic range and performance as compared to those of LRG (Table 5, Figure 9). Accordingly, it has been found to be upregulated in a wide variety of conditions, including inflammatory bowel disease,¹⁵ arthritis,¹⁶ Kawasaki vasculitis¹⁷ cancer,¹⁸ and sepsis.¹⁹

[0342] References cited in Example 3 and disclosed as superscript (i.e. “¹”) are listed below.

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EXAMPLE 4

Diagnostic lateral flow immunoassay test strips-design 1

[0343] The levels of biomarker proteins described herein can be determined using lateral flow immunoassay (LFIA) test strips as illustrated in Fig. 11-12. This test strip can be used in point-of-care testing (POCT). The test strip has a sample (S) position at one end of the test strip and a control (C) position found at the opposite end the test strip (Fig. 11A). There is a test (T) position located at the middle of the test strip, between S and T. For this embodiment of a test strip, the solid support **101** can be made of plastic or other non porous material, supporting the matrix **103**. Located at S is a defined quantity of dehydrated anti-biomarker protein antibody. The defined quantity of dehydrated anti-biomarker protein antibody, when rehydrated, will bind at saturation a fixed amount of biomarker antigen, meaning that this fixed amount of biomarker protein will completely occupy all of the Fv binding sites of that defined quantity of antibody. If there is additional biomarker protein in excess of the fixed amount of biomarker that is required to bind all of the amount of antibody from position S, the excess biomarker proteins will be free and are not bound to any antibody in the form of an antibody-biomarker complex. The fixed amount of biomarker protein is the predetermined reference level of biomarker protein which is the level found in healthy individuals who do not have acute appendicitis. The antibody at position S can be conjugated to colloidal gold beads or colored latex beads for visualization purposes. At position T, there is a defined quantity of biomarker protein immobilized on the test strip. This is the same biomarker protein that binds the antibody deposited at position S. At position C, there is another immobilized protein, an antibody immunoreactive to the anti-biomarker protein antibody located at the S position (Fig. 11).

[0344] The following is a description on how to use and interpret the results obtained for the test strip shown in Fig. 11. A sample of urine is applied at S. The water in the urine rehydrates the dehydrated anti-biomarker protein antibody that has been deposited at S. The dehydrated anti-biomarker protein antibody can be labeled with colloidal gold beads or colored latex beads. The biomarker protein in the urine binds to this rehydrated anti-biomarker protein antibody to form an antibody-biomarker complex. Any biomarker protein in the urine that is in excess of the rehydrated anti-biomarker protein antibody deposited at S will be free and is not bound to any antibody. A mixture of antibody-biomarker complex and free antibody or free biomarker will move by capillary action away from position S and will move toward the T

position and subsequently to the C position. When the biomarker protein of interest is below the reference level, the mixture of antibody and biomarker protein will contain free anti-biomarker protein antibody and antibody-biomarker protein complexes. At position T, any free anti-biomarker protein antibody will bind to the immobilized biomarker protein at T. The localized concentration of free anti-biomarker protein antibody that is colloidal gold or latex bead labeled will become visible as a colored line at the T position (Fig. 12B). There is free antibody only when the biomarker protein in the urine is below the threshold reference value found in healthy humans, which is the predetermined reference level of biomarker protein. When the protein of interest is at or above the predetermined reference level, the mixture of antibody and biomarker protein will contain all antibody-biomarker protein complexes and no free anti-biomarker protein antibody. At the T position, there will be no anti-biomarker protein antibody captured by the immobilized biomarker protein. Thus there will be no colloidal gold or latex bead labeled anti-protein antibody accumulation, and the area remains clear (Fig. 12A). At position C, the antibody-biomarker complex formed initially at S will be bound and captured by the immobilized antibody immunoreactive against the anti-protein antibody coming from the S position. This will in turn result in a concentration of a colloidal gold or latex bead labeled anti-protein antibody accumulated at the C position and will become visible as colored line at the C position. The C position result serves as a test control to indicate that there is functional anti-protein antibody in the test material and should always be present (Fig. 12A and 12B). When sufficient amount of labeled anti-biomarker protein antibody from the complex accumulates at C, a band becomes visible here. A band at C indicates that labeled antibody from S had moved to C. Therefore, a band at C indicates that the band at T is not a false positive. Arrowheads indicate the boundary limit that a urine sample should not cross on the test strip.

[0345] Fig. 12A-12D show the possible outcomes and interpretations of the results for such a test strip. Fig. 12A shows no band at position T but a distinct band at position C, indicating that the biomarker protein level is above predetermined reference level. Acute appendicitis is indicated. Fig. 12B shows a band at position T and a distinct band at position C, indicating that the biomarker protein level is below predetermined reference level. Acute appendicitis is not indicated. Fig. 12C shows a band at position T but no band at position C, indicating that the data at T may be a false positive. Fig. 12D shows no band at either positions T and C, indicating the data at T may be a false negative. Both Figs. 12C and 12D indicate invalid data and the lateral flow immunoassay should be repeated with a new test strip.

[0346] The defined quantity of dehydrated anti-protein antibody at S position is such that there is just enough antibody to bind the biomarker protein from the sample (e. g. urine) when the biomarker protein is at the reference/control level. The reference/control level can be the

level of the biomarker found in the samples of healthy individuals. Therefore, when the biomarker protein is at or above the reference level, all of the anti-biomarker antibody at the S position will be bound to the biomarker protein in the form of biomarker protein-antibody complex; there will be no free anti-biomarker protein antibody present.

[0347] The choice of the anti-biomarker protein antibody placed at the S position can be any antibody that is specifically immunoreactive to any of the proteins of interest, e. g. biomarker described herein. The antibody can be monoclonal, polyclonal, or a mixture of both monoclonal and polyclonal antibodies. Antibody-based moiety can also be used.

[0348] When only one biomarker protein is studied, the S position should have only one anti-biomarker protein antibody that specifically immunoreactive with just that one biomarker of interest (Fig. 13). A kit comprising test strips for use as POCT can have several single biomarker protein test strips. The kit can test for only one biomarker or more than one biomarker proteins. In this embodiment, the test strip can be labeled **131** on one end to identify the biomarker protein the test strip is used for, e. g. the label “L” represents leucine α -2 glycoprotein (LRG); “M” represents mannan-binding lectin serine protease 2 (MASP2); and “O” represents α -1-acid glycoprotein 1 (ORM) (see Fig. 13). On the other hand, if more than one, e.g. three biomarker proteins are to be studied simultaneously, the S position can have three different types of anti-biomarker protein antibodies, each type specifically immunoreactive to one biomarker protein and does not exhibit cross-reactivity with the other two non-ligand proteins (Fig. 14).

Arrowheads indicate the boundary limit that sample should not cross on the membrane. At positions T or C, up to three bands can be visible, each band corresponding to each of the biomarker protein that is being tested. When three proteins are to be studied simultaneously, all three protein types can be represented at the T position and at their respective quantities (Fig. 14). Figure 14 shows an alternative design where three proteins can be studied simultaneously on the same test strip. The positions of the expected results in the T and C positions for each biomarker are indicated **141**.

[0349] The test strip can be designed in a form of a dipstick test strip (Fig. 11B). As a dipstick test strip, the strip is dipped into a sample (e. g. urine) at the S position end with sample level not to exceed the boundary limit. The strip is then laid horizontally with the membrane surface facing up on a flat surface. A fixed amount of time is given for the antibody re-hydration, capillary action, and antibody biomarker protein binding reaction to take place. At the end of the fixed time, there should be visible bands at the C position and depending on the level of the protein of interest, there may or may not be a visible band at the T position (Fig. 12). Fig.13 shows a method of using three separate dipstick test strips to test for the three biomarkers of interest. Each dipstick test strip is labeled **131** to indicate which biomarker protein is being

tested. A diagnostic kit can comprise multiple types of single biomarker test strips, a type for each biomarker of interest.

EXAMPLE 5

Diagnostic lateral flow immunoassay Test strips-design 2

[0350] An alternative embodiment of the lateral flow immunoassay (LFIA) test strips for determining the level of biomarker protein level is illustrated in Fig. 15A-D. This test strip can be used in point-of-care testing. Here the test strip contains two different anti-biomarker protein antibodies specific for the same biomarker, each antibody binds the biomarker at a different epitope. This is a double sandwich LFIA test strip. The first antibody is labeled (e. g. colored latex beads), deposited on the solid support matrix but is not immobilized on it, (i. e. the antibody is mobile), and is deposited in excess at the S position. The second anti-biomarker protein antibody is not labeled but is immobilized and is in excess at position T. This second anti-biomarker protein antibody binds an epitope on the biomarker that is not affected by the binding of the first antibody. At position C, there is an excess of non-labeled antibody against the anti-biomarker antibody deposited at the S position. The antibody at C serves to capture any free labeled anti-biomarker antibody migrating from S. When sufficient free labeled anti-biomarker antibody is accumulated at C, a visible band appears. The band is a control to confirm that the band(s) observed on the test strip at T are due to the mobile antibody at the S position.

