CANNABINOIDS IN COMBINATION WITH NON -CANNABINOID CHEMOTHERAPEUTIC AGENTS (E.G. SERM OR ALKYLATING AGENTS)

The present invention relates to the use of one or more cannabinoids in combination with a non-cannabinoid chemotherapeutic agent in the manufacture of a medicament for use in the treatment of cancer. In particular the cancer to be treated is a brain tumour, more particularly a glioma, more particularly still a glioblastoma multiforme (GBM) and the preferred cannabinoids are tetrahydrocannabinol (THC), cannabidiol (CBD) or a combination thereof.

BACKGROUND TO THE INVENTION

Cancer a disease in which a group of cells display the traits of uncontrolled growth. This means that the cells grow and divide beyond the levels of normal limits. The cells are also able to invade and destroy surrounding tissues. In addition cancer cells sometimes also metastasize, meaning that they spread to other locations in the body via the blood or lymph.

Most cancers are caused by abnormalities in the genetic material of the cells. These abnormalities may be due to the effects of carcinogens. Other cancer-promoting genetic abnormalities may be randomly acquired through errors in DNA replication, or are inherited, and thus present in all cells from birth.

Genetic abnormalities found in cancer typically affect two general classes of genes. Cancer-promoting oncogenes are often activated in cancer cells, giving those cells new properties, such as hyperactive growth and division,

protection against programmed cell death, loss of respect for normal tissue boundaries, and the ability to become established in diverse tissue environments.

Tumour suppressor genes are often inactivated in cancer cells, resulting in the loss of normal functions in those cells, such as accurate DNA replication, control over the cell cycle, orientation and adhesion within tissues, and interaction with protective cells of the immune system.

There are many different types of cancer and the cancer is usually classified according to the type of tissue from which it originated.

Cancer is usually treated by one or more of the following: surgery, chemotherapy, radiation therapy, immunotherapy and monoclonal antibody therapy. The type of therapy depends upon the location and grade of the tumour and the stage of the disease.

Complete removal of the cancer without damage to the rest of the body is the goal of treatment. Sometimes this can be accomplished by surgery, but the propensity of cancers to invade adjacent tissue or to spread to distant sites by microscopic metastasis often limits its effectiveness. The effectiveness of chemotherapy is often limited by toxicity to other tissues in the body. Radiation can also cause damage to normal tissue.

Cancers are known to affect many areas of the body with the most common types of cancers including: cancer of the bile duct, cancer of the bladder, cancer of the bone, cancer of the bowel (including cancer of the colon and cancer of the rectum), cancer of the brain, cancer of the

breast, cancer of the neuroendocrine system (commonly known as a carcinoid), cancer of the cervix, cancer of the eye, cancer of the oesophagus, cancer of the head and neck (this group includes carcinomas that start in the cells that form the lining of the mouth, nose, throat, ear or the surface layer covering the tongue), Kaposi's sarcoma, cancer of the kidney, cancer of the larynx, leukaemia, cancer of the liver, cancer of the lung, cancer of the lymph nodes, Hodgkin's lymphoma, non-Hodgkin's lymphoma, melanoma, mesothelioma, myeloma, cancer of the ovary, cancer of the pancreas, cancer of the penis, cancer of the prostate, skin cancer, soft tissue sarcomas, cancer of the spinal cord, cancer of the stomach, testicular cancer, cancer of the thyroid, cancer of the vagina, cancer of the vulva and cancer of the uterus.

A tumour that develops in the brain can destroy or damage brain cells by producing inflammation, compressing other parts of the brain, inducing cerebral oedema (brain swelling) and can cause increases in intracranial pressure (pressure within the skull).

Each year, approximately 4300 people in the UK are diagnosed with a brain tumour. A primary brain tumour is a mass created by the growth or uncontrolled proliferation of cells in the brain. Malignant primary brain tumours are most likely to cause problems by spreading into the normal brain tissue which surrounds them and causing pressure and damage to the surrounding areas of the brain. These tumours rarely spread outside the brain to other parts of the body. However, secondary brain tumours occur when cancer cells from other parts of the body, such as the lung or breast spread to the brain.

Surgery is the treatment option of choice for many brain tumours. Some may be completely excised, but those that are deep or that infiltrate brain tissue may be debulked rather than removed.

Radiation therapy and chemotherapy may be recommended depending on the type of tumour involved.

