METHODS OF TREATING PROSTATE CANCER

CROSS-REFERENCE TO RELATED APPLICATIONS

Not applicable.

FIELD OF THE INVENTION

The present invention relates to the treatment of metastatic hormone-naïve prostate cancer in a human by administering a safe and/or an effective amount of niraparib to such human.

BACKGROUND OF THE INVENTION

Prostate cancer is the most common non-cutaneous malignancy in men and the second leading cause of death in men from cancer in the western world. Prostate cancer results from the uncontrolled growth of abnormal cells in the prostate gland. Once a prostate cancer tumor develops, androgens, such as testosterone, promote prostate cancer tumor growth. At its early stages, localized prostate cancer is often treated with local therapy including, for example, surgical removal of the prostate gland and radiotherapy. However, when local therapy fails to cure prostate cancer, as it does in up to a third of men, the disease progresses into incurable metastatic disease (i.e., disease in which the cancer has spread from one part of the body to other parts).

Treatment of metastatic prostate cancer Androgen deprivation therapy ("ADT") or androgen suppression therapy is performed to reduce the testicular production of testosterone. ADT includes surgical castration (orchiectomy) or the use of luteinizing hormone-releasing hormone ("LHRH") antagonists or agonists. Examples of LHRH antagonists include degarelix. Examples of LHRH agonists include goserelin acetate, histrelin acetate, leuprolide acetate, and triptorelin palmoate.

Abiraterone acetate is a prodrug of abiraterone, inhibits 17α hydroxylase/C17, 20-lyase (cytochrome P450c17 [CYP17]), a key enzyme in androgen biosynthesis. Abiraterone acetate in combination with prednisone has been approved for the treatment of men with

metastatic castration-resistant prostate cancer ("mCRPC") who have received prior chemotherapy containing docetaxel. The efficacy and safety of abiraterone acetate (1,000 mg daily tablet dose) and prednisone (5 mg twice daily) therapy in patients with mCRPC is established by the results of COU-AA-301 and COU-AA-302, both Phase 3, multinational, randomized, double-blind, placebo-controlled studies. Study COU-AA-301 was the first Phase 3 study to demonstrate that further lowering testosterone concentrations below that achieved with androgen deprivation therapy ("ADT") using CYP17 inhibition with abiraterone acetate improves survival in patients with mCRPC. COU-AA-302 demonstrated significantly improved overall survival ("OS") and radiographic progression-free survival ("rPFS") in chemotherapy-naïve patients with mCRPC treated with abiraterone acetate plus prednisone compared with placebo plus prednisone.

What is needed are data to determine whether abiraterone acetate in combination with low-dose prednisone and ADT is superior to ADT alone in improving rPFS and OS in subjects with mHNPC with high-risk prognostic factors.

Thus, the treatment of prostate cancer, including castrate resistant prostate cancer and metastatic castrate resistant prostate cancer, by way of PARP inhibition with niraparib in mCRPC patients, including those with DNA-repair anomalies. This treatment may follow chemotherapy or may be a chemo-naïve subject. This treatment may follow AR-targeted agents, e.g., enzalutamide, apalutamide, and bicalutamide. Therefore, niraparib may present another treatment option.

SUMMARY OF THE INVENTION

The present invention is directed to a method for treating prostate cancer in a human in need of such treatment comprising, consisting of, and/or consisting essentially of administering to the human a therapeutically effective amount of niraparib.

In an embodiment, the present invention is directed to a method of treating prostate cancer in a human in need of such treatment comprising, consisting of, and/or consisting essentially of administering to the human a therapeutically effective amount of niraparib,

wherein the prostate cancer is castration-resistant prostate cancer ("CRPC"), metastatic castration-resistant prostate cancer, and/or antiandrogen- resistant prostate cancer.

In another embodiment, the present invention is directed a method for treating prostate cancer in a human in need of such treatment comprising, consisting of and/or consisting essentially of administering niraparib to a human, wherein the human is carrying at least one DNA repair anomaly selected from the group consisting of BRCA-1, BRCA-2, FANCA, PALB2, CHEK2, BRIP1, HDAC2, and ATM.

In another embodiment, the present invention is directed a method for treating prostate cancer in a human in need of such treatment comprising, consisting of and/or consisting essentially of administering niraparib to a human, wherein the human is carrying at least one DNA repair anomaly that is either BRCA-1 or BRCA-2.

In another embodiment, the present invention is directed to a method of treating prostate cancer in a human in need of such treatment comprising, consisting of, and/or consisting essentially of administering to the human niraparib in an amount of, preferably, from about 30 mg/day to about 400 mg/day, more preferably 300 mg/day, and most preferably once daily oral administration in three 100 mg oral dosage forms.

In another embodiment, the present invention is directed to a composition comprising niraparib for the treatment of prostate cancer, antiandrogen resistant prostate cancer, castration-resistant prostate cancer, and metastatic castration-resistant prostate cancer.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1. Illustrates that niraparib inhibits the growth of human prostate tumor cell lines in vitro.

Figure 2. Illustrates that niraparib suppresses PAR formation in two human prostate tumor cell lines in vitro.

Figure 3. Illustrates that niraparib treatment induces increased γ-H2AX in 22RV1 cells in a dose-dependent manner, as measured by flow cytometry.

Figure 4. Illustrates that niraparib induces γ-H2AX in 22RV1, LNCaP AR-TB, and C4-2B cells in vitro.

Figure 5. Illustrates that niraparib treatment inhibits growth of C4-2B-luc prostate tumors in NSG male mice.

DETAILED DESCRIPTION OF THE INVENTION

The term “subject” refers to a mammal, most preferably a human, who has been or is the object of treatment, observation or experiment.

The term "treatment" refers to the treatment of a subject afflicted with a pathological condition and refers to an effect that alleviates the condition by killing the cancerous cells, but also to an effect that results in the inhibition of the progress of the condition, and includes a reduction in the rate of progress, a halt in the rate of progress, amelioration of the condition, and cure of the condition. Treatment as a prophylactic measure (i.e., prophylaxis) is also included.

The term “therapeutically effective amount” refers to an amount of niraparib that elicits the biological or medicinal response in a tissue system that is being sought by a researcher, veterinarian, medical doctor or other clinician, which includes alleviation or partial alleviation of the symptoms of the disease, syndrome, condition, or disorder being treated.

