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BCR-ABL VARIANTS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Application Nos. 61/110,512, filed October 31, 2008, and 12/472,319, filed May 26, 2009, each of which is hereby incorporated by reference.

FIELD OF THE INVENTION

[0002] The present inventions relate to BCR-ABL variants and resistance to kinase inhibitor therapy.

BACKGROUND OF THE INVENTION

[0003] The following description is provided to assist the understanding of the reader. None of the information provided or references cited is admitted to be prior art to the present invention.

[0004] Chronic Myelogenous Leukemia ("CML") is a cancer of bone marrow and blood cells. In CML, healthy bone marrow cells are replaced with leukemic cells; myeloid, erythroid, megakaryocytic and B lymphoid cells are among the blood cells which become leukemic due to the effects of a characteristic chromosomal translocation.

[0005] CML is associated with a specific chromosomal abnormality called Philadelphia chromosome. The genetic defect is caused by the reciprocal translocation designated t(9;22)(q34;q11), which refers to an exchange of genetic material between region q34 of chromosome 9 and region q11 of chromosome 22 (Rowley, J.D. Nature. 1973; 243: 290-3; Kurzrock et al. N. Engl. J. Med. 1988; 319: 990-998). This translocation results in a portion of the *bcr* ("breakpoint cluster region") gene from chromosome 22 (region q11) becoming fused with a portion of the *abl* gene on chromosome 9 (region q34).

[0006] The fused "*bcr-abl*" gene is located on chromosome 22, which is shortened as a result of the translocation. The fused gene retains the tyrosine kinase domain of the *abl* gene, which is constitutively active (Elefanty et al. EMBO J. 1990; 9: 1069-1078). This kinase activity activates various signal transduction pathways leading to uncontrolled cell growth

and division (*e.g.*, by promoting cell proliferation and inhibiting apoptosis). For example, BCR-ABL may cause undifferentiated blood cells to proliferate and fail to mature.

[0007] Treatment of CML may involve drug therapy (*e.g.*, chemotherapy), bone marrow transplants, or combinations of both. One class of drugs that may be used for treating CML are kinase inhibitors. For example, “imatinib mesylate” (also known as STI571 or 2-phenylaminopyrimidine or “Imatinib” for short) has proven effective for treating CML (Deininger et al., *Blood*. 1997; 90: 3691-3698; Manley, P.W., *Eur. J. Cancer*. 2002; 38: S19-S27). Imatinib is marketed as a drug under the trade name “Gleevec” or “Glivec.” Other examples of kinase inhibitor drugs for treating CML include nilotinib, dasatinib, Bosutinib (SKI-606) and Aurora kinase inhibitor VX-680.

[0008] Imatinib is an ATP competitive inhibitor of BCR-ABL kinase activity and functions by binding to the kinase domain of BCR-ABL and stabilizing the protein in its closed, inactive conformation. Monotherapy with imatinib has been shown to be effective for all stages of CML.

[0009] Resistance to imatinib remains a major problem in the management of patients with CML. Rates at which primary (failure to achieve any hematologic response) and secondary resistance (*i.e.*, hematologic recurrence) occurs varies dependent on the stage of diseases. Primary resistance has been reported in chronic-, accelerated-, or blast-phase at rates of 3%, 9%, and 51%, respectively (Melo, J.V. & Chuah, C. *Cancer Lett.* 2007; 249: 121-132; Hughes, T. *Blood*. 2006; 108: 28-37). Secondary resistance has been reported in these patients at rates of 22%, 32%, and 41%, respectively.

[0010] The complete mechanism of imatinib resistance in CML patients is unclear and a significant number of patients resistant to imatinib have no mutation in the *bcr-abl* gene. However, 35-45% of patients with imatinib resistance have mutations in the kinase domain of the BCR-ABL protein (Mahon, F.X. *Blood*. 2000; 96: 1070-1079). Most of the reported mutations disrupt critical contact points between imatinib and the tyrosine kinase receptor or induce a transition from the inactive to the active protein configuration, preventing imatinib binding (Nagar, B. *Cell*. 2003; 112: 859-871; Nagar et al., *Cancer Res.* 2002; 62: 4236-4243; Branford S. *Blood*. 2002; 99: 3472-3475; Branford et al. *Blood*. 2003; 102: 276-283). The T315I mutation (Gorre et al. *Science*. 2001; 293: 876-880; Hochhaus et al. *Leukemia*. 2002; 16: 2190-2196) and some mutations affecting the so-called P-loop of BCR-ABL confer a

greater level of resistance to imatinib (Branford et al. Blood. 2002; 99: 3472-3475; Branford et al. Blood. 2003; 102: 276-283; and Gorre et al. Blood. 2002; 100: 3041-3044) and even the new tyrosine kinase inhibitors that are currently used and tested in these patients (Hughes et al. Blood. 2006; 108: 28-37; Hochhaus, et al. Blood. 2006; 108: 225a). The role of Src family kinases has received particular interest as possible mechanism for imatinib resistance (Levinson et al. PLoS Biol. 2006; 4: e144). Overexpression and activation of the Lyn has been implicated in imatinib-resistance (Donato, N.J. Blood. 2003; 101: 690-698).

[0011] Furthermore, Chu et al. (N. Engl. J. Med. 2006; 355: 10) describe an insertion/truncation mutant of BCR-ABL in a CML patient resistant to imatinib. Chu et al. report that the mutant results from a 35 base insertion of *abl* intron 8 into the junction between exons 8 and 9, resulting in a new C-terminus and truncation of the normal C-terminus of the Abl portion of the fusion protein. Laudadio et al. (J. Mol. Diag. 2008; 10(2): 177-180) also reports a similar splice variant in CML patients that had undergone imatinib therapy.

SUMMARY OF THE INVENTION

[0012] The present inventions are based on a BCR-ABL splice variant that results from insertion/truncation of the *bcr-abl* transcript and the finding that the variant provides cells with resistance to kinase domain inhibitors such as imatinib. In one embodiment, the splice variant results from a 35 bp portion of intron 8 into the junction of exons 8 and 9, (exemplified in FIG. 1). The BCR-ABL insertion/truncation mutant also may be referred to as "35 INS BCR-ABL."

[0013] The inventions described herein include polynucleotides which encode all or portions of a novel BCR-ABL insertion/truncation splice variant and recombinant cells that express all or portions of the splice variant from a cDNA construct. Recombinant cells expressing the insertion/truncation BCR-ABL protein with an active kinase domain are useful for identifying drug candidates for treating CML. Methods for predicting likelihood for responsiveness to kinase inhibitor therapy are included along with methods, compositions and reagents for detecting the splice variant.

[0014] In one aspect, the invention provides a vector including a recombinant polynucleotide, in which the recombinant polynucleotide includes at least 40 contiguous nucleotides of SEQ ID NO: 9 or its complement. In one embodiment, the vector includes a

recombinant polynucleotide having a nucleotide sequence at least 95% identical to SEQ ID NO: 1. In other embodiments, the vector includes a recombinant polynucleotide having the nucleotide sequence of SEQ ID NO: 1.

[0015] In some embodiments, the recombinant polynucleotide is operably linked to an expression regulatory element which is capable of modulating the expression of the recombinant polynucleotide. In embodiment, the regulatory element may include any of a promoter, enhancer or poly-adenylation signal.

[0016] In some embodiments, the vector is an expression vector. The expression vector may be eukaryotic, prokaryotic or vector viral.

[0017] In another aspect, the invention provides genetically modified cells which include a recombinant polynucleotide, in which the recombinant polynucleotide includes at least 40 contiguous nucleotides of SEQ ID NO: 9 or its complement. In one embodiment, the genetically modified cells include a recombinant polynucleotide having a nucleotide sequence at least 95% identical to SEQ ID NO: 1. In other embodiments, the genetically modified cells include a recombinant polynucleotide having the nucleotide sequence of SEQ ID NO: 1. Also included are genetically modified cells that contain any of the vectors described above. In some embodiments, the recombinant polynucleotide is a cDNA construct while in other embodiments, the recombinant polynucleotide is genomic construct.

[0018] In some embodiments of the above aspect of the invention, the genetically modified cells are eukaryotic. In some embodiments, the genetically modified cells express a recombinant polypeptide, in which the recombinant polypeptide has Abl kinase activity.

[0019] In another aspect, the invention provides methods of identifying a compound for treating CML patients, including contacting genetically modified cells with a candidate compound, and assessing the effect of the candidate compound on the cells, in which the candidate compound is identified as a compound for treating CML patients when the effect of the candidate compound on the genetically modified cells is beneficial in the treatment of CML. In this method, the genetically modified cells express a BCR-ABL recombinant polypeptide having kinase activity, the polypeptide being encoded by some of the above described recombinant polynucleotides.

[0020] In some embodiments, the candidate compound is a kinase inhibitor. In some embodiments, the candidate compound is an inhibitor for BCR-ABL. In some embodiments, the candidate compound is selected from the group consisting of imatinib, dasatinib, bosutinib, and nilotinib.

[0021] In one embodiment, the effect of the compound on the cells is a reduction in the viability or growth rate of the cells or reduction of at least one activity of the expressed recombinant polypeptide. In one preferred embodiment, the effect is a reduction in the viability of the genetically modified cells. In another embodiment, the reduction in viability is reflected by an increase in apoptosis of the genetically modified cells. In one embodiment, the effect is the effect on the kinase activity of the expressed recombinant polypeptide. In one embodiment, the kinase activity is determined by testing the phosphorylation status of a substrate of BCR-ABL. In another embodiment, the effect is a reduction in growth rate of the cells. In one embodiment, the growth rate is measured by the amount of DNA synthesis. In one preferred embodiment, the cells are resistant to imatinib. In one embodiment, the cells are CML cells. In one preferred embodiment, the CML cells are K562 cells.

[0022] In another aspect, the invention provides a method for predicting likelihood for resistance of a CML patient with a BCR/Abl translocation to treatment with one or more BCR-ABL kinase inhibitors. In one approach, the method includes assessing the *bcr-abl* mRNA of the CML patient for the presence or absence of a polynucleotide sequence comprising at least 40 contiguous nucleotides of SEQ ID NO: 9 or a complement thereof; and further assessing for the presence or absence of at least one mutation in the *abl* portion of the *bcr-abl* gene. The presence of the polynucleotide sequence or a complement thereof in *bcr-abl* mRNA and presence of at least one mutation in the *abl* portion of the *bcr-abl* gene indicates that the patient has an increased likelihood of being resistant to treatment with one or more BCR-ABL kinase inhibitors relative to a CML patient having the mutation alone. In one embodiment, one or more kinase inhibitors are selected from a group consisting of imatinib, nilotinib, bosutinib, and dasatinib. In one preferred embodiment, the kinase inhibitor is imatinib.

[0023] In another approach, the method for predicting likelihood for resistance of a CML patient with a BCR/Abl translocation to treatment with one or more BCR-ABL kinase inhibitors includes assessing the *bcr-abl* mRNA of the CML patient for the amount of RNA encoding a full length BCR-ABL and the amount of RNA encoding a BCR-ABL

insertion/truncation splice variant encoded by at least 40 contiguous nucleotides of SEQ ID NO: 9 or a complement thereof; wherein the likelihood of resistance increases with increasing amounts of BCR-ABL mRNA insertion/truncation splice variant relative to full length BCR-ABL encoding mRNA. Patients expressing a higher level of the BCR-ABL insertion/truncation splice variant (i.e., having increased likelihood of resistance) are candidates for treatment using higher doses of BCR-ABL kinase inhibitors, relative to the dosage administered to patients expressing lower amounts (or no) BCR-ABL insertion/truncation splice variant.

[0024] In one embodiment, the BCR-ABL splice variant is encoded by sequence that comprises SEQ ID NO: 1. In another embodiment, the amounts of *bcr-abl* mRNA are determined using primers described in any of invention kits. In another embodiment, the amounts of *bcr-abl* mRNA are determined using PCR, preferably a nested PCR. In another embodiment, the sizes of the amplified products are between 200-300 bp in length.

[0025] In another aspect, the invention provides an antibody that specifically binds to an epitope having an amino acid sequence of SEQ ID NO: 10 or SEQ ID NO: 12, wherein the antibody specifically binds to an insertion/truncation mutant of BCR-ABL protein but does not bind to BCR-ABL protein without the insertion/truncation mutation. In some embodiments of the above aspects of the invention, the antibody is a monoclonal antibody.

[0026] In another aspect, the invention provides a kit for detecting the presence or absence of *bcr-abl* insertion/truncation splice variant mRNA including a first primer and a second primer, in which the first primer anneals to a portion of *bcr* exon b2 and the second primer anneals to a region at the junction of *abl* exon 9 and 10. The use of the first primer and the second primer in an amplification reaction is capable of generating an amplicon. The kit also may include a detectably labeled probe capable of hybridizing to the amplicon, in which the probe hybridizes to at least 10 contiguous nucleotides of SEQ ID NO: 4 or a complement thereof. In preferred embodiments, the first primer is SEQ ID NO: 5 or its complement. In another embodiment, the second primer is SEQ ID NO: 6 or its complement.

[0027] In another aspect, the invention provides a kit for detecting the presence or absence of *bcr-abl* insertion/truncation splice variant mRNA including a first primer and a second primer, in which the first primer anneals to a portion of *bcr* exon b2 and the second primer anneals to a region at the junction of *abl* exon 9 and 10 to generate a first amplicon,

and a third and a fourth primer, in which the third primer anneals to a portion of *abl* exon 8 and the fourth primer anneals to a portion of *abl* exon 9 to generate a second amplicon. In preferred embodiments, the kit also includes a detectably labeled probe capable of hybridizing to at least 10 contiguous nucleotides of SEQ ID NO: 4 or its complement. In preferred embodiments, the first primer is SEQ ID NO: 5 or its complement. In another embodiment, the second primer is SEQ ID NO: 6 or its complement. In some embodiments, the third primer is SEQ ID NO: 22 or its complement. In some embodiments, the fourth primer is SEQ ID NO: 23 or its complement.

[0028] In another aspect, the invention provides a method for detecting the presence or absence BCR-ABL insertion/truncation splice variant in a sample including detecting the presence or absence of a polypeptide that includes at least 15 contiguous amino acids of SEQ ID NO: 12, in which the presence of at least 15 contiguous amino acids of SEQ ID NO: 12 in a polypeptide identifies the presence of a insertion/truncation mutant of BCR-ABL protein in a sample. In some embodiments, the presence or absence of the polypeptide is determined by using an antibody that specifically binds to an epitope including the amino acid sequence of SEQ ID NO: 12 in which the antibody specifically binds to an insertion/truncation mutant of BCR-ABL protein and not to a BCR-ABL protein without such mutation.

[0029] In some embodiments, the presence or absence of the polypeptide is determined by assessing the size of the BCR-ABL protein. In another embodiment, the presence or absence of the polypeptide is determined by western blotting. In another embodiment, the presence or absence of the polypeptide is determined by flow cytometry. In some embodiments, the method simultaneously detects wild-type BCR-ABL protein and the insertion/truncation mutant of BCR-ABL protein.

[0030] In another aspect, the invention provides a kit for detecting the presence or absence of BCR-ABL insertion/truncation splice variant including an antibody that specifically binds to an epitope including 15 contiguous amino acids of SEQ ID NO: 12.

[0031] In another aspect, the invention provides a kit for detecting the presence or absence of BCR-ABL insertion truncation splice variant including an antibody that specifically binds to an epitope including 10 contiguous amino acids of SEQ ID NO: 10.

[0032] In another aspect, the invention provides a method for predicting the likelihood for drug resistance of a CML patient with a BCR/Abl translocation to treatment with one or

more BCR-ABL kinase inhibitors. In an embodiment, the method includes assessing the BCR-ABL polypeptide of the CML patient for the presence or absence of a polypeptide that includes at least 15 contiguous amino acids of SEQ ID NO: 12, in which the presence of at least 15 contiguous amino acids of SEQ ID NO: 12 in a polypeptide indicates an increased likelihood of being resistant to treatment with BCR-ABL kinase inhibitors. In another embodiment, the method includes assessing the BCR-ABL polypeptide of the CML patient for the presence or absence of a polypeptide that includes at least 10 contiguous amino acids of SEQ ID NO: 10, in which the presence of at least 10 contiguous amino acids of SEQ ID NO: 10 in a polypeptide indicates an increased likelihood of being resistant to treatment with BCR-ABL kinase inhibitors. In one embodiment, the kinase inhibitors are selected from a group consisting of imatinib, nilotinib, bosutinib, and dasatinib. In one preferred embodiment, the kinase inhibitor is imatinib.

[0033] In another approach, the method for predicting likelihood for resistance of a CML patient with a BCR/Abl translocation to treatment with one or more BCR-ABL kinase inhibitors includes assessing the BCR-ABL protein of the CML patient for the amount of full length BCR-ABL protein and the amount of an insertion/truncation mutant of BCR-ABL protein; wherein the likelihood of resistance increases with increasing amounts of insertion/truncation mutant of BCR-ABL protein relative to full length BCR-ABL protein. In an embodiment, the method includes assessing the BCR-ABL polypeptide of the CML patient for the amount of a polypeptide that includes at least 15 contiguous amino acids of SEQ ID NO: 12 and the amount of full length BCR-ABL polypeptide, wherein the likelihood of resistance increases with increasing amounts of BCR-ABL polypeptide that includes at least 15 contiguous amino acids of SEQ ID NO: 12 relative to full length BCR-ABL polypeptide. In another embodiment, the method includes assessing the BCR-ABL polypeptide of the CML patient for the amount of a polypeptide that includes at least 10 contiguous amino acids of SEQ ID NO: 10 and the amount of full length BCR-ABL polypeptide, wherein the likelihood of resistance increases with increasing amounts of BCR-ABL polypeptide that includes at least 10 contiguous amino acids of SEQ ID NO: 10 relative to full length BCR-ABL polypeptide. Patients expressing a higher level of the BCR-ABL insertion/truncation mutant protein (i.e., having increased likelihood of resistance) are candidates for treatment using higher doses of BCR-ABL kinase inhibitors, relative to the dosage administered to patients expressing lower amounts (or no) BCR-ABL insertion/truncation mutant protein.

[0034] In some embodiments, the presence or absence of the polypeptide is determined by assessing the size of the BCR-ABL protein. In another embodiment, the presence or absence of the polypeptide is determined by western blotting. In another embodiment, the presence or absence of the polypeptide is determined by flow cytometry. In some embodiments, the method simultaneously detects wild-type BCR-ABL protein and the insertion/truncation mutant of BCR-ABL protein.

[0035] In an embodiment, the invention provides a method for treating a CML patient found to be at increased risk of drug resistance by any of the above methods for assessing increased risk, by administering an increased dose of BCR-ABL kinase inhibitor relative to a CML patient not found to be at increased risk of drug resistance. In an embodiment, the invention provides a method for treating a CML patient found to be at increased risk of drug resistance by any of the above methods for assessing increased risk, by administering at least two kinase inhibitors to the patient. The kinase inhibitors may act synergistically. At least one kinase inhibitor may be a tyrosine kinase inhibitor. At least one kinase inhibitor may be imatinib, dasatinib, bosutinib, nilotinib, VX-480, or homoharringtonine (HHT). At least one kinase inhibitor may be a non-tyrosine kinase inhibitor.

[0036] In another aspect, the invention provides a method for treating patients diagnosed as having CML by administering synergistic combinations of tyrosine kinase inhibitors. Synergistic combinations may be identified using the methods provided herein. In some embodiments, the synergistic combinations include at least one of imatinib, nilotinib, and HHT. Specific synergistic combinations include, for example, imatinib/nilotinib and imatinib/HHT. The individual component drugs in the combination may be administered simultaneously or at different times. For example, imatinib and nilotinib, when used in combination may be administered simultaneously, while the components of the imatinib/HHT combination may be administered at different times. When administered at different times, the component drugs in a synergistic combination may be administered within 1, 2, 4, 8, 12, 24, 48 hours (or more) of each other. In one embodiment of the imatinib/HHT combination, HHT is administered about 24 hours prior to imatinib during each cycle of administration. In another embodiment, HHT is first administered alone, followed by a simultaneous administration of an imatinib/HHT combination within 24 hours.

[0037] As used herein, "subject" or "individual" is meant a human or any other animal that has cells that may contain a BCR/Abl translocation. A subject can be a patient, which

refers to a human presenting to a medical provider for diagnosis or treatment of a disease. A human includes pre and post natal forms.

[0038] "Patient" as used herein, refers to one who receives medical care, attention or treatment. As used herein, the term is meant to encompass a person diagnosed with a disease as well as a person who may be symptomatic for a disease but who has not yet been diagnosed.

[0039] "Sample" or "patient sample" as used herein includes biological samples such as tissues and bodily fluids. "Bodily fluids" may include, but are not limited to, blood, serum, plasma, saliva, cerebral spinal fluid, pleural fluid, tears, lactal duct fluid, lymph, sputum, urine, amniotic fluid, and semen. A sample may include a bodily fluid that is "acellular." An "acellular bodily fluid" includes less than about 1% (w/w) whole cellular material. Plasma or serum are examples of acellular bodily fluids. A sample may include a specimen of natural or synthetic origin.

[0040] "Plasma" as used herein refers to acellular fluid found in blood. "Plasma" may be obtained from blood by removing whole cellular material from blood by methods known in the art (e.g., centrifugation, filtration, and the like). As used herein, "peripheral blood plasma" refers to plasma obtained from peripheral blood samples.

[0041] "Serum" as used herein includes the fraction of plasma obtained after plasma or blood is permitted to clot and the clotted fraction is removed.

[0042] "Nucleic acid" or "nucleic acid sequence" as used herein refers to an oligonucleotide, nucleotide or polynucleotide, and fragments or portions thereof, which may be single or double stranded, and represent the sense or antisense strand. A nucleic acid may include DNA or RNA, and may be of natural or synthetic origin and may contain deoxyribonucleotides, ribonucleotides, or nucleotide analogs in any combination.

[0043] Non-limiting examples of polynucleotides include a gene or gene fragment, genomic DNA, exons, introns, mRNA, tRNA, rRNA, ribozymes, cDNA, recombinant polynucleotides, branched polynucleotides, plasmids, vectors, isolated DNA of any sequence, isolated RNA of any sequence, synthetic nucleic acid, nucleic acid probes and primers. Polynucleotides may be natural or synthetic. Polynucleotide may comprise modified nucleotides, such as methylated nucleotides and nucleotide analogs, uracyl, other sugars and

linking groups such as fluororibose and thiolate, and nucleotide branches. A nucleic acid may be modified such as by conjugation, with a labeling component. Other types of modifications included in this definition are caps, substitution of one or more of the naturally occurring nucleotides with an analog, and introduction of chemical entities for attaching the polynucleotide to other molecules such as proteins, metal ions, labeling components, other polynucleotides or a solid support. Nucleic acid may include nucleic acid that has been amplified (e.g., using polymerase chain reaction).

[0044] A fragment of a nucleic acid generally contains at least about 15, 20, 25, 30, 35, 40, 45, 50, 75, 100, 200, 300, 400, 500, 1000 nucleotides or more. Larger fragments are possible and may include about 2,000, 2,500, 3,000, 3,500, 4,000, 5,000, 7,500, or 10,000 bases.

[0045] “Gene” as used herein refers to a DNA sequence that comprises control and coding sequences necessary for the production of an RNA, which may have a non-coding function (e.g., a ribosomal or transfer RNA) or which may include a polypeptide or a polypeptide precursor. The RNA or polypeptide may be encoded by a full length coding sequence or by any portion of the coding sequence so long as the desired activity or function is retained.

[0046] “cDNA” as used herein refers to complementary or copy polynucleotide produced from an RNA template by the action of RNA-dependent DNA polymerase activity (e.g., reverse transcriptase). cDNA can be single stranded, double stranded or partially double stranded. cDNA may contain unnatural nucleotides. cDNA can be modified after being synthesized. cDNA may comprise a detectable label.

[0047] Although a sequence of the nucleic acids may be shown in the form of DNA, a person of ordinary skill in the art recognizes that the corresponding RNA sequence will have a similar sequence with the thymine being replaced by uracil i.e. “t” with “u”.

[0048] “Codon” as used herein refers to a sequence of three adjacent nucleotides (either RNA or DNA) constituting the genetic code that determines the insertion of a specific amino acid in a polypeptide chain during protein synthesis or the signal to stop protein synthesis. The term “codon” is also used to refer to the corresponding (and complementary) sequences of three nucleotides in the messenger RNA into which the original DNA is transcribed.

[0049] “Coding sequence” as used herein refers to a sequence of a nucleic acid or its complement, or a part thereof, that can be transcribed and/or translated to produce the mRNA for and/or the polypeptide or a fragment thereof. Coding sequences include exons in a genomic DNA or immature primary RNA transcripts, which are joined together by the cell's biochemical machinery to provide a mature mRNA. The anti-sense strand is the complement of such a nucleic acid, and the encoding sequence can be deduced therefrom.

[0050] “Non-coding sequence” as used herein refers to a sequence of a nucleic acid or its complement, or a part thereof, that is not transcribed into amino acid in vivo, or where tRNA does not interact to place or attempt to place an amino acid. Non-coding sequences include both intron sequences in genomic DNA or immature primary RNA transcripts, and gene-associated sequences such as promoters, enhancers, silencers, etc.

[0051] “Wild-type” as used herein refers to a gene or a gene product that has the characteristics of that gene or gene product when isolated from a naturally occurring source. A wild-type gene is that which is most frequently observed in a population and is thus arbitrarily designated the “normal” or “wild-type” form of the gene. “Wild-type” may also refer to the sequence at a specific nucleotide position or positions, or the sequence at a particular codon position or positions, or the sequence at a particular amino acid position or positions.

[0052] “Mutant”, or “modified” as used herein refers to a gene or gene product which displays modifications in sequence and or functional properties (i.e., altered characteristics) when compared to the wild-type gene or gene product. “Mutant”, or “modified” also refers to the sequence at a specific nucleotide position or positions, or the sequence at a particular codon position or positions, or the sequence at a particular amino acid position or positions which displays modifications in sequence and or functional properties (i.e., altered characteristics) when compared to the wild-type gene or gene product.

[0053] “Mutation” as used herein refers to a nucleic acid with at least a single nucleotide variation relative to the normal sequence or wild-type sequence. In the context of polypeptide, “mutation” refers to at least a single amino acid variation in a polypeptide sequence relative to the normal sequence or wild-type sequence. A mutation may include a substitution, a deletion, an inversion or an insertion. With respect to an encoded polypeptide, a mutation may be “silent” and result in no change in the encoded polypeptide sequence or a

mutation may result in a change in the encoded polypeptide sequence. For example, a mutation may result in a substitution in the encoded polypeptide sequence. A mutation may result in a frameshift with respect to the encoded polypeptide sequence.

[0054] The convention “NTwt###NTmut” is used to indicate a mutation that results in the wild-type nucleotide NTwt at position ### in the nucleic acid being replaced with mutant NTmut. The convention “AAwt###AAmut” is used to indicate a mutation that results in the wild-type amino acid AAwt at position ### in the polypeptide being replaced with mutant AAmut.

[0055] “Protein”, “peptide”, “polypeptide” and “polypeptide fragment” as used herein are used interchangeably to refer to polymers of amino acids (“an amino acid sequence”) of any length. The polymer can be linear or branched, it may comprise modified amino acids or amino acid analogs, and it may be interrupted by chemical moieties other than amino acids. The terms also encompass an amino acid polymer that has been modified naturally or by intervention; for example disulfide bond formation, glycosylation, lipidation, acetylation, phosphorylation, or any other manipulation of modification, such as conjugation with a labeling or bioactive component.

[0056] “Identity” and “identical” as used herein refer to a degree of identity between sequences. There may be partial identity or complete identity. A partially identical sequence is one that is less than 100% identical to another sequence. Preferably, partially identical sequences have an overall identity of at least 70% or at least 75%, more preferably at least 80% or at least 85%, most preferably at least 90% or at least 95% or at least 99%. Sequence identity determinations may be made for sequences which are not fully aligned. In such instances, the most related segments may be aligned for optimal sequence identity by and the overall sequence identity reduced by a penalty for gaps in the alignment.

[0057] “Insertion” or “addition”, as used herein refers to a change in an amino acid or nucleotide sequence resulting in the addition of one or more amino acid residues or nucleotides respectively, as compared to the naturally occurring molecule.

[0058] “Truncation”, as used herein refers to a change in an amino acid or nucleic acid sequence resulting in the loss of one or more positions in the sequence where amino acids residues or nucleotides, respectively, would be present as compared to the naturally occurring molecule.

[0059] “Insertion/truncation mutation” or “insertion/truncation mutant” in the context of BCR-ABL as used herein refers to a BCR-ABL protein with the addition of new amino acids at the c-terminal region of the protein and deletion of one or more amino acids at the c-terminal region of the protein as compared to the exemplary reference BCR-ABL protein amino acid sequence of SEQ ID NO: 11, such that the resultant protein will have a different c-terminal amino acid sequence than that of SEQ ID NO: 11. In preferred embodiments, such alternative splicing may result from insertion of a 35 bp portion of intron 8 into the junction of exon 8 and 9 in *bcr-abl* mRNA by alternative splicing, as depicted in FIG. 1. The insertion/truncation mutant also is referred to herein as “35 INS BCR-ABL.”