Glioma cell tumours can often be lethal. The characteristic diffuse infiltrative tumour growth of gliomas often makes the surgical removal of them impossible and this profoundly complicates the clinical management of these patients.

Glioblastoma multiforme (GBM) is the most common and most aggressive type of primary brain tumour and accounts for 52% of all primary brain tumour cases and 20% of all intracranial tumours.

Different approaches are being researched in order to improve the mortality rate of patients diagnosed with a glioma. These include therapies that target the glioma cells but leave normal cells unharmed, methods that limit the spread of the cancer cells and treatments that block the tumours life-sustaining molecules.

One such area of research involves the use of cannabinoids as anti-tumoural agents.

Cannabinoids are the active constituents of cannabis plants and they have been found to demonstrate numerous pharmacological properties.

For example EP1177790 (Guzman *et al.*) describes the treatment of cerebral tumours by the administration of a natural or synthetic cannabinoid, specifically THC. It is claimed that activation of specific receptors leads to selective death of the transformed cells.

Recently the cannabinoid CBD has been shown to possess anti-tumoural properties (Massi *et al.* 2004). The work described by this paper describes anti-proliferative effects both *in-vitro* using U87 and U373 human glioma cell lines and *in-vivo* using U87 human glioma cells subcutaneously implanted to nude mice.

Biochemical Pharmacology 2000, vol 6, p1807-1813 compared the effects of cannabinoids including THC and CBD with the estrogen receptor modulator Tamoxifen and concluded that the effects of the cannabinoids were modest and that there was no significant interaction between them and Tamoxifen.

Malignant gliomas are highly infiltrative and proliferative tumours, which follow a characteristic pattern of growth. Glioma cells invade the adjacent normal brain structures and surrounding large blood vessels.

In addition the applicant's earlier patent EP1802274 describes the use of the cannabinoid CBD to impede the progress of cancer cells migrating from their primary tumour location to a secondary site.

The applicant's co-pending application GB0810195.8, filed on 4 June 2008, describes the use of a combination of cannabinoids in the treatment of cancer.

SUMMARY OF INVENTION

According to the present invention there is provided the use of one or more cannabinoids in combination with a non-cannabinoid chemotherapeutic agent in the manufacture of a medicament for use in the treatment of cancer.

Preferably the one or more cannabinoids are selected from the group consisting of: tetrahydrocannabinol (THC); and cannabidiol (CBD).

In one embodiment a single, or predominantly single cannabinoid is used. The single cannabinoid being either THC or CBD.

Alternatively, and preferred, a combination of cannabinoids may be used.

The combined cannabinoids are preferably THC and CBD.

Preferably the THC and CBD are in the ratio of from between 20:1 to 1:20.

More preferably the THC and CBD are in the ratio of from between 5:1 to 1:5.

More preferably still, the THC and CBD are in the ratio of from between 2:1 to 1:2, more approximately 1:1.

Each cannabinoid is provided in a therapeutically effect amount. Dose ranges for the THC and CBD may be determined by reference to the cannabinoid content which is preferably in the range of between 5 and 100mg of the

total cannabinoids. Where a plurality of cannabinoids are used each may be used in an amount which would be considered sub-optimal if it were being used alone.

In one embodiment the non-cannabinoid chemotherapeutic agent is a selective estrogen receptor modulator.

Selective estrogen receptor modulators are a class of medicines that act upon the estrogen receptor. Their action is different in various tissues, thereby granting the possibility to selectively inhibit or stimulate estrogen-like action in various tissues.

Selective estrogen receptor modulators include: afimoxifene (4-hydroxytamoxifen); arzoxifene; bazedoxifene; clomifene; lasofoxifene; ormeloxifene; ormeloxifene; raloxifene; tamoxifen; or toremifene and they are used for a variety of medical indications.

Some selective estrogen receptor modulators used as anti-tumoural agents include raloxifene, tamoxifen or toremifine. These are preferred for use in the present invention.

In an alternative embodiment the non-cannabinoid chemotherapeutic agent may be an alkylating agent.

An alkylating agent is a type of anti-neoplastic agent that works by interfering with DNA in a number of ways.

Extra molecules, called alkyl groups, are added to DNA, which causes it to break apart as the cell tries to replace them. Alkylating agents also interfere with the bonds between DNA strands, stopping them from separating,

which is a step required in DNA replication. By replacing bases (important components of DNA) alkylating agents also create mismatching, another way to stop DNA being reproduced properly.

All these changes occur when a cell is preparing to divide, and the permanent damage they cause results in cessation of division and cell death.