The term “safe and effective amount” refers to an amount of niraparib that elicits the prevention or amelioration of disease progression and unacceptable toxicity in the human.

The term “composition” refers to a pharmaceutical product that includes the specified ingredients sometimes in therapeutically effective amounts, as well as any product that results, directly, or indirectly, from combinations of the specified ingredients in the specified amounts.

The term “pharmaceutically acceptable” as used herein pertains to compound, materials, compositions and/or dosage forms that are, within the scope of sound medical judgement, suitable for use in contact with the tissues of a human without excessive toxicity, irritations, allergic response, or other problem or complication, commensurate

with a reasonable benefit/risk ratio. Each carrier, excipient, etc. must all be "acceptable" in the sense of being compatible with the other ingredients of the formulation.

The term "androgen receptor" as used herein is intended to include the wild-type androgen receptor as well as androgen-resistant ARs and/or AR mutants associated with castration-resistant prostate cancer.

As used herein, the term "antiandrogen" refers to a group of hormone receptor antagonist compounds that is capable of preventing or inhibiting the biologic effects of androgens on normally responsive tissues in the body. In some embodiments, an anti-androgen is a small molecule. Antiandrogens include enzalutamide, apalutamide, and abiraterone acetate.

As used herein, the term "first-generation anti-androgen" refers to an agent that exhibits antagonist activity against a wild-type AR polypeptide. However, first-generation anti-androgens differ from second-generation anti-androgens in that first-generation anti-androgens can potentially act as agonists in CRPC. Exemplary first-generation anti-androgens include, but are not limited to, flutamide, nilutamide and bicalutamide.

As used herein, the term "second-generation anti-androgen" refers to an agent that exhibits full antagonist activity against a wild-type AR polypeptide. Second-generation anti- androgens differ from first-generation anti-androgens in that second-generation anti-androgens act as full antagonists in cells expressing elevated levels of AR, such as for example, in CRPC. Exemplary second-generation anti-androgens include 4-[7-(6-cyano-5-trifluoromethylpyridin-3-yl)-8-oxo-6-thioxo-5,7-diazaspiro[3.4]oct-5-yl]-2-fluoro-N methylbenzamide (also known as ARN-509; CAS No. 956104-40-8); 4-(3-(4- cyano-3-(trifluoromethyl)phenyl)-5,5-dimethyl-4-oxo-2-thioxoimidazolidin-l-yl)-2-fluoro-N-methylbenzamide (also known as MDV3100 or enzalutamide; CAS No: 915087-33-1) and RD162 (CAS No. 915087-27-3). In some embodiments, a second-generation anti-androgen binds to an AR polypeptide at or near the ligand binding site of the AR polypeptide.

As used herein, the term "third-generation anti-androgen" refers to an agent that exhibits full antagonist activity against a wild-type AR polypeptide and against mutant forms of the AR polypeptide, with mutations arising in the ligand binding domain (LBD) of the AR polypeptide as set forth below. Third-generation anti- androgens retain the differentiation from first-generation anti-androgens in that third-generation anti-androgens act as full antagonists in cells expressing elevated levels of AR, such as for example, in CRPC.

As used herein, the term "mutant" refers to an altered (as compared with a reference) nucleic acid or polypeptide, or to a cell or organism containing or expressing such altered nucleic acid or polypeptide.

As used herein, unless otherwise noted, the term "affect" or "affected" (when referring to a disease, syndrome, condition or disorder that is affected by antagonism of AR) includes a reduction in the frequency and / or severity of one or more symptoms or manifestations of said disease, syndrome, condition or disorder; and / or include the prevention of the development of one or more symptoms or manifestations of said disease, syndrome, condition or disorder or the development of the disease, condition, syndrome or disorder.

Embodiments of the present invention include prodrugs of niraparib. In general, such prodrugs will be functional derivatives of the compounds that are readily convertible *in vivo* into the required compound. Thus, in the methods of treating or preventing embodiments of the present invention, the term "administering" encompasses the treatment or prevention of the various diseases, conditions, syndromes and disorders described with the compound specifically disclosed or with a compound that may not be specifically disclosed, but which converts to the specified compound *in vivo* after administration to a patient. Conventional procedures for the selection and preparation of suitable prodrug derivatives are described, for example, in "Design of Prodrugs", ed. H. Bundgaard, Elsevier, 1985.

Androgen Receptor (AR)

Androgens bind to a specific receptor, the androgen receptor (AR), inside the cells of target tissues. The AR is expressed in numerous tissues of the body and is the receptor through which the physiological as well as the pathophysiological effects of endogenous androgen ligands, such as testosterone (T) and dihydrotestosterone (DHT), are expressed. Structurally, the AR is composed of three main functional domains: the ligand binding domain (LBD), the DNA-binding domain, and amino-terminal domain. A compound that binds to the AR and mimics the effects of an endogenous AR ligand is referred to as an AR agonist, whereas a compound that inhibits the effects of an endogenous AR ligand is termed an AR antagonist. Binding of androgen to the receptor activates it and causes it to bind to DNA binding sites adjacent to target genes. From there it interacts with coactivator proteins and basic transcription factors to regulate the expression of the gene. Thus, via its receptor, androgens cause changes in gene expression in cells. These changes ultimately have consequences on the metabolic output, differentiation or proliferation of the cell that are visible in the physiology of the target tissue. In the prostate, androgens stimulate the growth of prostate tissue and prostate cancer cells by binding to the AR that is present within the cytoplasm of androgen sensitive tissue.

Compounds that selectively modulate AR are of clinical importance in the treatment of or prevention of a variety of diseases, conditions, and cancers, including, but not limited to, prostate cancer, benign prostatic hyperplasia, hirsutism in women, alopecia, anorexia nervosa, breast cancer, acne, musculoskeletal conditions, such as bone disease, hematopoietic conditions, neuromuscular disease, rheumatological disease, cancer, AIDS, cachexia, for hormone replacement therapy (HRT), employed in male contraception, for male performance enhancement, for male reproductive conditions, and primary or secondary male hypogonadism.