[0351] Initially before use, there is no visible band at position T and C of the test strip (Fig. 15B). When a fluid sample (e. g. urine) is placed at the S position, the water in the urine rehydrates the dehydrated anti-biomarker protein antibody that has been deposited at S. The dehydrated anti-biomarker protein antibody can be labeled with colloidal gold beads or colored latex beads. The biomarker protein in the urine binds to this rehydrated anti-biomarker protein antibody to form an antibody-biomarker complex. A mixture of free anti-biomarker antibody and biomarker protein:antibody complexes is formed. The mixture migrates by capillary action towards the T and the C positions. The second anti-biomarker antibody immobilized at T will capture all the biomarker protein: antibody complexes but not the free anti-biomarker protein antibody. The localized concentration of anti-biomarker protein:antibody complexes that is colloidal gold or latex bead labeled will become visible as a colored line at the T position (Fig. 15C). Only when the biomarker protein is at or above the reference level will sufficient labeled antibody be captured at T to produce a visible band (Fig. 15C). When the biomarker is below the reference level, no visible band should appear at the T position (Fig. 15D).

[0352] At position C, free anti-biomarker antibody initially from S will be bound and captured by the immobilized antibody immunoreactive against the antibody coming from the S position. This will in turn result in a concentration of a colloidal gold or latex bead labeled anti-protein antibody accumulated at the C position and will become visible as colored line at the C position. The C position result serves as a test control to indicate that there is functional anti-protein antibody in the test material and should always be present. A band at C indicates that labeled antibody from S had moved to C. Therefore, a band at C indicates that the band at T is not a false positive or that the absence of a band at T is a false negative.

EXAMPLE 6

Diagnostic lateral flow immunoassay Test strips-design 3

[0353] An alternative embodiment of the lateral flow immunoassay (LFIA) test strips for determining the level of biomarker protein level is illustrated in Fig. 16. This test strip can be used in point-of-care testing. The test strip is as described in Fig. 11 having a sample (S), a test (T), and a control (C) positions, all three spatially arranged as shown in Fig. 11 and Fig. 15. For this embodiment of a test strip, the solid support **161** can be made of plastic or other non porous material, supporting the matrix **163**. In this embodiment, the S position contain an excess amount of dehydrate anti-biomarker protein antibody (first antibody) that can be labeled (e. g. colloidal gold or color latex bead). Similar to the embodiments in Fig. 11-14, the anti-biomarker protein antibody at S is mobile; once the antibody is re-hydrated, the antibody moves by capillary action towards the T and C positions.

[0354] The T position contains a second anti-biomarker protein antibody that is also immunoreactive to the biomarker protein of interest, but to a different epitope on the biomarker (Fig. 16). This second antibody is in excess and is immobilized on the matrix. This second anti-biomarker protein antibody binds a part of the biomarker protein that is different from the part of the protein that is bound by the first anti-biomarker protein antibody found at the S position. In this embodiment, the second antibody at the T position will bind and capture both free unbound biomarker protein and biomarker protein-antibody complexes, and concentrate them at the T position.

[0355] The C position contains a defined quantity of biomarker protein immobilized on the membrane (Fig. 16B). The defined quantity is the predetermined reference value of the biomarker protein being analyzed on the test strip. The reference/control level can be the level of the biomarker found in the samples of healthy men. When the excess free anti-biomarker protein antibody from the S position arrives and bind the immobilized biomarker protein at C,

gradually accumulation at C produces a concentration of labeled first antibody will become visible as a colored line at the C position (Fig. 17A, B, D).

[0356] An application of a fluid sample (e. g. urine) at the S position will re-hydrate the excess amount of anti-biomarker protein antibody there. All of the biomarker protein of interest should be bound to the excess anti-biomarker protein antibody. A fluid mixture of free biomarker protein antibody and biomarker protein-antibody complex is formed and will move along the membrane by capillary action towards the T position and then subsequently to the C position. At the T position, all of the biomarker protein-antibody complex will be captured and immobilized by the second anti-biomarker protein antibody. The localized concentration of biomarker protein-antibody complexes, wherein the anti-biomarker protein antibody that is colloidal gold or latex bead labeled, will become visible as a colored line at the T position (Fig. 17A, B, D). With increasing amount of biomarker protein-antibody complexes and concentrated at the T position, the colored line expands and develops into a band. The greater the level of biomarker in the sample, the wider the colored band at the T position (Fig. 17A and B).

[0357] When excess free anti- biomarker protein antibody from the S position arrives to the C position and bind to the immobilized reference amount of biomarker protein there, another color line become visible. Since there is a reference amount of immobilized biomarker protein at the C position, the thickness of the visible colored line at the C position defines the reference value of protein. By comparing the thickness of the color band at the T and C positions on the same test strip, one can estimate whether the biomarker protein level is below or greater than the reference value of the protein. When the biomarker protein level is equal or greater than the reference value, the color band at the T position will be equal or larger than the color band at the C position respectively (Fig. 17A and B). Acute appendicitis is indicated. When the biomarker protein level is below the threshold level, the color band at the T position will be smaller or even absent than the color band at the C position (Fig. 17C and D). Acute appendicitis is not indicated. The C position band also serves as a test control to confirm that there is functional anti-protein antibody at the S position and that the functional anti-biomarker protein antibody is derived from the S position (Fig. 17E and F). Fig. 17E shows a band at position T but no band at position C, indicating that the data at T may be a false positive. Fig. 17F shows no band at either positions T and C, indicating the data at T may be a false negative. Both Figs. 17E and 17F indicate invalid data and that the lateral flow immunoassay should be repeated with a new test strip.

[0358] When only one biomarker protein is studied, the S position should have only one anti-biomarker protein antibody that specifically immunoreactive with just that one biomarker of interest. A kit comprising test strips for use as POCT can have several single biomarker protein

test strips. The kit can test for only one biomarker or more than one biomarker proteins. In this embodiment, the test strip can be labeled **181** on one end to identify the biomarker protein the test strip is used for, e.g. the label “L” represents leucine α -2 glycoprotein (LRG); “M” represents mannan-binding lectin serine protease 2 (MASP2); “O” represents α -1-acid glycoprotein 1 (ORM) and “S” represents α -1-antichymotrypsin (SERPINA3) (see Fig. 18). On the other hand, if more than one, e.g. three biomarker proteins are to be studied simultaneously, the S position can have three different types of anti-biomarker protein antibodies, each type specifically immunoreactive to one biomarker protein and does not exhibit cross-reactivity with the other two non-ligand proteins (Fig. 19). Figure 19 shows an alternative embodiment of a test strip where three biomarker proteins can be studied simultaneously on the same test strip. The positions for each biomarker on the single strip are indicated **191**.

[0359] The test strip can be designed in a form of a dipstick test strip (Fig. 16B). As a dipstick test strip, the strip is dipped into a sample (e. g. urine) at the S position end with sample level not to exceed the boundary limit. The strip is then laid horizontally with the membrane surface facing up on a flat surface. A fixed amount of time is given for the antibody re-hydration, capillary action, and antibody biomarker protein binding reaction to take place. At the end of the fixed time, there should be visible bands at the C position and depending on the levels of the biomarker protein(s) of interest, there may or may not be a visible band at the T position (Fig. 18 and 19) and the bands can be of different thickness. Fig.18 shows a method of using four separate dipstick test strips to test for the four biomarkers of interest. Such test strip can be the component of a diagnostic kit. Each dipstick test strip is labeled **181** to indicate which biomarker protein is being tested. A diagnostic kit can comprise multiple types of single biomarker test strips, a type for each biomarker of interest.

What is claimed is:

1. Use of a device comprising:
 - a. a protein-binding agent which specifically binds to an appendicitis biomarker protein comprising leucine α -2 glycoprotein (LRG); and
 - b. at least one solid support for the protein binding-agent in (a), wherein the protein-binding agent is deposited on the solid support;

to identify a subject having acute appendicitis, wherein if the appendicitis biomarker comprising leucine α -2 glycoprotein (LRG) specifically binds to the protein-binding agent, the subject is likely to have acute appendicitis.