[0060] Several variants of BCR-ABL are known in the art. Exemplary BCR-ABL protein sequences include but are not limited to NCBI protein database accession numbers: ABX82708, ABX82702, AAA35594.

[0061] “Heterozygous” as used herein refers to having different alleles at one or more genetic loci in homologous chromosome segments. “Heterozygous” also refers to a sample, a cell, a cell population or an organism in which different alleles at one or more genetic loci may be detected. Heterozygous samples may also be determined via methods known in the art such as, for example, nucleic acid sequencing. For example, if a sequencing electropherogram shows two peaks at a single locus and both peaks are roughly the same size, the sample may be characterized as heterozygous. Or, if one peak is smaller than another, but is at least about 25% the size of the larger peak, the sample may be characterized as heterozygous. In some embodiments, the smaller peak is at least about 15% of the larger peak. In other embodiments, the smaller peak is at least about 10% of the larger peak. In other embodiments, the smaller peak is at least about 5% of the larger peak. In other embodiments, a minimal amount of the smaller peak is detected.

[0062] “Homozygous” as used herein refers to having identical alleles at one or more genetic loci in homologous chromosome segments. “Homozygous” may also refer to a sample, a cell, a cell population or an organism in which the same alleles at one or more genetic loci may be detected. Homozygous samples may be determined via methods known in the art, such as, for example, nucleic acid sequencing. For example, if a sequencing electropherogram shows a single peak at a particular locus, the sample may be termed “homozygous” with respect to that locus.

[0063] “Hemizygous” as used herein refers to a gene or gene segment being present only once in the genotype of a cell or an organism because the second allele is deleted. As used herein “hemizygous” may also refer to a sample, a cell, a cell population or an organism in which a allele at one or more genetic loci may be detected only once in the genotype.

[0064] “Zygosity status” as used herein refers to a sample, a cell population, or an organism as appearing heterozygous, homozygous, or hemizygous as determined by testing methods known in the art and described herein. The term “zygosity status of a nucleic acid” means determining whether the source of nucleic acid appears heterozygous, homozygous, or hemizygous. The “zygosity status” may refer to differences in a single nucleotide in a sequence. In some methods, the zygosity status of a sample with respect to a single mutation may be categorized as homozygous wild-type, heterozygous (i.e., one wild-type allele and one mutant allele), homozygous mutant, or hemizygous (i.e., a single copy of either the wild-type or mutant allele). Because direct sequencing of plasma or cell samples as routinely performed in clinical laboratories does not reliably distinguish between hemizygosity and homozygosity, in some embodiments, these classes are grouped. For example, samples in which no or a minimal amount of wild-type nucleic acid is detected are termed “hemizygous/homozygous mutant.” In some embodiments, a “minimal amount” may be between about 1-2%. In other embodiments, a minimal amount may be between about 1-3%. In still other embodiments, a “minimal amount” may be less than 1%.

[0065] “Hybridize” or “hybridization” as used herein refers to the pairing of substantially complementary nucleotide sequences (strands of nucleic acid) to form a duplex or heteroduplex through formation of hydrogen bonds between complementary base pairs. Hybridization and the strength of hybridization (i.e., the strength of the association between the nucleic acids) is influenced by such factors as the degree of complementarity between the nucleic acids, stringency of the conditions involved, and the T_m of the formed hybrid. An oligonucleotide or polynucleotide (e.g., a probe or a primer) that is specific for a target nucleic acid will “hybridize” to the target nucleic acid under suitable conditions.

[0066] “Specific hybridization” as used herein refers to an indication that two nucleic acid sequences share a high degree of complementarity. Specific hybridization complexes form under permissive annealing conditions and remain hybridized after any subsequent washing steps. Permissive conditions for annealing of nucleic acid sequences are routinely determinable by one of ordinary skill in the art and may occur, for example, at 65°C in the

presence of about $6\times$ SSC. Stringency of hybridization may be expressed, in part, with reference to the temperature under which the wash steps are carried out. Such temperatures are typically selected to be about 5°C to 20°C lower than the thermal melting point (T_m) for the specific sequence at a defined ionic strength and pH. The T_m is the temperature (under defined ionic strength and pH) at which 50% of the target sequence hybridizes to a perfectly matched probe. Equations for calculating T_m and conditions for nucleic acid hybridization are known in the art.

[0067] "Stringent hybridization conditions" as used herein refers to hybridization conditions at least as stringent as the following: hybridization in 50% formamide, 5x SSC, 50 mM NaH_2PO_4 , pH 6.8, 0.5% SDS, 0.1 mg/mL sonicated salmon sperm DNA, and 5x Denhart's solution at 42°C . overnight; washing with 2x SSC, 0.1% SDS at 45°C .; and washing with 0.2x SSC, 0.1% SDS at 45°C . In another example, stringent hybridization conditions should not allow for hybridization of two nucleic acids which differ over a stretch of 20 contiguous nucleotides by more than two bases.

[0068] "Complement" as used herein refers to the complementary sequence to a nucleic acid according to standard Watson/Crick pairing rules. A complement sequence can also be a sequence of RNA complementary to the DNA sequence or its complement sequence, and can also be a cDNA. The complement of a nucleic acid sequence as used herein refers to an polynucleotide which, when aligned with the nucleic acid sequence such that the 5' end of one sequence is paired with the 3' end of the other, is in "antiparallel association". For example, for the sequence "5'-A-G-T-3'" is complementary to the sequence "3'-T-C-A-5'". Certain bases not commonly found in natural nucleic acids may be included in the nucleic acids of the present invention and include, for example, inosine and 7-deazaguanine. Complementarity need not be perfect; stable duplexes may contain mismatched base pairs or unmatched bases. Those skilled in the art of nucleic acid technology can determine duplex stability empirically considering a number of variables including, for example, the length of the oligonucleotide, base composition and sequence of the oligonucleotide, ionic strength and incidence of mismatched base pairs.

[0069] "Substantially complementary" as used herein refers to two sequences that hybridize under stringent hybridization conditions. The skilled artisan will understand that substantially complementary sequences need not hybridize along their entire length.

[0070] Oligonucleotides can be used as primers or probes for specifically amplifying (i.e., amplifying a particular target nucleic acid sequence) or specifically detecting (i.e., detecting a particular target nucleic acid sequence) a target nucleic acid generally are capable of specifically hybridizing to the target nucleic acid.

[0071] "Oligonucleotide" as used herein refers to a molecule that has a sequence of nucleic acid bases on a backbone comprised mainly of identical monomer units at defined intervals. The bases are arranged on the backbone in such a way that they can enter into a bond with a nucleic acid having a sequence of bases that are complementary to the bases of the oligonucleotide. The most common oligonucleotides have a backbone of sugar phosphate units. A distinction may be made between oligodeoxyribonucleotides that do not have a hydroxyl group at the 2' position and oligoribonucleotides that have a hydroxyl group in this position. Oligonucleotides also may include derivatives, in which the hydrogen of the hydroxyl group is replaced with organic groups, e.g., an allyl group. Oligonucleotides of the method which function as primers or probes are generally at least about 10-15 nucleotides long and more preferably at least about 15 to 25 nucleotides long, although shorter or longer oligonucleotides may be used in the method. The exact size will depend on many factors, which in turn depend on the ultimate function or use of the oligonucleotide. The oligonucleotide may be generated in any manner, including, for example, chemical synthesis, DNA replication, reverse transcription, PCR, or a combination thereof. The oligonucleotide may be modified. For example, the oligonucleotide may be labeled with an agent that produces a detectable signal (e.g., a fluorophore).

[0072] "Primer" as used herein refers to an oligonucleotide that is capable of acting as a point of initiation of synthesis when placed under conditions in which primer extension is initiated (e.g., primer extension associated with an application such as PCR). The primer is complementary to a target nucleotide sequence and it hybridizes to a substantially complementary sequence in the target and leads to addition of nucleotides to the 3'-end of the primer in the presence of a DNA or RNA polymerase. The 3'-nucleotide of the primer should generally be complementary to the target sequence at a corresponding nucleotide position for optimal expression and amplification. An oligonucleotide "primer" may occur naturally, as in a purified restriction digest or may be produced synthetically. The term "primer" as used herein includes all forms of primers that may be synthesized including

peptide nucleic acid primers, locked nucleic acid primers, phosphorothioate modified primers, labeled primers, and the like.

[0073] Primers are typically between about 10 and about 100 nucleotides in length, preferably between about 15 and about 60 nucleotides in length, more preferably between about 20 and about 50 nucleotides in length, and most preferably between about 25 and about 40 nucleotides in length. In some embodiments, primers can be at least 8, at least 12, at least 16, at least 20, at least 25, at least 30, at least 35, at least 40, at least 45, at least 50, at least 55, at least 60 nucleotides in length. An optimal length for a particular primer application may be readily determined in the manner described in H. Erlich, PCR Technology, Principles and Application for DNA Amplification (1989).

[0074] "Probe" as used herein refers to nucleic acid that interacts with a target nucleic acid via hybridization. A probe may be fully complementary to a target nucleic acid sequence or partially complementary. The level of complementarity will depend on many factors based, in general, on the function of the probe. A probe or probes can be used, for example to detect the presence or absence of a mutation in a nucleic acid sequence by virtue of the sequence characteristics of the target. Probes can be labeled or unlabeled, or modified in any of a number of ways well known in the art. A probe may specifically hybridize to a target nucleic acid.

[0075] Probes may be DNA, RNA or a RNA/DNA hybrid. Probes may be oligonucleotides, artificial chromosomes, fragmented artificial chromosome, genomic nucleic acid, fragmented genomic nucleic acid, RNA, recombinant nucleic acid, fragmented recombinant nucleic acid, peptide nucleic acid (PNA), locked nucleic acid, oligomer of cyclic heterocycles, or conjugates of nucleic acid. Probes may comprise modified nucleobases, modified sugar moieties, and modified internucleotide linkages. A probe may be fully complementary to a target nucleic acid sequence or partially complementary. A probe may be used to detect the presence or absence of a target nucleic acid. Probes are typically at least about 10, 15, 20, 25, 30, 35, 40, 50, 60, 75, 100 nucleotides or more in length.

[0076] "Target nucleic acid" as used herein refers to a nucleic acid molecule (e.g., DNA or RNA) containing a sequence that has at least partial complementarity with a primer oligonucleotide and/or a probe oligonucleotide. A probe may specifically hybridize to a target nucleic acid.

[0077] “Flanking” as used herein refers to a primer hybridizes to a target nucleic acid adjoining a region of interest sought to be amplified on the target. The skilled artisan will understand that preferred primers are pairs of primers that hybridize upstream of a region of interest, one on each strand of a target double stranded DNA molecule, such that nucleotides may be added to the 3' end of the primer by a suitable DNA polymerase. Primers that flank mutant JAK2 sequences do not actually anneal to the mutant sequence but rather anneal to sequence that adjoins the mutant sequence.

[0078] “Amplification” or “amplifying” as used herein refers to the production of additional copies of a nucleic acid sequence. Amplification may be exponential or linear. A target nucleic acid may be either DNA or RNA. The sequences amplified in this manner form an “amplicon” or “amplification product”. Amplification is generally carried out using polymerase chain reaction (PCR) technologies known in the art. While the exemplary methods described hereinafter relate to amplification using the polymerase chain reaction (PCR), numerous other methods are known in the art for amplification of nucleic acids (e.g., isothermal methods, rolling circle methods, etc.). The skilled artisan will understand that these other methods may be used either in place of, or together with, PCR methods. See, e.g., Saiki, “Amplification of Genomic DNA” in PCR Protocols (1990), Innis et al., Eds., Academic Press, San Diego, CA, pp 13-20; Wharam, et al., Nucleic Acids Res. (2001), Jun 1; 29(11):E54-E54; Hafner, et al., Biotechniques (2001), 4:852-6, 858, 860.

[0079] “Amplification reaction system” as used herein refers to any in vitro means for multiplying the copies of a target sequence of nucleic acid. The term “amplification reaction mixture” refers to an aqueous solution comprising the various reagents used to amplify a target nucleic acid.

[0080] “Assay” or “assaying” as used herein refers to qualitative or quantitative analysis or testing.

[0081] “Sequencing” as used herein refers to determining the sequence of a polynucleotide (or protein) using methods that determine the base identity at multiple base positions or determine the base identity at a single position. The term “direct sequencing” means that the letters of the genetic code of the molecule of interest are sequenced for reading. For example, if the molecule of interest is RNA, then the letters of RNA are read

directly rather than the DNA sequence as alternative splicing during translation may result in different RNA sequences.

[0082] “Detecting” as used herein in context of detecting a signal from a detectable label to indicate the presence of a nucleic acid of interest in the sample (or the presence or absence of a protein of interest in the sample) does not require the method to provide 100% sensitivity and/or 100% specificity. As is well known, “sensitivity” is the probability that a test is positive, given that the person has a genomic nucleic acid sequence, while “specificity” is the probability that a test is negative, given that the person does not have the genomic nucleic acid sequence. A sensitivity of at least 50% is preferred, although sensitivities of at least 60%, at least 70%, at least 80%, at least 90% and at least 99% are clearly more preferred. A specificity of at least 50% is preferred, although specificity of at least 60%, at least 70%, at least 80%, at least 90% and at least 99% are clearly more preferred. Detecting also encompasses assays with false positives and false negatives. False negative rates may be 1%, 5%, 10%, 15%, 20% or even higher. False positive rates may be 1%, 5%, 10%, 15%, 20% or even higher.

[0083] “Detectable label” as used herein refers to a molecule or a compound or a group of molecules or a group of compounds used to identify a nucleic acid or protein of interest. In some cases, the detectable label may be detected directly. In other cases, the detectable label may be a part of a binding pair, which can then be subsequently detected. Signals from the detectable label may be detected by various means and will depend on the nature of the detectable label. Detectable labels may be isotopes, fluorescent moieties, colored substances, and the like. Examples of means to detect detectable label include but are not limited to spectroscopic, photochemical, biochemical, immunochemical, electromagnetic, radiochemical, or chemical means, such as fluorescence, chemifluorescence, or chemiluminescence, or any other appropriate means.

[0084] “TaqMan® PCR detection system” as used herein refers to a method for real time PCR. In this method, a TaqMan® probe which hybridizes to the nucleic acid segment amplified is included in the PCR reaction mix. The TaqMan® probe comprises a donor and a quencher fluorophore on either end of the probe and in close enough proximity to each other so that the fluorescence of the donor is taken up by the quencher. However, when the probe hybridizes to the amplified segment, the 5'-exonuclease activity of the Taq polymerase

cleaves the probe thereby allowing the donor fluorophore to emit fluorescence which can be detected.

[0085] "Vector" as used herein refers to a recombinant DNA or RNA plasmid or virus that comprises a heterologous polynucleotide capable of being delivered to a target cell, either in vitro, in vivo or ex-vivo. The heterologous polynucleotide can comprise a sequence of interest and can be operably linked to another nucleic acid sequence such as promoter or enhancer and may control the transcription of the nucleic acid sequence of interest. As used herein, a vector need not be capable of replication in the ultimate target cell or subject. The term vector may include expression vector and cloning vector.

[0086] Suitable expression vectors are well-known in the art, and include vectors capable of expressing a polynucleotide operatively linked to a regulatory sequence, such as a promoter region that is capable of regulating expression of such DNA. Thus, an expression vector refers to a recombinant DNA or RNA construct, such as a plasmid, a phage, recombinant virus or other vector that, upon introduction into an appropriate host cell, results in expression of the inserted DNA. Appropriate expression vectors include those that are replicable in eukaryotic cells and/or prokaryotic cells and those that remain episomal or those which integrate into the host cell genome.

[0087] "Promoter" as used herein refers to a segment of DNA that controls transcription of polynucleotide to which it is operatively linked. Promoters, depending upon the nature of the regulation, may be constitutive or regulated. Exemplary eukaryotic promoters contemplated for use in the practice of the present invention include the SV40 early promoter, the cytomegalovirus (CMV) promoter, the mouse mammary tumor virus (MMTV) steroid-inducible promoter, Moloney murine leukemia virus (MMLV) promoter. Exemplary promoters suitable for use with prokaryotic hosts include T7 promoter, beta-lactamase promoter, lactose promoter systems, alkaline phosphatase promoter, a tryptophan (trp) promoter system, and hybrid promoters such as the tac promoter.

[0088] "Antibody" as used herein refers to a polypeptide, at least a portion of which is encoded by at least one immunoglobulin gene, or fragment thereof, and that can bind specifically to a desired target molecule. The term includes naturally-occurring forms, as well as fragments and derivatives. Fragments within the scope of the term "antibody" include those produced by digestion with various proteases, those produced by chemical cleavage

and/or chemical dissociation, and those produced recombinantly, so long as the fragment remains capable of specific binding to a target molecule. Among such fragments are Fab, Fab', Fv, F(ab')₂, and single chain Fv (scFv) fragments. Derivatives within the scope of the term include antibodies (or fragments thereof) that have been modified in sequence, but remain capable of specific binding to a target molecule, including: interspecies chimeric and humanized antibodies; antibody fusions; heteromeric antibody complexes and antibody fusions, such as diabodies (bispecific antibodies), single-chain diabodies, and intrabodies (see, e.g., Marasco (ed.), *Intracellular Antibodies: Research and Disease Applications*, Springer-Verlag New York, Inc. (1998) (ISBN: 3540641513)). As used herein, antibodies can be produced by any known technique, including harvest from cell culture of native B lymphocytes, harvest from culture of hybridomas, recombinant expression systems, and phage display.

[0089] “Specifically binds to an epitope” as used herein in the context of an antibody refers to binding of an antibody specifically to an epitope such that the antibody can distinguish between two proteins with and without such epitope.

[0090] In preferred embodiments, antibodies binding to epitopes comprising SEQ ID NO: 12 or SEQ ID NO: 10, specifically binds to insertion/truncation mutant of BCR-ABL proteins and can distinguish from BCR-ABL proteins without such mutation.

[0091] “Neoplastic disease” as used herein refers to a condition characterized by an abnormal growth of new cells such as a tumor. A neoplasm includes solid and non-solid tumor types such as a carcinoma, sarcoma, leukemia and the like. A neoplastic disease may be malignant or benign.

[0092] “CML patient” as used herein refers to a patient diagnosed with CML or suspected of having CML. One of ordinary skill in the art is capable of diagnosing CML using suitable diagnostic criteria.

[0093] “Diagnose” or “diagnosis” or “diagnosing” as used herein refer to distinguishing or identifying a disease, syndrome or condition or distinguishing or identifying a person having a particular disease, syndrome or condition. Usually, a diagnosis of a disease or disorder is based on the evaluation of one or more factors and/or symptoms that are indicative of the disease. That is, a diagnosis can be made based on the presence, absence or amount of a factor which is indicative of presence or absence of the disease or condition. Each factor or

symptom that is considered to be indicative for the diagnosis of a particular disease does not need be exclusively related to the particular disease; i.e. there may be differential diagnoses that can be inferred from a diagnostic factor or symptom. Likewise, there may be instances where a factor or symptom that is indicative of a particular disease is present in an individual that does not have the particular disease.

[0094] “Treatment,” “treating,” or “treat” as used herein refers to care by procedures or application that are intended to relieve illness or injury. Although it is preferred that treating a condition or disease will result in an improvement of the condition, the term treating as used herein does not indicate, imply, or require that the procedures or applications are at all successful in ameliorating symptoms associated with any particular condition. Treating a patient may result in adverse side effects or even a worsening of the condition which the treatment was intended to improve.

[0095] “Monitoring treatment of CML patient” as used herein refers to the process by which the skilled artisan can predict the course or outcome of treatment of CML patients. In some embodiments, such treatment of CML patients may include treating CML patients with tyrosine kinase inhibitors for BCR-ABL protein. Exemplary BCR-ABL tyrosine kinase inhibitors include, but not limited to imatinib, dasatinib, nilotinib, Bosutinib (SKI-606) Aurora kinase inhibitor VX-680. In one preferred embodiment, the tyrosine kinase inhibitor for BCR-ABL is imatinib.

[0096] “Isolated”, as used herein when referring to a nucleic acid or protein molecule means that the molecule is apart from its natural environment and/or is substantially separated from other cellular components which naturally accompany such molecule. For example, any nucleic acid or protein that has been produced synthetically (e.g., by serial base condensation) is considered to be isolated. Likewise, nucleic acids or proteins that are recombinantly expressed, cloned, produced by a synthetic in vitro reaction are considered to be isolated. An isolated nucleic acid or protein is at least 25% free, preferably at least 30% free, preferably at least 40% free, preferably at least 50% free, preferably at least 60% free, more preferably at least 75% free, and most preferably at least 90% free from other components with which it is naturally associated.

[0097] “Substantially pure” as used herein with reference to a nucleic acid (or protein), means that the nucleic acid (or protein) represents more than 50% of the biological molecules in a sample. The sample may exist in solution or as a dry preparation.

[0098] “Substantially all” as used herein means between about 60-100%, more preferably, between about 70-100%; more preferably between about 80-100%, more preferably between about 90-100%, and more preferably between about 95-100%.

[0099] “Including” as used herein has the same meaning as the term comprising.

[00100] “About” as used herein means in quantitative terms, plus or minus 10%.

[00101] “Ratio” as used herein refers to the relation in degree or number between two similar things. For example, the relative amount of mutant to wild-type nucleic acid in a sample may be referred to as a ratio of wild-type to mutant nucleic acid.

BRIEF DESCRIPTION OF FIGURES

[00102] FIG. 1 provides a sequence for an exemplary segment of *bcr-abl* genomic nucleic acid showing exon 8, intron 8 and intron 9. The exons are depicted in upper case letters and the intron in lowercase letters with the exception that the bold underlined uppercase sequence within intron 8 is highlighted to show the 35 bp segment of intron 8 which inserts into the junction of exons 8 and 9 forming the 35 INS BCR-ABL.

[00103] FIG. 2 shows a portion of an exemplary cDNA sequence of *bcr-abl* insertion/truncation splice variant. Sequences derived from *abl* exons 8 and 9 are depicted in lowercase. Sequence derived from the 35 bp insert from *abl* intron 8 is shown in bold uppercase. The 3'-terminal region of *abl* exon 8 and 5'-terminal region of exon 9 flanking the 35 bp insert is shown in bold lowercase and underlined.

[00104] FIG. 3. shows the amino acid sequence alignment of the c-terminus of wild type ABL protein (SEQ ID NO: 29) and translated amino acid sequence of the *bcr-abl* mRNA splice variant (SEQ ID NO: 30) resulting in the insertion/truncation mutant 35 INS BCR-ABL described in FIG. 2. Position numbering is based on the wild type ABL protein (GenBank accession number AAA51561). The 10 *abl* intron 8 derived amino acids begins at amino acid 475, replacing C with Y and ends with amino acid 484 (but shown as position 485 due to the alignment).

[00105] FIG. 4. shows the relative non-bonding interaction energies (compared to wild-type) from simulations between a selected set of amino acids from the two indicated BCR-ABL mutants and imatinib. Relative non-bonding interaction energies are represented as the average over the last 15 ns simulations with a sampling frequency of 1 ps. Unit is Kcal/mol.

[00106] FIG. 5. shows maps of expression vectors pMIG/*bcr-abl* (wildtype) and pMIG/35 INS *bcr-abl* (splice variant).

[00107] FIG. 6 shows the relative frequency of individual BCR-ABL kinase domain mutations detected in a group of 245 patients, 219 of which have CML and 26 of which have Ph-positive acute lymphoblastic leukemia. The numbering of amino acids is based on the Abl protein variant B (which includes Abl exon 1b but not exon 1a). The letters inside the circles denote the amino acid encoded by the corresponding mutated nucleotide. At some positions, 2 or 3 possible mutant nucleotides encode different amino acids. The percentage of patients in the series with each mutation specified on the y axis is color-coded as shown in the box.

[00108] FIG. 7 shows the effect of imatinib concentration on the viability of cells transfected with increasing amounts of a vector encoding the 35 INS BCR-ABL splice variant (vector shown in FIG. 5B). The concentrations of imatinib range from zero to 10 μ M are shown from left to right, respectively, for each cell transfection dose. The lines illustrate the trend of MTT activity as a function of increasing vector concentration.

[00109] FIG. 8 shows the effect of imatinib concentration on phosphorylation of CrkL protein in K562 cells transfected with control (empty) pMIG vector (left panel) or transfected with 35 INS BCR-ABL splice variant (right panel)

[00110] FIG. 9 shows the effect of increasing concentrations of vector encoding 35 INS BCR-ABL splice variant (vector shown in FIG. 5) on proliferation of K562 cells either untreated (left panel) or treated with imatinib (right panel). Proliferation was measured as incorporation of BrdU into DNA.

[00111] FIG. 10 shows the detection of BCR-ABL and 35 INS BCR-ABL splice variant in CML patient samples. Lysates prepared from the human cell line K562 and a patient cell sample containing 82.3% of BCR-ABL as 35 INS splice variant were subjected to immunoprecipitation (IP) with anti-BCR antibody (7c6) or anti-IgG antibody. The resulting

immune-complexes were analyzed by Western blotting developed using antibodies specific to different epitopes of Abl (ABL K12 is directed against kinase domain and H300 is directed to the C-terminus). The lysates were also analyzed by Western blotting with anti-actin antibody. FIG. 10B shows six patient samples with various percentages of 35 INS BCR-ABL splice variant evaluated by western blotting using BCR 7c6 antibody for immunoprecipitation and ABL K12 for the developing antibody. The percentages of 35 INS BCR-ABL relative to full length BCR-ABL was determined by RT/PCR coupled with hemi-nested PCR as described in Example 2.

[00112] FIG. 11 shows an exemplary nucleotide sequence of intron 8 of *abl* (nucleotides 148-1,647 of SEQ ID NO: 3). The bold and underlined sequence represents an exemplary sequence of the 35 bases inserted into the junction of *abl* exons 8 and 9 in the 35 INS BCR-ABL splice variant.

[00113] FIG. 12 shows the effect of 35 INS BCR-ABL truncation mutant on resistance to selected kinase inhibitors in CML cells. (A) The effect of the kinase inhibitor drugs on cell proliferation as measured by MTT. (B) Induction of apoptosis measured by caspase-3 activation. (C) FACS analysis of transfected K562 cells after imatinib mesylate treatment.

[00114] FIG. 13 shows the effects of BCR-ABL kinase inhibitors on various phosphorylation substrates in the absence and presence of 35 INS BCR-ABL expression in a CML cell line.

[00115] FIG. 14 shows the effects of combinations of imatinib mesylate with nilotinib or HHT on BCR-ABL135INS kinase activity in a CML cell line. The effects of drug combinations were assessed by caspase-3 assay (left) and proliferation assay (right).

[00116] FIG. 15 shows the effects of combinations of imatinib with nilotinib or HHT on 35 INS BCR-ABL kinase activity in a CML cell line. Isobolograms depict combination index (CI) values plotted against fraction of cells affected for (A) imatinib and nilotinib, (B) imatinib and dasatinib, and (C) imatinib and HHT.

[00117] FIG. 16 shows the kinetics of BIM induction after treatment with (A) imatinib and (B) imatinib + HHT continuously.

DETAILED DESCRIPTION OF THE INVENTION

[00118] Embodiments of the present invention are based on a *bcr-abl* splice variant that encodes a C-terminal truncated BCR-ABL protein that renders cells resistant to treatment with kinase domain inhibitors such as imatinib. As demonstrated herein, increasing amounts of the truncation mutant correlate directly with resistance and a majority of drug-resistant CML patients have at least some cells expressing the truncation mutation. Embodiments of the invention described herein include polynucleotides which encode all or portions of the splice variant and cells that express all or portions of the splice variant. Recombinant cells expressing the truncated BCR-ABL protein with an active kinase domain are useful for identifying drug candidates for treating CML. Methods for predicting likelihood for responsiveness to kinase inhibitor therapy are included along with methods, compositions and reagents for detecting the splice variant. Methods of treating patients at increased risk of having or developing drug resistance by administering combinations of drugs are also included.

[00119] Variants of the *bcr-abl* mRNA

[00120] Several variants of *bcr-abl* mRNA have been reported. Many of the known sequences are full length cDNA sequences and some are partial cDNA sequences. Exemplary *bcr-abl* mRNA sequences include but are not limited to: NCBI GenBank accession numbers: EU216072, EU216071, EU216070, EU216069, EU216068, EU216067, EU216066, EU216065, EU216064, EU216063, EU216062, EU216061, EU216060, EU216059, EU216058, EU236680, DQ912590, DQ912589, DQ912588, DQ898315, DQ898314, DQ898313, EF423615, EF158045, S72479, S72478, AY789120, AB069693, AF487522, AF113911, AF251769, M30829, M30832, M17542, M15025, and M17541. An exemplary cDNA sequence of *bcr-abl* is provided as SEQ ID NO: 19.

[00121] *bcr-abl* splice variants: Alternative splicing may result in *bcr-abl* mRNA variants. In some embodiments, CML patients undergoing BCR-ABL tyrosine kinase inhibitor therapy (for example, imatinib), may exhibit an insertion of 35 nucleotides from *abl* intron 8 at the junction of *abl* exons 8 and 9 of the *bcr-abl* mRNA due to alternate splicing. Exemplary cDNA sequence of alternately spliced *bcr-abl* mRNA is provided as SEQ ID NO: 26.