Castration Resistant Prostate Cancer

Agents that block the action (antiandrogens) of endogenous hormones (e.g., testosterone) are highly effective and routinely used for the treatment of prostate cancer (androgen ablation therapy). While initially effective at suppressing tumor growth, these androgen ablation therapies eventually fail in almost all cases, leading CRPC. Most, but

not all, prostate cancer cells initially respond to androgen withdrawal therapy. However, with time, surviving populations of prostate cancer cells emerge because they have responded to the selective pressure created by androgen ablation therapy and are now refractory to it. Not only is the primary cancer refractory to available therapies, but cancer cells may also break away from the primary tumor and travel in the bloodstream, spreading the disease to distant sites (especially bone). This is known as metastatic castration resistant prostate cancer ("mCRPC"). Among other effects, this causes significant pain and further bone fragility in the subject.

In some embodiments, the subject's prostate cancer is resistant to or non-responsive to antiandrogen treatment, including, but not limited to, enzalutamide, apalutamide and abiraterone acetate ("antiandrogen resistance").

The preparation of niraparib, 2-[4-[(3S)-piperidin-3-yl]phenyl]indazole-7-carboxamide, may be found in U.S. Patent No. 8,071,623, issued on December 6, 2011 and entitled Amide Substituted Indazoles as Poly(ADP-Ribose)Polymerase (PARP) Inhibitors, which claims the benefit of U.S. provisional patent application No. 60/921,310, filed on February 16, 2010., as well as U.S. Patent No. 8,436,185, issued on May 7, 2013 and entitled Pharmaceutically Acceptable Salts of 2-[4-[(3S)-piperidin-3-yl]phenyl]-*2H*-indazole-7-carboxamide, which claims the benefit of U.S. provisional patent application No. 61/010,333 filed on January 8, 2008, each of which is incorporated herein by reference.

The invention also provides pharmaceutical compositions comprising niraparib and a pharmaceutically acceptable carrier. The pharmaceutical compositions containing the active ingredient may be in a form suitable for oral use, for example, as tablets, troches, lozenges, aqueous or oily suspensions, dispersible powders or granules, emulsions, hard or soft capsules, or syrups or elixirs.

Compositions intended for oral use may be prepared according to any method known to the art for the manufacture of pharmaceutical compositions and such compositions may contain one or more agents selected from the group consisting of sweetening agents, flavoring agents, coloring agents and preserving agents in order to

provide pharmaceutically elegant and palatable preparations. Tablets contain the active ingredient in admixture with non-toxic pharmaceutically acceptable excipients which are suitable for the manufacture of tablets. These excipients may be for example, inert diluents, such as calcium carbonate, sodium carbonate, lactose, calcium phosphate or sodium phosphate; granulating and disintegrating agents, for example, microcrystalline cellulose, sodium croscarmellose, corn starch, or alginic acid; binding agents, for example starch, gelatin, polyvinyl-pyrrolidone or acacia, and lubricating agents, for example, magnesium stearate, stearic acid or talc. The tablets may be uncoated or they may be coated by known techniques to mask the unpleasant taste of the drug or delay disintegration and absorption in the gastrointestinal tract and thereby provide a sustained action over a longer period. For example, a water-soluble taste masking material such as hydroxypropyl-methylcellulose or hydroxypropylcellulose, or a time delay material such as ethyl cellulose, cellulose acetate butyrate may be employed.

Formulations for oral use may also be presented as hard gelatin capsules wherein the active ingredient is mixed with an inert solid diluent, for example, calcium carbonate, calcium phosphate or kaolin, or as soft gelatin capsules wherein the active ingredient is mixed with water-soluble carrier such as polyethyleneglycol or an oil medium, for example peanut oil, liquid paraffin, or olive oil.

Aqueous suspensions contain the active material in admixture with excipients suitable for the manufacture of aqueous suspensions. Such excipients are suspending agents, for example sodium carboxymethylcellulose, methylcellulose, hydroxypropylmethyl-cellulose, sodium alginate, polyvinylpyrrolidone, gum tragacanth and gum acacia; dispersing or wetting agents may be a naturally-occurring phosphatide, for example lecithin, or condensation products of an alkylene oxide with fatty acids, for example polyoxyethylene stearate, or condensation products of ethylene oxide with long chain aliphatic alcohols, for example heptadecaethyleneoxycetanal, or condensation products of ethylene oxide with partial esters derived from fatty acids and a hexitol such as polyoxyethylene sorbitol monooleate, or condensation products of ethylene oxide with partial esters derived from fatty acids and hexitol anhydrides, for example polyethylene

sorbitan monooleate. The aqueous suspensions may also contain one or more preservatives, for example ethyl, or n-propyl p-hydroxybenzoate, one or more coloring agents, one or more flavoring agents, and one or more sweetening agents, such as sucrose, saccharin or aspartame.

Oily suspensions may be formulated by suspending the active ingredient in a vegetable oil, for example arachis oil, olive oil, sesame oil or coconut oil, or in mineral oil such as liquid paraffin. The oily suspensions may contain a thickening agent, for example beeswax, hard paraffin or cetyl alcohol. Sweetening agents such as those set forth above, and flavoring agents may be added to provide a palatable oral preparation. These compositions may be preserved by the addition of an anti-oxidant such as butylated hydroxyanisol or alpha-tocopherol.

Dispersible powders and granules suitable for preparation of an aqueous suspension by the addition of water provide the active ingredient in admixture with a dispersing or wetting agent, suspending agent and one or more preservatives. Suitable dispersing or wetting agents and suspending agents are exemplified by those already mentioned above. Additional excipients, for example sweetening, flavoring and coloring agents, may also be present. These compositions may be preserved by the addition of an anti-oxidant such as ascorbic acid.

The pharmaceutical compositions of the invention may also be in the form of an oil-in-water emulsion. The oily phase may be a vegetable oil, for example olive oil or arachisoil, or a mineral oil, for example liquid paraffin or mixtures of these. Suitable emulsifying agents may be naturally occurring phosphatides, for example soy bean lecithin, and esters or partial esters derived from fatty acids and hexitol anhydrides, for example sorbitan monooleate, and condensation products of the said partial esters with ethylene oxide, for example polyoxyethylene sorbitan monooleate. The emulsions may also contain sweetening, flavoring agents, preservatives and antioxidants.

Syrups and elixirs may be formulated with sweetening agents, for example glycerol, propylene glycol, sorbitol or sucrose. Such formulations may also contain a demulcent, a preservative, flavoring and coloring agents and antioxidant. The

pharmaceutical compositions may be in the form of a sterile injectable aqueous solution. Among the acceptable vehicles and solvents that may be employed are water, Ringer's solution and isotonic sodium chloride solution.