2. The use of claim 1, wherein the protein-binding agent deposited on the solid support specifically binds to the appendicitis biomarker polypeptide leucine α -2 glycoprotein (LRG) of SEQ ID NO: 1.
3. The use of claim 1 or claim 2, wherein the device further comprises at least one additional different protein-binding agent deposited on the solid support, wherein the additional protein-binding agent specifically binds to an appendicitis biomarker protein selected from the group consisting of: S100-A8 (calgranulin); α -1-acid glycoprotein 1 (ORM); plasminogen (PLG); mannan-binding lectin serine protease 2 (MASP2); zinc- α -2-glycoprotein (AZGP1); apolipoprotein D (ApoD); and α -1-antichymotrypsin (SERPINA3).
4. The use of claim 1 or claim 2, wherein the device further comprises at least one additional different protein-binding agent deposited on the solid support, wherein the additional protein-binding agent specifically binds to an appendicitis biomarker protein selected from the group consisting of: adipocyte specific adhesion molecule; AMBP; amyloid-like protein 2; angiotensin converting enzyme 2; BAZ1B; carbonic anhydrase 1; CD14; chromogranin A; FBLN7; FXR2; hemoglobin α ; hemoglobin β ; interleukin-1 receptor antagonist protein; inter- α -trypsin inhibitor; lipopolysaccharide binding protein; lymphatic vessel endothelial hyaluronan acid receptor 1; MLKL; nicastrin; novel protein (Accession No: IPI00550644); PDZK1 interacting protein 1;

PRIC285; prostaglandin-H2 D-isomerase; Rcl; S100-A9; serum amyloid A protein; SLC13A3; SLC2A1; SLC2A2; SLC4A1; SLC9A3; SORBS1; SPRX2; supervillin; TGFbeta2R; TTYH3; VA0D1; vascular adhesion molecule 1; versican; VIP36; α -1-acid glycoprotein 2; and β -1,3-galactosyltransferase.

5. The use of any one of claims 1 to 4, wherein the solid support is in the format of a dipstick, a microfluidic chip or a cartridge.
6. The use of any one of claims 1 to 5, wherein the protein-binding agent is an antibody, antibody fragment, aptamer, small molecule or variant thereof.
7. The use of any one of claims 1 to 6, wherein the amount of bounded appendicitis biomarker on the device is measured and compared to a reference level for that biomarker protein, and a level of measured appendicitis biomarker protein above the reference level for that biomarker protein indicates that the subject is likely to have acute appendicitis.
8. The use of any one of claims 1 to 7, wherein the device is used with a urine sample for diagnosing acute appendicitis.
9. A method to identify the likelihood of a human subject having acute appendicitis comprising:
 - a) measuring the level of a first appendicitis biomarker protein comprising leucine α -2 glycoprotein (LRG) in a urine sample from the human subject; and
 - b) comparing the level of the first appendicitis biomarker protein measured in step (a) to a reference level for the measured biomarker;wherein a level of measured biomarker above the reference level for the biomarker indicates that the subject is likely to have acute appendicitis.
10. The method of claim 9, further comprising determining the level of albumin in the urine sample from the human subject.
11. The method of claim 9 or claim 10, further comprising measuring the level of at least a second appendicitis biomarker protein, wherein the second biomarker

protein is selected from a group consisting of: adipocyte specific adhesion molecule; calgranulin A (S100-A8); α -l-acid glycoprotein 1 (ORM); plasminogen (PLG); mannan-binding lectin serine protease 2 (MASP2); Zinc- α -2-glycoprotein (AZGP1); α -1-antichymotrypsin (SERPINA3); apolipoprotein D (ApoD); AMBP; amyloid-like protein 2; angiotensin converting enzyme 2; BAZ1B; carbonic anhydrase 1; CD14; chromogranin A; FBLN7; FXR2; hemoglobin α ; hemoglobin β ; interleukin-1 receptor antagonist protein; inter- α -trypsin inhibitor; lipopolysaccharide binding protein; lymphatic vessel endothelial hyaluronan acid receptor 1; MLKL; nicastrin; novel protein (Accession No: IPI00550644); PDZK1 interacting protein 1; PRIC285; prostaglandin-H2 D-isomerase; Rel; S100-A9; serum amyloid A protein; SLC13A3; SLC2A1; SLC2A2; SLC4A1; SLC9A3; SORBS1; SPRX2; supervillin; TGFbeta2R; TTYH3; VA0D1; vascular adhesion molecule 1; versican; VIP36; α -1-acid glycoprotein 2; and β -1,3-galactosyltransferase.

12. The method of any one of claims 9 to 11 or the use of claim 7, wherein the reference level is selected from: (i) a level of the biomarker in a urine sample of a healthy human not having acute appendicitis; (ii) an average level of the biomarker in a plurality of urine samples from a population of healthy humans not having acute appendicitis; or (iii) a normalized level of the biomarker in a urine sample of a healthy human not having acute appendicitis, wherein the normalization is performed against the level of albumin in the urine sample of a healthy human not having acute appendicitis.

13. The method of any one of claims 9 to 12, wherein the measuring step a) is performed by: an immunoassay, including an Enzyme-Linked Immunosorbent Assay (ELISA), a radioimmunoassay, a diffusion immunoassay, a fluoroimmunoassay, a chemiluminescent immunoassay, a counting immunoassay, a lateral flow immunochromatographic assay, and a magnetic immunoassay; an immunoprecipitation assay; mass spectrometry; Western Blotting; or a dipstick.

14. A device for diagnosing the likelihood of acute appendicitis comprising:

- a. protein-binding agent which specifically binds to an appendicitis biomarker protein comprising leucine α -2 glycoprotein (LRG); and

- b. at least one solid support for the protein binding-agent in (a), wherein the protein-binding agent is deposited on the solid support;

wherein the device further comprises at least one additional different protein-binding agent deposited on the solid support, wherein the additional protein-binding agent specifically binds to an appendicitis biomarker protein selected from the group consisting of: S100-A8 (calgranulin); α -1-acid glycoprotein 1 (ORM); plasminogen (PLG); mannan-binding lectin serine protease 2 (MASP2); zinc- α -2-glycoprotein (AZGP1); apolipoprotein D (ApoD); and α -1-antichymotrypsin (SERPINA3).