[00122] In preferred embodiments, the 35 base insert of *abl* intron 8 (nucleotides positions 132744926 to 132744960 of GenBank accession number NC_00009) is SEQ ID NO: 4.

[00123] 5'-actttgataaccgtgaagaagaacaagatagaag-3' (SEQ ID NO: 4)

[00124] In preferred embodiments, insertion of 35 bp sequence of *abl* intron 8 (SEQ ID NO: 4) at the junction of *abl* exons 8 and 9 due to alternate splicing will create a new splice variant of *bcr-abl* mRNA comprising a sequence of SEQ ID NO: 1.

[00125] 5'-catttgagatattgcttgggaaattgctacctatggcatgtcccttaccgggaattgacctgtcccaggtgtatgagctgctagagaaggactaccgcatggagcgcccagaaggctgccagagaaggctctatgaactcatgcgagcactttgataaccgtgaagaagaacaagatagaagggtggcagtggaatccctctgaccggccctccttctgtaaatccacc aagcctttgaaacaatgtccaggaatccagtatctcagacg-3' (SEQ ID NO: 1)

[00126] Exemplary nucleic acid sequence of *abl* exons 8 and 9 and *abl* intron 8 can be found in GenBank accession number NC_00009 between nucleic acid positions 132743623 and 132745365. FIG. 1 shows an exemplary *abl* exons 8 and 9 and intron 8. The 35 base pair insertion sequence of *abl* intron 8 is indicated with highlighting.

[00127] Exemplary *abl* intron 8 sequence is listed in nucleotides 148-1,647 of SEQ ID NO: 3 and shown in FIG. 11.

[00128] FIG. 2 shows a portion of exemplary *bcr-abl* mRNA splice variant. Nucleic acid sequences of *abl* exon 8, 35 base insert sequence and *abl* exon 9 are indicated. SEQ ID NO: 26 provides an exemplary cDNA sequence of alternately spliced *bcr-abl* in which the 35 base insert from intron 8 is located at nucleotides 2933-2967. SEQ ID NO: 19 provides an exemplary cDNA sequence of *bcr-abl* without the 35 base alternative splicing insert. The junction of *abl* exons 8 and 9 is located at the TG nucleotides 2932-2933.

[00129] In preferred embodiments, *bcr-abl* splice variant mRNA can be detected by detecting SEQ ID NO: 1 or portions and complements thereof. In preferred embodiments, *bcr-abl* splice variant mRNA can be detected by detecting SEQ ID NO: 4 or complements thereof.

[00130] In other embodiments, *bcr-abl* splice variant mRNA resulting from alternate splicing can be detected by detecting the sequences encompassing the junction of 35 bp *abl* 8 insert and *abl* exons 8. In preferred embodiments, *bcr-abl* splice variant mRNA can be detected by detecting SEQ ID NO: 15 or a complement thereof. In preferred embodiments, *bcr-abl* splice variant mRNA can be detected by detecting a polynucleotide comprising SEQ

ID NO: 16 or a complement thereof. In other embodiments, *bcr-abl* splice variant mRNA can be detected by detecting at least 25 nucleotides comprising SEQ ID NO: 16 or a complement thereof. In some embodiments, *bcr-abl* splice variant mRNA can be detected by detecting at least 1000 nucleotides comprising SEQ ID NO: 16 or a complement thereof. In some embodiments, *bcr-abl* splice variant mRNA can be detected by detecting 15 or fewer nucleotide sequences comprising SEQ ID NO: 13. Sequences of SEQ ID NO: 13, SEQ ID NO: 15 and SEQ ID NO: 16 are shown below.

[00131] 5'-gagcatacttgg-3' (SEQ ID NO: 13)

[00132] 5'-aactcatgcgagcatacttgataaccgtg-3' (SEQ ID NO: 15)

[00133] 5'-atgcgagcatacttgataa-3' (SEQ ID NO: 16)

[00134] In preferred embodiments, *bcr-abl* splice variant mRNA resulting from alternate splicing can be detected by detecting the sequences encompassing the junction of 35 bp insert of *abl* intron 8 (SEQ ID NO: 4) and *abl* exon 9. In preferred embodiments, *bcr-abl* splice variant mRNA can be detected by detecting SEQ ID NO: 17 or a complement thereof. In preferred embodiments, *bcr-abl* splice variant mRNA can be detected by detecting a polynucleotide comprising SEQ ID NO: 18 or a complement thereof. In other embodiments, *bcr-abl* splice variant mRNA can be detected by detecting at least 25 nucleotides comprising SEQ ID NO: 18 or a complement thereof. In some embodiments, *bcr-abl* splice variant mRNA can be detected by detecting at least 1000 nucleotides comprising SEQ ID NO: 18 or a complement thereof. In some embodiments, *bcr-abl* splice variant mRNA can be detected by detecting 15 or fewer nucleotide sequences comprising SEQ ID NO: 14. Sequences of SEQ ID NO: 14, SEQ ID NO: 17 and SEQ ID NO: 18 are shown below.

[00135] 5'-tagaaggttggc-3' (SEQ ID NO: 14)

[00136] 5'-agaacaagatagaaggttggcagtggaatc-3' (SEQ ID NO: 17)

[00137] 5'-gaaggttggcagtggaatcc-3' (SEQ ID NO: 18)

[00138] In preferred embodiments, *bcr-abl* splice variant mRNA can be detected by detecting at least 100 contiguous nucleotides of SEQ ID NO: 1 or a complement thereof, and SEQ ID NO 13 or SEQ ID NO: 14 or both.

[00139] In preferred embodiments, *bcr-abl* splice variant mRNA can be detected by detecting at least 40 contiguous nucleotides of SEQ ID NO: 9.

[00140] Sequence of SEQ ID NO: 9 is shown below:

[00141] 5'-gagcatactttgataaccgtgaagaaagaacaagatagaagggtggc-3' (SEQ ID NO: 9)

[00142] Splice variant of any of the known *bcr-abl* mRNA sequences listed above and also of any unknown *bcr-abl* mRNA sequence that comprises at least 40 contiguous nucleotides of SEQ ID NO: 9 that results from alternate splicing producing a *bcr-abl* mRNA variant may be detected using the methods herein. The resulting *bcr-abl* mRNA after such alternative splicing may comprise a nucleic acid sequence preferably at least 90% identical to, more preferably at least 95% identical to, and most preferably identical to the entire length of the sequence of SEQ ID NO: 1 or a complement thereof.

[00143] Although a sequence of the nucleic acids of SEQ ID NO: 1, 3, 4-9, and 13-18 are shown in the form of DNA, a person of ordinary skill in the art recognizes that the corresponding RNA sequence will have a similar sequence with the thymine being replaced by uracil i.e. "t" with "u".

[00144] Variants of BCR-ABL protein

[00145] Several variation of BCR-ABL protein sequence is known in the art. Some of the amino acid sequences are for full length protein and some are amino acid sequences for a fragment of BCR-ABL protein. Exemplary BCR-ABL protein sequence include but not limited to the NCBI protein database accession numbers: ABX82708, ABX82702, AAA35594, ACA62749, ABX82713, CAM33013, CAA10377, CAA10376, AAL99544, AAA88013, CAM33009, ABX82714, ABX82712, ABX82711, ABX82710, ABX82709, ABX82707, ABX82706, ABX82705, ABX82704, ABX82703, ABX82701, ABX82700, ABZ01959, ABW90981, AAL05889, AAA87612, CAM33011, CAP08044, ABM21758, AAD04633, AAF89176, ABZ01958, ABO09836, ABZ01957, ABK56838, ABK56837, ABK56836, ABK19807, ABK19806, ABK19805, AAA35596, AAF61858, AAA35595, AAA35592.

[00146] Exemplary amino acid sequence of full length BCR-ABL protein without the insertion/truncation mutation is provided in SEQ ID NO: 11.

[00147] Insertion/truncation mutant of BCR-ABL protein: In some embodiments, CML patients undergoing BCR-ABL tyrosine kinase inhibitor therapy (for example, imatinib), may have a *bcr-abl* splice variant mRNA due to the insertion of 35 nucleotides from *abl* intron 8 at the junction of *abl* exons 8 and 9 of the *bcr-abl* mRNA due to alternate splicing. In preferred embodiments, the sequence of the 35 base insert may be SEQ ID NO: 4. The insertion of SEQ ID NO: 4 at the *abl* exon 8/9 junction creates a premature stop codon at nucleotide 30 of the *abl* intron 8 derived sequence resulting in a new c-terminal region for the BCR-ABL protein with the insertion of 10 new amino acids derived from the *abl* intron sequence and truncation of 653 c-terminal amino acids. The truncated 653 amino acids include a part of the kinase domain and the amino acids encoded by the entire last exon. Exemplary amino acid sequence of the insertion/truncation mutant of BCR-ABL protein is listed as SEQ ID NO: 20.

[00148] In preferred embodiments, the amino acid sequence of the c-terminal region of the BCR-ABL protein encoded by the *bcr-abl* splice variant mRNA may comprise a sequence shown in SEQ ID NO: 2.

[00149] Sequence of SEQ ID NO: 2 is shown below:

[00150] MSPYPGIDLSQVYELLEKDYRMERPEGCPEKVYELMRAYFDNREERTR
(SEQ ID NO: 2)

[00151] Amino acid sequence of the 10 new amino acids derived from *abl* intron 8 and inserted at the c-terminal region of the BCR-ABL protein encoded by the *bcr-abl* splice variant mRNA is provided as SEQ ID NO: 10.

[00152] Sequence of SEQ ID NO: 10 is shown below:

[00153] YFDNREERTR (SEQ ID NO: 10)

[00154] In preferred embodiments, c-terminal region of the BCR-ABL protein encoded by the *bcr-abl* splice variant mRNA may comprise a sequence of at least 15 contiguous amino acids of SEQ ID NO: 2 from amino acid positions 34 to 48 and represented as SEQ ID NO: 12.

[00155] Sequence of SEQ ID NO: 12 is shown below:

[00156] ELMRAYFDNREERTR (SEQ ID NO: 12)

[00157] The insertion/truncation mutant of BCR-ABL protein of any of the known BCR-ABL protein sequence listed above and also of any unknown BCR-ABL protein sequence resulting from alternate splicing comprising a c-terminal region amino acid sequence of SEQ ID NO: 12 may be detected herein. In some embodiments, the resulting insertion/truncation mutant of BCR-ABL protein will have an amino acid sequence of the c-terminal region preferably at least 90% identical to, more preferably at least 95% identical to, and most preferably identical to the entire length of the amino acid sequence of SEQ ID NO: 2.

[00158] Mutations in the ABL kinase domain: CML patients undergoing tyrosine kinase inhibitor therapy (such as, imatinib, nilotinib, dasatinib, Bosutinib (SKI-606) and Aurora kinase inhibitor VX-680) may develop resistance to such inhibitors. Several underlying mechanisms of resistance to kinase inhibitors have been identified. One major cause is the presence of point mutations within the ABL kinase domain of BCR-ABL. In one embodiment, such mutations inhibit the ability of imatinib to bind to BCR-ABL by altering the binding sites or preventing the kinase domain from assuming the inactive conformation required for imatinib binding (O'Hare et al. Blood. 2007; 110: 2242–2249). Point mutations develop in approximately 35% to 70% of patients displaying resistance to imatinib, either spontaneously or through the evolutionary pressure of imatinib (Branford et al. Blood. 2003; 102: 276–283).

[00159] More than 40 distinct resistance-conferring mutations have been detected; the majority fall within four regions of the kinase domain: the ATP-binding loop (P-loop) of the ABL kinase domain, the contact site, the SHY binding site (activation loop), and the catalytic domain (Hughes et al. Blood. 2006;108: 28–37). A list of such mutations are shown in FIG. 6 and incorporated herein by reference. Approximately 85% of all imatinib-resistant mutations are associated with amino acid substitutions at just seven residues (P-loop: M244V, G250E, Y253F/H and E255K/V; contact site: T315I; and catalytic domain: M351T and F359V). The most frequently mutated region of BCR-ABL is the P-loop, accounting for 36% to 48% of all mutations.

[00160] The importance of P-loop mutations is further underlined by in vitro evidence suggesting that these mutations are more oncogenic with respect to un-mutated BCR-ABL as well as other mutated variants. In various biological assays, P-loop mutants Y253F and

E255K exhibited an increased transformation potency relative to un-mutated BCR-ABL. Overall, the relative transformation potencies of various mutations were found to be as follows: Y253F > E255K > native BCR-ABL $\geq$ T315I > H396P > M351T. Transformation potency also correlated with intrinsic BCR-ABL kinase activity in this study.

[00161] In some embodiments, CML patients undergoing kinase inhibitor therapy may develop two kinds of mutations: a) an insertion/truncation mutant of BCR-ABL due to alternate splicing and b) one or more point mutations in the kinase domain of ABL. The association of these mutations in CML patients resistant to imatinib are shown in Table 1.

[00162] In preferred embodiments, the alternate splice variant of *bcr-abl* mRNA can be detected simultaneously with the detection of mutations in *abl* portion of *bcr-abl* mRNA. In another embodiment, the mutations in the *abl* portion of *bcr-abl* mRNA can be detected separately. Several methods are known in the art for detection of the presence or absence of such mutations. Non limiting examples include, DNA sequencing, detection by hybridization of a detectably labeled probe, detection by size, allele specific PCR, ligation amplification reaction (LAR), detection by oligonucleotide arrays.

[00163] Insertion/truncation mutant of Abl protein

[00164] In some embodiments, transcripts *abl* gene may exhibit alternate splicing. The alternate splicing may result in the insertion of 35 nucleotides from *abl* intron 8 at the junction of *abl* exons 8 and 9 of the *bcr-abl* mRNA. Insertion of the 35 nucleotides of *abl* intron 8 at the junction of *abl* exons 8 and 9 may result in the generation of ten new codons and also a stop codon resulting in an insertion/truncation mutant. Exemplary nucleic acid sequence of *abl* intron 8 is listed as nucleotides 148-1,647 SEQ ID NO: 3 and shown in FIG. 11. In the insertion/truncation mutant protein, a portion of the c-terminus of the Abl protein will be truncated and 10 new amino acids will be added to the c-terminus. Exemplary amino acid sequence of wild-type Abl protein is provided as SEQ ID NO: 24. Exemplary amino acid sequence of the insertion/truncation mutant protein is provided as SEQ ID NO: 25.

[00165] In preferred embodiments, *bcr-abl* splice variant mRNA resulting from alternate splicing can be detected simultaneously with the splice variant of *abl* mRNA. In other preferred embodiments, the splice variant of *abl* mRNA may be detected simultaneously with detection of the presence or absence of other mutations in the *abl* gene.

[00166] In another embodiment, the presence or absence of the insertion/truncation mutant of Abl protein may be detected. In some embodiments, the presence or absence of the insertion/truncation mutant of Abl protein may be detected simultaneously with the detection of the presence or absence of insertion/truncation mutant of BCR-ABL protein. In some other embodiments, the presence or absence of the insertion/truncation mutant of Abl protein may be detected simultaneously with the detection of the presence or absence of other mutation in the Abl protein.

[00167] Biological Sample Collection and Preparation

[00168] Sample: Sample may contain polynucleotide or polypeptide. Sample may be of biological and non-biological origin. The sample may be of human or non-human origin. The sample may be obtained from eukaryotic or prokaryotic organisms, or environment. The sample may be solid, liquid, and semisolid, with or without any cell or tissue. The sample may include, but are not limited to, amniotic fluid, biopsies, blood, blood cells, bone marrow, cerebrospinal fluid, fecal samples, excrements, fine needle biopsy samples, peritoneal fluid, plasma, serum, pleural fluid, bronchial alveolar lavage, bronchial wash, saliva, semen, serum, sputum, tears, buccal swab, tissue, tissue homogenates, frozen tissue, paraffin sections of tissue, tissue culture media, cells, cell lysates, cell from culture, cell culture supernatant, fetus, embryo, urine, microbes, virus, mycoplasma.

[00169] In one embodiment, the sample may be obtained from an individual who is suspected of having a disease, or a genetic abnormality. In another embodiment sample may be obtained from a healthy individual who is assumed of having no disease, or a genetic abnormality. In preferred embodiments, the sample may be obtained from CML patients undergoing kinase inhibitor therapy. In another embodiment, sample may be obtained from CML patients not undergoing kinase inhibitor therapy.

[00170] Sample Collection: Methods of obtaining samples are well known to those of skill in the art and include, but are not limited to, aspirations, tissue sections, drawing of blood or other fluids, surgical or needle biopsies, collection of paraffin embedded tissue, collection of body fluids, collection of stool, urine, buccal swab and the like.

[00171] Sample Preparation: The nucleic acid (DNA or RNA) or polypeptide may be isolated from the sample according to any methods well known to those of skill in the art. If necessary, the sample may be collected or concentrated by centrifugation and the like. The

sample may be subjected to lysis, such as by treatments with enzymes, heat, surfactants, ultrasonication, or a combination thereof. The lysis treatment is performed in order to obtain a sufficient amount of nucleic acid or polypeptide. The sample may be subjected to liquid chromatography to partially purify the nucleic acid or polypeptide. In some embodiments, the whole cell lysates or tissue homogenate may be used as source of nucleic acid or polypeptide without further isolation and purification.

[00172] Suitable DNA isolation methods include phenol and chloroform extraction, see Sambrook, et al., *Molecular Cloning: A Laboratory Manual* (1989), Second Edition, Cold Spring Harbor Press, Plainview, NY.

[00173] Numerous commercial kits also yield suitable DNA including, but not limited to, QIAamp™ mini blood kit, Agencourt Genfind™, Roche Cobas® Roche MagNA Pure® or phenol: chloroform extraction using Eppendorf Phase Lock Gels®. Total DNA (e.g., genomic, mitochondrial, microbial, viral,) can be purified from any biological sample such as whole blood, plasma, serum, buffy coat, bone marrow, other body fluids, lymphocytes, cultured cells, tissue, and forensic specimens using commercially available kits e.g., QIAamp DNA and QIAamp DNA Blood mini kits from Qiagen. Viral RNA can be purified from whole blood, plasma, serum, buffy coat, bone marrow, other body fluids, lymphocytes, cultured cells, tissue, and forensic specimens using commercially available kits e.g., QIAamp Viral RNA mini kit.

[00174] In another embodiment, nucleic acid may be mRNA or cDNA generated from mRNA or total RNA may be used. RNA is isolated from cells or tissue samples using standard techniques, see, e.g., Sambrook, et al., *Molecular Cloning: A Laboratory Manual*, Second Edition (1989), Cold Spring Harbor Press, Plainview, NY. In addition, reagents and kits for isolating RNA from any biological sample such as whole blood, plasma, serum, buffy coat, bone marrow, other body fluids, lymphocytes, cultured cells, tissue, and forensic specimens are commercially available e.g., RNeasy Protect Mini kit, RNeasy Protect Cell Mini kit, QIAamp RNA Blood Mini kit, RNeasy Protect Saliva Mini kit, Paxgene Blood RNA kit from Qiagen; MELT™, RNeaqueous®, ToTALLY RNA™, RiboPure™-Blood, Poly(A)Purist™ from Applied Biosystems; TRIZOL® reagent, Dynabeads® mRNA direct kit from Invitrogen.

[00175] In one embodiment, the nucleic acid is isolated from paraffin embedded tissue. Methods of extracting nucleic acid from paraffin embedded tissue are well known in the art e.g., paraffin blocks containing the tissue are collected, de-waxed by treatment with xylene, treated with proteinase to remove protein contaminants, and then finally extracted with phenol and chloroform, followed by ethanol precipitation. Alternatively, nucleic acid from a paraffin embedded tissue can be isolated by commercially available kits e.g., EZ1 DNA kit, QIAamp DNA Mini Kit from Qiagen; Paraffin Block RNA Isolation Kit, RecoverAll™ Total Nucleic Acid Isolation Kit from Ambion.

[00176] Nucleic acid need not be extracted, but may be made available by suitable treatment of cells or tissue such as described in US Patent application 11/566169.

[00177] Nucleic Acid Amplification

[00178] Nucleic acid extracted can be amplified using nucleic acid amplification techniques well known in the art. Nucleic acid amplification can be linear or exponential. Many of these amplification methods can also be used to detect the presence of mutations simply by designing oligonucleotide primers or probes to interact with or hybridize to a particular target sequence in a specific manner. By way of example, but not by way of limitation these techniques can include the polymerase chain reaction (PCR) reverse transcriptase polymerase chain reaction (RT-PCR), nested PCR, ligase chain reaction. See Abravaya, K., et al., Nucleic Acids Res. (1995), 23:675-682, branched DNA signal amplification; Urdea, M. S., et al., AIDS (1993), 7(suppl 2):S11-S14; amplifiable RNA reporters, Q-beta replication, transcription-based amplification, boomerang DNA amplification, strand displacement activation, cycling probe technology, isothermal nucleic acid sequence based amplification (NASBA). See Kievits, T. et al., J Virological Methods (1991), 35:273-286, Invader Technology, or other sequence replication assays or signal amplification assays.

[00179] Primers:

[00180] Oligonucleotide primers for use in these methods can be designed according to general guidance well known in the art as described herein, as well as with specific requirements as described herein for each step of the particular methods described.

[00181] In some embodiments, oligonucleotide primers for cDNA synthesis and PCR are 10 to 100 nucleotides in length, preferably between about 15 and about 60 nucleotides in

length, more preferably 25 and about 50 nucleotides in length, and most preferably between about 25 and about 40 nucleotides in length. There is no standard length for optimal hybridization or polymerase chain reaction amplification.

[00182] Methods of designing primers have been described in U.S. Patent Application: 10/921482. Primers useful in the methods described herein are also designed to have a particular melting temperature (T_m) by the method of melting temperature estimation. Commercial programs, including Oligo™, Primer Design and programs available on the internet, including Primer3 and Oligo Calculator can be used to calculate a T_m of a polynucleotide sequence useful according to the invention.

[00183] T_m of a polynucleotide affects its hybridization to another polynucleotide (e.g., the annealing of an oligonucleotide primer to a template polynucleotide). In the subject methods, it is preferred that the oligonucleotide primer used in various steps selectively hybridizes to a target template or polynucleotides derived from the target template (i.e., first and second strand cDNAs and amplified products). Typically, selective hybridization occurs when two polynucleotide sequences are substantially complementary (at least about 65% complementary over a stretch of at least 14 to 25 nucleotides, preferably at least about 75%, more preferably at least about 90% complementary). See Kanchisa, M., Polynucleotides Res. (1984), 12:203, incorporated herein by reference. As a result, it is expected that a certain degree of mismatch at the priming site is tolerated. Such mismatch may be small, such as a mono-, di- or tri-nucleotide. In preferred embodiments, 100% complementarity is preferred.

[00184] Probes

[00185] Probes are capable of hybridizing to at least a portion of the nucleic acid of interest or a reference nucleic acid. Probes may be an oligonucleotide, artificial chromosome, fragmented artificial chromosome, genomic nucleic acid, fragmented genomic nucleic acid, RNA, recombinant nucleic acid, fragmented recombinant nucleic acid, peptide nucleic acid (PNA), locked nucleic acid, oligomer of cyclic heterocycles, or conjugates of nucleic acid. Probes may be used for detecting and/or capturing nucleic acid of interest.

[00186] Typically, probes can be about 10 bases, about 20 bases, about 25 bases, about 30 bases, about 35 bases, about 40 bases, about 50 bases, about 60 bases, about 75 bases, about 100 bases long.

[00187] However, longer probes are possible. Longer probes can be about 200 bases, about 300 bases, about 400 bases, about 500 bases, about 750 bases, about 1,000 bases, about 1,500 bases, about 2,000 bases, about 2,500 bases, about 3,000 bases, about 3,500 bases, about 4,000 bases, about 5,000 bases, about 7,500 bases, about 10,000 bases long.

[00188] In some embodiments in all aspects of this invention, probes consist of a detectable label or a plurality of detectable labels. In one preferred embodiment, the detectable label associated with the probe can generate a detectable signal directly. In another embodiment, the detectable label associated with the probe can be detected indirectly using a reagent, wherein the reagent includes a detectable label, and binds to the label associated with the probe. In one embodiment the reagent including a detectable label is a labeled antibody. In another embodiment the reagent including a detectable label is a primary antibody/secondary antibody pair, wherein the detectable label may be in the primary antibody, or in the secondary antibody or in both.

[00189] Detectable label

[00190] The term “detectable label” as used herein refers to a molecule or a compound or a group of molecules or a group of compounds associated with an oligonucleotide (e.g., a probe or primer) and is used to identify the probe hybridized to a genomic nucleic acid or reference nucleic acid.

[00191] Detectable labels include but are not limited to fluorophores, isotopes (e.g., ^{32}P , ^{33}P , ^{35}S , ^3H , ^{14}C , ^{125}I , ^{131}I), electron-dense reagents (e.g., gold, silver), nanoparticles, enzymes commonly used in an ELISA (e.g., horseradish peroxidase, beta-galactosidase, luciferase, alkaline phosphatase), chemiluminiscent compound, colorimetric labels (e.g., colloidal gold), magnetic labels (e.g., DynabeadsTM), biotin, digoxigenin, haptens, proteins for which antisera or monoclonal antibodies are available, ligands, hormones, oligonucleotides capable of forming a complex with the corresponding oligonucleotide complement.

[00192] One general method for real time PCR uses fluorescent probes such as the TaqMan® probes, molecular beacons, and Scorpions. Real-time PCR quantifies the initial amount of the template with more specificity, sensitivity and reproducibility, than other forms of quantitative PCR, which detect the amount of final amplified product. Real-time PCR does not detect the size of the amplicon. The probes employed in ScorpionTM and TaqMan®

technologies are based on the principle of fluorescence quenching and involve a donor fluorophore and a quenching moiety.

[00193] TaqMan® probes (Heid, et al., *Genome Res* 6: 986-994, 1996) use the fluorogenic 5' exonuclease activity of Taq polymerase to measure the amount of target sequences in cDNA samples. TaqMan® probes are oligonucleotides that contain a donor fluorophore usually at or near the 5' base, and a quenching moiety typically at or near the 3' base. The quencher moiety may be a dye such as TAMRA or may be a non-fluorescent molecule such as 4-(4 -dimethylaminophenylazo) benzoic acid (DABCYL). See Tyagi, et al., 16 *Nature Biotechnology* 49-53 (1998). When irradiated, the excited fluorescent donor transfers energy to the nearby quenching moiety by FRET rather than fluorescing. Thus, the close proximity of the donor and quencher prevents emission of donor fluorescence while the probe is intact.

[00194] TaqMan® probes are designed to anneal to an internal region of a PCR product. When the polymerase (e.g., reverse transcriptase) replicates a template on which a TaqMan® probe is bound, its 5' exonuclease activity cleaves the probe. This ends the activity of the quencher (no FRET) and the donor fluorophore starts to emit fluorescence which increases in each cycle proportional to the rate of probe cleavage. Accumulation of PCR product is detected by monitoring the increase in fluorescence of the reporter dye (note that primers are not labeled). If the quencher is an acceptor fluorophore, then accumulation of PCR product can be detected by monitoring the decrease in fluorescence of the acceptor fluorophore.

[00195] In a preferred embodiment, the detectable label is a fluorophore. The term “fluorophore” as used herein refers to a molecule that absorbs light at a particular wavelength (excitation frequency) and subsequently emits light of a longer wavelength (emission frequency). The term “donor fluorophore” as used herein means a fluorophore that, when in close proximity to a quencher moiety, donates or transfers emission energy to the quencher. As a result of donating energy to the quencher moiety, the donor fluorophore will itself emit less light at a particular emission frequency that it would have in the absence of a closely positioned quencher moiety.

[00196] The term “quencher moiety” as used herein means a molecule that, in close proximity to a donor fluorophore, takes up emission energy generated by the donor and either dissipates the energy as heat or emits light of a longer wavelength than the emission wavelength of the donor. In the latter case, the quencher is considered to be an acceptor fluorophore. The quenching moiety can act via proximal (i.e., collisional) quenching or by

Förster or fluorescence resonance energy transfer ("FRET"). Quenching by FRET is generally used in TaqMan® probes while proximal quenching is used in molecular beacon and Scorpion™ type probes.