The sterile injectable preparation may also be a sterile injectable oil-in-water microemulsion where the active ingredient is dissolved in the oily phase. For example, the active ingredient may be first dissolved in a mixture of soybean oil and lecithin. The oil solution then introduced into a water and glycerol mixture and processed to form a microemulsion.

The injectable solutions or microemulsions may be introduced into a patient's blood stream by local bolus injection. Alternatively, it may be advantageous to administer the solution or microemulsion in such a way as to maintain a constant circulating concentration of the instant compound. In order to maintain such a constant concentration, a continuous intravenous delivery device may be utilized. An example of such a device is the Deltec CADD-PLUS™ model 5400 intravenous pump.

The pharmaceutical compositions may be in the form of a sterile injectable aqueous or oleagenous suspension for intramuscular and subcutaneous administration. This suspension may be formulated according to the known art using those suitable dispersing or wetting agents and suspending agents which have been mentioned above. The sterile injectable preparation may also be a sterile injectable solution or suspension in a non-toxic parenterally acceptable diluent or solvent, for example as a solution in 1,3-butanediol. In addition, sterile, fixed oils are conventionally employed as a solvent or suspending medium. For this purpose, any bland fixed oil may be employed including synthetic mono- or diglycerides. In addition, fatty acids such as oleic acid find use in the preparation of injectables.

Niraparib may also be administered in the form of suppositories for rectal administration of the drug. These compositions can be prepared by mixing the drug with a suitable non-irritating excipient which is solid at ordinary temperatures but liquid at the rectal temperature and will therefore melt in the rectum to release the drug. Such materials include cocoa butter, glycerinated gelatin, hydrogenated vegetable oils, mixtures of

polyethylene glycols of various molecular weights and fatty acid esters of polyethylene glycol.

For topical use, creams, ointments, jellies, solutions or suspensions, etc., containing the instant compounds are employed. (For purposes of this application, topical application shall include mouth washes and gargles.)

Niraparib can be administered in intranasal form via topical use of suitable intranasal vehicles and delivery devices, or via transdermal routes, using those forms of transdermal skin patches well known to those of ordinary skill in the art. To be administered in the form of a transdermal delivery system, the dosage administration will, of course, be continuous rather than intermittent throughout the dosage regimen. Niraparib may also be delivered as a suppository employing bases such as cocoa butter, glycerinated gelatin, hydrogenated vegetable oils, mixtures of polyethylene glycols of various molecular weights and fatty acid esters of polyethylene glycol.

When niraparib is administered to a subject, the selected dosage level will depend on a variety of factors including, but not limited to, the activity of the particular compound, the severity of the individual's symptoms, the route of administration, the time of administration, the rate of excretion of the compound, the duration of the treatment, other drugs, compounds, and/or materials used in combination, and the age, sex, weight, condition, general health, and prior medical history of the patient. The amount of niraparib and route of administration will ultimately be at the discretion of the physician, although generally the dosage will be to achieve local concentrations at the site of action which achieve the desired effect without causing substantial harmful or deleterious side-effects.

Administration in vivo can be effected in one dose, continuously or intermittently (e.g. in divided doses at appropriate intervals) throughout the course of treatment. Methods of determining the most effective means and dosage of administration are well known to those of skill in the art and will vary with the formulation used for therapy, the purpose of the therapy, the target cell being treated, and the subject being treated. Single or multiple administrations can be carried out with the dose level and pattern being selected by the treating physician.

In general, a suitable dose of niraparib is in the range of about 100 μg to about 250 mg per kilogram body weight of the subject per day. Where the active compound is a salt, an ester, prodrug, or the like, the amount administered is calculated on the basis of the parent compound and so the actual weight to be used is increased proportionately.

A therapeutically effective amount of niraparib or a pharmaceutical composition thereof for the treatment of prostate cancer includes a dose range from about 30 mg/day to about 400 mg/day of niraparib, or any particular amount or range therein, in particular about 300 mg/day, and once daily oral administration in three 100 mg oral dosage forms. Optimal dosages of niraparib to be administered may be readily determined and will vary with the particular compound used, the mode of administration, the strength of the preparation and the advancement of the disease, syndrome, condition or disorder. In addition, factors associated with the particular subject being treated, including subject gender, age, weight, diet and time of administration, will result in the need to adjust the dose to achieve an appropriate therapeutic level and desired therapeutic effect. The above dosages are thus exemplary of the average case. There can be, of course, individual instances wherein higher or lower dosage ranges are merited, and such are within the scope of this invention.

Niraparib may be administered in any of the foregoing compositions and dosage regimens or by means of those compositions and dosage regimens established in the art whenever use of niraparib is required for a subject in need thereof.

EXAMPLES

The following Examples are set forth to aid in the understanding of the invention, and are not intended and should not be construed to limit in any way the invention set forth in the claims which follow thereafter.

Example 1

In vitro cytotoxicity of niraparib in human prostate tumor lines

The cytotoxicity of niraparib was tested in several human prostate tumor lines in vitro. None of the tumor lines is known to be BRCA-1 or BRCA-2 deficient.

Methods:

In vitro cytotoxicity of niraparib was assessed in 5 human prostate cancer cell lines: C4-2B, LNCaP, LNCaP AR.TB, VCaP, and 22Rv1. C4-2B, LNCaP, LNCaP AR.TB, and 22Rv1 cell lines were grown in RPMI1640+GlutaMAX™-I medium (Life Technologies #61870-036) supplemented with 10% heat-inactivated fetal bovine serum (FBS) (Life Technologies #16140-071) and non-essential amino acids (NEAA) (Life Technologies #11140-050); and VCaP cells were grown in DMEM+GlutaMAX™-I medium (Life Technologies ##10569-010) with 10% FBS and NEAA. VCaP cells were subcultured every 7 days; other lines were split every 3-4 days.

Cell growth kinetics of each cell line were determined by seeding cells at several densities and monitoring growth at intervals up to 7 days. Growth was determined using the Promega Cell TiterGlo reagent (#G7571) to measure cellular ATP by means of a chemiluminescent luciferin-luciferase reaction. Plates were read on a Perkin-Elmer Envision plate reader, and luminescence values were plotted in order to identify seeding densities that resulted in log-phase growth and a cell density within the linear range of the Cell TiterGlo assay at the desired time point.