Preferably the alkylating agent is selected from the group consisting of: alkyl sulfonates; busulfan; ethyleneimines and methylmelamines; hexamethymelamine; altretamine; thiotepa; nitrogen mustards; cyclophosphamide; mechlorethamine; mustine; uramustine; uracil mustard; melphalan; chlorambucil; ifosfamide; nitrosureas; carmustine; cisplatin; streptozocin; triazenes; decarbazine; imidazotetrazines; and temozolomide.

Alkylating agents used as anti-tumoural agents include: cisplatin, temozolamide and carmustine and these are preferred in the practice of the present invention.

The cancer to be treated may be a brain tumour.

Brain tumours are usually classified according to the location of the tumour and the type of cell that the cancer has developed from.

For example different types of brain tumour include: acoustic neuroma, astrocytoma, CNS lymphoma, ependymoma, haemangioblastoma, medulloblastoma, meningioma, glioma, mixed glioma, oligodendroglioma, pineal region tumours and pituitary tumours.

Gliomas are tumours of the glial cells; these cells support and protect nerve cells in the brain. Gliomas comprise nearly half of all primary brain tumours and a fifth of all primary spinal cord tumours.

The combined therapy of the invention is particularly useful where the brain tumour is a glioma tumour, more particularly glioblastoma multiforme (GBM).

The one or more cannabinoids may be present as plant extracts, as pure compounds, or a combination of the two.

A plant extract is defined as an extract from a plant material as described by the Guidance for Industry Botanical Drug Products Draft Guidance, August 2000, US Department of Health and Human Services, Food and Drug Administration Centre for Drug Evaluation and Research.

Plant material is defined as a plant or plant part (e.g. bark, wood, leaves, stems, roots, flowers, fruits, seeds, berries or parts thereof) as well as exudates.

More preferably the plant extract is in the form of a botanical drug substance.

A botanical drug substance is defined as follows. Botanical drug substances which are derived from cannabis plants include primary extracts prepared by such processes as for example, maceration, percolation, extraction with solvents such as C1 to C5 alcohols (e.g. ethanol), Norflurane (HFA134a), HFA227, liquid carbon dioxide under pressure and extraction using a hot gas. The primary extract may be further purified by

supercritical or subcritical extraction, vaporisation and chromatography. When solvents such as those listed above are used the resultant extract may contain non-specific lipid-soluble material. This can be removed by a variety of processes including winterisation, which involves chilling to -20°C followed by filtration to remove waxy ballast, extraction with liquid carbon dioxide and by distillation.

Botanical drug substances are formulated into Botanical Drug Products which are defined in the Guidance for Industry Botanical Drug Products Draft Guidance, August 2000, US Department of Health and Human Services, Food and Drug Administration Centre for Drug Evaluation and Research as: "A botanical product that is intended for use as a drug; a drug product that is prepared from a botanical drug substance."

The one or more cannabinoids may be administered separately, sequentially or simultaneously to the non-cannabinoid anti-tumoural agent.

The one or more cannabinoids may be presented together with the non-cannabinoid chemotherapeutic agent in the form of a kit together with or without instructions to their use.

Certain aspects of this invention are further described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a bar chart showing the cell viability of human U87 MG astrocytoma cells after treatment with THC,

CBD or a combination of THC and CBD in comparison to a control;

Figures 2a and 2b are bar charts showing in vivo cell viability data at different concentrations on two cell lines, U87MG (Fig 2a) and T98G (Fig 2b);

Figures 3a, 3b and 3c provide data suggestive of the mechanism of action of the combination for U87MG cells.

Figure 4 is a bar chart showing the cell viability of human U87 MG astrocytoma cells after treatment with an exemplary cannabinoid, THC, or a combination of an exemplary cannabinoid THC and an exemplary non-cannabinoid anti-tumour agent, tamoxifen in comparison to a control; and

Figure 5 is a bar chart showing the cell viability of human U87 MG astrocytoma cells after treatment with an exemplary cannabinoid THC, or a combination of an exemplary cannabinoid THC and an exemplary non-cannabinoid anti-tumour agent, cisplatin in comparison to a control.

SPECIFIC DESCRIPTION

The following examples 1 to 5 illustrate how one or more cannabinoids are effective in the treatment of cancer cells both *in vitro* and *in vivo*.

Example 6 goes on to demonstrate, using a single cannabinoid for illustrative purposes, how the combination of one or more cannabinoids with a non-

cannabinoid anti-tumoural agent may be better than the use of the non-cannabinoid anti-tumoural agent alone.