[00197] Suitable fluorescent moieties include but are not limited to the following fluorophores working individually or in combination:

4-acetamido-4'-isothiocyanatostilbene-2,2'-disulfonic acid; acridine and derivatives: acridine, acridine isothiocyanate; Alexa Fluors: Alexa Fluor® 350, Alexa Fluor® 488, Alexa Fluor® 546, Alexa Fluor® 555, Alexa Fluor® 568, Alexa Fluor® 594, Alexa Fluor® 647 (Molecular Probes); 5-(2'-aminoethyl)aminonaphthalene-1-sulfonic acid (EDANS); 4-amino-N-[3-vinylsulfonyl]phenyl]naphthalimide-3,5 disulfonate (Lucifer Yellow VS); N-(4-anilino-1-naphthyl)maleimide; anthranilamide; Black Hole Quencher™ (BHQ™) dyes (biosearch Technologies); BODIPY dyes: BODIPY® R-6G, BOPIPY® 530/550, BODIPY® FL; Brilliant Yellow; coumarin and derivatives: coumarin, 7-amino-4-methylcoumarin (AMC, Coumarin 120), 7-amino-4-trifluoromethylcoumarin (Coumarin 151); Cy2®, Cy3®, Cy3.5®, Cy5®, Cy5.5®; cyanosine; 4',6-diaminidino-2-phenylindole (DAPI); 5', 5''-dibromopyrogallol-sulfonephthalein (Bromopyrogallol Red); 7-diethylamino-3-(4'-isothiocyanatophenyl)-4-methylcoumarin; diethylenetriamine pentaacetate; 4,4'-diisothiocyanatodihydro-stilbene-2,2'-disulfonic acid; 4,4'-diisothiocyanatostilbene-2,2'-disulfonic acid; 5-[dimethylamino]naphthalene-1-sulfonyl chloride (DNS, dansyl chloride); 4-(4'-dimethylaminophenylazo)benzoic acid (DABCYL); 4-dimethylaminophenylazophenyl-4'-isothiocyanate (DABITC); Eclipse™ (Epoch Biosciences Inc.); eosin and derivatives: eosin, eosin isothiocyanate; erythrosin and derivatives: erythrosin B, erythrosin isothiocyanate; ethidium; fluorescein and derivatives: 5-carboxyfluorescein (FAM), 5-(4,6-dichlorotriazin-2-yl)aminofluorescein (DTAF), 2',7'-dimethoxy-4'5'-dichloro-6-carboxyfluorescein (JOE), fluorescein, fluorescein isothiocyanate (FITC), hexachloro-6-carboxyfluorescein (HEX), QFITC (XRITC), tetrachlorofluorescein (TET); fluorescamine; IR144; IR1446; lanthamide phosphors; Malachite Green isothiocyanate; 4-methylumbelliferone; ortho cresolphthalein; nitrotyrosine; pararosaniline; Phenol Red; B-phycoerythrin, R-phycoerythrin; allophycocyanin; o-phthalaldehyde; Oregon Green®; propidium iodide; pyrene and derivatives: pyrene, pyrene butyrate, succinimidyl 1-pyrene butyrate; QSY® 7; QSY® 9; QSY® 21; QSY® 35 (Molecular Probes); Reactive Red 4 (Cibacron® Brilliant Red 3B-A); rhodamine and derivatives: 6-carboxy-X-rhodamine (ROX), 6-carboxyrhodamine (R6G),

lissamine rhodamine B sulfonyl chloride, rhodamine (Rhod), rhodamine B, rhodamine 123, rhodamine green, rhodamine X isothiocyanate, riboflavin, rosolic acid, sulforhodamine B, sulforhodamine 101, sulfonyl chloride derivative of sulforhodamine 101 (Texas Red); terbium chelate derivatives; N,N,N',N'-tetramethyl-6-carboxyrhodamine (TAMRA); tetramethyl rhodamine; tetramethyl rhodamine isothiocyanate (TRITC).

[00198] Detection of nucleic acid by size:

[00199] Methods for detecting the presence or amount of polynucleotides are well known in the art and any of them can be used in the methods described herein so long as they are capable of separating individual polynucleotides by the difference in size of the amplicons. The separation technique used should permit resolution of nucleic acid as long as they differ from one another by at least one nucleotide. The separation can be performed under denaturing or under non-denaturing or native conditions--i.e., separation can be performed on single- or double-stranded nucleic acids. It is preferred that the separation and detection permits detection of length differences as small as one nucleotide. It is further preferred that the separation and detection can be done in a high-throughput format that permits real time or contemporaneous determination of amplicon abundance in a plurality of reaction aliquots taken during the cycling reaction. Useful methods for the separation and analysis of the amplified products include, but are not limited to, electrophoresis (e.g., agarose gel electrophoresis, capillary electrophoresis (CE)), chromatography (HPLC), and mass spectrometry.

[00200] In one embodiment, CE is a preferred separation means because it provides exceptional separation of the polynucleotides in the range of at least 10-1,000 base pairs with a resolution of a single base pair. CE can be performed by methods well known in the art, for example, as disclosed in U.S. Pat. Nos. 6,217,731; 6,001,230; and 5,963,456, which are incorporated herein by reference. High-throughput CE apparatuses are available commercially, for example, the HTS9610 High throughput analysis system and SCE 9610 fully automated 96-capillary electrophoresis genetic analysis system from Spectrumedix Corporation (State College, Pa.); P/ACE 5000 series and CEQ series from Beckman Instruments Inc (Fullerton, Calif.); and ABI PRISM 3100 genetic analyzer (Applied Biosystems, Foster City, Calif.). Near the end of the CE column, in these devices the amplified DNA fragments pass a fluorescent detector which measures signals of fluorescent

labels. These apparatuses provide automated high throughput for the detection of fluorescence-labeled PCR products.

[00201] The employment of CE in the methods described herein permits higher productivity compared to conventional slab gel electrophoresis. By using a capillary gel, the separation speed is increased about 10 fold over conventional slab-gel systems.

[00202] With CE, one can also analyze multiple samples at the same time, which is essential for high-throughput. This is achieved, for example, by employing multi-capillary systems. In some instances, the detection of fluorescence from DNA bases may be complicated by the scattering of light from the porous matrix and capillary walls. However, a confocal fluorescence scanner can be used to avoid problems due to light scattering (Quesada et al., *Biotechniques* (1991), 10:616-25).

[00203] In some embodiments, nucleic acid may be analyzed and detected by size using agarose gel electrophoresis. Methods of performing agarose gel electrophoresis are well known in the art. See Sambrook et al., *Molecular Cloning: A Laboratory Manual* (2nd Ed.) (1989), Cold Spring Harbor Press, N.Y.

[00204] DNA sequencing:

[00205] In some embodiments, detection of nucleic acid is by DNA sequencing. Sequencing may be carried out by the dideoxy chain termination method of Sanger et al. (*Proceedings of the National Academy of Sciences USA* (1977), 74, 5463-5467) with modifications by Zimmermann et al. (*Nucleic Acids Res.* (1990), 18:1067). Sequencing by dideoxy chain termination method can be performed using Thermo Sequenase (Amersham Pharmacia, Piscataway, NJ), Sequenase reagents from US Biochemicals or Sequatherm sequencing kit (Epicenter Technologies, Madison, Wis.). Sequencing may also be carried out by the "RR dRhodamine Terminator Cycle Sequencing Kit" from PE Applied Biosystems (product no. 403044, Weiterstadt, Germany), Taq DyeDeoxy™ Terminator Cycle Sequencing kit and method (Perkin-Elmer/Applied Biosystems) in two directions using an Applied Biosystems Model 373A DNA or in the presence of dye terminators CEQ™ Dye Terminator Cycle Sequencing Kit, (Beckman 608000). Alternatively, sequencing can be performed by a method known as Pyrosequencing (Pyrosequencing, Westborough, Mass.). Detailed protocols for Pyrosequencing can be found in: Alderborn et al., *Genome Res.* (2000), 10:1249-1265.

[00206] Genetically modifying host cells by introducing recombinant nucleic acid

[00207] The recombinant nucleic acid (e.g., cDNA or genomic DNA) encoding at least a portion of *bcr-abl* or its variants may be introduced into host cells thereby genetically modifying the host cell. Host cells may be used for cloning and/or for expression of the recombinant nucleic acid. Host cells can be prokaryotic, for example bacteria. Host cell can be also be eukaryotic which includes but not limited to yeast, fungal cell, insect cell, plant cell and animal cell. In preferred embodiment, the host cell can be a mammalian cell. In another preferred embodiment host cell can be human cell. In one preferred embodiment, the eukaryotic host cell may be K562 cell. K562 cells were the first human immortalized myelogenous leukemia line to be established and are a *bcr-abl* positive erythroleukemia line derived from a CML patient in blast crisis (Lozzio & Lozzio, Blood. 1975; 45(3): 321-334; Drexler, H.G. The Leukemia-Lymphoma Cell Line Factsbook. (2000), Academic Press.

[00208] Host cells may comprise wild-type genetic information. The genetic information of the host cells may be altered on purpose to allow it to be a permissive host for the recombinant DNA. Examples of such alterations include mutations, partial or total deletion of certain genes, or introduction of non-host nucleic acid into host cell. Host cells may also comprise mutations which are not introduced on purpose.

[00209] Several methods are known in the art to introduce recombinant DNA in bacterial cells that include but are not limited to transformation, transduction, and electroporation, see Sambrook, et al., Molecular Cloning: A Laboratory Manual (1989), Second Edition, Cold Spring Harbor Press, Plainview, NY. Non limiting examples of commercial kits and bacterial host cells for transformation include NovaBlue Singles™ (EMD Chemicals Inc, NJ, USA), Max Efficiency® DH5α™, One Shot® BL21 (DE3) E. coli cells, One Shot® BL21 (DE3) pLys E. coli cells (Invitrogen Corp., Carlsbad, CA, USA), XL1-Blue competent cells (Stratagene, CA, USA). Non limiting examples of commercial kits and bacterial host cells for electroporation include Zappers™ electrocompetent cells (EMD Chemicals Inc, NJ, USA), XL1-Blue Electroporation-competent cells (Stratagene, CA, USA), ElectroMAX™ A. tumefaciens LBA4404 Cells (Invitrogen Corp., Carlsbad, CA, USA).

[00210] Several methods are known in the art to introduce recombinant nucleic acid in eukaryotic cells. Exemplary methods include transfection, electroporation, liposome mediated delivery of nucleic acid, microinjection into to the host cell, see Sambrook, et al.,

Molecular Cloning: A Laboratory Manual (1989), Second Edition, Cold Spring Harbor Press, Plainview, NY. Non limiting examples of commercial kits and reagents for transfection of recombinant nucleic acid to eukaryotic cell include Lipofectamine™ 2000, Optifect™ Reagent, Calcium Phosphate Transfection Kit (Invitrogen Corp., Carlsbad, CA, USA), GeneJammer® Transfection Reagent, LipoTAXI® Transfection Reagent (Stratagene, CA, USA). Alternatively, recombinant nucleic acid may be introduced into insect cells (e.g. sf9, sf21, High Five™) by using baculo viral vectors.

[00211] In one preferred embodiment, an exemplary vector comprising the cDNA sequence of bcr-abl splice variant (pCMV/GFP/35INS *bcr-abl*, shown in FIG. 5B) may be transfected into K562 cells. Stable transfected K 562 cells may be developed by transfecting the cells with varying amounts of the pCMV/GFP/35INS *bcr-abl* vector (0 ng-500 ng) using various methods known in the art. In one exemplary method, The ProFection® Mammalian Transfection System— Calcium Phosphate (Promega Corporation, WI, USA) may be used. This is a simple system containing two buffers: CaCl₂ and HEPES-buffered saline. A precipitate containing calcium phosphate and DNA is formed by slowly mixing a HEPES-buffered phosphate solution with a solution containing calcium chloride and DNA. These DNA precipitates are then distributed onto eukaryotic cells and enter the cells through an endocytic-type mechanism. This transfection method has been successfully used by others (Hay et al. J. Biol. Chem. 2004; 279: 1650–58). The transfected K562 cells can be selected from the non-transfected cells by using the antibiotics Neomycin and Ampicillin. Expression of the spliced variant of *bcr-abl* can be assessed from the co-expression of the reporter gene GFP.

[00212] Alternatively, in a 24-well format complexes are prepared using a DNA (μg) to Lipofectamine™ 2000 (Invitrogen Corporation, Carlsbad, CA, USA) (μl) ratio of 1:2 to 1:3. Cells are transfected at high cell density for high efficiency, high expression levels, and to minimize cytotoxicity. Prior to preparing complexes, 4-8 x 10⁵ cells are plated in 500 μl of growth medium without antibiotics. For each transfection sample, complexes are prepared as follows: a. DNA is diluted in 50 μl of Opti-MEM® I Reduced Serum Medium without serum (Invitrogen Corporation, Carlsbad, CA, USA) or other medium without serum and mixed gently. b. Lipofectamine™ 2000 is mixed gently before use and the mixture is diluted to appropriate amount in 50 μl of Opti-MEM® I Medium. The mixture is incubated for 5 minutes at room temperature. c. After 5 minute incubation, the diluted DNA is combined

with diluted Lipofectamine™ 2000 (total volume = 100 μ l) and is mixed gently. The mixture is incubated for 20 minutes at room temperature. 100 μ l of complexes is added to each well containing cells and medium. The contents are mixed gently by rocking the plate back and forth. Cells are incubated at 37°C in a CO₂ incubator for 18-48 hours prior to testing for transgene expression. Medium may be changed after 4-6 hours. Cells are passaged at a 1:10 (or higher dilution) into fresh growth medium 24 hours after transfection. Selective medium (containing Neomycin and Ampicillin) is added the following day.

[00213] Antibody Production and Screening

[00214] Various procedures known in the art may be used for the production of antibodies to epitopes of the BCR-ABL protein and the insertion truncation mutant of BCR-ABL protein. Such antibodies include but are not limited to polyclonal, monoclonal, chimeric, single chain, Fab fragments and fragments produced by a Fab expression library. Antibodies that specifically bind to an epitope of SEQ ID NO: 2 are useful for detection and diagnostic purposes.

[00215] In preferred embodiments, the antibodies may bind specifically to an epitope comprising at least 15 contiguous amino acids of SEQ ID NO: 2 from amino acid positions 34 to 48 and represented as SEQ ID NO: 12. In another embodiment, antibodies may specifically bind to an epitope comprising the amino acid sequences of SEQ ID NO: 10. Antibodies specifically binding to an epitope comprising SEQ ID NO: 12 or SEQ ID NO: 10 will specifically detect and distinguish insertion truncation mutant of BCR-ABL protein from other BCR-ABL proteins without such insertion/truncation mutation. Antibodies specifically binding to an epitope comprising SEQ ID NO: 12 or SEQ ID NO: 10 may be monoclonal or polyclonal. Such antibodies are useful for detection and diagnostic purposes.

[00216] Monoclonal antibodies that bind BCR-ABL protein and the insertion truncation mutant of BCR-ABL protein may be radioactively labeled allowing one to follow their location and distribution in the body after injection. Radioactivity tagged antibodies may be used as a non-invasive diagnostic tool for imaging de novo cells of tumors and metastases.

[00217] Immunotoxins may also be designed which target cytotoxic agents to specific sites in the body. For example, high affinity BCR-ABL protein and insertion truncation mutant of BCR-ABL protein specific monoclonal antibodies may be covalently complexed to bacterial or plant toxins, such as diphtheria toxin, abrin or ricin. A general method of preparation of

antibody/hybrid molecules may involve use of thiol-crosslinking reagents such as SPDP, which attack the primary amino groups on the antibody and by disulfide exchange, attach the toxin to the antibody. The hybrid antibodies may be used to specifically eliminate BCR-ABL protein and insertion truncation mutant of BCR-ABL protein expressing cells.

[00218] For the production of antibodies, various host animals may be immunized by injection with the full length or fragment of BCR-ABL protein and the insertion truncation mutant of BCR-ABL protein including but not limited to rabbits, mice, rats, etc. Various adjuvants may be used to increase the immunological response, depending on the host species, including but not limited to Freund's (complete and incomplete), mineral gels such as aluminum hydroxide, surface active substances such as lysolecithin, pluronic polyols, polyanions, peptides, oil emulsions, keyhole limpet hemocyanin, dinitrophenol, and potentially useful human adjuvants such as BCG (bacilli Calmette-Guerin) and *Corynebacterium parvum*.

[00219] Monoclonal antibodies to BCR-ABL protein and the insertion truncation mutant of BCR-ABL protein may be prepared by using any technique which provides for the production of antibody molecules by continuous cell lines in culture. These include but are not limited to the hybridoma technique originally described by Kohler and Milstein, (Nature (1975), 256:495-497), the human B-cell hybridoma technique (Koshor et al., Immunology Today (1983), 4:72; Cote et al. Proc. Natl. Acad. Sci. (1983), 80:2026-2030) and the EBV-hybridoma technique (Cole et al., Monoclonal Antibodies and Cancer Therapy (1985), Alan R. Liss, Inc., pp. 77-96). In addition, techniques developed for the production of "chimeric antibodies" (Morrison et al., Proc. Natl. Acad. Sci. USA (1984), 81:6851-6855; Neuberger et al., Nature (1984), 312:604-608; Takeda et al., Nature (1985), 314:452-454) by splicing the genes from a mouse antibody molecule of appropriate antigen specificity together with genes from a human antibody molecule of appropriate biological activity can be used.

Alternatively, techniques described for the production of single chain antibodies (U.S. Pat. No. 4,946,778) can be adapted to produce BCR-ABL protein and insertion truncation mutant of BCR-ABL protein-specific single chain antibodies.

[00220] Antibody fragments which contain specific binding sites of BCR-ABL protein and insertion truncation mutant of BCR-ABL protein may be generated by known techniques. For example, such fragments include but are not limited to: the F(ab')₂ fragments which can be produced by pepsin digestion of the antibody molecule and the Fab fragments which can

be generated by reducing the disulfide bridges of the F(ab')₂ fragments. Alternatively, Fab expression libraries may be constructed (Huse et al., Science. 1989; 246: 1275-1281) to allow rapid and easy identification of monoclonal Fab fragments with the desired specificity to BCR-ABL protein and insertion/truncation mutant of BCR-ABL protein.

[00221] Kits

[00222] The present inventions also contemplate diagnostic systems in kit form. A diagnostic system of the present inventions may include a kit which contains, in an amount sufficient for at least one assay, any of the hybridization assay probes, amplification primers, and/or antibodies against BCR-ABL wild type and insertion/truncation mutant in a packaging material. Typically, the kits will also include instructions recorded in a tangible form (e.g., contained on paper or an electronic medium) for using the packaged probes, primers, and/or antibodies in a detection assay for determining the presence or amount of *bcr-abl* splice variant mRNA or BCR-ABL insertion/truncation mutant protein in a test sample.

[00223] The various components of the diagnostic systems may be provided in a variety of forms. For example, the required enzymes, the nucleotide triphosphates, the probes, primers, and/or antibodies may be provided as a lyophilized reagent. These lyophilized reagents may be pre-mixed before lyophilization so that when reconstituted they form a complete mixture with the proper ratio of each of the components ready for use in the assay. In addition, the diagnostic systems of the present inventions may contain a reconstitution reagent for reconstituting the lyophilized reagents of the kit. In preferred kits for amplifying target nucleic acid derived from a CML patients, the enzymes, nucleotide triphosphates and required cofactors for the enzymes are provided as a single lyophilized reagent that, when reconstituted, forms a proper reagent for use in the present amplification methods.

[00224] In one embodiment, the kit may comprise at least three lyophilized oligonucleotides: a primer pair to amplify a portion of *bcr-abl* mRNA comprising exons 8 and 9, and a detectably labeled probe capable of hybridizing to the amplicon generated. In some preferred kits, at least three lyophilized oligonucleotides: the detectably labeled probe, and the primer pair for amplification of at least a portion of *bcr-abl* mRNA may have sequences of SEQ ID NO: 4, 5, 6 or complements and fragments thereof respectively. In some preferred kits, at least four lyophilized oligonucleotide reagents may be provided having sequences of SEQ ID NO: 5, 6, 7, and 8 or complements and fragments thereof. In

some preferred kits at least five lyophilized oligonucleotide reagents may be provided having sequences of SEQ ID NO: 4, 5, 6, 7, and 8 or complements and fragments thereof.

[00225] Some preferred kits may further comprise to a solid support for anchoring the nucleic acid of interest on the solid support. The target nucleic acid may be anchored to the solid support directly or indirectly through a capture probe anchored to the solid support and capable of hybridizing to the nucleic acid of interest. Examples of such solid support include but are not limited to beads, microparticles (for example, gold and other nano particles), microarray, microwells, multiwell plates. The solid surfaces may comprise a first member of a binding pair and the capture probe or the target nucleic acid may comprise a second member of the binding pair. Binding of the binding pair members will anchor the capture probe or the target nucleic acid to the solid surface. Examples of such binding pairs include but are not limited to biotin/streptavidin, hormone/receptor, ligand/receptor, antigen/antibody.

[00226] In other preferred kits, lyophilized antibodies against BCR-ABL wild type and insertion/truncation mutant protein are provided. In some preferred kits a primary/secondary antibody pair may be provided. Some preferred kits may further comprise to a solid support for anchoring the BCR-ABL wild type and insertion/truncation mutant protein. Such anchoring of the BCR-ABL wild type and insertion/truncation mutant protein may be through biotin/streptavidin, antigen/antibody interactions.

[00227] Typical packaging materials would include solid matrices such as glass, plastic, paper, foil, micro-particles and the like, capable of holding within fixed limits hybridization assay probes, and/or amplification primers of the present invention. Thus, for example, the packaging materials can include glass vials used to contain sub-milligram (e.g., picogram or nanogram) quantities of a contemplated probe, primer, or antibodies or they can be microtiter plate wells to which probes, primers, or antibodies of the present inventions have been operatively affixed, i.e., linked so as to be capable of participating in an amplification and/or detection method of the present invention.

[00228] The instructions will typically indicate the reagents and/or concentrations of reagents and at least one assay method parameter which might be, for example, the relative amounts of reagents to use per amount of sample. In addition, such specifics as maintenance, time periods, temperature, and buffer conditions may also be included.

[00229] The diagnostic systems of the present inventions contemplate kits having any of the hybridization assay probes, amplification primers, or antibodies described herein, whether provided individually or in one of the preferred combinations described above, for use in determining the presence or amount of *bcr-abl* splice variant mRNA or BCR-ABL insertion/truncation mutant protein in a test sample.

[00230] Identifying a compound for treating CML patients

[00231] In one preferred embodiment, cell lines expressing BCR-ABL (both wild-type and/or mutant) proteins may be utilized to screen compounds for treating CML patients. In preferred embodiments, the compounds may be targeting BCR-ABL protein. In some embodiments, the compounds may be inhibitor of Abl kinase activity. Non-limiting examples of kinase inhibitors include but not limited to imatinib, dasatinib, nilotinib, Bosutinib (SKI-606) and Aurora kinase inhibitor VX-680. In other embodiments, the compounds may not be an inhibitor of Abl kinase activity.

[00232] The effect of the compounds on the cells may be assessed. Several parameters may be assessed for identifying the compounds that may be beneficial for treatment of CML patients. Non-limiting examples of the parameters that may be assessed includes cell viability, cell proliferation, apoptosis, kinase activity of BCR-ABL protein, additional mutations in BCR-ABL protein, additional mutation in Abl protein.

[00233] In one embodiment, human chronic myeloid leukemia (CML) cell lines expressing BCR-ABL (both wild-type and/or mutant) proteins may be used to study the effect of such compounds on their effect on the cells. Non-limiting examples of human chronic myeloid leukemia (CML) cell lines include BV173, K562, KCL-22, and KYO-1, LAMA84, EM2, EM3, BV173, AR230, and KU812 (Mahon, F.X., Blood. 2000; 96: 1070-1079; Lerma et al. Mol. Cancer Ther. 2007; 6(2): 655-66).

[00234] In other embodiments, non-CML cells may be transfected with expression vectors comprising *bcr-abl* gene or variants of *bcr-abl* gene including splice variants of *bcr-abl* gene resulting in genetically modified cells comprising the recombinant polynucleotide. Thus, the transfected cells will be able to express BCR-ABL protein or its variants. The genetically modified cells can be used to screen compounds for treating CML patients.

[00235] In yet other embodiments, CML cell lines, for example BV173, K562, KCL-22, and KYO-1, LAMA84, EM2, EM3, BV173, AR230, and KU812 may be transfected with expression vectors comprising splice variants of *bcr-abl* gene resulting in genetically modified cells comprising the recombinant polynucleotide. The gene product of the splice variants of *bcr-abl* gene, the insertion/truncation mutant of BCR-ABL may impart partial or total resistance to Abl kinase inhibitors to these genetically modified cells. The genetically modified cells may be used to screen compounds for treating CML. The compounds may be inhibitors of Abl kinase activity or these compounds may have other mechanism of action.

[00236] The CML cell lines and the genetically modified cell lines as discussed above may be grown in appropriate growth medium and using appropriate selective antibiotics. Methods for cell culture is well known in the art (Sambrook, et al., Molecular Cloning: A Laboratory Manual (1989), Second Edition, Cold Spring Harbor Press, Plainview, NY). Several growth media for cell culture are commercially available. Non-limiting examples include GIBCO® RPMI Media 1640, Dulbecco's Modified Eagle Medium (DMEM), DMEM: Nutrient Mixture F-12 (DMEM/F12), Minimum Essential Media (Invitrogen Corp., Carlsbad, CA, USA), RF-10 medium. Non-limiting examples of selective antibiotics include ampicillin, neomycin, Geneticin®, Hygromycin B.

[00237] In one preferred embodiment, K562 cells (ATCC catalog no: CCL-243) may be genetically modified by transfecting with different amounts of the expression vector pCMV/GFP/35INS *bcr-abl*. In one embodiment, the amount the expression vector pCMV/GFP/35INS *bcr-abl* used for transfection can be 0 ng, or can be at least about: 1ng, 2ng, 5ng, 7.5ng, 10ng, 12.5 ng, 15ng, 20ng, 25ng, 30ng, 40ng, 50ng, 60ng, 75ng, 100ng, 125ng, 200ng, 500ng, 750ng, or 1µg. The transfected cells may be grown in RF-10 medium with neomycin/and or ampicillin.

[00238] Assessing the effect of a compound for treatment of CML on genetically modified cells

[00239] Several parameters may be assessed for identifying the compounds that may be beneficial for treatment of CML patients. Non-limiting examples of the parameters that may be assessed includes cell viability, cell proliferation, apoptosis, kinase activity of BCR-ABL protein, additional mutations in BCR-ABL protein, additional mutation in Abl protein.

[00240] Kinase activity of BCR-ABL:

[00241] The effect of a compound on the kinase activity of the BCR-ABL is assessed by monitoring tyrosine phosphorylation profile of the cellular proteins. CrkL is a substrate of BCR-ABL tyrosine kinase (Ren et al. Genes Dev. 1994; 8(7): 783-95). Genetically modified cells comprising recombinant *bcr-abl* or variant so of *bcr-abl* including the splice variant are grown in presence of various amounts of a compound for treating CML patients. In a preferred embodiment, the compounds are Abl tyrosine kinase inhibitors. Non-limiting examples of kinase inhibitors include imatinib, nilotinib, dasatinib, Bosutinib (SKI-606) and Aurora kinase inhibitor VX-680. Amount of phosphorylated CrkL protein can be measured by using detectably labeled anti-phospho CrkL antibody. In one embodiment, the detectable label is phycoerythrin. The signal can be detected by Flow cytometer. Alternatively, the signal can be detected by Fluorescent Microtiter plate reader.

[00242] Sequencing of the Abl kinase domain:

[00243] To further investigate the reason for some cells that do not overexpress BCR-ABL but that have higher resistance to a compound that target the ATP-binding site of the Abl kinase domain (such as imatinib, nilotinib, dasatinib, and Aurora kinase inhibitor VX-680) than their sensitive counterparts, the entire kinase domain of K562-sensitive and -resistant cells can be sequenced. Sequencing can be performed using ABI prism 377 automated DNA sequencer (PE Applied Biosystems; USA). Sequence analysis can performed using the GCG version 10 software.

[00244] Prediction of the Likelihood of Drug Resistance in CML Patients or Subjects Suspected of Having CML

[00245] Methods of the invention can be used for predicting the likelihood that a CML patient or a subject suspected of having CML with a BCR/Abl translocation will be resistant to treatment with one or more BCR-ABL kinase inhibitors. In an embodiment, a sample from a CML patient or a subject suspected of having CML is assessed for the presence or absence of a polynucleotide sequence comprising at least 40 contiguous nucleotides of SEQ ID NO: 9 or a complement thereof. Methods for detecting the presence or absence of said sequence are provided above. The presence of the polynucleotide sequence or a complement thereof in *bcr-abl* mRNA indicates that the patient has an increased likelihood of being resistant to treatment with one or more BCR-ABL kinase inhibitors relative to a patient not having the polynucleotide sequence.

[00246] In another embodiment, *bcr-abl* mRNA of a CML patient or a subject suspected of having CML is assessed for the presence or absence of a polynucleotide sequence comprising at least 40 contiguous nucleotides of SEQ ID NO: 9 or a complement thereof; and further assessing for the presence or absence of at least one mutation in the *abl* portion of the *bcr-abl* gene. Methods for detecting the presence or absence of a polynucleotide sequence comprising at least 40 contiguous nucleotides of SEQ ID NO: 9 or a complement thereof, are provided above. Methods for detecting at least one mutation in the *abl* portion of the *bcr-abl* gene are provided above and generally known in the art. The presence of the polynucleotide sequence or a complement thereof in *bcr-abl* mRNA and presence of at least one mutation in the *abl* portion of the *bcr-abl* gene indicates that the patient has an increased likelihood of being resistant to treatment with one or more BCR-ABL kinase inhibitors relative to a CML patient having the mutation alone.