For niraparib cytotoxicity experiments, cells were harvested by brief trypsinization and each line was seeded to the inner 60 wells of 96-well plates in 100 µL of medium at an appropriate density for a 7-day treatment. The outer wells of each plate were filled with Dulbecco's phosphate buffered saline (DPBS; Life Technologies #14190-144) to reduce evaporation from test wells. Cells were rested overnight in the plates at 37 °C in a humidified 5% CO_2 incubator. Treatment was initiated by addition of 50 µL of 3X niraparib (final concentrations 500, 125, 31.3, 7.8, 1.95, 0.49, 0.12, 0.03 µM) in the appropriate medium to triplicate wells. The final vehicle concentration was 0.5% DMSO.

Cells were cultured for 7 days. Relative cell viability after treatment was determined using Cell TiterGlo reagent, as above. All luminescent output values were normalized to percent inhibition based on mean luminescence of the untreated control wells, and the mean percent inhibition of the vehicle control wells was subtracted from each treatment value. Percent inhibition was plotted vs log µM concentration in GraphPad

Prism 7.00. Nonlinear regression and calculation of EC_{50} values were performed using the log(agonist) vs. response -- Variable slope (four parameters) fit.

Results:

Results of the cytotoxicity assay are shown in Figure 1 and Table 1. Growth of each cell line was reduced in a dose-dependent fashion by increasing concentrations of niraparib. C4-2B cells appeared to be the most sensitive, with an EC_{50} value of ~1.2 μM. VCaP cells appeared to be the least sensitive with an EC_{50} value of 4.1 μM.

Cell Line	**EC_{50}, μM**
C4-2B	1.222
LNCaP	3.502
LNCaP AR.TB	2.140
VCaP	4.099
22Rv1	3.517

Table 1. EC_{50} values for 7-day niraparib treatment of human prostate tumor cell lines.

Example 2

Inhibition of PAR formation by niraparib

The ability of niraparib to inhibit the formation of poly(ADP)ribose (PAR) was tested in two human prostate tumor lines in vitro. Neither of the tumor lines is known to be BRCA-1 or BRCA-2 deficient.

Methods:

PAR inhibition using niraparib was assessed in 2 human prostate cancer cell lines, C4-2B and VCaP. The C4-2B cell line was grown in RPMI1640+GlutaMAX™-I medium supplemented with 10% FBS and NEAA and split every 3-4 days. VCaP cells were grown in DMEM+GlutaMAX™-I medium with FBS and NEAA and subcultured every 7 days.

Cells were harvested by brief trypsinization and each line was seeded into 6-well plates in 1 mL of medium at an appropriate density. An extra 500 µL of complete medium was added, for a total volume per well of 1.5 mL. Cells were rested overnight in the plates at 37°C in a humidified 5% CO_2 incubator. The next day, medium was removed from plates and cells were washed using 1 mL serum free medium (RPMI or DMEM respectively). Treatment was initiated by addition of 1 mL of niraparib (final concentrations 100, 10, 1, 0.1, 0.01 and 0 µM in 0.1% DMSO) in the appropriate medium to triplicate wells. Plates were returned to the incubator for two hours.

Following treatment, extracts were prepared using reagents and procedures provided in the HT PARP in vivo Pharmacodynamic Assay II (Trevigen #4520-096-K). Medium was removed from each well and placed into separate labeled microfuge tubes, and the plates were placed on ice. The tubes were spun at 1500 rpm for 4 minutes to pellet any cells that detached from the plate during drug incubation. Lysis buffer was prepared using 24.5 mL of cell lysis reagent with 250 µL of 100 mM PMSF (in ethanol; Sigma #93482) and 250 µL 100X Protease Inhibitor Cocktail (Thermo Scientific #78429). Lysis buffer (300 µL) was added to each well of the plates, on ice. Adherent cells were scraped into lysis buffer and kept on ice for at least 15 minutes. Supernatant was removed from the microfuge tubes, and the cell lysates from the 6-well plates were added to each tube from the corresponding tubes. SDS (20% w/v) was added to bring the final SDS concentration to 1%. The cell extracts were heated to 95-100°C for 5 minutes. After cooling to room temperature, 0.01 volume of 100X magnesium cation and 3 µL DNase were added to each tube. Tubes were briefly vortexed and returned to a 37°C incubator for 90 minutes. After the incubation, tubes were centrifuged at 10,000 x g for 10 minutes at room temperature. If a pellet was present, it was removed using a pipette tip and extracts were transferred to a 96 well dilution plate. Cell extracts were frozen at -80°C until used for protein quantitation and the PAR ELISA assay. The ELISA assay protocol was performed according to the manufacturer's instructions.

Protein quantitation was performed using the detergent-compatible Biorad DC protein assay kit II (#500-0002) with the Biorad Quick Start Bovine Serum Albumin

Standard Set (#5000207) according to the manufacturer's 96-well plate protocol. ELISA lysis buffer was spiked into the standards, and an equal volume of PBS was added to all sample wells to correct for any effect of the lysis buffer on protein readings. Samples were assayed in duplicate. Buffer A' (25 µL) was added to all wells of the plate, and 200 µL of Buffer B was immediately added to each well. Plates were incubated for 15 minutes at room temperature on a shaker. Absorbance was read at 750 nm on a Molecular Devices M5 plate reader, using the DC Protein Assay protocol in SoftMax Pro version 6.3 software. Linear regression of the standard curve, interpolation of sample protein values, and replicate averaging were performed in the software. Data was exported to Excel, where any corrections for sample dilution were performed.

Luminescence values of PAR ELISA standards and samples were analyzed in GraphPad Prism version 7, where linear regression of the standard curve and interpolation of sample values were calculated. Interpolated PAR values (pg PAR/mL) were corrected for sample dilution and divided by the corresponding protein concentration to yield pg PAR/mg of protein. These values were graphed in GraphPad Prism v7.

Results:

The results from the PAR assay are shown in Figure 2. PAR was reduced in a dose-dependent fashion by increasing concentrations of niraparib in each cell line.

Example 3

Niraparib induces γ-H2AX in human prostate tumor lines in vitro

The ability of niraparib to induce double stranded breaks in DNA was measured in 3 human prostate cancer cell lines 22RV1, LNCaP AR.TB, and C4-2B. Double stranded breaks in DNA are followed by phosphorylation of adjacent histone γ-H2AX, and this phosphorylation can be measured by antibody staining and flow cytometry.

Methods:

22RV1, LNCaP AR.TB, and C4-2B cell lines were grown as outlined above. Cell lines were passaged every 3-4 days.