Figure 1

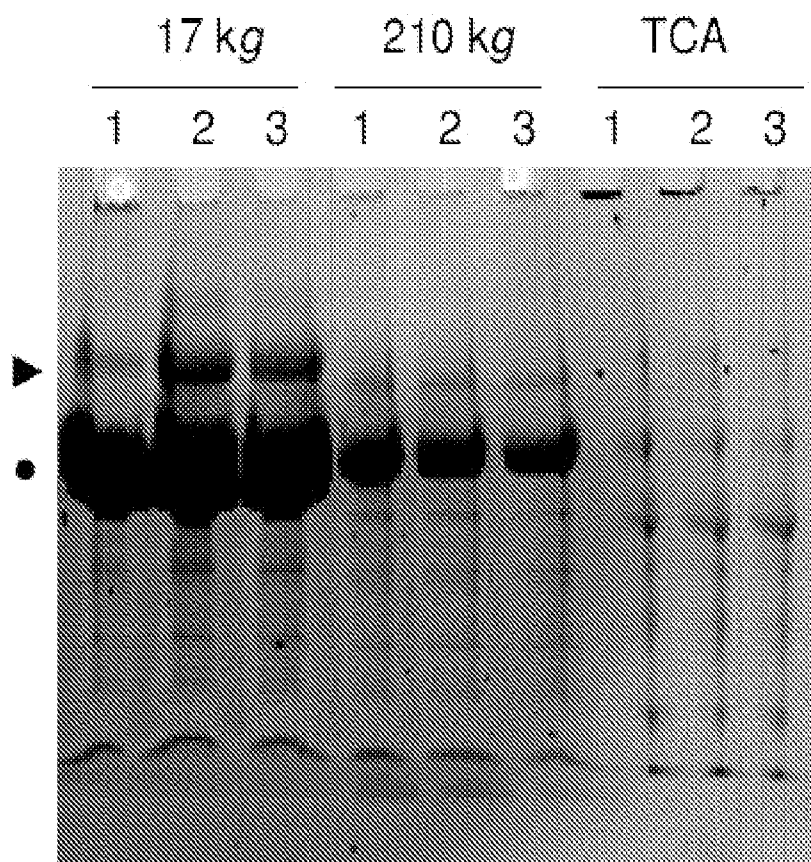


Figure 2A

Fig. 2

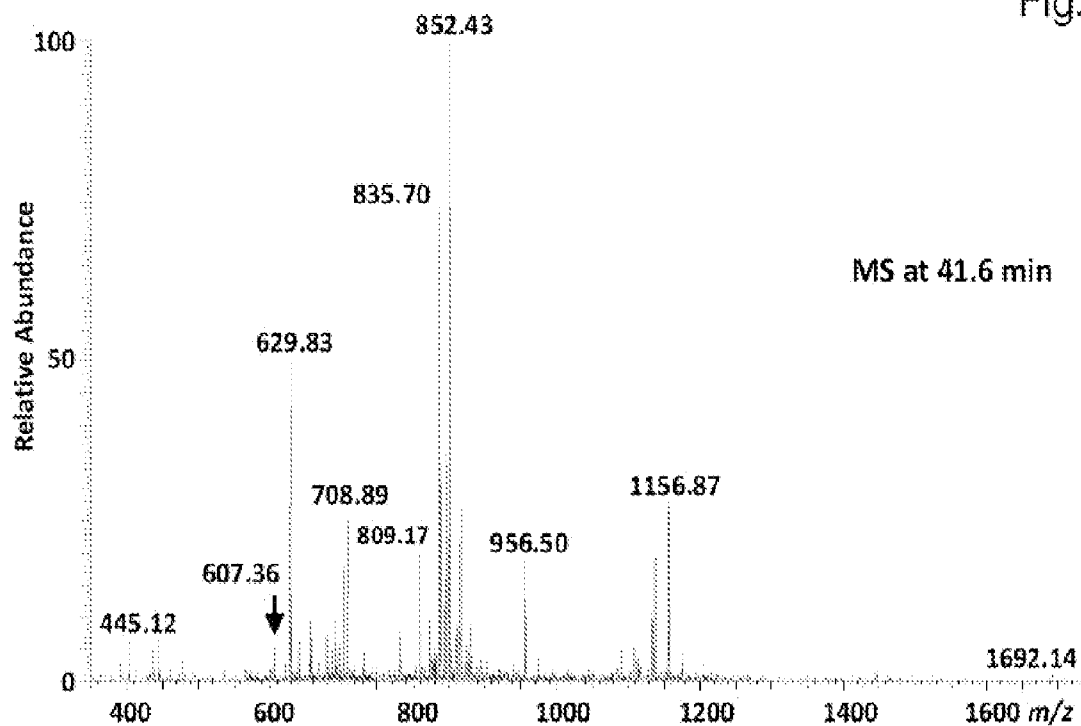


Figure 2B