[00247] In another embodiment, a sample from a CML patient or a subject suspected of having CML is assessed for the increased likelihood of drug resistance by measuring the amount of RNA encoding a full length BCR-ABL and the amount of RNA encoding a BCR-ABL insertion/truncation splice variant encoded by at least 40 contiguous nucleotides of SEQ ID NO: 9 or a complement thereof; wherein the likelihood of resistance increases with increasing amounts of BCR-ABL mRNA insertion/truncation splice variant relative to full length BCR-ABL encoding mRNA. The percentage of BCR-ABL that is insertion/truncation variant mRNA can be 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, or 100% of the total BCR-ABL corresponding mRNA.

[00248] In another embodiment, a sample from a CML patient or a subject suspected of having CML is assessed for the presence or absence of a polypeptide sequence having an amino acid sequence of SEQ ID NO: 10 or SEQ ID NO: 12 or an epitope thereof. Methods for detecting the absence or presence of such polypeptides are discussed above. The presence of the polypeptide sequence or an epitope thereof indicates that the patient has an increased likelihood of being resistant to treatment with one or more BCR-ABL kinase inhibitors relative to a patient not having the polynucleotide sequence.

[00249] In another embodiment, a sample from a CML patient or a subject suspected of having CML is assessed for the increased likelihood of drug resistance by measuring the amount of full length BCR-ABL polypeptide and the amount of BCR-ABL truncation mutant polypeptide; wherein the likelihood of resistance increases with increasing amounts of BCR-

ABL truncation mutant polypeptide relative to full length BCR-ABL polypeptide. In another embodiment, a sample from a CML patient or a subject suspected of having CML is assessed for the amount of a polypeptide sequence having an amino acid sequence of SEQ ID NO: 10 or SEQ ID NO: 12 or an epitope thereof and the amount of full length BCR-ABL polypeptide. The percentage of BCR-ABL that is insertion/truncation variant polypeptide, can be 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, or 100% of the total BCR-ABL corresponding polypeptide.

[00250] Drug Dosage Adjustment and Combination Drug Therapy

[00251] Patients expressing BCR-ABL insertion/truncation splice variant mRNA or polypeptide (i.e., having increased likelihood of resistance) are candidates for treatment using higher doses of BCR-ABL kinase inhibitors, relative to the dosage administered to patients expressing lower amounts (or no) BCR-ABL insertion/truncation splice variant or can be candidates for combination therapy using two or more kinase inhibitors.

[00252] In an embodiment, a patient found to have an increased likelihood of resistance by any of the methods disclosed above is administered an increased dosage of BCR-ABL kinase inhibitor. In another embodiment, a patient found to have an increased likelihood of resistance by any of the methods disclosed above is administered a combination of two or more BCR-ABL kinase inhibitors. In another embodiment, one of the kinase inhibitors is not a tyrosine kinase inhibitor. The BCR-ABL kinase inhibitor can be imatinib, nilotinib, dasatinib, Bosutinib (SKI-606) or Aurora kinase inhibitor VX-680. The BCR-ABL kinase inhibitor can be homoharringtonine (HHT) or MK0457. The two or more BCR-ABL kinase inhibitors can act synergistically. At least two of the inhibitors can be imatinib and nilotinib. At least two of the inhibitors can be imatinib and HHT. The patient or subject can be drug resistant or not drug resistant. The patient or subject can be treatment-naïve.

[00253] While not wishing to be bound by theory, it is believed that by administering a combination of inhibitors before a CML patient demonstrates drug resistance, drug resistance progression can be delayed or prevented.

[00254] The invention will now be described in greater detail by reference to the following non-limiting examples.

EXAMPLE 1

Sample Collection

[00255] Patients: Peripheral blood samples were collected from CML patients with or without imatinib resistance. Some of imatinib resistant patients were also resistant to nilotinib and dasatinib. The diagnosis of CML was established based on the examination of bone marrow morphology, cytogenetic, FISH, and molecular studies. The majority of tested samples were fresh, but a significant number used cells frozen in freezing mix and stored at -70°C.

[00256] Peripheral Blood Samples: Venous blood (5-8 ml) was collected from patients diagnosed with CML using BD Vacutainer™ CPT™ tubes (Beckton Dickinson, NJ, USA, Catalog number: 362760) by venous puncture. Peripheral mononuclear cells and platelets were isolated using manufacturer's protocol. Briefly, venous blood collected into the CPT™ tube was mixed with the anticoagulant present in the tube by inversion. The blood sample was centrifuged at 1500-1800 RCF for 20 min at room temperature (18°C-25°C). Plasma was removed from the top by aspiration without disturbing the white cell layer containing peripheral mononuclear cells and platelets. The peripheral mononuclear cells and platelets were carefully removed with a Pasteur pipette and collected in a separate tube.

[00257] RNA Extraction: Total RNA was isolated from the isolated peripheral mononuclear blood cells and platelets using MagNA Pure Compact RNA Isolation Kit (Roche Applied Sciences, Indianapolis, Indiana, Catalog number: 04802993001). Briefly, the prefilled cartridges provided in the kit were penetrated by the disposable piercing tool. Samples were lysed by incubation in lysis buffer containing chaotropic salt and Proteinase K. RNA was bound to the surfaces of the added Magnetic Glass Particles and DNA was degraded by incubation with DNase. After several washing steps to remove unbound substances, the purified RNA was eluted and transferred to the Elution Tubes. RNA was dissolved in 50 µl of water and was used in subsequent RT/PCR reaction.

[00258] cDNA Synthesis: One (1) to five (5) micrograms of RNA in 13 µl of DEPC-treated water was added to a clean microcentrifuge tube. One microliter of either oligo (dT)₁₈ (0.5 µg/µl) or random hexamer solution (50 ng/µl) was added and mixed gently. The mixture was heated to 70°C for 10 min, followed by incubation on ice for one minute. The reaction mixture was centrifuged briefly, followed by the addition of 2 µl of 10× Synthesis buffer

(200 mM Tris-HCl, pH 8.4, 500 mM KCl, 25 mM Magnesium chloride, 1 mg/ml of BSA), one μ l of 10 mM each of dNTP mix, 2 μ l of 0.1 M DTT, one μ l of SuperScript II RT (200 U/ μ l) (Life Technologies, GIBCO BRL, Gaithersburg, MD). After gentle mixing, the reaction mixture was subjected to brief centrifugation, and incubated at room temperature for 10 min. The reaction mixture was further incubated at 42°C for 50 minutes. The reaction was terminated by incubating at 70°C for 15 min, and then placing it on ice. The reaction mixture was briefly centrifuged, and 1 μ l of RNase H (2 Units) was added followed by incubation at 37°C for 20 min.

EXAMPLE 2

bcr-abl Mutation Detection and Analysis

[00259] Amplification of the kinase domain of *bcr-abl* gene: The kinase domain of the *bcr-abl* gene was amplified by polymerase chain reaction (PCR) using the cDNA derived from CML patient's mRNA as template. The *abl* kinase domain was further amplified by hemi-nested PCR to generate an 863 bp amplicon.

[00260] The primers used for the first round of PCR are as follows:

BCR-Forward: 5'- TGA CCA ACT CGT GTG TGA AAC TC-3' (SEQ ID NO: 5)

ABL-R2 Reverse: 5'- TCC ACT TCG TCT GAG ATA CTG GAT T-3' (SEQ ID NO: 6)

[00261] The primers for the hemi-nested PCR are as follows:

ABL-F1 Forward: 5'- CGC AAC AAG CCC ACT GTC T-3' (SEQ ID NO: 7)

ABL-R2 Reverse: 5'- TCC ACT TCG TCT GAG ATA CTG GAT T-3' (SEQ ID NO: 6)

[00262] The forward primer, BCR-Forward (SEQ ID NO: 5) annealed to *bcr* exon b2 and the reverse primer having a sequence of ABL-R2 (SEQ ID NO: 6) annealed to the junction of *abl* exon 9 and 10. This primer pair will not amplify cDNA with the normal *abl* gene.

[00263] To the reaction mixture comprising cDNA (2 μ g), 8 μ l of 10 $\times$ synthesis buffer (200 mM Tris-HCl, pH 8.4, 500 mM KCl, 25 mM magnesium chloride, 1 mg/ml of BSA), 68 μ l sterile double-distilled water, 1 μ l amplification primer SEQ ID NO: 5 (10 μ M), 1 μ l amplification primer SEQ ID NO: 6 (10 μ M), 1 μ l Taq DNA polymerase (2-5 U/ μ l) were added. The reaction mixture was mixed gently and the reaction mixture was overlayed with

mineral oil. The reaction mixture was heated to 94°C for 5 minutes to denature remaining RNA/cDNA hybrids. PCR amplification was then performed in an automated thermal-cycler for 15-50 cycles, at 94°C for 1 minute, 55°C for 30 to 90 seconds, and 72°C for 2 minutes.

[00264] The inner forward primer, ABL-F1 Forward (SEQ ID NO: 7) and the same reverse primer ABL-R2 (SEQ ID NO: 6) were both labeled with Cy5®. The reaction mixture (50 µl) comprised a 5 µl of the product from the first PCR, 20 pmol of each primer and was amplified using the PCR reaction conditions as before.

[00265] Sequencing of PCR products: The nested (863 bp) PCR product was sequenced with 4 sequencing primers to ensure that the entire Abl kinase domain was 2X covered by dye terminator chemistry and ABI sequencer (Applied Biosystems, Foster City, CA). The 4 sequencing primers used are as follows:

ABL-F1 Forward: 5'-CGC AAC AAG CCC ACT GTC T-3' (SEQ ID NO: 7)

ABL-F2 Forward: 5'-TGG TAG GGG AGA ACC ACT TG-3' (SEQ ID NO: 8)

ABL-R1 Reverse: 5'-CAA GTG GTT CTC CCC TAC CA-3' (SEQ ID NO: 21)

ABL-R2 Reverse: 5'-TCC ACT TCG TCT GAG ATA CTG GAT T-3' (SEQ ID NO: 6)

[00266] Sequencing indicated a 35 bp insertion mutation in 27 patients (1.5%). Most of these samples showed a mixture of mutant and wild-type transcripts (mixed genotype). Rare samples (N = 4) showed 100% alternatively spliced transcript without residual wild-type transcript. Sequence analysis showed that the 35 bp insert is a portion of normal sequence in the *abl* intron 8 that is inserted at the junction of *abl* exon 8 and exon 9 as shown in FIG. 2.

[00267] Nested PCR: The overall sensitivity of direct sequencing is approximately 20%. Therefore, low level transcript of the alternatively spliced *bcr-abl* transcript would not be detected by sequencing. To increase sensitivity of detecting 35 INS BCR-ABL, RT/PCR coupled with hemi-nested PCR was employed. RT/PCR provided the first round amplification of the fusion transcript. The RT/PCR reaction containing the *bcr-abl* kinase domain enriched amplicon was used as a template for a nested PCR reaction targeting *abl* exon 8-9 splice junction where the 35 bp insertion of *abl* introns 8 occurs. The expected size of the amplicon with 35 bp insertion is 253 bp and without the insertion is 218 bp.

[00268] Nested PCR was carried out with the following primers:

[00269] 35 ins-Fwd: (6-Fam) 5'-CGT CTG GGC ATT TGG AGT AT-3' (SEQ ID NO: 22)

[00270] 35 ins-Rev: 5'-TCA AAG GCT TGG TGG ATT TC-3' (SEQ ID NO: 23)

[00271] Analysis of Nested PCR Products: Nested PCR products were analyzed by ABI PRISM® 3100 Genetic analyzer (Applied Biosystems, Foster City, CA) by capillary electrophoresis. The size of the PCR fragments was analyzed by GeneScan® analysis software. The sizes were found to be 253 bp with the 35 bp insert and 218 bp without the insert. The percent of amplicons with insertion was assessed by measuring the ratio of the peak height of the 253 bp fragment to that of the total peak height (253 bp and 218 bp). Only samples having a 253 bp fragment peak >5% of the total peak were considered to be positive for the insertion/truncation mutation.

[00272] The percentage of the alternatively spliced of the total *bcr-abl* transcript is calculated (Table 1). As shown in Table 1, the highest rate of expression of the alternatively spliced *bcr-abl* is in the imatinib-resistant chronic phase CML (73%). Patients resistant to imatinib in Acc/blast phase have a lower rate of expression (21%). In contrast, newly diagnosed patients, in general, do not express the alternatively spliced *bcr-abl* mRNA. The alternatively spliced *bcr-abl* transcript detected in one untreated patient from 29 newly diagnosed patients. This patient had primary resistance and died within one year of diagnosis. Stored samples from patients treated with interferon- α but were resistant to therapy were also tested and only 20% of these patients expressed the alternatively spliced *bcr-abl*, albeit at low levels. The levels of the expression of the alternatively spliced *bcr-abl* varied between samples (Table 1). Only 20% of the patients in the chronic phase who expressed the alternatively spliced *bcr-abl* had a point mutation in the *abl* gene.

[00273] Table 1. Frequency of alternatively spliced *bcr-abl* transcript in CML patients.

Patients	N tested	Positive (%)	% Median (range)	Association with <i>abl</i> point mutation (%)
Resistant Chronic Phase	288	210 (73)	16 (1-100)	42 of 168 (25)
Resistant, Accelerated/Blast phase	38	8 (21)	17 (12-100)	5 of 8 (63)
Newly Diagnosed	29	1 (3)	10	None
Previously treated with INF- α	25	5 (20)	7 (5-20)	Not Available

[00274] The results show that there is more association between kinase therapy resistance and the expression of the alternatively spliced *bcr-abl* in patients in the chronic phase. The frequency of the expression of the alternatively spliced *bcr-abl* in newly diagnosed patients or in patients treated by therapy other than imatinib is low and suggests that imatinib therapy selects for subclones that are capable of expressing the clones that express the alternatively spliced *bcr-abl*.

[00275] Sequence Confirmation: All samples with 253 bp fragment peak >20% of the total peak were confirmed by sequencing. Sequencing was performed in both forward and reverse direction using by dye terminator chemistry and ABI sequencer (Applied Biosystems, Foster City, CA) and using the primers below:

ABL-F1 Forward: 5'-CGC AAC AAG CCC ACT GTC T-3' (SEQ ID NO: 7)

ABL-F2 Forward: 5'-TGG TAG GGG AGA ACC ACT TG-3' (SEQ ID NO: 8)

ABL-R1 Reverse: 5'-CAA GTG GTT CTC CCC TAC CA-3' (SEQ ID NO: 21)

ABL-R2 Reverse: 5'-TCC ACT TCG TCT GAG ATA CTG GAT T-3' (SEQ ID NO: 6)

[00276] Translated amino acid sequence data of the *bcr-abl* insertion mutant was aligned with the wild type sequence *c-abl* oncogene (GenBank cDNA clone NM_005157) using ClustalW software (EMBL). Alignment results indicated that the insertion of 35 bp sequence of *abl* intron 8 at the splice junction of *abl* exon 8 and 9 in *bcr-abl* mRNA created a BCR-ABL protein with 10 novel amino acids inserted after amino acid 474 and a premature stop codon after 10 intron encoded amino acids (amino acid 484) (FIG. 3).

EXAMPLE 3**Splice Variant Prediction**

[00277] To understand the mechanism of insertion of the 35 bp *abl* intron 8 sequence into the junction of *abl* exons 8 and 9 in the *bcr-abl* gene, sequences of *abl* introns 8 and 9, and exons 8 and 9 were analyzed by GrailExp (Computational Biology at Oak Ridge National Laboratory, Oak Ridge, TN, USA) and FGENES (Softberry Inc., Mount Kisco, NY, USA) softwares for possible exon sites. Both softwares predicted that an insertion of 35 bp sequence from *abl* intron 8 between exon 8 and 9 will create an alternatively spliced *bcr-abl* mRNA with a new exon between exons 8 and 9 resulting in an insertion/truncation mutation (Table 2). Thus, the possible mechanism of the 35 bp insertion is aberrant RNA splicing.

[00278] Table 2. The predicted exon regions by two pattern-matching based programs. The numbers are the beginning and the end positions of the predicted exons ("GrailExp" and "FGENES"), and the observed exon positions ("*abl* exon 8" and 35 nucleotide insertion region). The numbering is based on the GenBank NC_000009.

35NT	GrailExp		FGENES		ABL exon 8		35NT insertion region	
Predicted exon region 1	132743694	132743861	132743773	132743865	132743623	132743775		
Predicted exon region 2	132744926	132745072	132744926	132745072			132744926	132745072

EXAMPLE 4**Homology Modeling**

[00279] To understand the effect of the 35 bp insertion mutation on the activity of the BCR-ABL protein, the 3-D structure of the complex of the kinase domain of the mutated BCR-ABL protein with imatinib was compared to the kinase domain of wild-type Abl protein complexed with imatinib.

[00280] A homology model of BCR-ABL insertion/truncation mutant complexed with imatinib was generated using homology modeling software MODELLER, version 9v2 (Fiser, A. & Sali, A., Methods Enzymol. (2003), 374: 461-491) and using the crystal structure of

BCR-ABL complexed with imatinib (chain A, PDB code: 1IEP, Nagar et al., Cancer Res. (2002), 62: 4236-4243) as template. The mutated and wild-type protein sequences of BCR-ABL were aligned using ClustalW software (EMBL). The aligned sequences were used as the input alignment to the MODELLER software and a global energy minimization was performed.

[00281] The modeled structure of the insertion/truncation mutant BCR-ABL protein obtained by the MODELLER software was similar to template wild type BCR-ABL structure. There was a slight conformational change after residue 475 and cutoff after residue 484. No global effect on the structure of BCR-ABL protein was observed due to the mutation despite a global energy minimization was performed in the homology modeling process.

EXAMPLE 5

Molecular Dynamics Simulation

[00282] To further understand the effect of the 35 bp insertion mutation, molecular dynamic simulation of the insertion/truncation mutant BCR-ABL protein was performed using the three dimensional model of the insertion/truncation mutant BCR-ABL protein generated by the MODELLER software as the initial structure.

[00283] The simulated system contains 28,597 atoms (*ABL*: 4,207; imatinib: 68; water: 24,291; sodium ion: 19; chloride ion: 12). All preparation steps were done using the Visual Molecular Dynamics software package version 1.8.6 (Humphrey et al., J. Mol. Graphics (1996), 14:33-38). All molecular dynamics (MD) simulations were performed using the NAMD package, version 2.6 (Larkin et al., Bioinformatics (2007), 23:2947-2948) with the CHARMM27 force field (Mackerell et al., Encyclopedia of Computational Chemistry (1998), Vol. 1 (ed. Schreiner, P.R.) 271-277 (John Wiley & Sons, Chichester) and Brooks et al., J. Comput. Chem. (1983), 4:187-217). Full periodic boundary conditions were used along with the smooth particle mesh Ewald (PME) method (Essman et al., J. Chem. Phys. (1995), 103:8577-8593). Totally, a 20 ns MD production simulation was performed after a 10 ns solvent/ion equilibration simulation.

[00284] Molecular dynamic simulation showed that after 20 ns, the insertion/truncation mutant BCR-ABL protein exhibited major conformational changes in many regions of the Abl domain. Not only the insertion region (after residue 474) but also almost every alpha-

helix of C-loop have significantly different conformations compared the homology model. In N-loop, the C-Helix moved into a different orientation and a position shift relative to the imatinib. Long-time simulations were necessary for studying the mutants of BCR-ABL to catch these global conformational movements.

[00285] The reduction of the interaction between C-helix and imatinib is the main reason of T315I imatinib resistance. The relative movement of C-Helix and nearby residues for T315I, insertion/truncation mutant, and E286K (as a control comparison) was evident. The patterns of C-helix movement were different for these three mutants: T315I showed larger movement for the whole C-helix; while the insertion/truncation mutant showed large movements scattered in different regions; and E286K had larger movement at E286 residue. The different movement patterns of C-helix may suggest that the cause of the movement is due to the packing changes near-T315 in the case of T315I; while in the case of the insertion/truncation mutant, the movement is due to the global conformational changes in many regions.

[00286] To further quantitatively identify the possible effect on the imatinib resistance of the insertion/truncation mutant of BCR-ABL protein, the interaction energy between imatinib and each residue of C-helix is calculated and shown in FIG. 4. In the case of T315I, the interaction energy changes of E286 and M290 are the main contributions of T315I drug resistance. Although the relative position changes of C-helix for the insertion/truncation mutant seem smaller than the changes of T315I, the insertion/truncation mutant in fact exhibited larger interaction changes due to the movement of C-helix and the binding between the imatinib and C-helix is weakened significantly. The calculated relative (to wide-type Abl protein) interaction energies change between C-helix (residues 278 to 290) and imatinib are 3.79 and 5.05 kcal/mole for T315I and 35INS, respectively; while the total binding energies of imatinib are 6.84 and 7.65 kcal/mole higher than wild-type for T315I and the insertion/truncation mutant respectively.

[00287] In the case of T315I, the binding energy losses of T315I/imatinib were mainly due to the relative position changes of residues E286 and M290 to imatinib, T315I mutation caused significant movement (over 40% on residue 280) of the whole C-helix (278-290). Another Abl tyrosine kinase inhibitor drug, nilotinib has close contact with E286, similar to imatinib (Weisberg et al., Br. J. Cancer (2006), 94:1765-1769). Another Abl tyrosine kinase inhibitor drug, dasatinib did not seem to interact directly with E286 residue; however T315I

mutation still causes resistance to dasatinib (Weisberg et al., Br. J. Cancer (2006), 94:1765-1769). The resistance to dasatinib is most likely due to the effects of the T315I on whole C-helix and preventing the formation of an active Src site.

[00288] The interaction between residue M290 and imatinib is not reduced for the insertion/truncation mutant. Based on the simulation results, it seems likely that the insertion/truncation mutant will exhibit similar drug-resistance. The shift of the whole C-helix may suggest that a new drug with significant different binding mode, probably with much less interaction with C-helix but still with the ability to block the direct contact between the C-helix and the activation loop, is needed to overcome the resistance due to T315I and the insertion/truncation mutation.

EXAMPLE 6

[00289] Cloning of a cDNA encoding 35 INS BCR-ABL.

[00290] Plasmid pMIG-p210-BCR-ABL was obtained from Owen N. Witte (Howard Hughes Medical Institute/UCLA). This vector is a mammalian retroviral expression vector having high copy ampicillin resistance (modified pMSCV 2.2). The insertion/mutation construct pMIG-35INS-BCR-ABL was made by site-directed mutagenesis using the QuickChange Kit (Stratagene, La Jolla, CA) using the primers:

BCR/ABL/35INS F1: GAACTCATGC GAGCATACTT TGATAACCGT
GAAGAAAGAA CAAGATAGAA GGTTGGCAGT
GGAATC (SEQ ID NO: 27)

BCR/ABL/35INS R1: GATTCCACTG CCAACCTTCT ATCTTGTTCT
TTCTTCACGG TTATCAAAGT ATGCTCGCAT GAGTTC
(SEQ ID NO: 28).

Authenticity of all constructs was confirmed by DNA sequencing. The vector map is shown in FIG. 5.

EXAMPLE 7

[00291] Transfection of pMIG/35 INS *bcr-abl* into K562 cells

[00292] K562 cells were cultured in RPMI 1640 medium supplemented with 10% heat-inactivated fetal bovine serum. Transfection of K562 cells was accomplished using Fugene™ 6 transfection reagent (Roche, Indianapolis, IN) protocol, holding total DNA content constant, and was performed according to the method described in Zhang et al., J. Biol. Chem. 283: 24047-24060, 2008.

EXAMPLE 8

[00293] Viability of K562 cells transfected with pCMV/GFP/35 INS *bcr-abl* at increasing concentration of imatinib

[00294] K562 cells transfected with the indicated amounts of pMIG/35 INS *bcr-abl* plasmid (0, 0.01, 0.05 or 0.10 μ g), holding total vector concentration constant by adding pMIG “empty vector”, were cultured for 48 hours with imatinib (0, 0.62, 1.25, 2.5 and 10 μ M) 24 hours post-transfection as indicated in FIG. 7. The viability of the cells determined by MTT value for each pMIG/35 INS *bcr-abl* plasmidtransfection level is shown in FIG. 7. Cell viability was observed to increase linearly with increasing amounts of pMIG/35 INS *bcr-abl* plasmid used to transfect the cells. These results demonstrate that the 35 INS *bcr-abl* gene product provides a dose dependent resistance to imatinib sensitivity .

EXAMPLE 9

[00295] Detection of the level of phosphorylation of CrkL at increasing concentration of imatinib.

[00296] K562 cells untransfected or transfected with pMIG/35 INS *bcr-abl* (0.10 μ g) were incubated with various concentrations of imatinib (0, 0.15, 0.31, 0.62, 1.25 and 2.50 μ M) and evaluated for the kinase activity of BCR-ABL demonstrated by phosphorylation of CrkL as described (Chan, et al., Methods Mol. Biol. 2007, 387:83). As shown in FIG. 8, the amount of phosphorylated CrkL in untransfected cells was reduced with increasing imatinib concentration showing that sensitivity of the expressed endogenous full length BCR-ABL to the activity of the drug. In contrast, K562 cells transfected with pMIG/35 INS *bcr-abl*, and which express both full length and the insertion/truncation 35 INS BCR-ABL gene product,

showed little impact on CrkL phosphorylation at the lower doses of imatinib. Thus, expression of 35 INS BCR-ABL gene product in K562 cells conferred resistance to imatinib as evidenced by sustained CrkL phosphorylation at all but the highest doses of imatinib.

EXAMPLE 10

[00297] Proliferation of K562 cells transfected with pMIG/35 INS *bcr-abl* in presence of imatinib.

[00298] K562 cells transfected with varying amounts of pMIG/35 INS *bcr-abl* (0, 0.01, 0.10 μ g) were cultured with (0.62 μ M) or without imatinib and evaluated for cell proliferation by measuring BrdU incorporation as described (Lin et al., Leuk Res. 2002, 26(6):551-9). As shown in FIG. 9, left panel, the fraction of cells synthesizing DNA (right hand peak) was not impacted by the amounts of vector used for transfection. Treatment with imatinib showed a reduction in cell proliferation except when the highest amounts of pMIG/35 INS *bcr-abl* vector (0.10 μ g) was used for transfection. Thus, expression of 35 INS BCR-ABL gene product in K562 cells made them resistant to the cell growth inhibitory effects of imatinib.

EXAMPLE 11

[00299] Detection of expression of BCR-ABL and the insertion/truncation mutant of 35 INS BCR-ABL gene product in CML patients.

[00300] The percentages of 35 INS BCR-ABL relative to full length BCR-ABL gene product in patient samples was determined by RT/PCR coupled with semi-nested PCR as described in Example 2. Lysates prepared from the human cell line K562 and a patient cell sample containing 82.3% of BCR-ABL as 35 INS splice variant were subjected to western blotting to evaluate the relative protein concentration of the 35 INS BCR-ABL mutant. The lysates were immunoprecipitated with either anti-BCR antibody (7c6) (Santa Cruz Biotechnology) or anti-IgG antibody as indicated. The resulting immune-complexes were analyzed by western blotting developed using antibodies to different epitopes of Abl. The ABL K12 antibody (Santa Cruz Biotechnology) is directed against the kinase domain while the H300 antibody (Santa Cruz Biotechnology) is directed against the C-terminus of Abl. The lysates were also analyzed by western blotting with anti-actin antibody as a loading control. The results shown in FIG. 10A identify full length (210 kD) BCR-ABL in K562 cells and both full length (210 kD) and 35 INS truncated BCR-ABL (145 kD) in the patient

sample. The H300 Abl C-terminal specific antibody failed to detect the BCR-ABL 35 INS product confirming that the native C-terminus of the Abl portion of the BCR-ABL 35 INS product was missing as predicted by the encoding sequence from the splice variant.

[00301] FIG. 10B shows six patient samples with various percentages of 35 INS BCR-ABL splice variant evaluated by western blotting using BCR 7c6 antibody for immunoprecipitation and ABL K12 for the developing antibody. The truncated BCR-ABL 35 INS product was visualized in most patient samples.

EXAMPLE 12

[00302] Determination of the effect of BCR-ABL kinase inhibitors on proliferation and caspase 3 activation of K562 cells transfected with BCR-ABL135INS.

[00303] K562 cells were cotransfected with an increasing amount (0 to 100 ng) of plasmid pMIG/35 INS BCR-ABL and 100 ng of either pMIG/BCR-ABL1p210 or empty plasmid (pMIG). At 24 h after transfection, cells were treated for 48 h with various inhibitors: 1.2 μ M imatinib, 5 nM nilotinib, 5 nM dasatinib, 100 nM HHT, or 2 μ M MK0457. The effect of the drugs on cell proliferation was measured by MTT assay (FIG. 18A, right panel; mean $\pm$ S.D; n = 3). Dose response to cell death curves of K562 cells exposed to drugs were generated with the CalcuSyn® software package (Biosoft, Ferguson, MO) for each of at least three experiments. The doses that inhibited proliferation by 50% (IC50) were determined by the median-effect method.

[00304] To perform caspase assays, K562 cells were transiently transfected in 6-well dishes using the above procedure. At 24 h post-transfection, cells were suspended in caspase lysis buffer (10 mM HEPES [pH 7.4], 25 mM NaCl, 0.25% Triton X-100, 1 mM EDTA, and 5 mM dithiothreitol) and normalized for protein content. Typically, 15–25 μ g of lysates were analyzed for protease activity by continuously measuring the release of fluorogenic substrate Ac-DEVD-aminofluoromethylcoumarin product from EMD (San Diego, CA) at 37°C, as described (Capdeville et al., Nat. Rev. Drug Discov. 2002, 1:493).