For each cell line, $2x10^5$ cells were seeded in each well of a 12-well plate (Falcon #353043) in a volume of 1 mL of media. Cells were rested overnight in a 37°C humidified

5% CO_2 incubator, then 1 mL of media containing 2X concentrated serially diluted niraparib was added to achieve final concentrations of 200, 100, 50, 25, 12.5, 6.25, 3.13, 1.57, 0.78, 0.39, 0.2, and 0.1 μM in triplicate wells. The final vehicle concentration was 0.2% DMSO and triplicate wells of vehicle and media controls were also obtained for each cell line. Plates were incubated for another 18 hours.

Following the 18 hour incubation with drug, each well of cells was harvested by first transferring the 2 mL of media into a 15 mL conical tube (Corning #430798). 500 μL of cell dissociation buffer (Gibco #13151-014) was then added to the well and allowed to sit for 5 minutes. Using a 1 mL pipette, 1 mL of media was added to the well, cells were dislodged by pipetting, and the cell-containing media was transferred to the corresponding 15 mL conical tube. Tubes were centrifuged at 1200 rpm for 5 minutes, the supernatant was discarded, and the pelleted cells were resuspended and transferred to a 96-well v-bottom plate (Costar #3896). Plates were centrifuged at 1800 rpm for 3 minutes, supernatant discarded, then wells were washed with 200 μL of DPBS. This process was repeated for a total of 3 washes. Cells were then stained with 100 μL of DPBS containing a 1:800 dilution of Invitrogen Live/Dead fixable aqua (Invitrogen #L34957) for 20 minutes at 4°C. Cells were then washed with 150 μL BD Pharmingen Stain Buffer (stain buffer; BD #554657) and centrifuged at 1800 rpm for 3 minutes. Cells were washed again 2 times with 200 μL stain buffer and then once with DPBS.

Cells were fixed with 100 μL -20°C 70% ethanol/H_2O and plates were stored at -20°C for 2 hours. Cells were washed 3 times with stain buffer centrifuging at 2200 rpm for 3 minutes between each wash. Cells were then incubated with 100 μL of a 1:1 dilution stain buffer and AXELL biotin-free Fc receptor blocker (Accurate Chemical & Scientific Corp #NB309) for 20 minutes at 4°C. Cells were washed with 150 μL of stain buffer then centrifuged at 2200 rpm for 3 minutes, supernatant discarded, then cells were incubated with 50 μL stain buffer containing 0.2% v/v Triton X-100 (Acros Organics #21568-2500) for 2 hours at room temperature in the dark along with 1:100 dilutions of γ-H2AX antibody (Biolegend #613408).

Cells were washed once with 200 µL stain buffer containing 0.2% v/v Triton X-100, and then washed once with 200 µL stain buffer only. Cells were resuspended in 80 µL of stain buffer and 50 µL was analyzed on a BD Fortessa flow cytometer. Data were analyzed using TreeStar FlowJo v9.8.5. Data was gated on live cells, then following doublet discrimination, the entire population was assessed for γ-H2AX antibody signal. Results were graphed In GraphPad Prism v7.

Results:

Representative histograms for the 22RV1 cell line are shown in Figure 3, depicting the effect of different concentrations of niraparib. Drug-treated samples were compared to vehicle and media controls and are graphed in Figure 4. The lowest concentrations where γ-H2AX signal rises significantly above vehicle control are indicated in Table 2. The results show that, in each prostate tumor line, niraparib induces γ-H2AX in a dose-dependent manner.

Cell line	1st Significant Concentration (µM)
22RV1	1.57
LnCaP.AR.TB	3.13
C4-2B	1.57

Table 2. Minimum concentration of niraparib that induces significant change in γ-H2AX

Example 4

Niraparib inhibits the growth of C4-2B human prostate tumors in mice

The activity of niraparib was tested in the pre-established human prostate subcutaneous C4-2B model in non-obese diabetic (NOD) severe combined immunodeficient (scid) gamma (NOD.Cg-Prkdc Il2rg/SzJ) (NSG) mice. This tumor model is not believed to be BRCA-1 or BRCA-2 deficient.

Methods:

Vehicle was 0.5% Methyl cellulose (Methocel™ F4M) prepared and kept at 4°C in the dark. All formulations were made to be dosed at a volume of 10 ml/kg body weight. NSG male mice (Jackson Laboratories) were used. Animals were habituated for one week prior to any experimental procedures being performed. Mice were group housed (5 per

cage) in disposable IVC-cages (Innovive, San Diego, CA, USA) under a 12-h light:dark cycle at a temperature of 19 to 22 ºC and 35 to 40% humidity. Mice were fed an autoclaved high fat (6%) diet laboratory chow and water ad libitum.

Mice were injected with LNCaP C4-2B-luc tagged cells (1 x 10^6 tumors cells in a 200 µl volume of Cultrex®:RPMI 1640 medium (1:1 ratio) on the right flank. Mice were randomized per tumor volumes (tumor volume = 241 ± 14 mm^3), with 10 mice per treatment group. Mice were dosed daily by gavage (p.o.) with either vehicle, or vehicle containing niraparib as indicated below at 10 ml/kg dosing volume. Start of treatment = Day 1. Mice were treated through study day 24.

Group 1 0 mg/kg Vehicle (0.5% Methocel F4M) dosed QD p.o.

Group 2 25 mg/kg niraparib in 0.5% Methocel F4M dosed QD p.o.

Group 3 50 mg/kg niraparib in 0.5% Methocel F4M dosed QD p.o.

For each individual animal, body weight and tumor volume [using the formula: Tumor Volume (mm3) = (a x b^2/2); where 'a' represents the length, and 'b' the width of the tumor as determined by caliper measurements], were monitored twice weekly throughout the study. For the pre-established tumors, a time-course of tumor growth is expressed as mean ± standard error of the mean (SEM).

Results:

The vehicle treated mice started to reach ethical limits for tumor volume around study day 22 onwards (see Figure 5 for individual tumor volumes). Tumor volume data was presented up to study day 24 (when 9 of 10 vehicle-treated mice remained on study). After 18, 22, and 24 days of treatment, group 3 dosed daily with 50 mg/kg niraparib p.o. showed significant inhibition/delay in tumor growth, with tumor growth inhibition (TGI) values of ~40% on these days. Significant differences in tumor growth were observed on days 18, 22 and 24 (*$p<0.05$; **$p<0.01$; ***$p<0.001$). Mice dosed at 25 mg/kg of niraparib did not show significant tumor growth inhibition, though there was modest TGI of ~12% on days 22 and 24.