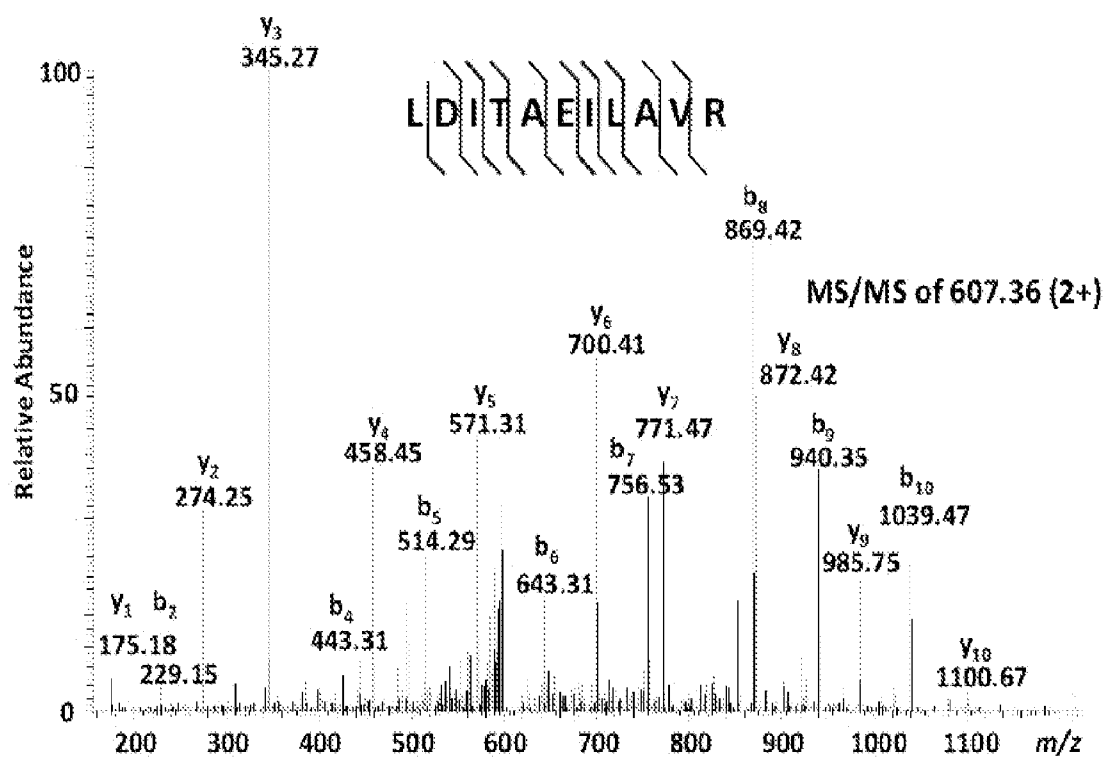
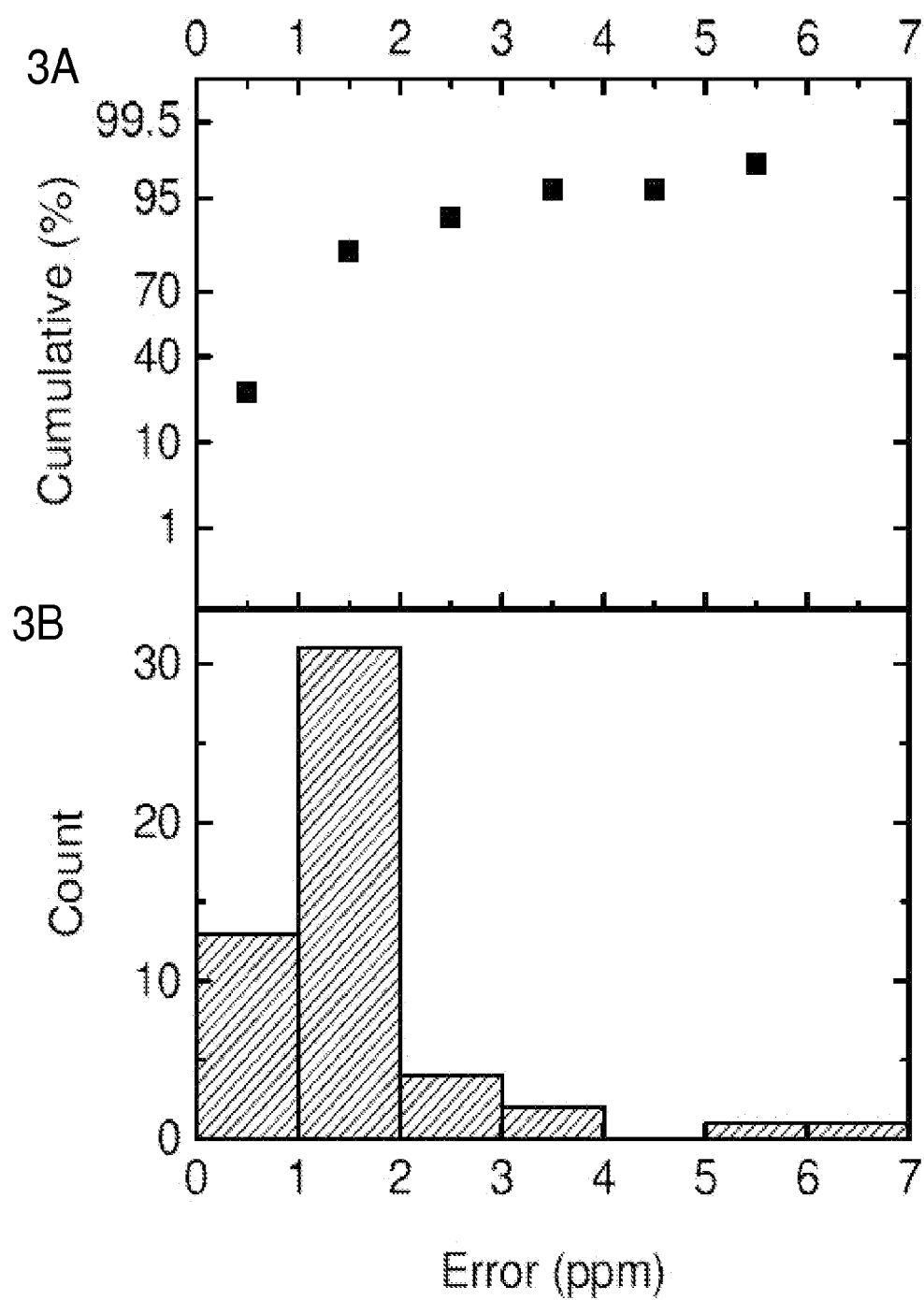
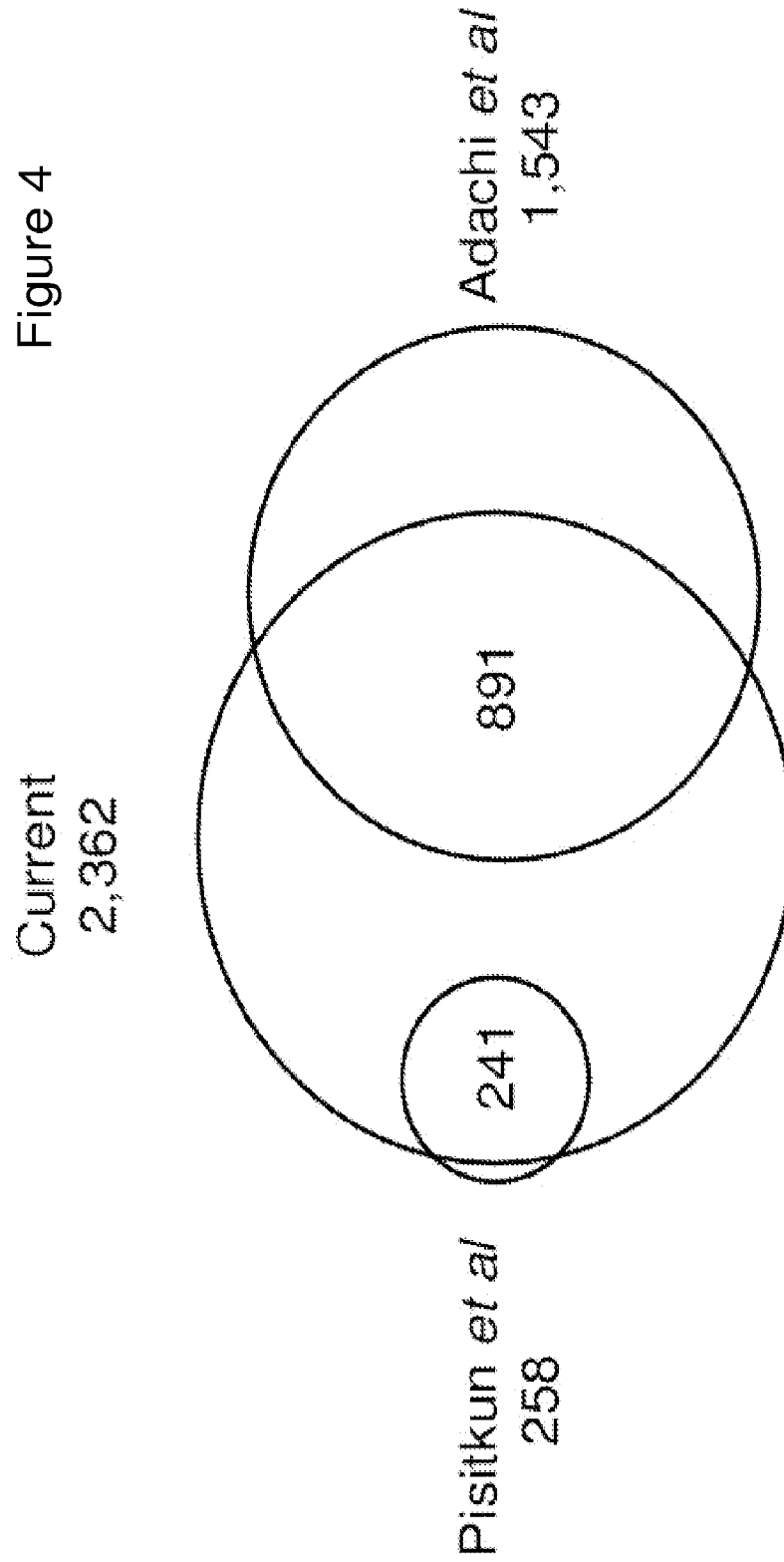