[00305] Imatinib, nilotinib, and dasatinib induced cell death in K562 cells, whereas transfection with the pMIG/35 INS *bcr-abl* construct induced resistance to cellular death. This pattern of resistance was dose dependent (see Table 3), in that the IC50 increased proportionally with the amount of pMIG/35 INS *bcr-abl* plasmid transfected into the CML

cells. Relative to empty vector (pMIG) or wild-type pMIG/BCR-ABL1p210 vector, transfection with pMIG/35 INS *bcr-abl* vector yielded markedly increased IC₅₀ values for imatinib (2.6-fold), nilotinib (1.7-fold), and dasatinib (1.4-fold). In contrast, 35 INS BCR-ABL expression did not induce resistance to Aurora kinase inhibitor MK0457 or to HHT, an inhibitor of protein synthesis. Therefore, the resistance caused by 35 INS BCR-ABL expression appear to be specific to Abl kinase inhibitors, and not to HHT or Aurora inhibitors. The effect of pCMV/GFP/BCR-ABL1p210 transfection in K562 CML cells was also tested. Expression of wild-type BCR-ABL1p210 did not induce resistance to imatinib, dasatinib, nilotinib, MK0457, or HHT.

Table 3. Effect of pMIG/35 INS *bcr-abl* transfection on IC₅₀ values of various drugs in K562 CML cells

Drug	IC ₅₀ (nM)				
	Empty vector pCMV/GFP	pMIG/35 INS <i>bcr-abl</i>			pMIG/BCR- ABL1p210 0.1 µg DNA
		0.01 µg DNA	0.05 µg DNA	0.1 µg DNA	
Imatinib	474	503	920	1261	407
Nilotinib	42	52	54	71	42
Dasatinib	12	12	14	14	11
HHT	63	61	49	54	54
MK-0457	1809	1998	1985	1536	1792

*IC₅₀ values indicate the median-effect dose in K562 cells carrying the wild-type BCR-ABL1 gene transfected with varying amounts of plasmid containing mutant BCR-ABL1, as determined by MTT assay.

[00306] Induction of apoptosis measured by caspase-3 activation (mean [SD]; n = 3) in K562 cells transfected with the different plasmids as described above and shown in FIG. 12B. Nilotinib and dasatinib are more potent than imatinib. Gene transfer of 35 INS BCR-ABL induced resistance to imatinib, nilotinib, and dasatinib, inhibiting caspase-3 activity, but did not affect the rate of caspase-3 activation in cells treated with MK0457 or HHT. In contrast, control transfection of BCR-ABL1p210 and empty vector did not affect the efficiency of the drugs.

EXAMPLE 13

[00307] Determination of the effect of BCR-ABL kinase inhibitors on tyrosine kinase activity of K562 cells transfected with pMIG/35 INS *bcr-abl*.

[00308] K562 cells were cotransfected with increasing amounts of plasmid encoding pMIG/35 INS *bcr-abl* and either 100 ng of pMIG/BCR-ABL1p210 or the same amount of control vector (empty vector plasmid). At 24 h after transfection, cells were treated for 48 h

with 1.2 μ M imatinib mesylate and subjected to FACS analysis as described (Chan, et al., Methods Mol. Biol. 2007, 387:83). Rabbit polyclonal IgG anti-Lyn, anti-Aurora A, and anti-Aurora B were obtained from Santa Cruz Biotechnology, (Santa Cruz, CA); rabbit polyclonal IgG anti-p-Src, anti-p-Stat5, and anti-p-Crk1 were obtained from Cell Signaling (Danvers, MA). Goat anti-rabbit PE (Santa Cruz Biotechnology) was used as the secondary antibody. LYN, p-CRKL, p-SRC, p-STAT5, and Aurora A and B status were monitored. All experiments were repeated at least three times. Asterisk indicates $p < 0.05$ relative to Control (empty vector). Results are shown in FIG. 12C.

[00309] Tyrosine kinase assay was performed using the Universal Tyrosine Kinase Assay Kit (GenWay Biotech, San Diego, CA) according to the manufacturer's instruction. The universal protein tyrosine kinase substrate peptide, Poly (Glu-Tyr) (4:1, 20-50 kDa) was pre-coated onto 96-well microtiter plates. Serial dilutions of prepared cell extract and 5-point standards (with known tyrosine kinase activities) were added to the plate in triplicates along with an ATP-containing kinase buffer. After incubation at 37°C for 30 min to allow phosphorylation of tyrosine residues, the sample solution was removed and the wells washed with Washing buffer (PBS with 0.05% Tween-20) and blocked with Blocking solution. Anti-phosphotyrosine (PY20)-horse radish peroxidase (HRP) conjugate was then added to the plate. After incubation at 37°C for 30 min, the PY20-HRP solution was replaced by HRP substrate solution (TMBZ). For colorimetric determination of PTK activity, the sample's specific absorbance at 450 nm was calculated from the standard curve. The results are shown in Table 4.

Table 4. Effect of transfection with mutant BCR-ABL1^{35INS} allele on tyrosine kinase (TK) activity in K562 cells exposed to various TK inhibitors

Drug treatment	Relative tyrosine kinase activity (%)		
	Empty vector	BCR-ABL1 ^{p210}	BCR-ABL1 ^{35INS}
None	100	100	100
Imatinib (1.2 μ M)	57.3	87.7	100
Nilotinib (5 nM)	23.4	33.1	76.2
Dasatinib (5 nM)	15.6	20.6	42.7
MK 0457 (2 μ M)	87.3	96.7	100
Homoharringtonine (X μ M)	59.8	79.2	75.4

Experiments were performed in triplicate. TK data are expressed as activity relative to the no-drug control for each group.

[00310] The effect of BCR-ABL kinase inhibitors on phosphorylation state of various substrates (CrkL, LYN, pSRC, pSTAT5, and Aurora A and B) in K562 cells transfected with pMIG/35 INS *bcr-abl* was also investigated (see FIG. 13) using the methods described in Example 9. Imatinib, nilotinib, and dasatinib inhibited phosphorylation of CrkL, a substrate of BCR-ABL kinase, as well as LYN, pSRC, and pSTAT5, but had no effect on Aurora A and B. However, transfection with pMIG/35 INS *bcr-abl* conferred dose-dependent resistance of kinases to inhibition by imatinib. 35 INS BCR-ABL expression had no effect on inhibition by HTT or MK 0457. In a control experiment, transfecting these cells with wild-type pMIG/BCR-ABL1p210 had no effect on the dephosphorylation effects of the various kinases.

EXAMPLE 14

[00311] The effect of BCR-ABL kinase inhibitor combinations on caspase-3 activity and cell death of K562 cells transfected with BCR-ABL135INS.

[00312] The effects of drug combinations were assessed by caspase-3 assay and proliferation assay and the results are shown in FIG. 14. K562 cells transfected with either pMIG/35 INS *bcr-abl* construct or control (empty) vector (CT) were incubated with (A) imatinib and nilotinib or (B) imatinib and dasatinib for 48 hours. The combinations were in a fixed molar ratio (imatinib:nilotinib, 10:1; imatinib:dasatinib, 125:1) based on the IC50 values from Table 3. To assess the effect of imatinib in combination with HTT (molar ratio =

45:1), cells were incubated for 24 hours with HHT and then for another 24 hours with HHT and imatinib. The results are shown in Table 5.

Table 5. Drug combination index values in K562 CML cells with or without K562 BCR-ABL^{35INS}-expression

Drug Combination (ratio) Cell Line	Combination Index Values		
	ED ₅₀	ED ₇₅	ED ₉₀
Imatinib:Nilotinib (10:1)			
K562	0.33	0.78	1.84
K562 BCR-ABL ^{35INS}	0.34	0.92	2.48
Imatinib:Dasatinib (125:1)			
K562	1.59	1.19	0.92
K562 BCR-ABL ^{35INS}	1.45	1.23	1.04
Imatinib:HHT (45:1)*			
K562	0.37	0.79	1.69
K562 BCR-ABL ^{35INS}	0.35	0.69	1.37

* Drug added sequentially.

ED₅₀, median effective dose (as opposed to concentration) at which 50% of individuals exhibit the specified quantal effect.

[00313] The effects of drug combinations on cell proliferation were assessed by MTT assays after incubation of cells for 24 hours with each individual drug and drug combination. The combinations were done either in a fixed molar ratio based on the median effect dose (Dm; drug dose required for 50% inhibition of survival) of each single drug, or in a matrix using five concentrations for each drug that achieve 10% to 50% inhibition alone. The effects of drug combinations were estimated using CalcuSyn software, which was developed based on the median-effect method created by Chou and Talalay (Adv. Enzyme Regul. 1984, 22:27). A calculated combination index (CI) of < 1 indicates synergy; a CI of 1 indicates an additive effect; and a CI of > 1 indicates antagonism. Isobolograms in FIG. 15 show combination index (CI) values plotted against fraction of cells affected. K562 CML cells were transfected either with BCR-ABL135INS construct or empty control vector (CT) after incubation with imatinib and nilotinib (A), imatinib and dasatinib (B) together for 48 hours or (C) Imatinib and HHT combination at a 45:1 molar ratio. Cells were incubated 24 hours with HHT and then for another 24 hours with HHT together with imatinib.

[00314] The combination of imatinib with nilotinib resulted strong synergy. Apoptosis demonstrated by the caspase-3 assay confirmed this synergy. This combination killed BCR-ABL135INS-expressing cells, resistant to imatinib and nilotinib separately, at the same rate as control cells. The combination of imatinib and dasatinib had an additive effect in caspase assays and slightly antagonist to slightly additive as shown in the isobologram. Synergy was

observed when imatinib was given 24 hours after HHT. This result was confirmed by apoptosis assay.

EXAMPLE 15

[00315] Kinetics of BIM induction after treatment with imatinib versus combination of imatinib plus HHT.

[00316] Upregulation of prosurvival Bcl-2 like proteins has been shown to influence response to cancer therapy. Imatinib enhances transcription of several proapoptotic proteins, including BIM (Kuroda et al., Proc. Natl. Acad. Sci. 2006, U.S.A. 103:14097). K562 cells transfected with empty control (CT) vector or pCMV/GFP/35 INS *bcr-abl* were treated with imatinib (A) or imatinib + HHT (B) continuously. Lysates were prepared at the times indicated and examined by caspase-3 assay (left) or by immunoblots using specific antibodies for BIM and actin (right) (see FIG. 16).

[00317] Caspase-3 activation in CML K562 cells increased with time after continuous treatment with imatinib, and this increase was inhibited in cells transfected with the BCR-ABL135INS construct. For caspase-3 induction after sequential addition of HHT and imatinib, at 24 hours, HHT induced apoptosis at the same rate in both cell types. BIM was expressed at increased levels and migrated with faster mobility (due to dephosphorylation) after 24 to 48 hours' incubation with imatinib. K562 cells transfected with pMIG/35 INS *bcr-abl* exhibited reduced BIM expression relative to K562 parental cells. Surprisingly, the level of BIM induced by the combination of drugs was similar in the 2 different cell types. BIM was not induced by HHT treatment at 24 hours.

[00318] While not wishing to be bound by theory, given the requirement of dimerization for kinase activation, it may be that the truncated mutant 35 INS BCR-ABL has a dominant-negative effect on the native BCR-ABL via formation of heterodimers with decreased transphosphorylation. Along with BAD, BIM appears to be an integral component of imatinib-mediated CML cell killing (*Id.*). While not wishing to be bound by theory, the finding that 35 INS BCR-ABL expression reduces BIM overexpression, and that the loss of overexpression can be overcome by cotreatment with imatinib plus HHT, suggests an additional mechanistic reason that BCR-ABL135INS causes resistance to kinase inhibitors.

[00319] Unless otherwise defined, 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 invention belongs. All nucleotide sequences provided herein are presented in the 5' to 3' direction.

[00320] The inventions illustratively described herein may suitably be practiced in the absence of any element or elements, limitation or limitations, not specifically disclosed herein. Thus, for example, the terms "comprising", "including," containing", etc. shall be read expansively and without limitation. Additionally, the terms and expressions employed herein have been used as terms of description and not of limitation, and there is no intention in the use of such terms and expressions of excluding any equivalents of the features shown and described or portions thereof, but it is recognized that various modifications are possible within the scope of the invention claimed.

[00321] Thus, it should be understood that although the present invention has been specifically disclosed by preferred embodiments and optional features, modification, improvement and variation of the inventions embodied therein herein disclosed may be resorted to by those skilled in the art, and that such modifications, improvements and variations are considered to be within the scope of this invention. The materials, methods, and examples provided here are representative of preferred embodiments, are exemplary, and are not intended as limitations on the scope of the invention.

[00322] All publications, patent applications, patents, and other references mentioned herein are expressly incorporated by reference in their entirety, to the same extent as if each were incorporated by reference individually. In case of conflict, the present specification, including definitions, will control.

What is claimed is:

1. An isolated nucleic acid comprising a nucleotide sequence at least 95% identical to at least 40 contiguous nucleotides of SEQ ID NO: 9 or a complement thereof.
2. The nucleic acid of claim 1, wherein said recombinant polynucleotide comprises a nucleotide sequence at least 95% identical to SEQ ID NO: 1 or complement thereof.
3. The nucleic acid of claim 1, wherein said nucleic acid comprises the nucleotide sequence of SEQ ID NO: 1 or a complement thereof.
4. The nucleic acid of any one of claims 1-3, wherein said nucleic acid is present within an expression vector.
5. An isolated polypeptide comprising at least 15 amino acids, wherein the C-terminus of said polypeptide comprises the amino acid sequence of SEQ ID NO.: 10.
6. The polypeptide of claim 5, wherein said polypeptide is at least 95% identical to SEQ ID NO.: 20.
7. The polypeptide of claim 5, wherein said polypeptide is at least 99% identical to SEQ ID NO.: 20.
8. The polypeptide of claim 5, wherein said polypeptide comprises the amino acid sequence of SEQ ID NO.: 20.
9. The polypeptide of any one of claims 5-8, wherein said polypeptide comprises at least 50 amino acids.
10. Cells comprising a recombinant polynucleotide, wherein said recombinant polynucleotide comprises at least 40 contiguous nucleotides of SEQ ID NO: 9 or a complement thereof.
11. The cells of claim 10, wherein said recombinant polynucleotide comprises a nucleotide sequence at least 95% identical to SEQ ID NO: 1 or complement thereof.
12. The cells of claim 10, wherein said recombinant polynucleotide comprises a nucleotide sequence of SEQ ID NO: 1 or complement thereof.

13. The cells of any one of claims 10-12 wherein said cells express a recombinant polypeptide encoded by the recombinant polynucleotide, and wherein said recombinant polypeptide has kinase activity.

14. A kit for detecting the presence or absence of *bcr-abl* splice variant mRNA comprising:

a) a first primer and a second primer, wherein said first primer anneals to a portion of *bcr* exon b2 and said second primer anneals to a region at the junction of *abl* exon 9 and 10, wherein the use of said first and second primers in an amplification reaction is capable of generating an amplicon; and

b) a detectably labeled probe capable of hybridizing to said amplicon, wherein said probe hybridizes to at least 10 contiguous nucleotides of SEQ ID NO: 4 or a complement thereof.

15. The kit of claim 14, wherein said first primer is SEQ ID NO: 5 or a complement thereof.

16. The kit of any one of claims 14-15, wherein said second primer is SEQ ID NO: 6 or a complement thereof.

17. The kit of any one of claims 14-16, further comprising a third and a fourth primer, wherein said third primer anneals to a portion of *abl* exon 8 and said fourth primer anneals to a portion of *abl* exon 9, wherein the use of said first and second primers in an amplification reaction is capable of generating a second amplicon.

18. The kit of claim 17, wherein said third primer is SEQ ID NO: 22 or a complement thereof.

19. The kit of any one of claims 17-18, wherein said fourth primer is SEQ ID NO: 23 or a complement thereof.

20. An antibody that specifically binds to an epitope comprising the amino acid sequence of SEQ ID NO: 12 wherein said antibody specifically binds to an insertion/truncation mutant of BCR-ABL protein and not to a BCR-ABL protein without such mutation.

21. The antibody of claim 20, wherein said antibody is monoclonal.

22. An antibody that specifically binds to an epitope comprising the amino acid sequence of SEQ ID NO: 10 wherein said antibody specifically binds to an insertion/truncation mutant of BCR-ABL protein and not to a BCR-ABL protein without such mutation.

23. The antibody of claim 22, wherein said antibody is monoclonal.

24. A method for identifying the presence or absence of a insertion/truncation mutant of BCR-ABL protein in a sample, comprising:

detecting the presence or absence of a polypeptide comprising at least 15 contiguous amino acids of SEQ ID NO: 12, wherein the presence of said at least 15 contiguous amino acids of SEQ ID NO: 12 in a polypeptide identifies the presence of a insertion/truncation mutant of BCR-ABL protein in a sample.

25. The method of claim 24, wherein the presence or absence of said polypeptide is determined by assessing the size of said BCR-ABL protein.

26. The method of claim 24, wherein the presence or absence of said polypeptide is determined by using an antibody that specifically binds to an epitope comprising the amino acid sequence of SEQ ID NO: 12 wherein said antibody specifically binds to an insertion/truncation mutant of BCR-ABL protein and not to a BCR-ABL protein without such mutation.

27. A method for predicting the likelihood for resistance of a CML patient with a BCR/ABL translocation to treatment with one or more BCR-ABL kinase inhibitors, comprising:

assessing the *bcr-abl* mRNA of the CML patient for the presence or absence of a polynucleotide sequence comprising at least 40 contiguous nucleotides of SEQ ID NO: 9 or a complement thereof; and

indicating that the patient has an increased likelihood of being resistant to treatment with one or more BCR-ABL kinase inhibitors when said polynucleotide sequence or complement thereof is present.

28. The method of claim 27, wherein said one or more kinase inhibitors are selected from a group consisting of imatinib, nilotinib, bosutinib, and dasatinib.

29. The method of claim 28, wherein said one or more kinase inhibitors is imatinib.

30. The method of any one of claims 27-29, further comprising assessing the nucleic acid of the CML patient for the presence or absence of at least one mutation in the *abl* portion of the *bcr-abl* gene, wherein the presence of said at least one mutation in the *abl* portion indicates that the patient has a further increased likelihood of being resistant to treatment with one or more BCR-ABL kinase inhibitors.

31. The method of claim 27, further comprising:

assessing the *bcr-abl* mRNA of the CML patient for the amounts of RNA encoding a full length BCR-ABL, wherein the likelihood of resistance increases with increasing amounts of *bcr-abl* mRNA insertion/truncation splice variant relative to full length *bcr-abl* encoding mRNA.

32. The method of claim 31 wherein the BCR-ABL splice variant is encoded by sequence that comprises SEQ ID NO: 1.

33. A method for predicting likelihood for resistance of a CML patient with a BCR-ABL translocation to treatment with one or more BCR-ABL kinase inhibitors, comprising:

detecting the presence or absence of a polypeptide comprising at least 15 contiguous amino acids of SEQ ID NO: 12; or,

detecting the presence or absence of a polypeptide comprising at least 10 contiguous amino acids of SEQ ID NO: 10,

wherein the presence of said at least 15 contiguous amino acids of SEQ ID NO: 12 or at least 10 contiguous amino acids of SEQ ID NO: 10 in a polypeptide indicates that the patient has an increased likelihood of being resistant to treatment with one or more BCR-ABL kinase inhibitors.

34. A method for treating a patient diagnosed as having CML comprising administering to said patient a synergistic combination of tyrosine kinase inhibitors.

35. The method of claim 34, wherein said combination comprises imatinib or nilotinib.
36. The method of claim 34, wherein said combination comprises imatinib and nilotinib.
37. The method of any one of claims 34-36, wherein at least two of said tyrosine kinase inhibitors are administered simultaneously.
38. The method of any one of claims 37-37, wherein said combination comprises imatinib and HHT.
39. The method of claim 38, wherein said patient is administered HHT prior to being administered imatinib.

1/22

FIGURE 1

CATTGGAGTATTGCTTTGGGAAATTGCTACCTATGGCATGTCCCCTTACCCGGG
AATTGACCTGTCCCAGGTGTATGAGCTGCTAGAGAAGGACTACCGCATGGAGCG
CCCAGAAGGCTGCCAGAGAAGGTCTATGAACTCATGCgtaagccttcacgctgttctcagga
gtatatgtgggcattccaggaaattcaactgtgcaggagtgtgtacacaaagttgaaagttttccatgagctctctccattccagttctca
gatgcagctaattagccatttgctacattgacctttattacagataaatagtagtgctgactgtctttaaagcaaaaatggtattga
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ttttttttttttttgagacggagtttcgctctgtcgccaggctggagtacaatggcgcaatgttgctcactcaacctccacctcct
ggttcaagcgattctcctgcctcagcctcccaagtagctgggattacaggeatgcaccaccgcccggctaattttgtatttttagtaga
gatgggggtttctccatgttagtcaggctggtctccaaactcccaacctcaggtgatctgcctgcctcgccctcccaagtgtgcgattac
aggcgtgagccaccgcccagctgcgaggtgattttatctgctgtttatactgattacatatgtgtatctgtactatgcacacacag
gatgtttcatatatcttataaggtatttatatggccatttctacactgtttccacacatgtcttccacgtccatatattcagatctctccctct
ccctacctcttattatgtatagctgcccagctactccatttcactcaticatccggctctttgatgtgcatttggtgtttacacattgttg
gttttgccttataaacaagcagaacaaatattcatgtacacgaatctctgggcactttggctggtatttctaaaagttgaactgttggtt
ccaagaactgtgtgggttttaattttgatacattttaccaaaactgttaaaaaaggttgccattgtatgctccagtcagacgcatatggga
gtgactgttcctgtgcccagctactaggctttgtcagctctgttagtctctcatgttagtctcatttcatgagaattttttacitcagACTTT
GATAACCGTGAAGAAAGAACAGATAGAAGgtgagctgttggcttagtaattttctacacctactagagcgg
gactgggaaaaatatttgaatgcagttcttctgtcactgtctctctggggtttacaatccatattcctgccagcatctaacgtctttc
aaattcttaattgtctataacaggacatgatgacattcactgtttgactgttgccagcaaaagatggttagcaggattggaatgttgctttcat
tctagacttttcttgagaactgtageccccgtattgctagccagatctcatggatgatctgactgggtttcatctgtccagGTTGGC
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AATGTTCCAGGAATCCAGTATCTCAGACG

(SEQ ID NO: 3)

FIGURE 2

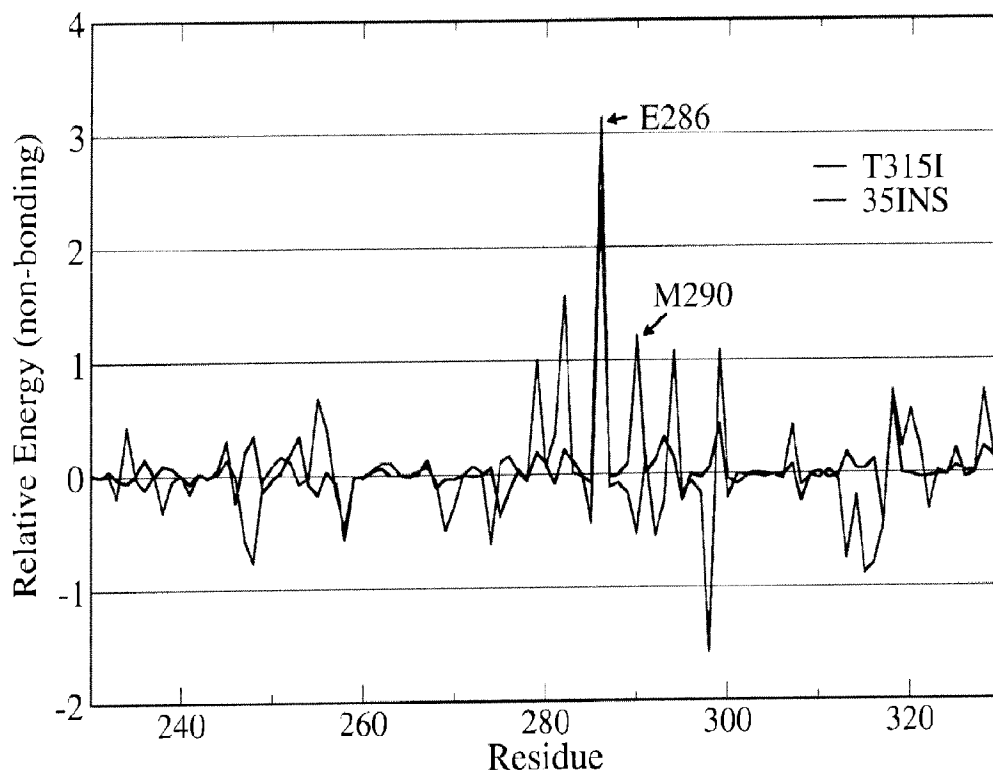
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GAAGAAAGAACAAGATAGAAGggtggcagtggaatccctctgaccggccctcctttgtgaaatccaccaagc
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(SEQ ID NO: 1)

Figure 3

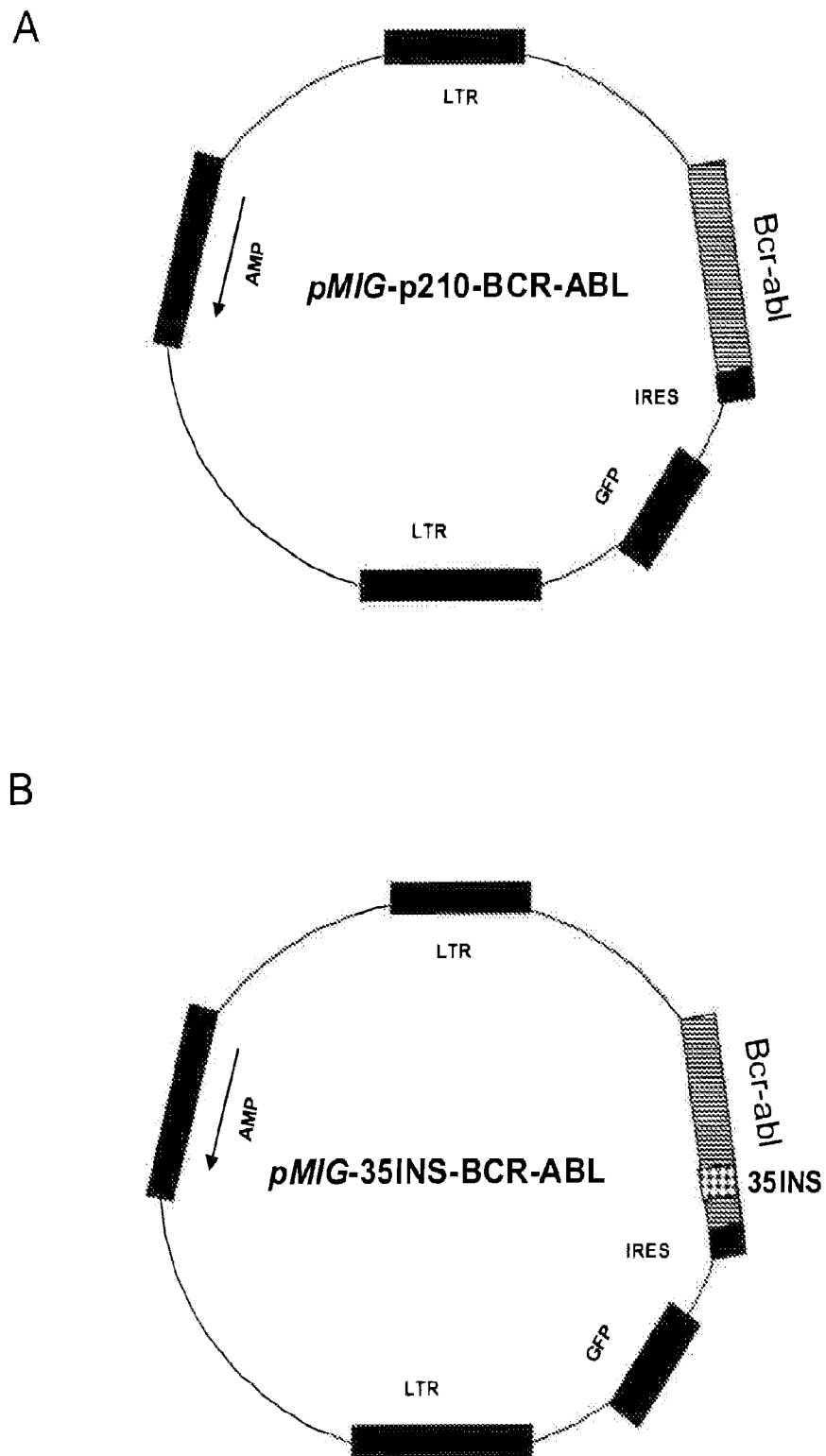
	230	240	250	260	270
	...	...	...	...	...
WT	MDPSSPNYDKWEMERTDITMKHKLGGGQYGEVYEGVWKKYSLTVAVKTLK				
35INS	MDPSSPNYDKWEMERTDITMKHKLGGGQYGEVYEGVWKKYSLTVAVKTLK				
	280	290	300	310	320
	...	...	...	...	...
WT	EDTMEVEEFLKEAAVMKEIKHPNLVQLLGVCTREPPFYIITEFMTYGNLL				
35INS	EDTMEVEEFLKEAAVMKEIKHPNLVQLLGVCTREPPFYIITEFMTYGNLL				
	330	340	350	360	370
	...	...	...	...	...
WT	DYLRECNRQEVSAVVLLYMATQISSAMEYLEKKNFIHRDLAARNCLVGEN				
35INS	DYLRECNRQEVSAVVLLYMATQISSAMEYLEKKNFIHRDLAARNCLVGEN				
	380	390	400	410	420
	...	...	...	...	...
WT	HLVKVADFGLSRLMTGDTYTAHAGAKFPIKWTAPESLAYNKFSIKSDVWA				
35INS	HLVKVADFGLSRLMTGDTYTAHAGAKFPIKWTAPESLAYNKFSIKSDVWA				
	430	440	450	460	470
	...	...	...	...	...
WT	FGVLLWEIATYGMSPYPGIDLSQVYELLEKDYRMERPEGCPEKVYELMRA				
35INS	FGVLLWEIATYGMSPYPGIDLSQVYELLEKDYRMERPEGCPEKVYELMRA				
	480	490			
	...	...	...	...	...
WT	CWQWNPSDRPSFAEIHQAFETMFQ				
35INS	YFD-NREERTR				