Example 5

A multicenter, open-label study is carried out to assess the efficacy and safety of once daily dosing of 300 mg niraparib in male subjects over the age of 18 years with mCRPC and DNA-repair anomalies who have had at least one line of taxane-based chemotherapy and at least one line of antiandrogen therapy (e.g., abiraterone acetate, enzalutamide, apalutamide). The study will enroll approximately 100 subjects. Subjects will be monitored for safety during the study period, and up to 30 days after the last dose of study drug. Treatment will continue until disease progression, unacceptable toxicity, death, or the sponsor terminates the study.

The study will consist of 4 phases; a Prescreening Phase for biomarker evaluation only, a Screening Phase, a Treatment Phase, and a Follow-up Phase. The efficacy evaluations include the following: Tumor measurements: chest, abdomen, and pelvis CT or MRI scans and whole body bone scans (^{99mTc}), serum PSA, survival status, CTC, and symptomatic skeletal event (SSE).

Niraparib, 300 mg, will be provided as capsules (3 x 100 mg) for once daily oral administration. The capsules must be swallowed whole. Subjects should take their dose in the morning (with or without food). Although not considered study medication, subjects who have not undergone surgical castration must continue to receive regularly prescribed GnRHa. All GnRHa therapies should be recorded in the concomitant medication section of the eCRF.

A treatment cycle is defined as 28 days. Subjects will begin taking niraparib on Day 1 of Cycle 1. Sufficient quantities of niraparib for each treatment cycle will be distributed on the first day of each cycle. If subjects miss a dose, then that dose should be replaced if the subject remembers within an approximate 12-hour window. Otherwise, subjects should take the next dose the following day, without compensating for the missed dose. Missed doses should be recorded in the eCRF.

Prescreening Phase for Biomarker Evaluation

The Prescreening Phase will evaluate if a potential subject is biomarker-positive for DNA-repair anomalies. All subjects will be required to sign a specific ICF for the

Prescreening Phase and provide baseline demographic characteristics and disease-specific medical history. The Prescreening Phase may occur any time prior to the Screening Phase.

The process for determining biomarker-positivity will be different for subjects who enter the Prescreening Phase before a blood-based assay is available, compared with those subjects who enter after a blood-based assay is available. The 2 processes are described below.

Process for Determining Biomarker-positivity Before a Blood-based Assay is Available

The Subject signs the prescreening ICF. If the subject has had tumor tissue previously analyzed by the FoundationOne® gene panel, then after the subject grants a release, the FoundationOne® data can be reviewed to determine eligibility based on the criteria defined in Table 1 If the subject is biomarker-positive, they are eligible to enter the Screening Phase. If the subject has not had tumor tissue previously analyzed by the FoundationOne® gene panel, then they must have either archival or recently collected (recommended) tumor tissue analyzed for biomarker-positivity by a sponsor-approved test. If the subject is biomarker-positive, they are eligible to enter the Screening Phase.

Blood samples will also be collected from all subjects during the Prescreening Phase and stored for when a blood-based assay becomes available. At the time a blood-based assay becomes available, the stored blood sample will be analyzed for concordance with the tumor tissue sample results. This analysis may occur at any time after the blood-based assay becomes available.

Process for Determining Biomarker-positivity After a Blood-based Assay is Available

Subject signs the prescreening ICF. Subject has blood collected and sent for analysis of biomarker-positivity. If the subject has had tumor tissue previously analyzed by the FoundationOne® gene panel, then after the subject grants a release, the FoundationOne® data can be reviewed to determine eligibility based on the criteria defined in Table 1. If the subject is biomarker-positive, they are eligible to enter the Screening Phase and do not need to wait for results of the blood-based analysis. If the

FoundationOne® gene panel is negative, the subject may still be considered eligible if they are determined to be biomarker-positive by the blood-based assay. If the subject has not had tumor tissue previously analyzed by the FoundationOne® gene panel and archival tissue is available, then a request for retrieval and analysis of the archived tumor tissue is initiated. If the blood-based assay results are biomarker-positive, then the subject is eligible to enter the Screening Phase and does not need to wait for results of the archival tumor tissue-based analysis. The results from the archival tumor tissue-based analysis, when they are available, may be used in conjunction with the blood-based results for concordance and bridging studies.

At the discretion of the study sponsor, if the blood-based assay results are negative, then the archival tumor tissue-based results may be used to determine eligibility.

If no archival tumor tissue is available, then the subject must agree to have tumor tissue collected.

If the blood-based assay results are biomarker-positive, then the recent tumor tissue must be collected prior to Cycle 1 Day 1 for later use in concordance and bridging studies. Analysis of the recently collected tumor tissue may occur any time during the study and the results may not be required prior to the subject entering the Screening Phase.

At the discretion of the study sponsor, if the blood-based assay results are negative, then the recently collected tumor tissue may be used to determine eligibility.

Once subjects are identified as biomarker-positive during the Prescreening Phase, the Screening Phase should start within 30 days.

Screening Phase

All biomarker-positive subjects must sign the main study ICF prior to the conduct of any study-related procedures in the Screening Phase. During this phase, eligibility criteria will be reviewed and a complete clinical evaluation will be performed as specified in the Time and Events Schedule. Screening procedures will be performed up to 35 days before Cycle 1 Day 1, unless otherwise specified. Imaging will be accepted up to 8 weeks prior to Cycle 1 Day 1. Screening clinical safety laboratory evaluations can be used for Cycle 1 Day 1 assessments if performed within 14 days of Cycle 1.

Subjects who do not meet all inclusion criteria, or who meet an exclusion criterion, may be rescreened once. Rescreening is at the discretion of the investigator and requires sponsor approval and agreement. Subjects who are to be rescreened must sign a new ICF before rescreening. Subjects rescreened within 35 days of planned enrollment may use the initial screening laboratory results, computed tomography (CT)/magnetic resonance imaging (MRI) and bone scans (if still within 8 weeks of Cycle 1 Day 1) to determine eligibility if not the reason for the rescreening.