Example 1: The effect of THC and CBD at inhibiting cancer cell growth *in vitro*.

Tetrahydrocannabinol (THC) and cannabidiol (CBD) in the form of cannabis plant extracts were dissolved in ethanol to a concentration of 100mM this was stored at -20°C until required.

Before use the cannabis plant extracts were further diluted to the desired concentration, ensuring that the concentration of ethanol was below 0.001%.

U87 human glioma cells were used throughout this experiment. The cells were maintained at 37°C in a humidified atmosphere with 5% CO_2 and 95% air.

Cells were cultured in a $75cm^2$ culture flask in Dulbecco's Modified Eagle Medium (DMEM), which had been supplemented with 4mM L-glutamine, 100 units/ml penicillin, 100 mg/ml streptomycin, 1% sodium pyruvate, 1% non-essential amino acids and 10% heat-inactivated fetal bovine serum.

The viability of the human U87 MG astrocytoma cells were examined at various cannabinoid concentrations. The THC and CBD extracts were compared against pure THC and CBD.

Results:

Table 1: Cell viability of human U87 MG astrocytoma cells in culture

	IC50 µM (pure cannabinoids)	IC50 µM (cannabis plant extract)	IC50 µM (equivalent of pure in cannabis plant extract)
THC	0.37	0.64	0.43
CBD	0.47	0.72	0.47

As can be seen from Table 1 above the THC and CBD extracts compare very favourably in activity to their corresponding pure compounds, when the amount of cannabinoid in the extract is adjusted to an equivalent amount of pure compound.

This shows that THC and CBD and their extracts are effective in inhibiting glioma cell growth.

Example 2: The effect of a combination of THC and CBD extracts at inhibiting cancer cell growth *in vitro*.

This experiment tested whether a combination of THC and CBD extracts were as effective at inhibiting cell growth as the extracts alone.

The methods used were as described in Example 1 above.

Results:

Figure 1 details a bar chart describing the cell viability of human U87 MG astrocytoma cells versus the THC and CBD extracts alone and in combination with one another.

As can be seen when the THC and CBD are used in combination the cell viability is significantly reduced in comparison to the cell viability after treatment with either THC or CBD alone.

This data suggests that the cannabinoids THC and CBD would be more effective in the treatment of tumours when used in combination.

Example 3: The effect of a combination of THC and CBD at inhibiting cancer cell growth *in vivo*.

This experiment tested whether the combination of THC and CBD extracts were also effective *in vivo*.

Human U87 MG astrocytoma cells were xenografted to nude mice and the test compounds were injected peritumourally at a concentration of 15 mg/kg per day.

Results:

Table 2: Tumour volume relative to zero time following 15 days of treatment

	Tumour volume
Vehicle	9.2 ± 0.6
Pure THC	5.1 ± 0.4
THC extract	6.6 ± 0.3
THC:CBD (1:1) extract	4.8 ± 0.3

As can be observed in Table 2 above the tumour volume after treatment with the 1:1 combination of THC and CBD extracts is significantly superior to the treatment with either the pure THC or the THC extract alone.

This data suggests that the cannabinoids THC and CBD would be more effective in the treatment of tumours when used in combination.

Example 4: Effect of cannabinoid concentration on cell viability in two different cell lines.

The action of THC, CBD, and a 1:1 ratio mix of THC and CBD were studied at different concentrations on two cell lines: U87MG and T98G. The cell viability data is illustrated in Figs 2a and 2b.

Referring to Fig 2a it will be seen that ineffective / sub-optimal doses of THC and CBD at 0.1ug/ml and 0.25ug/ml (greater than 90% cell viability)gave way to a statistically significant decrease in cell viability in combination (SAT), which data showed a dose dependant relationship with increased concentration (greater cyto-toxicity at 0.25ug/ml).

Similar results were obtained with cell line T98G, (an alternative human glioma cell line) as is shown in Fig 2b.

Example 5: Investigation of mechanism of action.

THC is known to induce cell death using a signalling route involving the gene ATG1 and pan-caspase. The results of an investigation looking at S6 phosphorylation, LC3 lipidation and the effect of an ATG1 and a pan-caspase inhibitor are shown in Figs 3a, 3b and 3c respectively.

It can be seen from Fig 3a that the THC:CBD combination (compare to control C):

- Inhibits mTORC1 activity (as determined by the levels of S6 phosphorylation);and
- Promotes accumulation of the lipidated form LC3 (a hall mark of autophagy).