FIGURE 4



4/22

FIGURE 5



5/22

FIGURE 6

Relative frequency of individual BCR-ABL kinase domain mutations detected in patients

Amino Acid Sequence of Wild-type BCR-ABL	Amino Acid Sequence of the Kinase Domain Mutant of BCR-ABL	% of Patients Having the Mutation
M 237	M 237 I	<2%
M 244	M 244 V	2-10%
L 248	L 248 V	<2%
G 250	G 250 A	<2%
G 250	G 250 E	2-10%
Q 252	Q 252 R	<2%
Q 252	Q 252 E	<2%
Q 252	Q 252 H	> 10%
Y 253	Y 253 F	2-10%
Y 253	Y 253 H	2-10%
E 255	E 255 V	2-10%
E 255	E 255 K	> 10%
D 276	D 276 G	<2%
V 289	V 289 I	<2%
V 304	V 304 G	<2%
F 311	F 311 I	<2%
F 311	F 311 L	<2%
T 315	T 315 N	<2%
T 315	T 315 I	> 10%
F 317	F 317 L	2-10%
G 321	G 321 E	<2%
M 343	M 343 T	<2%
M 351	M 351 T	> 10%
E 352	E 352 G	<2%
Y 353	Y 353 H	<2%
E 355	E 355 D	<2%
E 355	E 355 G	2-10%
F 359	F 359 A	<2%
F 359	F 359 C	<2%
F 359	F 359 V	2-10%
V 371	V 371 A	<2%
E 373	E 373 G	<2%
V 379	V 379 I	<2%
F 382	F 382 L	<2%
L 387	L 387 M	<2%
T 389	T 389 A	<2%
H 396	H 396 P	<2%
H 396	H 396 R	2-10%
S 417	S 417 Y	<2%
E 459	E 459 K	<2%
F 486	F 486 S	<2%

6/22

FIGURE 7

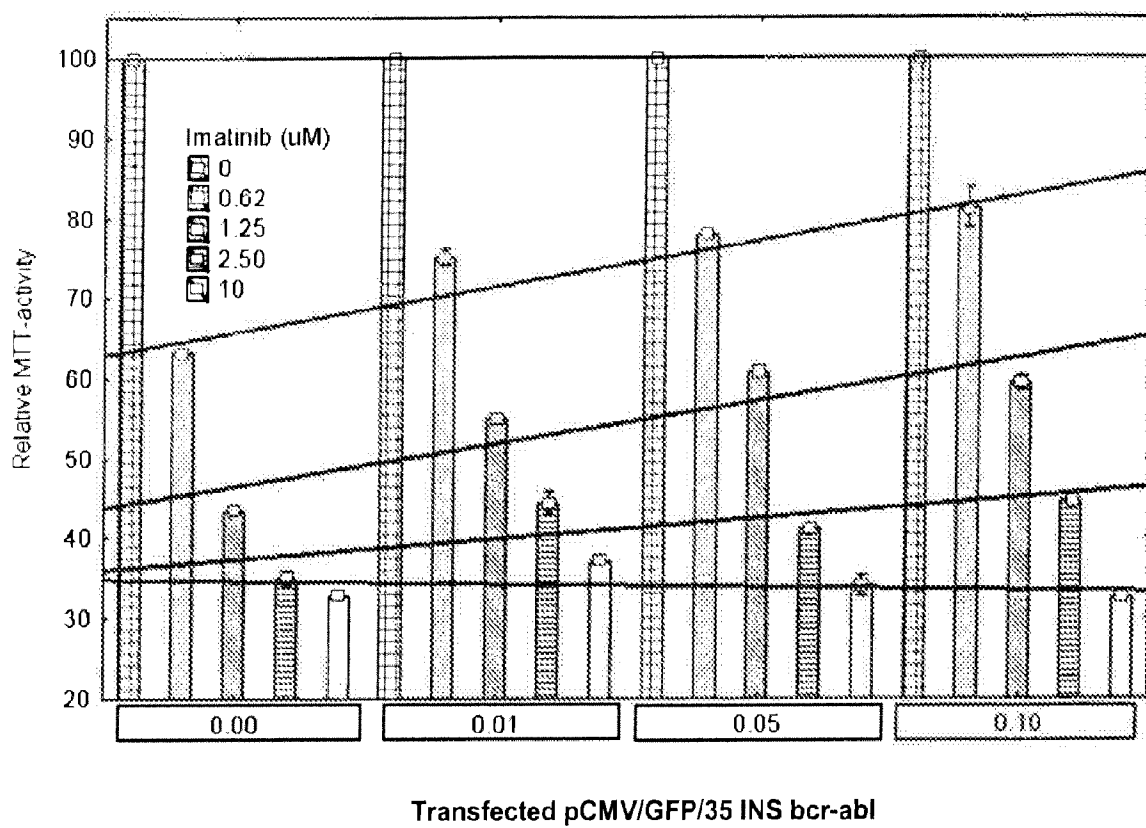


FIGURE 8

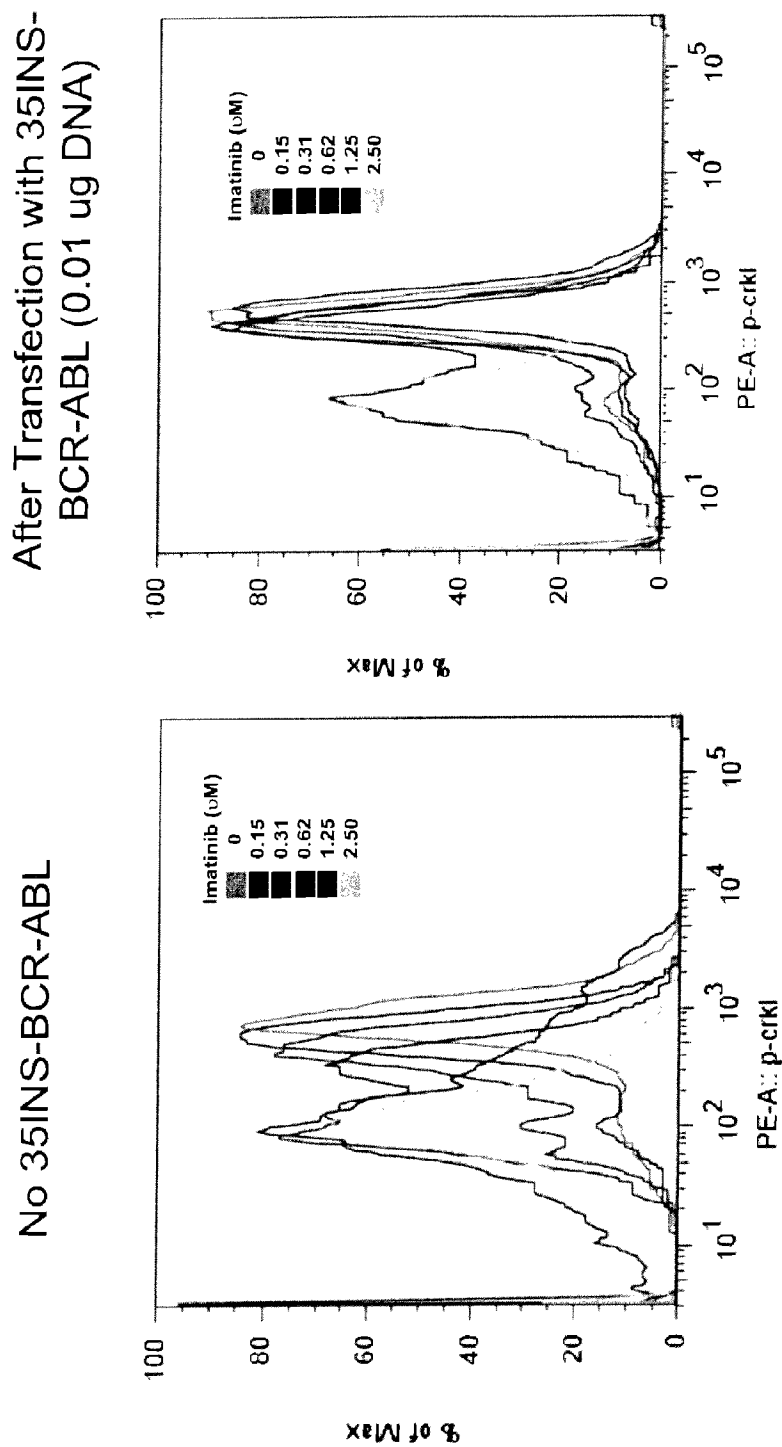


FIGURE 9

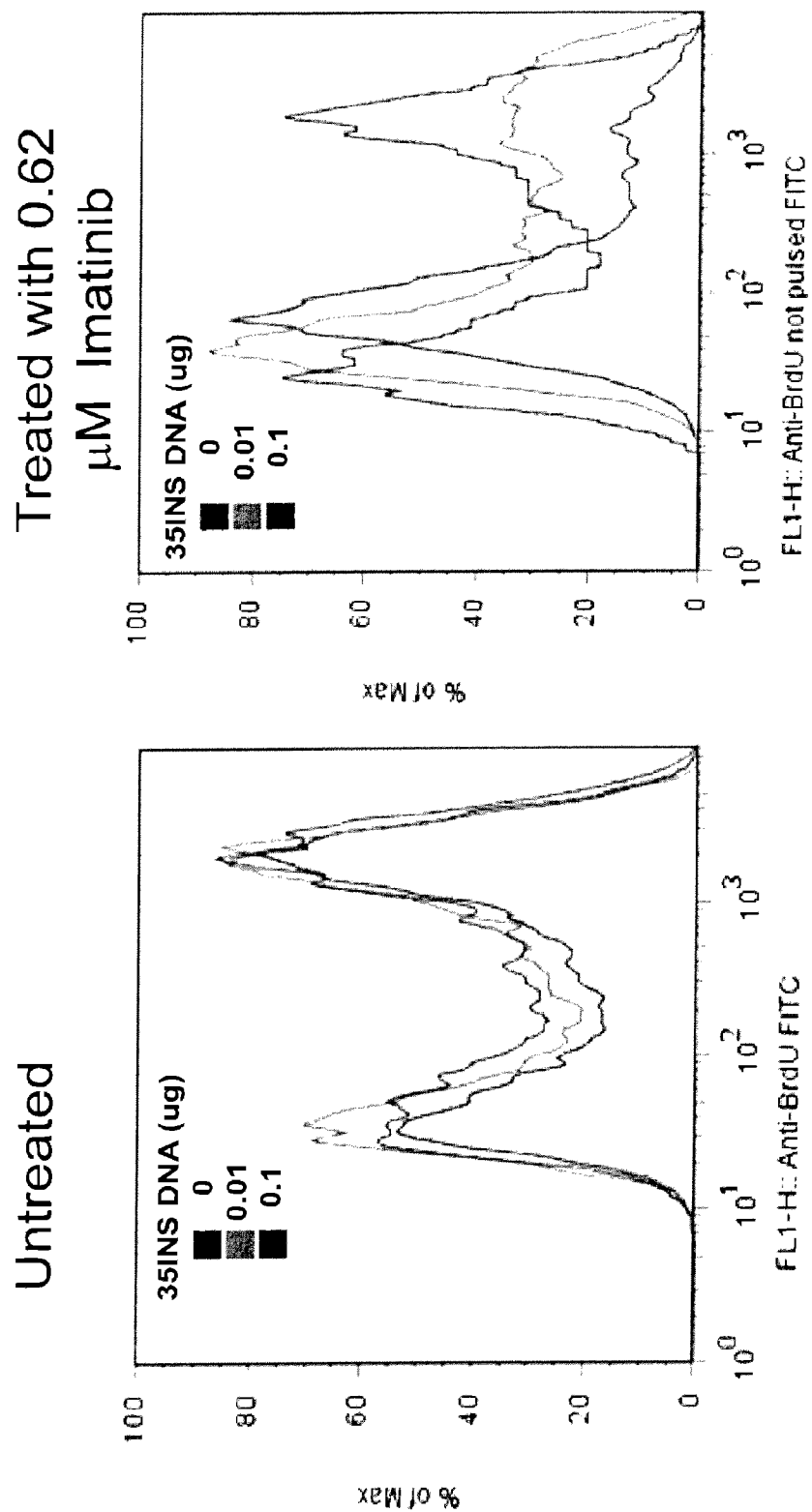
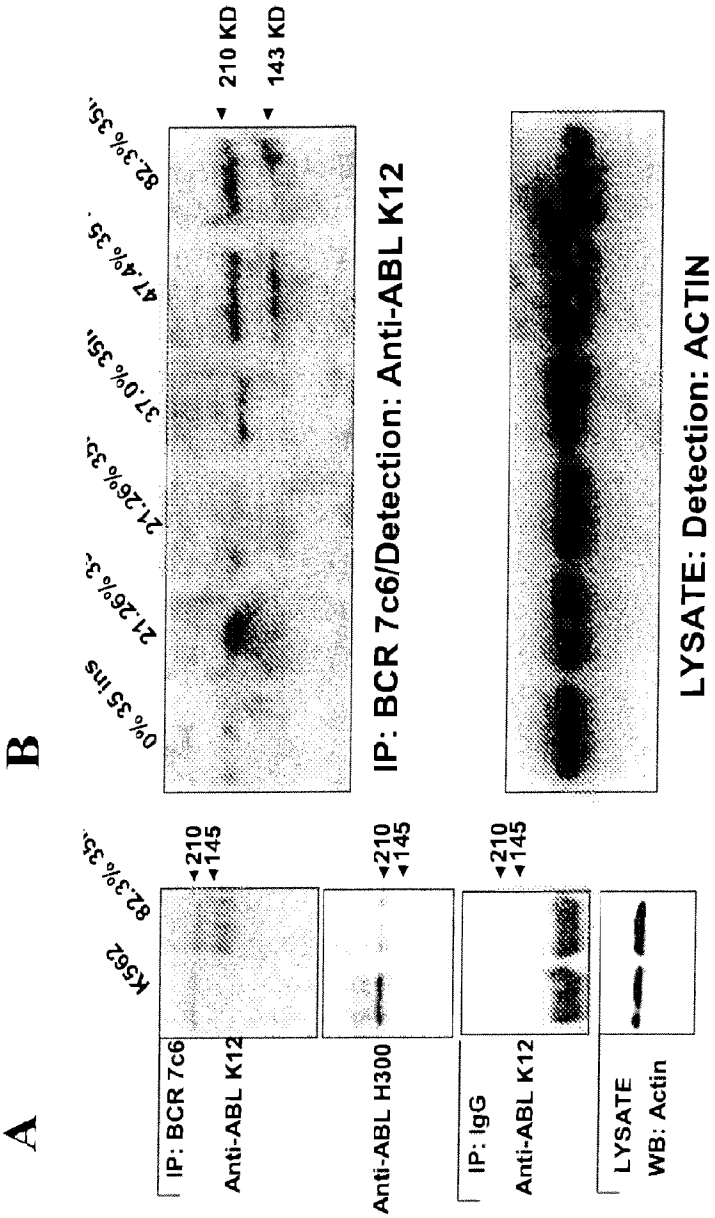


FIGURE 10



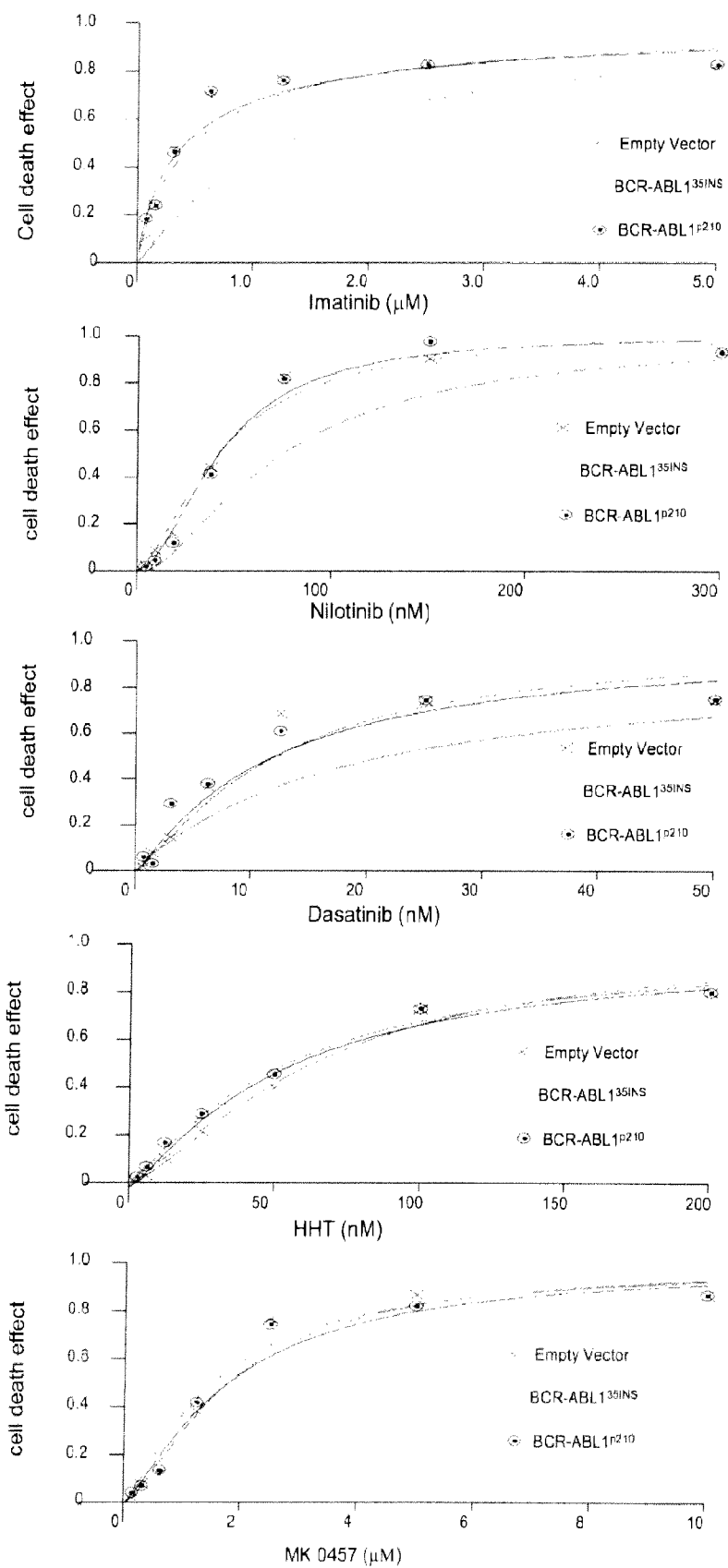
10/22

FIGURE 11

5'-GTAAGCCTTCCTCAGCCTGTTCTCACGAGTATATGTGGGCATTCCAGGAAATT
CAACTGTGCAGGAGTGTGTACACAAAGTTGAAAGTTTTTCCATGAGCTCTCTCCA
TTCCAGTTCTTCAGATGCAGCTAATGTAGCCATTTGCTACCTATTGACCTTTATTT
ACAGATAAATAGTATGTGCGTGACTTGTCTTTTAAAGCAAAAATGGTATTGATAG
ATACCAAACCTGGGTGTATTCCTAAATACAGATTCTGGGCCCTGCTTTCACAGA
CATTCTGCTATAGTAGCTAAGCTCATGAGGTGATTTTTTTTTTTTTTTTTTTTGAGA
CGGAGTTTCGCTCTTGTGCGCCAGGCTGGAGTACAATGGCGCAATGTTGGCTCAC
TTCAACCTCCACCTCCCTGGTTCAAGCGATTCTCCTGCCTCAGCCTCCCAAGTAGC
TGGGATTACAGGCATGCACCACCACGCCCCGGCTAATTTTGTATTTTAGTAGAGA
TGGGGTTTCTCCATGTTAGTCAGGCTGGTCTCCAACCTCCCAACCTCAGGTGATCT
GCCTGCCTCGGCCTCCCAAAGTGCTGCGATTACAGGCGTGAGCCACCACGCCCAG
CTGCGAGGTGATTTTTATCTGGTCGTTTTATACTGATTACATATGTGTTATCTGTA
CTATGCACACACAGGATGTTTTCATATATCTTATAAGGTATTTATATGGCCATTTT
TTACACTGTTTTCCACACATGTCTTTCCACGTCCATATATTCAGATCTCTCCCTCT
CCCTACCTCTTATTTATGTATAGCTGCCCAGTACTCCATTTCACTCATTATCCGG
TCCTCTTTTGATGTGCATTTGGTTGTTTTACACATTTGTTTGGTTTTGCCCTTATA
AACAAAGCAGAAACAAATATTCATGTACACGAATCTCTGGGCACTTTGGCTGGT
ATTTCTAAAAGTTGAACTGTTGGTTCCAAGAACTGTGTGGGTTTTAAATTTTGATA
CATTTTACCAAACCTGTTAAAAAAGGTTGTGCCATTGTATGCTCCAGTCAGACGCA
TATGGGAGTGACTGTTCCCTGGTCCCCAGTACTAGGCTTTGTCAGTCTGTTTAGTCC
TCATGTTAGTCTCATTTTCATGAGAATTTCTTTACTTCAGACTTTGATAACCGTG
AAGAAAGAACAAGATAGAAGGTGAGCTGTTTGGCTTAGTAATTTCTACACCTA
CTAGAGCGGGACTGGGAAAAATATATTTGTAAATGCAGTTCTTGCTGTCAGTGT
TCTCTGGGGTTTTACAATCCATATTCCTGCCAGCATCTAACGTCTTTTCAAATTCT
TAATGTCTATAACAGGACATGATGACATTCATCGTTTTGACTTGTTGCAGCAAAA
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TAGCCCCGTATTGCTAGCCAGATCTCATGGATGATCTGACTTGGGTTTCATCTGTC
CAG-3'

(SEQ ID NO: 3)