Treatment Phase

The Treatment Phase will begin at Cycle 1 Day 1 and will continue until the study drug is discontinued. The last measurements taken on Day 1 of Cycle 1 before administration of the study drug or at screening (whichever value was last) will be defined as the baseline values. Visits for each cycle will have a ±3-day window, unless otherwise specified. Study visits will be calculated from the Cycle 1 Day 1 date. Subjects may have imaging performed within ±7 days of visits requiring images. Refer to the Time and Events Schedule for treatment visits and assessments during the Treatment Phase.

For PK and pharmacodynamics sampling days, the subject must not take the study drug at home on the morning of study visits. Study drug should be taken at the site. Details of PK and pharmacodynamics sampling days and times are provided in the Time and Events Schedule. Additional details regarding PK sampling are provided in Section **Error! Reference source not found.**. Details of blood sample handling and storage procedures for PK and pharmacodynamics are provided in the laboratory manual.

Clinical evaluations and laboratory studies may be repeated more frequently, if clinically indicated. Study drug treatment will continue until disease progression, unacceptable toxicity, death, or the sponsor terminates the study. Once the subject discontinues study drug, the subject must complete the End-of-Treatment (EoT) visit within 30 days after the last dose of study drug, and enter the Follow-up Phase.

End-of-Treatment Visit

An End of Treatment visit must be scheduled within 30 days after the last dose of study drug or prior to administration of a new anti-prostate cancer therapy, whichever

occurs first. If a subject is unable to return to the site for the EoT visit, the subject should be contacted to collect AEs that occurred within 30 days after the last dose of study drug.

Follow-up Phase

Once a subject has completed the Treatment Phase, survival follow-up and SSEs will be performed every 3 months either via clinic visits, telephone interview, chart review, or other convenient methods. Deaths regardless of causality and SAEs thought to be related to study drugs will be collected and reported within 24 hours of discovery or notification of the event. If the follow-up information is obtained via telephone contact, then written documentation of the communication must be available for review in the source documents.

Biomarker-positive sample for DNA-repair anomalies

To evaluate if subjects are biomarker-positive, a blood-based assay may become available during the study that will provide a more rapid method than tissue-based analysis for determining biomarker-positive status, while being more convenient for the subjects. Prior to the blood-based assay becoming available, tumor tissue (either archival or recently collected) will require analysis. To ensure that all subjects, regardless of when they enter the study, have the same biomarker data available for analysis (i.e., for concordance and bridging studies), both tumor tissue and blood samples will be collected from all subjects who sign the prescreening informed consent form (ICF). The process for determining biomarker-positivity will be different for subjects who enter the Prescreening Phase before the blood-based assay is available, compared with those subjects who enter after the blood-based assay is available. However, the status of biomarker-positivity in both tumor tissue and blood will be assessed for all subjects.

To be eligible for the study, subjects must be confirmed biomarker-positive by tumor tissue (either archival or recently collected), or blood testing when available. The biomarkers of interest for this study and the biomarker-positivity criteria are listed in Table 3. Analyses will be performed to define a proxy for bi-allelic loss (e.g., mutation co-

expression frequency with copy number loss) and these proxies may be used to determine biomarker-positivity as that information becomes available.

Table 3: Biomarker Panel and Criteria for Positivity

Genes	Definition	Genomic Lesion Required for Positivity[Error! Reference source not found.]
BRCA-1	Breast Cancer gene 1	- Homozygous deletion - Heterozygous deletion + deleterious mutation - Copy neutral loss of heterozygosity + deleterious mutation
BRCA-2	Breast Cancer gene 2	
FANCA	Fanconi Anemia Complementation Group A gene	
PALB2	Partner and Localizer of BRCA2 gene	
CHEK2	Checkpoint Kinase 2 gene	
BRIP1	BRCA1 Interacting Protein C-terminal Helicase 1 gene	
HDAC2	Histone Deacetylase 2 gene	
ATM	Ataxia Telangiectasia Mutated gene	
ATM	Ataxia Telangiectasia Mutated gene	Mono-allelic deleterious mutation in the kinase catalytic domain
Control Genes		
AR	Androgen Receptor gene	
TP53	Tumor Protein 53 gene	

Mono-allelic loss in all genes will be acceptable for entry into the study until the existing algorithm for bi-allelic loss is validated.

Circulating Tumor Cells

Blood samples will be collected in a Cellsave tube at timepoints specified in the Time and Events Schedule. CTC enumeration will be evaluated at the central laboratory, to assess response to study drug.

Whole Blood for RNA

Whole blood samples will be collected in a Paxgene tube. Multiple ribonucleic acid (RNA) transcripts found in prostate tumors are detectable in the RNA and analysis of

these samples will allow evaluation of potential mechanisms of resistance that may emerge with niraparib.

Circulating Tumor DNA

Plasma samples collected during the course of treatment will be used to screen for changes in the levels or types of DNA-repair anomalies observed over time by circulating tumor DNA (ctDNA), and to monitor for potential markers of resistance to niraparib.

While the foregoing specification teaches the principles of the present invention, with examples provided for the purpose of illustration, it will be understood that the practice of the invention encompasses all of the usual variations, adaptations and/or modifications as come within the scope of the following claims and their equivalents.

We claim:

1. A method of treating prostate cancer in a human in need of such treatment comprising administering to the human a safe and effective amount of niraparib.

2. A method of claim 1, wherein the prostate cancer is castration-resistant prostate cancer or metastatic castration-resistant prostate cancer.

3. A method of claim 2, wherein the prostate cancer is antiandrogen resistant.

4. A method as in claim 3, wherein the human is carrying at least one DNA repair anomaly selected from the group consisting of BRCA-1, BRCA-2, FANCA, PALB2, CHEK2, BRIP1, HDAC2, and ATM.

5. A method of claim 4, where in the DNA repair anomaly is BRCA-1 or BRCA-2.

6. A method of claim 5, wherein the prostate cancer is castration-resistant prostate cancer.

7. A method of claim 5, wherein the prostate cancer is metastatic castration-resistant prostate cancer.

8. A method of claim 6, wherein niraparib is administered in an amount of from about 30 mg/day to about 400 mg/day.

9. A method of claim 8, wherein the amount of niraparib administered is about 300 mg/day.

10. A method of claim 9, wherein niraparib is administered as once daily oral administration in three 100 mg oral dosage forms.

11. A method of treating castration and antiandrogen resistant prostate cancer in a human comprising administering three 100 mg oral dosage forms niraparib once daily to the human.