Figure 3





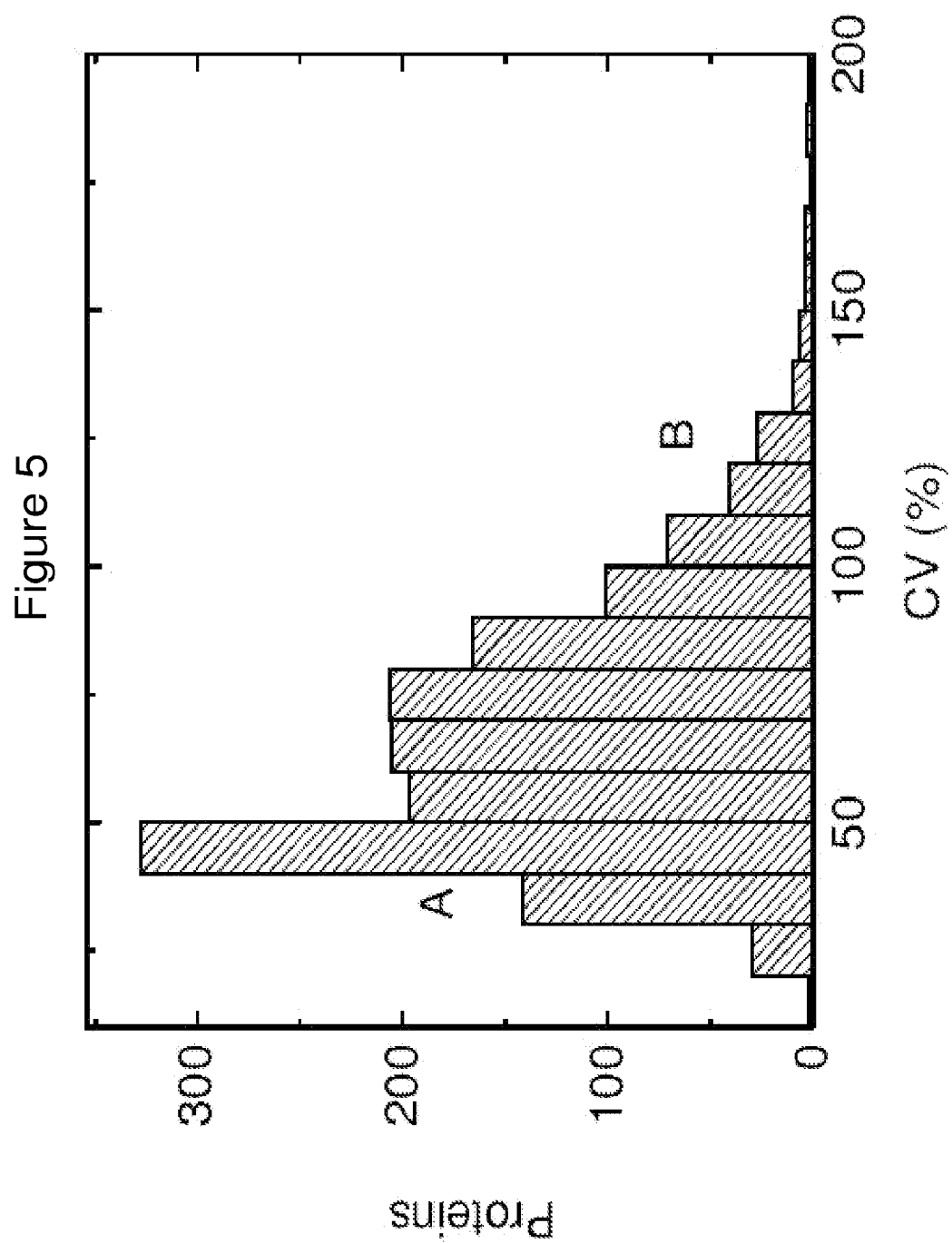


Figure 7

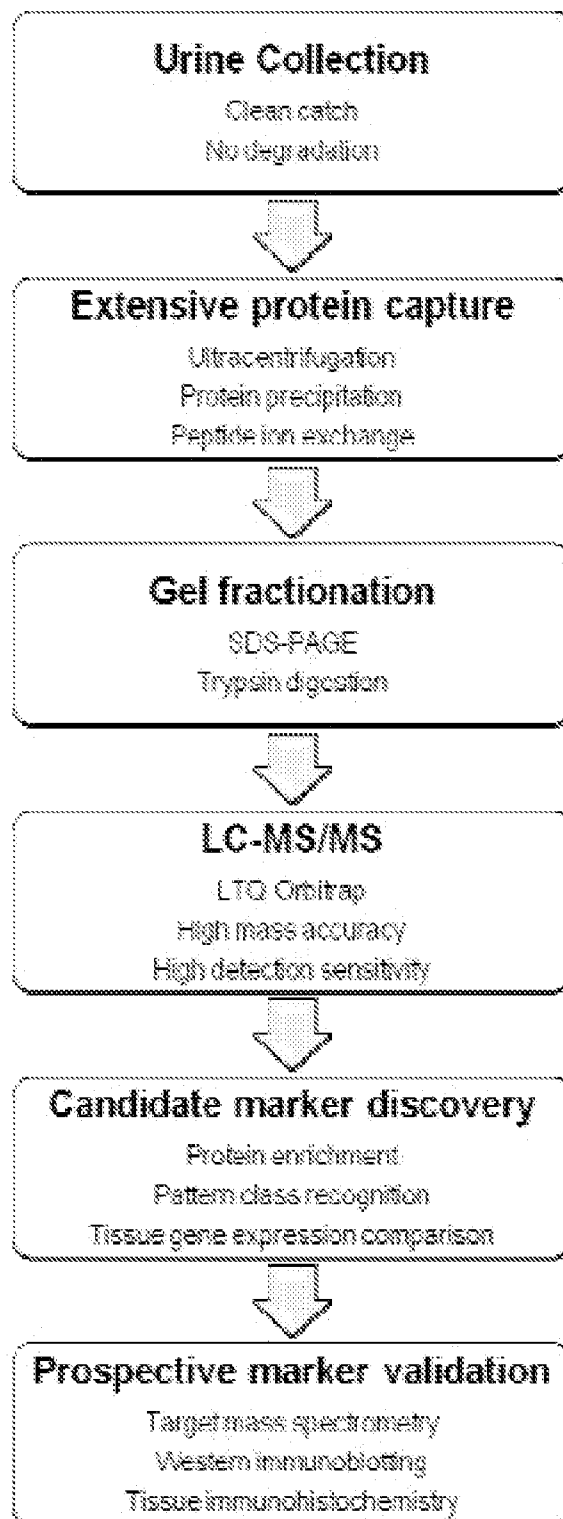


Figure 8

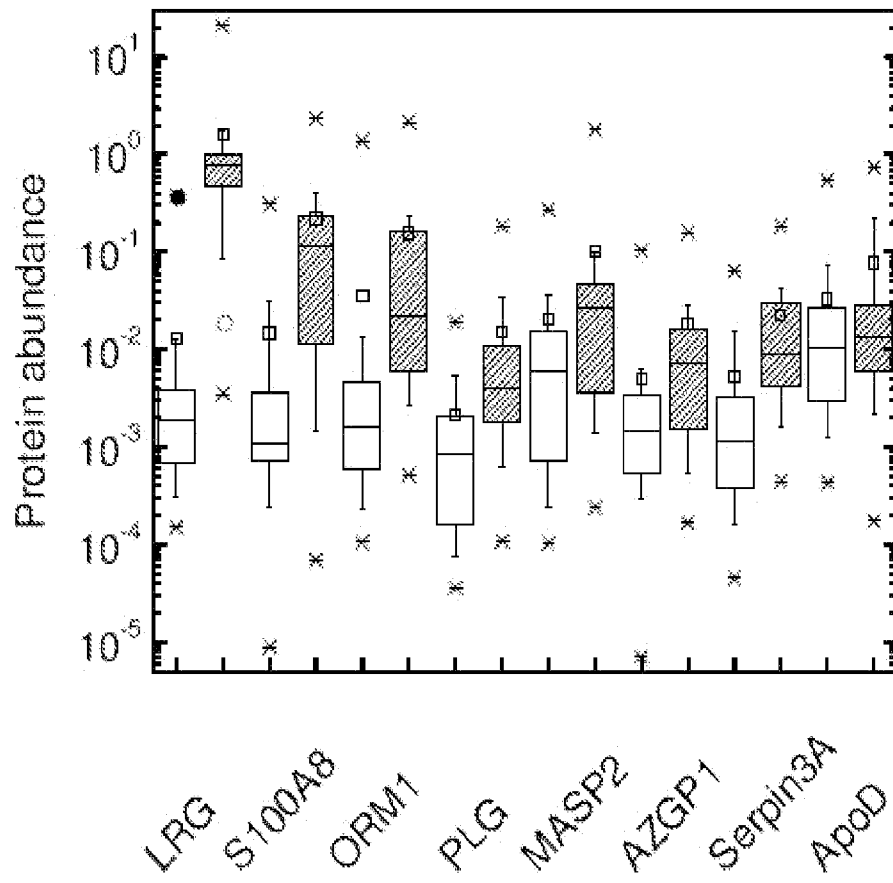


Figure 9A

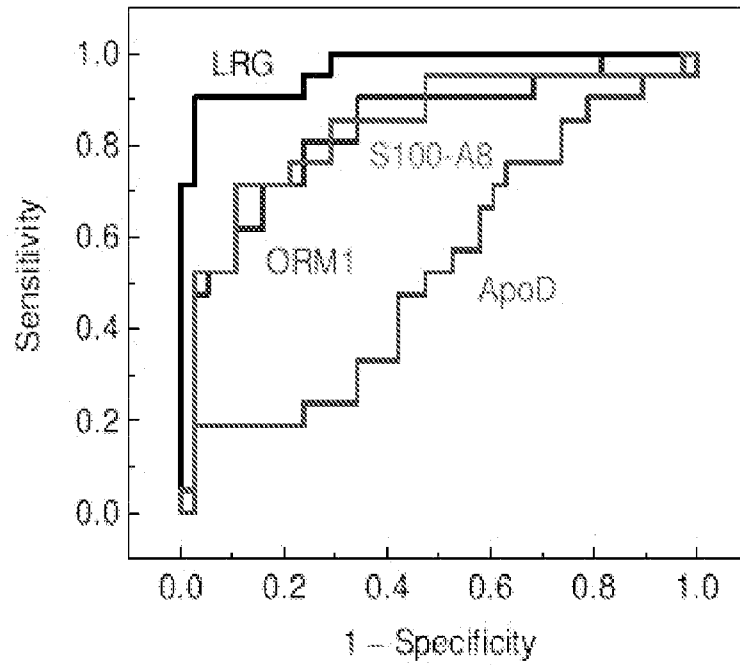


Figure 9B

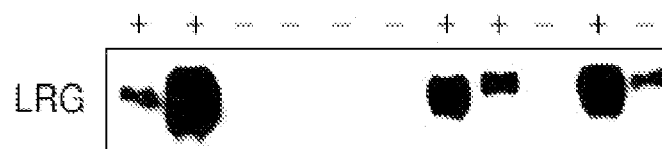


Figure 10A

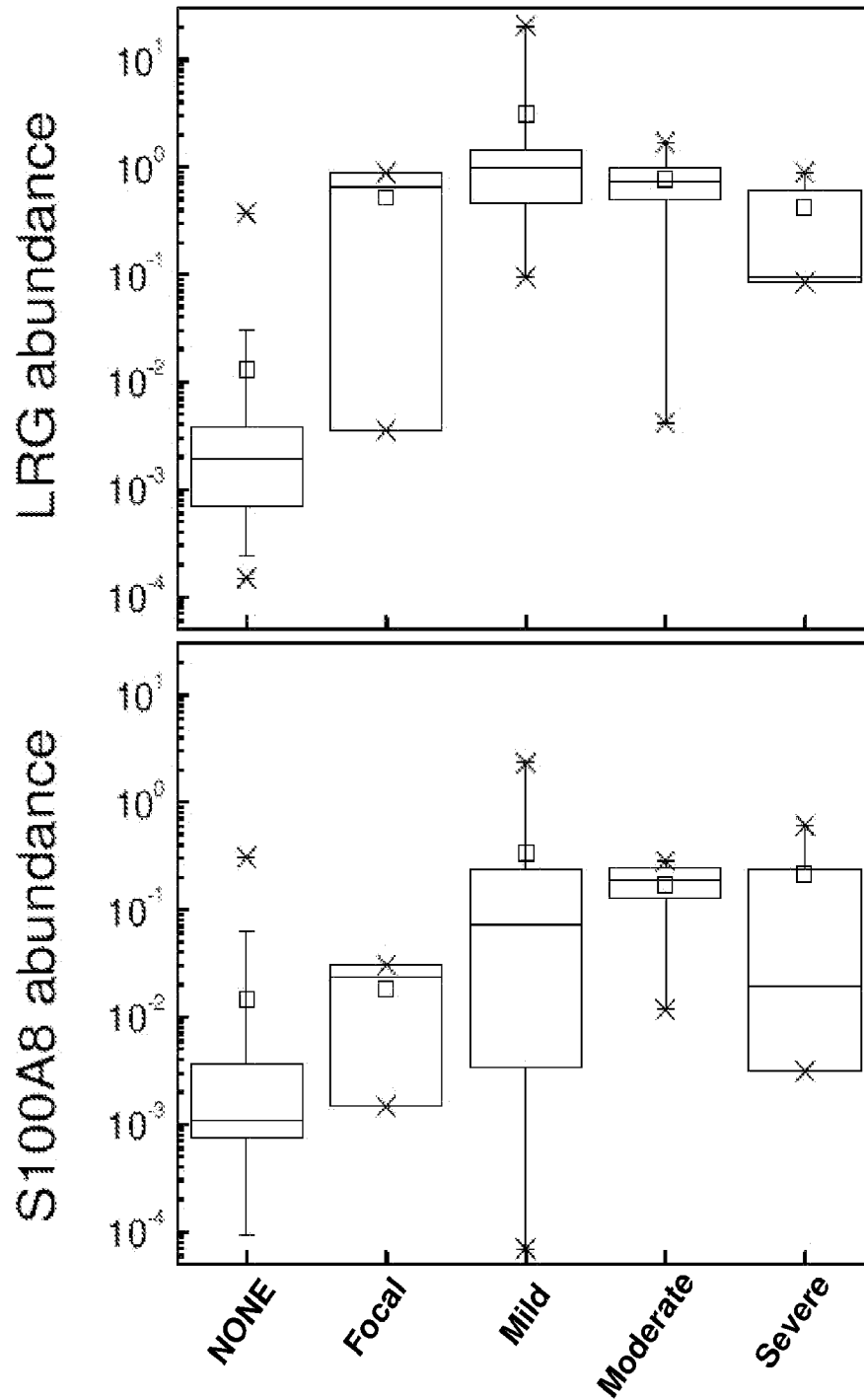


Figure 10B