11/22
Figure 12A



12/22
Figure 12B

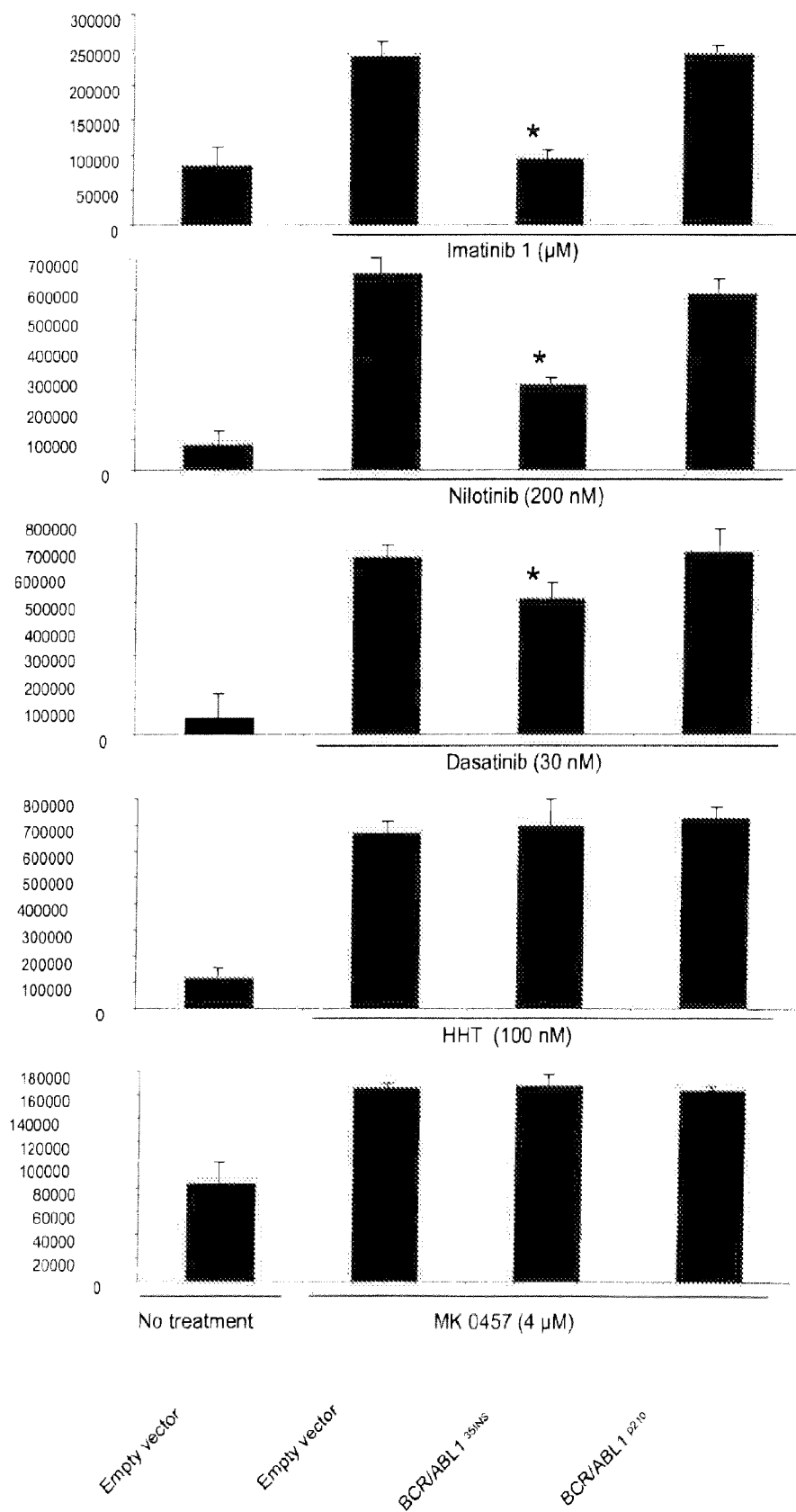


Figure 12C

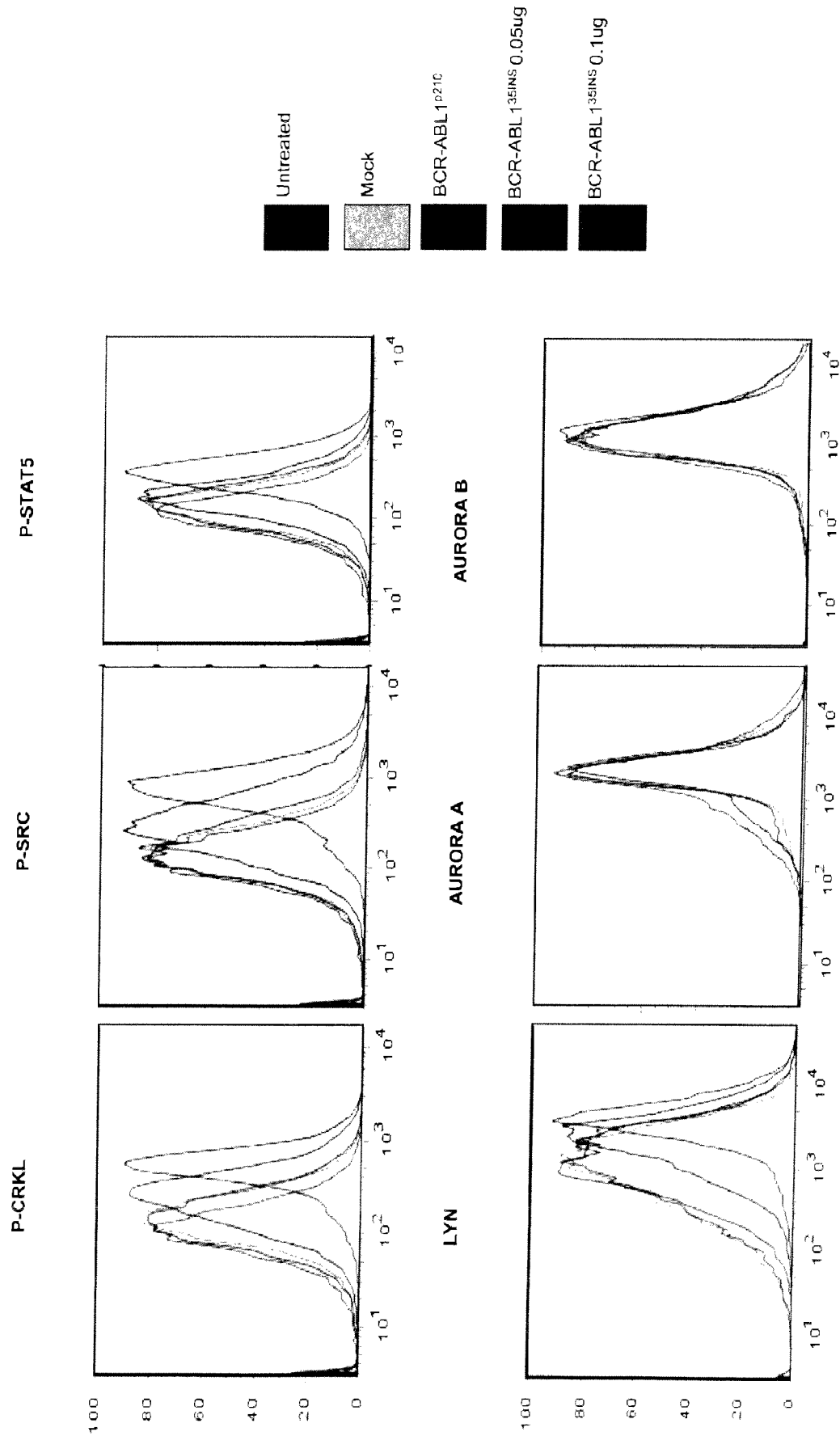
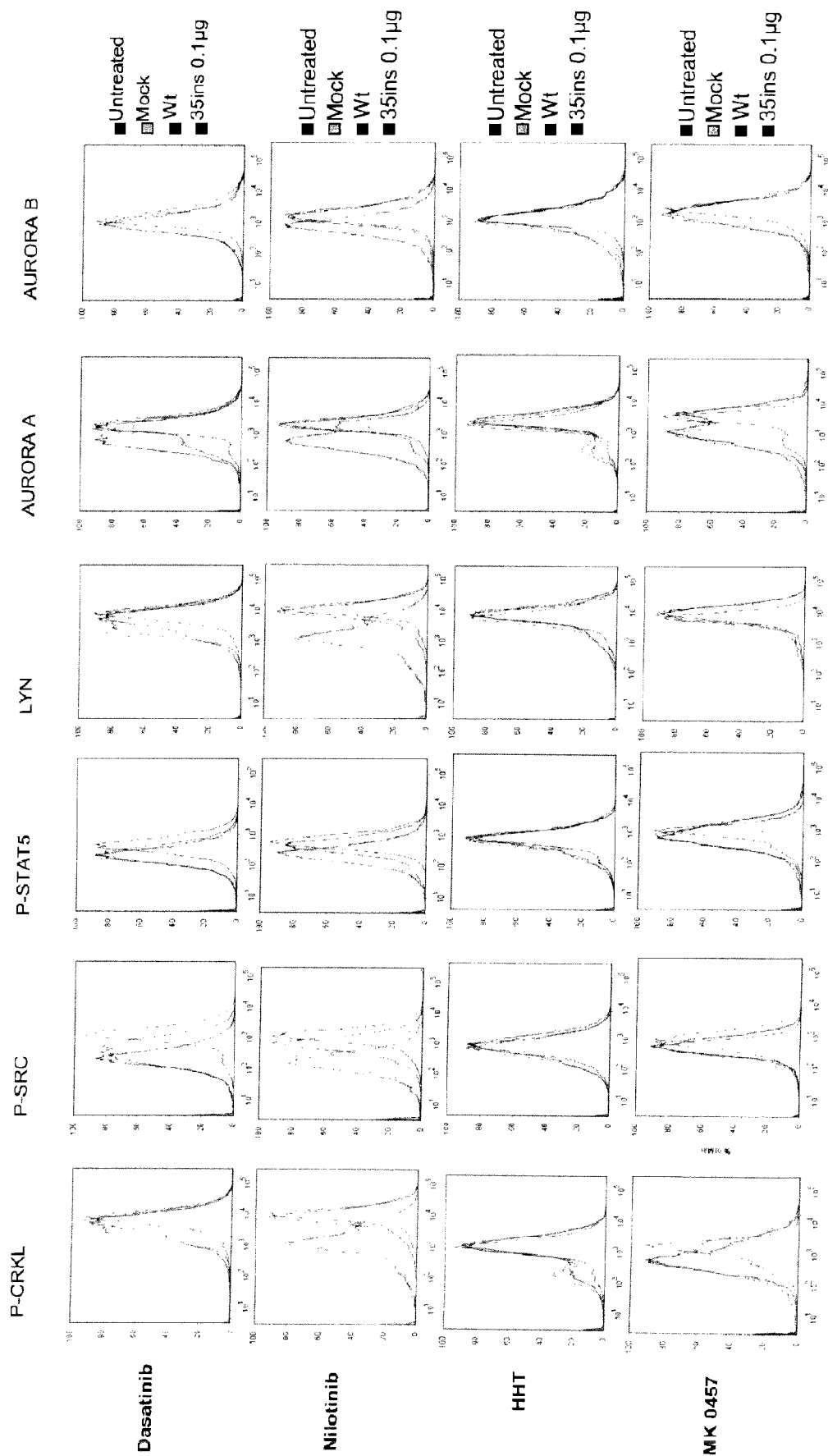


Figure 13



15/22

Figure 14A

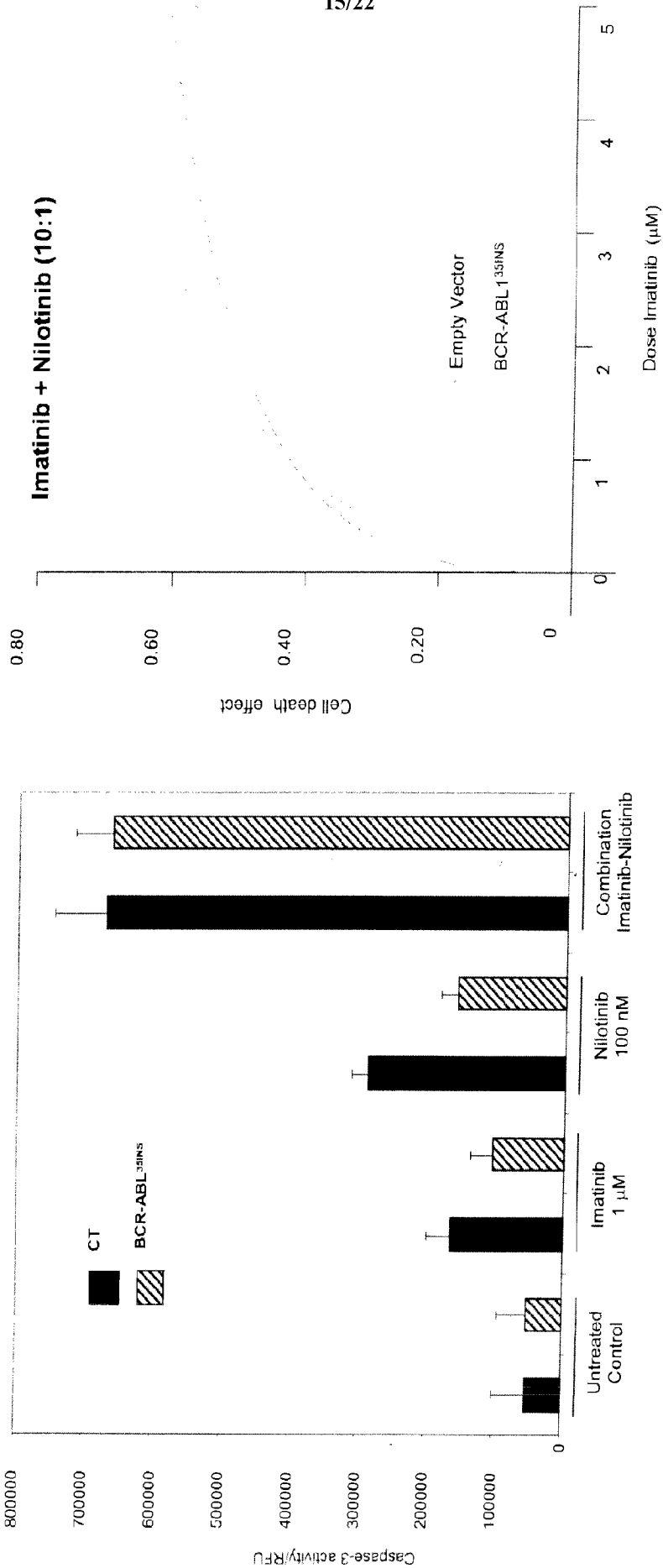


Figure 14B

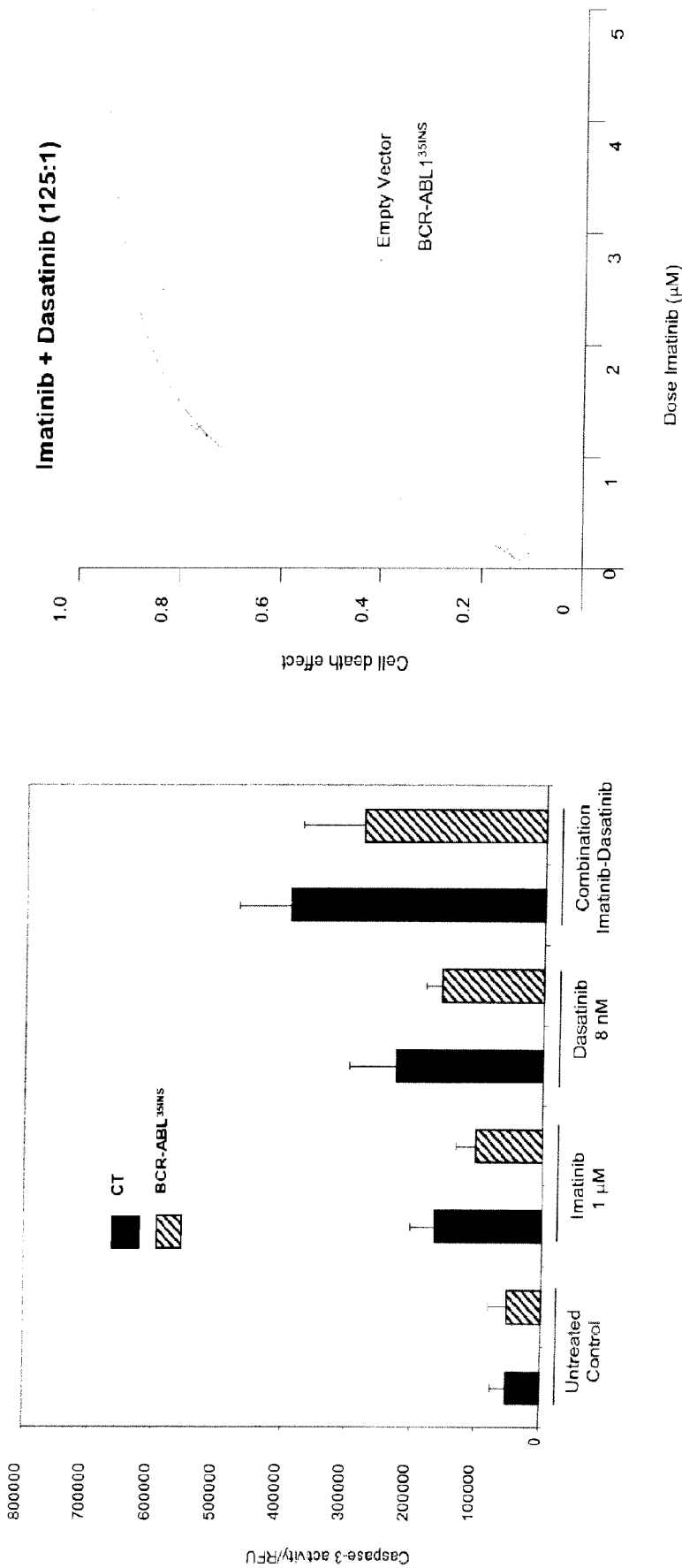


Figure 14C

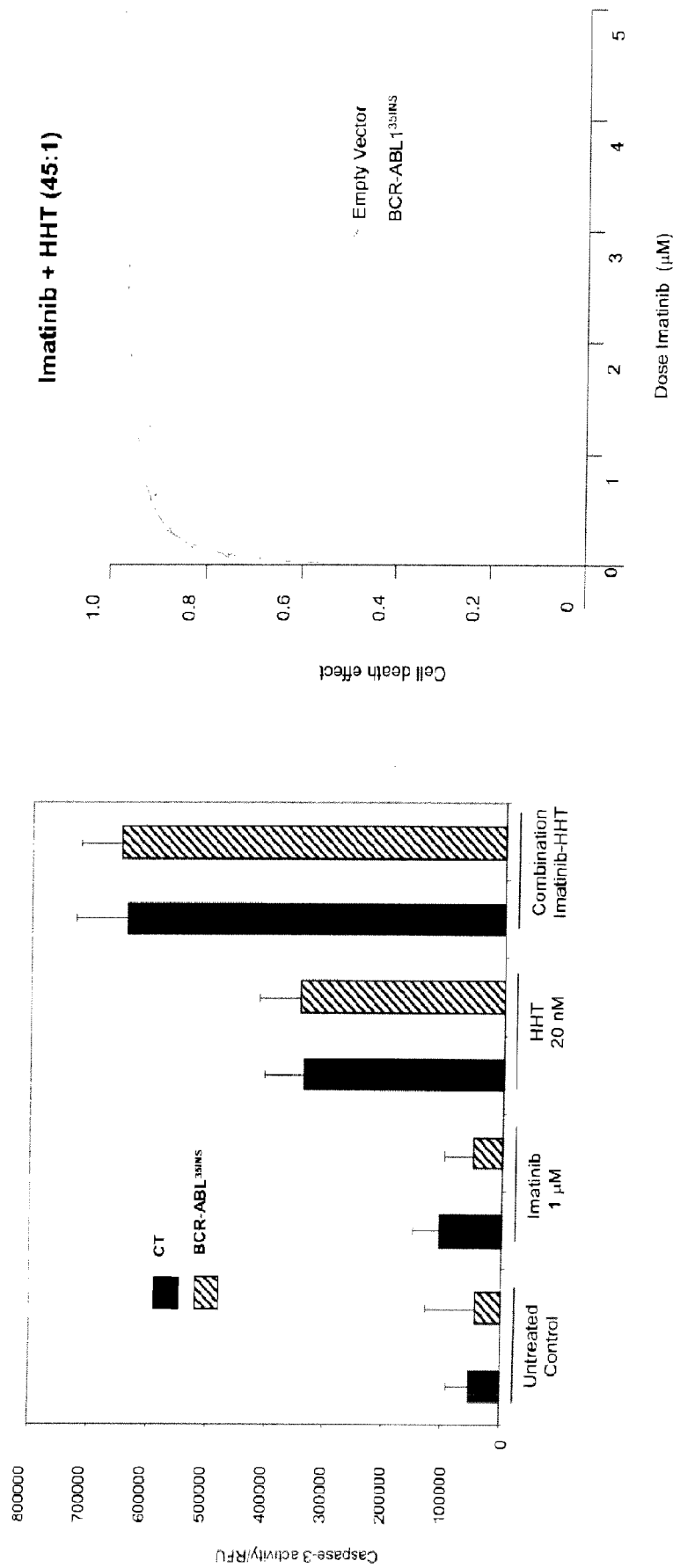


Figure 15A

Imatinib+Nilotinib

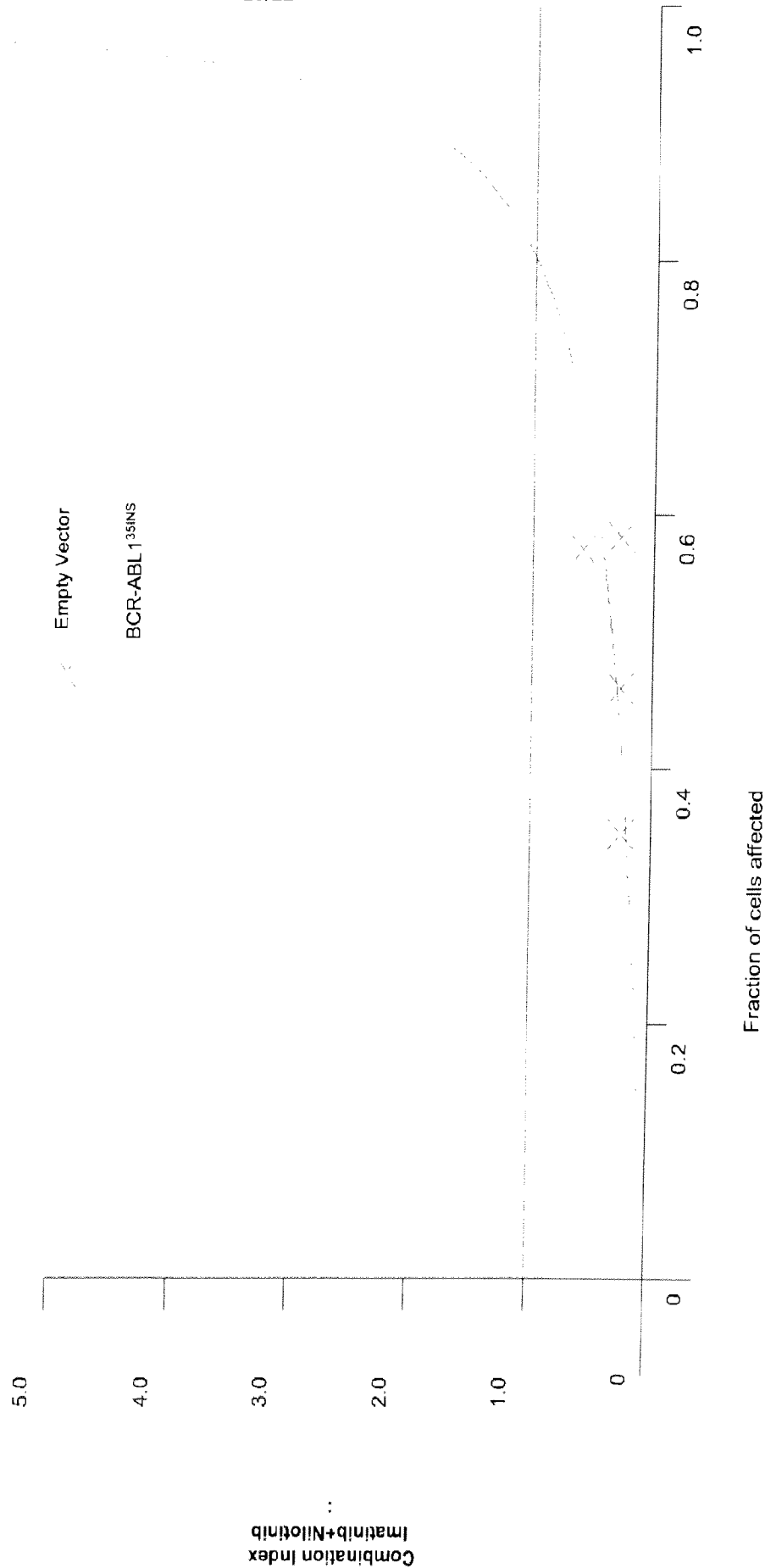


Figure 15B

Imatinib+Dasatinib

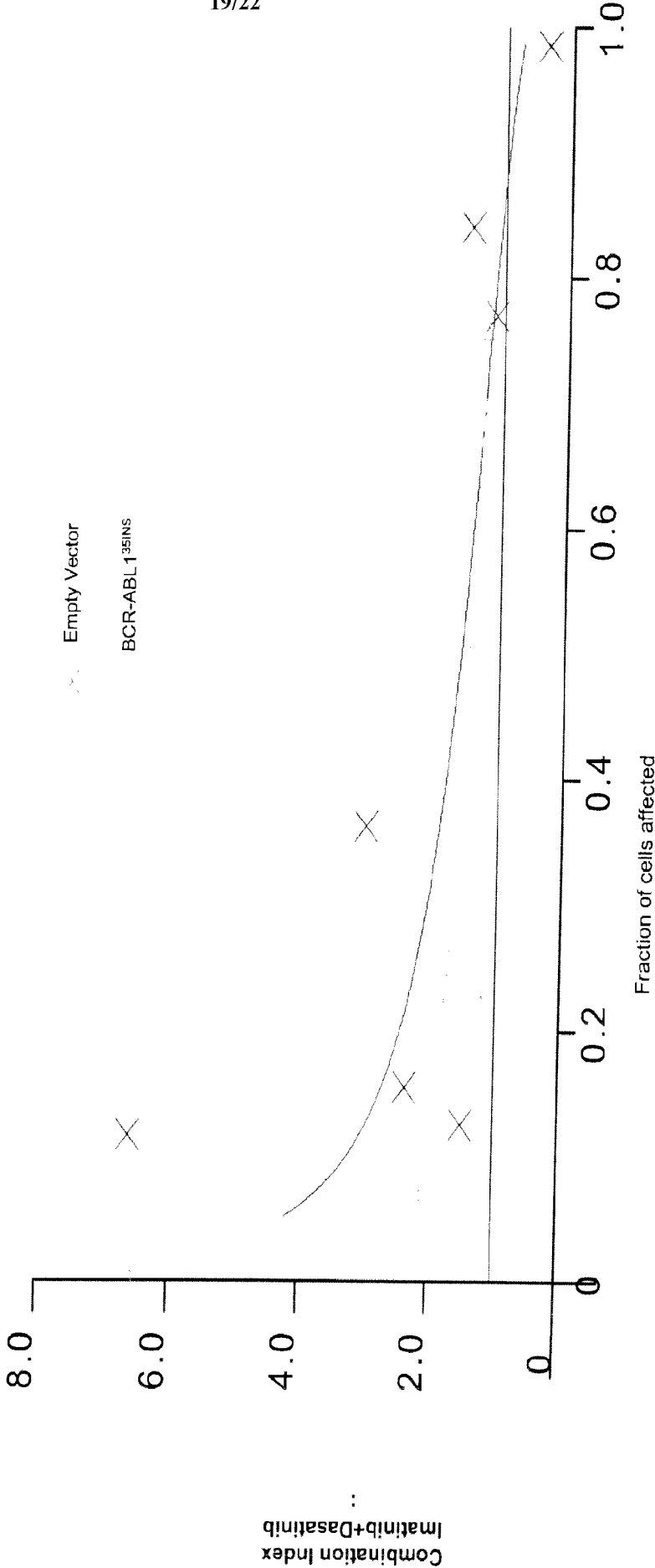


Figure 15C

Imatinib+HHT (sequential)

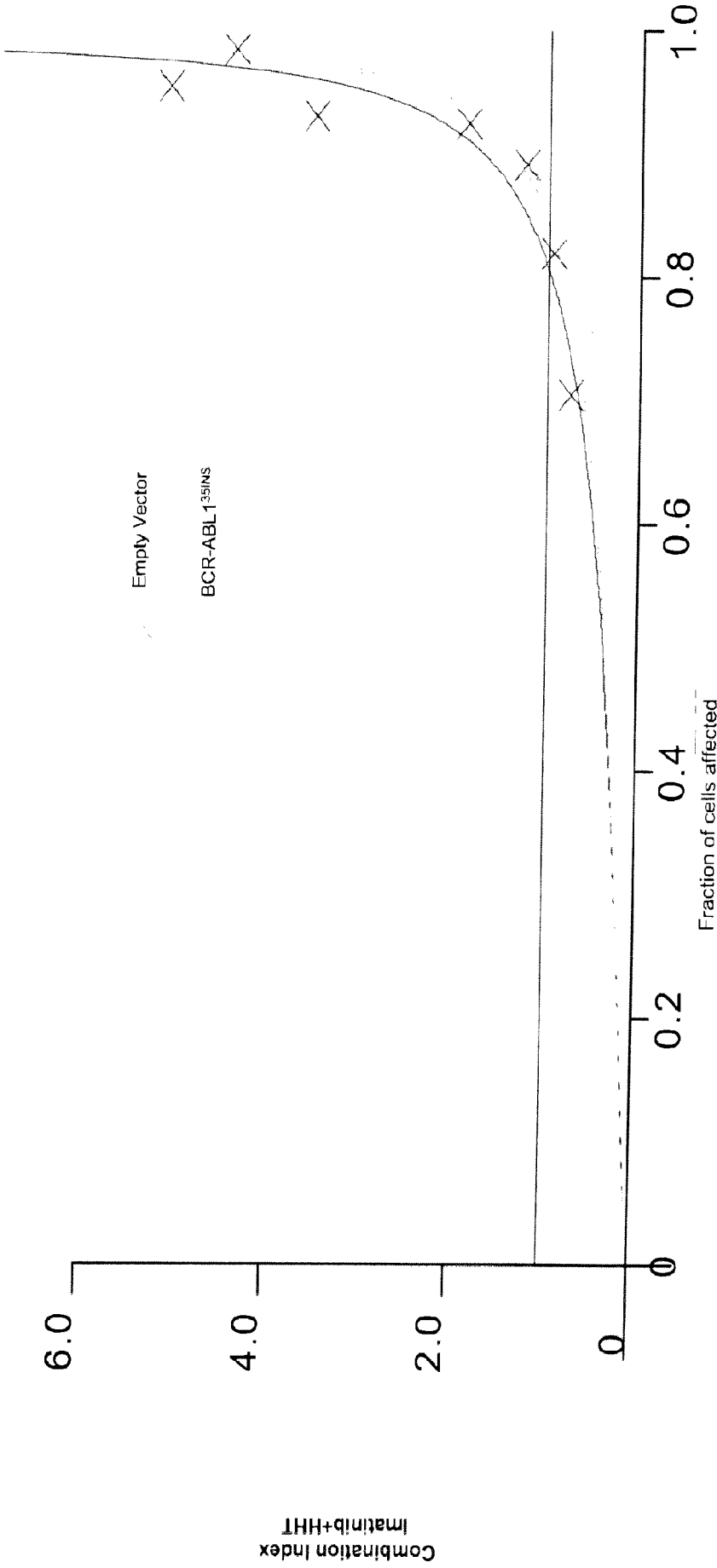


Figure 16A

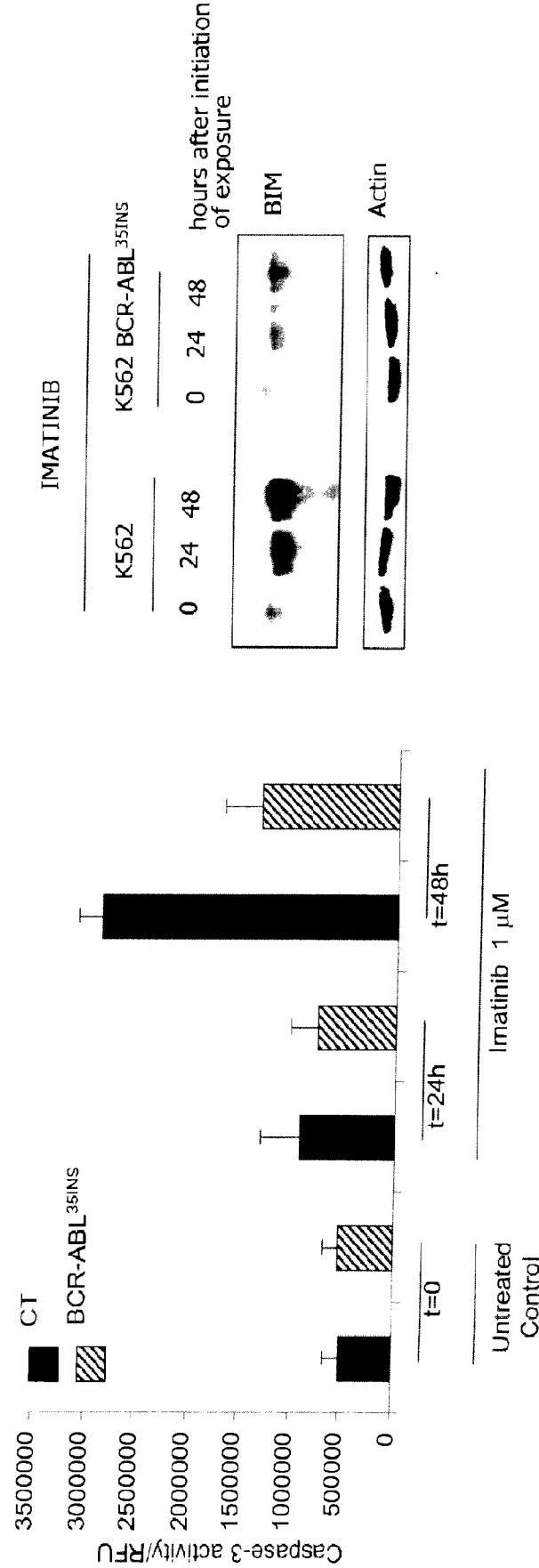


Figure 16B