Fig 3b shows that silencing the essential autophagy gene ATG1, with a selective (siATG10) siRNA inhibitor reduces induced cell death compared to cells transfected with a control siC.

Finally, Fig 3c shows that cells treated with the pan-capase inhibitor Z-VAD also prevent induced cell death.

Example 6: The effect of an exemplary cannabinoid extract in combination with exemplary non-cannabinoid anti-tumoural agents at inhibiting cancer cell growth *in vitro*.

This experiment tested whether a cannabinoid-containing medicine might be useful in combination with non-cannabinoid anti-tumoural agents.

Cell viability assays were performed as described in Example 1 above.

Results:

Figures 4 and 5 detail bar charts which illustrate the cell viability of human U87 MG astrocytoma cells when treated with either THC, an anti-tumoural agent or a combination of the two versus a control.

As can be seen from these figures both exemplary anti-tumoural agents that were tested; tamoxifen and cisplatin, were more efficient at reducing cell viability when used in combination with an exemplary cannabinoid, THC. It would be readily apparent from Examples 1 to 5 that similar benefits would be expected with CBD and a combination of THC and CBD.

The combination of Examples 1 to 6 demonstrate that the combination of one or more cannabinoids with a non-cannabinoid anti-tumoural drug produces a more beneficial effect than the use of the non-cannabinoid anti-tumoural drug alone.

CLAIMS

1. Use of one or more cannabinoids in combination with a non-cannabinoid chemotherapeutic agent in the manufacture of a medicament for use in the treatment of cancer.

2. Use as claimed in claim 1, wherein the one or more cannabinoids are selected from the group consisting of: tetrahydrocannabinol (THC); and cannabidiol (CBD).

3. Use as claimed in claim 2, wherein the one or more cannabinoid is THC.

4. Use as claimed in claim 2, wherein the one or more cannabinoid is CBD.

5. Use as claimed in any of the preceding claims, wherein the one or more cannabinoid comprise both THC and CBD.

6. Use as claimed in claim 5, wherein the THC and CBD are in the ratio of from between 20:1 to 1:20.

7. Use as claimed in claim 5, wherein the THC and CBD are in the ratio of approximately 1:1.

8. Use as claimed in any of the preceding claims, wherein the cannabinoid content is in the range of between 5 and 100mg of the total cannabinoids present.

9. Use as claimed in any of the preceding claims, wherein the non-cannabinoid chemotherapeutic agent is a selective estrogen receptor modulator.

10. Use as claimed in claim 9, wherein the selective estrogen receptor modulator is selected from the group consisting of: afimoxifene (4-hydroxytamoxifen); arzoxifene; bazedoxifene; clomifene; lasofoxifene; ormeloxifene; ormeloxifene; raloxifene; tamoxifen; and toremifene.

11. Use as claimed in claim 10, wherein the selective estrogen receptor modulator is one of: raloxifene; tamoxifen; and toremifene.

12. Use as claimed in any of claims 1 to 8, wherein the non-cannabinoid chemotherapeutic agent is an alkylating agent.

13. Use as claimed in claim 12, wherein the alkylating agent is selected from the group consisting of: alkyl sulfonates; busulfan; ethyleneimines and methylmelamines; hexamethymelamine; altretamine; thiotepa; nitrogen mustards; cyclophosphamide; mechlorethamine; mustine; uramustine; uracil mustard; melphalan; chlorambucil; ifosfamide; nitrosureas; carmustine; cisplatin; streptozocin; triazenes; decarbazine; imidazotetrazines; and temozolomide.

14. Use as claimed in claim 13, wherein the alkylating agent is one of: cisplatin; temozolamide; and carmustine.

15. Use as claimed in any of the preceding claims, wherein the cancer to be treated is a brain tumour.

16. Use as claimed in claim 15, wherein the brain tumour is a glioma tumour.

17. Use as claimed in claim 16, wherein the brain tumour is a glioblastoma multiforme (GBM).

18. Use as claimed in claim 1, wherein the one or more cannabinoids are present as plant extracts, as pure compounds, or a combination of the two.

19. Use as claimed in claim 18, wherein the plant extract is in the form of a botanical drug substance.

20. Use as claimed in any of the preceding claims, wherein the one or more cannabinoids are administered separately, sequentially or simultaneously to the non-cannabinoid anti-tumoural agent.