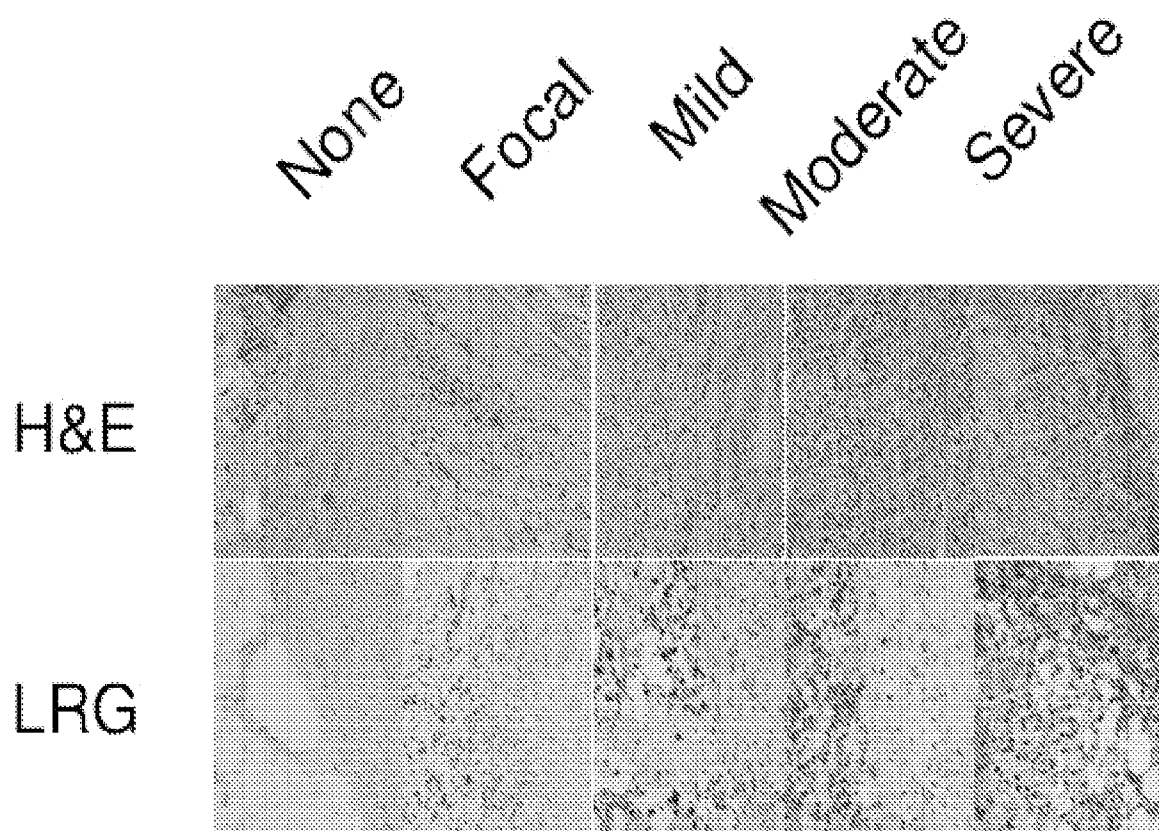


Figure 11A
(Top View)

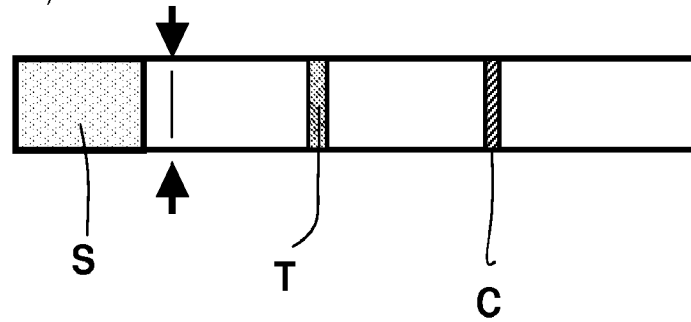


Figure 11B
(Cross Section View)

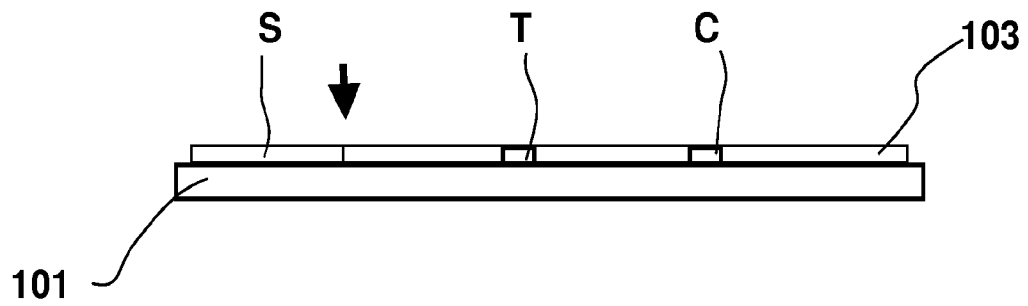


Figure 12A

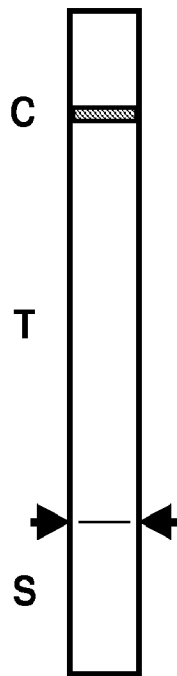


Figure 12C

Figure 12B

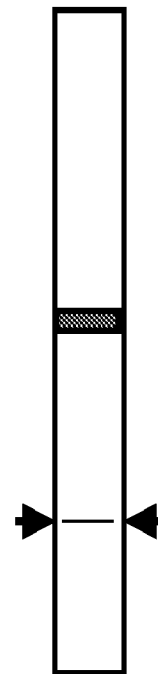
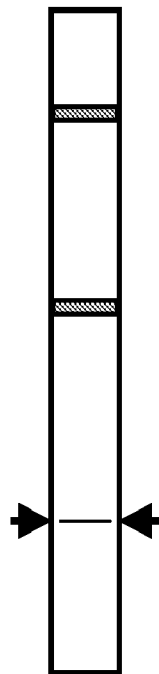


Figure 12D

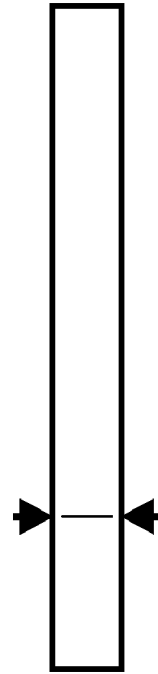


Figure 13

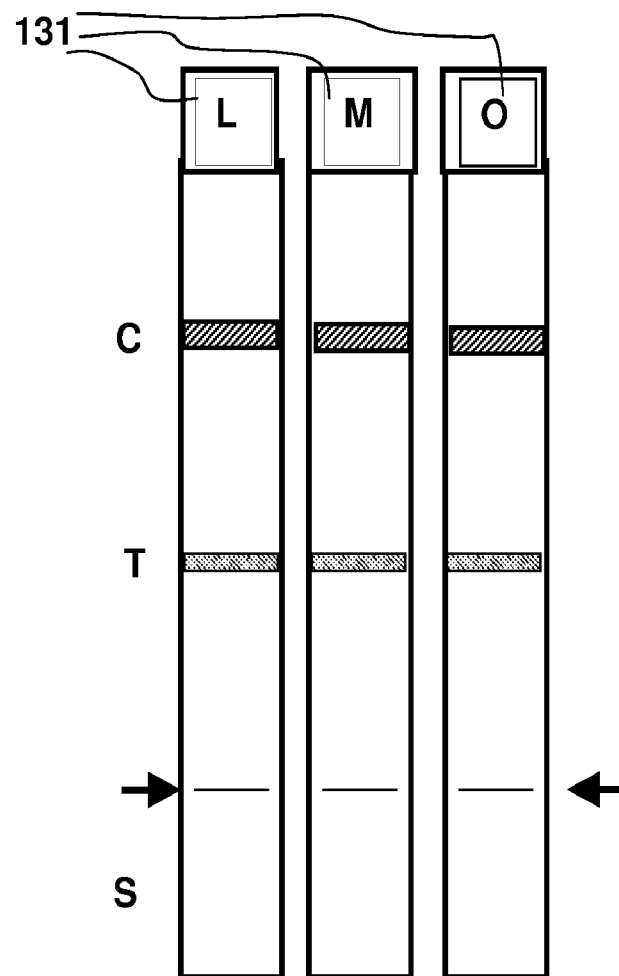


Figure 14

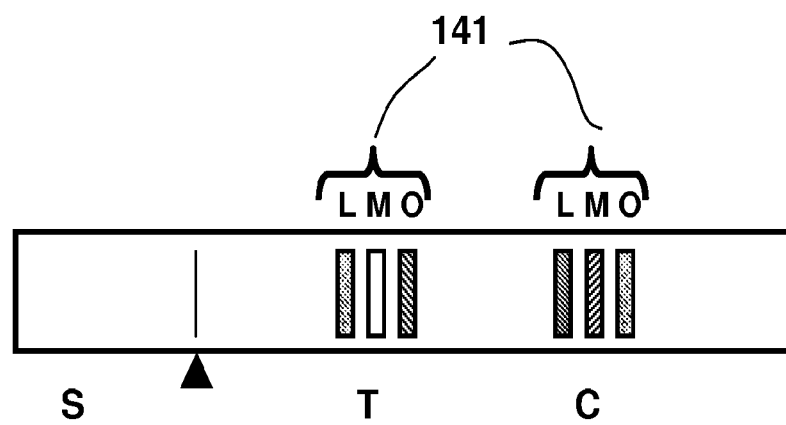


Figure15A

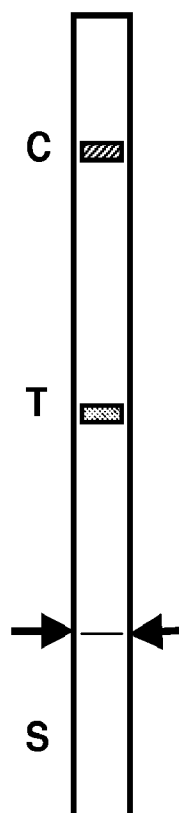


Figure15B

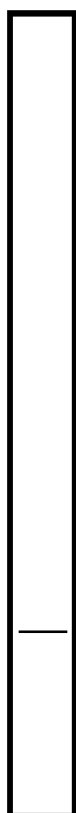


Figure15C



Figure15D



Figure 16A
(Top View)

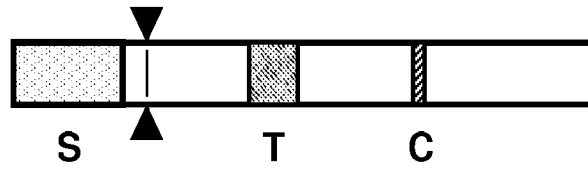


Figure 16B
(Cross Section View)

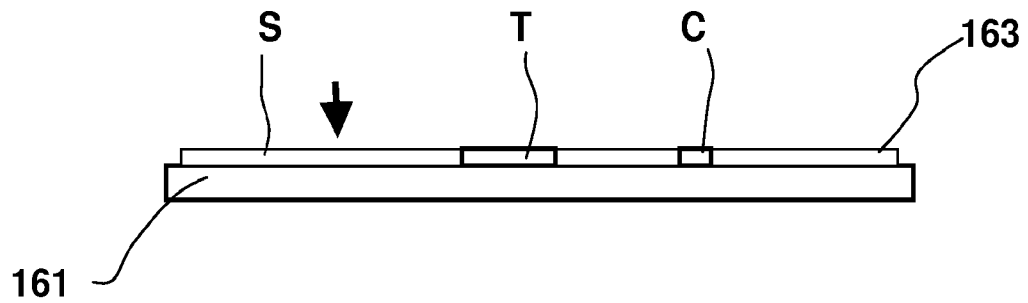


Figure 17A



Figure 17B

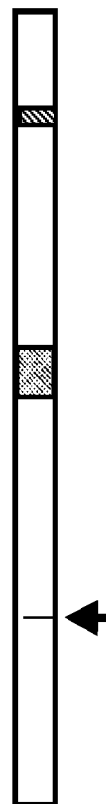


Figure 17C

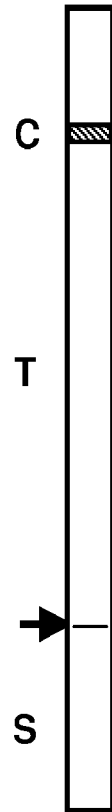


Figure 17D

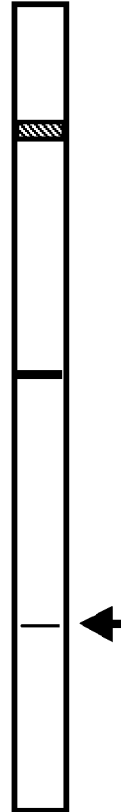


Figure 17E

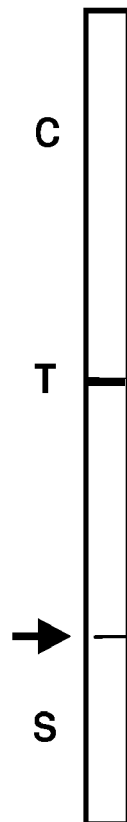


Figure 17F

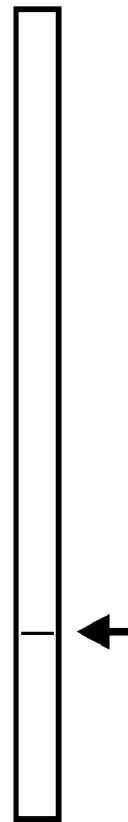


Figure 18

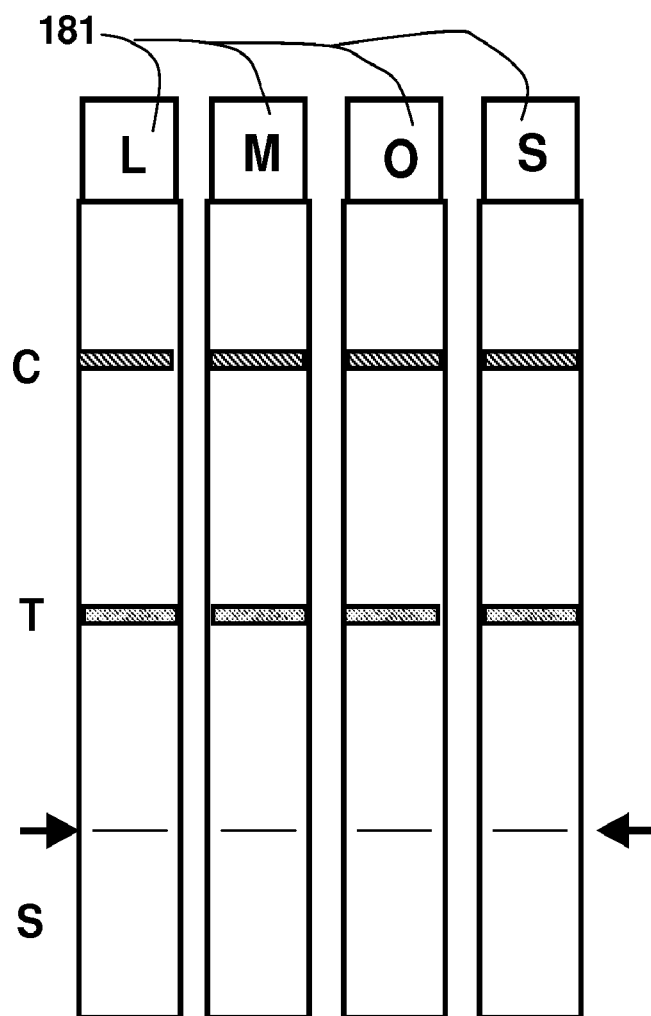


Figure 19

