

# Chemotherapy 101 for Radiation Oncology Workers

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*March 9, 2013*

## Category 1) Alkylating agents

Alkylating agents directly damage DNA to prevent the cancer cell from reproducing. As a class of drugs, these agents are not phase-specific; in other words, they work in all phases of the cell cycle. Alkylating agents are used to treat many different cancers, including **leukemia, lymphoma, Hodgkin disease, multiple myeloma, and sarcoma**, as well as cancers of the lung, breast, and ovary.

Because these drugs damage DNA, they can cause long-term damage to the bone marrow. In rare cases, this can eventually lead to acute leukemia. The risk of leukemia from alkylating agents is “dose-dependent,” meaning that the risk is small with lower doses, but goes up as the total amount of the drug used gets higher. The risk of leukemia after getting alkylating agents is highest about 5 to 10 years after treatment.

*There are different classes of alkylating agents, including:*

**Nitrogen mustards:** such as mechlorethamine (nitrogen mustard)- Hodgkins Disease

chlorambucil, cyclophosphamide (Cytoxan<sup>®</sup>), Ifosfamide (Ifex) Sarcoma

Bendamustine (Treanda)  
melphalan

Lymphoma  
Myeloma

**Nitrosoureas:**

streptozocin  
carmustine (BCNU)

Islet Cell Cancer  
Brain Cancer

**Triazines:**

dacarbazine (DTIC)  
Temozolomide (Temodar<sup>®</sup>)

Melanoma  
Brain Cancer

**Ethylenimines:**

thiotepa and altretamine (hexamethylmelamine) Ovarian Cancer

## Category 2) The **platinum** drugs

**Cisplatin** Testis and Lung Cancer  
**carboplatin**-Lung, Ovary, Breast Cancer

**Oxalaplatin**- Colon Cancer

are sometimes grouped with alkylating agents because they kill cells in a similar way. These drugs are less likely than the alkylating agents to cause leukemia later on. They have significant toxicity including nausea, vomiting, neuropathy, and renal toxicity

## Category 3) Antimetabolites

Antimetabolites are a class of drugs that interfere with DNA and RNA growth by substituting for the normal building blocks of RNA and DNA. These agents damage cells during the S phase. They are commonly used to treat leukemias, cancers of the breast, ovary, and the intestinal tract, as well as other types of cancer.

***Examples of antimetabolites include:***

<b>5-fluorouracil (5-FU)</b>	<b>Colon</b>
<b>6-mercaptopurine (6-MP)</b>	<b>Leukemia</b>
<b>Capecitabine (Xeloda®)</b>	<b>Colon Cancer</b>
<b>Cladribine (2CDA)</b>	<b>Hairy Cell Leukemia</b>
<b>Cytarabine (Ara-C®)</b>	<b>Leukemia</b>
<b>Fludarabine (Fludara)</b>	<b>Lymphoma</b>
<b>Gemcitabine (Gemzar®)</b>	<b>Pancreas Cancer</b>
<b>Hydroxyurea (Hydrea)</b>	<b>Leukemia</b>
<b>Methotrexate</b>	<b>Trophoblastic Disease</b>
<b>Pemetrexed (Alimta®)</b>	<b>Lung Cancer</b>

## Category 4) **Anti-tumor antibiotics**

### **Anthracyclines**

Anthracyclines are anti-tumor antibiotics that interfere with enzymes involved in DNA replication. These drugs work in all phases of the cell cycle. They are widely used for a variety of cancers. A major consideration when giving these drugs is that they can permanently damage the heart if given in high doses. For this reason, lifetime dose limits are often placed on these drugs.

*Examples of anthracyclines include:*

**Daunorubicin (Daunoxome)**      **Leukemia**

**Doxorubicin (Adriamycin<sup>®</sup>)**      **Breast Cancer**

**Epirubicin (Ellence)**      **Breast Cancer**

**Idarubicin (Idamycin)**      **Leukemia**



## Other anti-tumor antibiotics:

Anti-tumor antibiotics that are not anthracyclines include:

**Actinomycin-D**

**Bleomycin**

**Doxil (liposomal doxorubicin)**

**Mitomycin-C**

**Sarcoma**

**Testis Cancer**

**Ovarian Cancer**

**Anal Cancer**

**Mitoxantrone** is an anti-tumor antibiotic that is similar to doxorubicin in many ways, including the potential for damaging the heart. This drug also acts as a topoisomerase II inhibitor and can lead to treatment-related leukemia.

Mitoxantrone is used to treat **prostate cancer, breast cancer, lymphoma, and leukemia.**

## Category 5) Topoisomerase inhibitors

These drugs interfere with enzymes called topoisomerases, which help separate the strands of DNA so they can be copied. They are used to treat certain **leukemias**, as well as **lung, ovarian, gastrointestinal, and other cancers**.

Examples of **topoisomerase I inhibitors** include:

**topotecan (Hycamtin)**

**Ovarian Cancer**

**irinotecan (Camptosar)**

**Colon Cancer**

Examples of **topoisomerase II inhibitors** include:

**etoposide (Vepesid)**

**Testis Cancer**

teniposide

Mitoxantrone also inhibits topoisomerase II.

Treatment with topoisomerase II inhibitors increases the risk of a second cancer — **acute myelogenous leukemia (AML)**. With this type of drug, a secondary leukemia can be seen as early as 2 to 3 years after the drug is given.

## Category 6) Mitotic inhibitors

Mitotic inhibitors are often plant alkaloids and other compounds derived from natural products. They can stop mitosis or inhibit enzymes from making proteins needed for cell reproduction.

These drugs work during the M phase of the cell cycle but can damage cells in all phases. They are used to treat many different types of cancer including **breast, lung, myelomas, lymphomas, and leukemias**. These drugs are known for their potential to cause peripheral nerve damage, which can be a dose-limiting side effect.

Examples of *mitotic inhibitors* include:

**Taxanes:**

paclitaxel (Taxol<sup>®</sup>)

docetaxel (Taxotere<sup>®</sup>)

Abraxane (nano particle albumin bound-taxol)

**Epothilones:**

ixabepilone (Ixempra<sup>®</sup>)

Breast Cancer

**Vinca alkaloids:**

vinblastine (Velban<sup>®</sup>)

Hodgkins Disease,

vincristine (Oncovin<sup>®</sup>)

Hodgkins Disease,

vinorelbine (Navelbine<sup>®</sup>)

Breast Cancer

Estramustine (Emcyt<sup>®</sup>)

Prostate Cancer

## Category 7) Corticosteroids

Steroids are natural hormones and hormone-like drugs that are useful in treating some types of cancer (**lymphoma, leukemias, and multiple myeloma**), as well as other illnesses. When these drugs are used to kill cancer cells or slow their growth, they are considered chemotherapy drugs.

Corticosteroids are also commonly used as **anti-emetics** to help prevent nausea and vomiting caused by chemotherapy. They are used before chemotherapy to help prevent severe allergic reactions (hypersensitivity reactions), too. When a corticosteroid is used to prevent vomiting or allergic reactions, it's not considered chemotherapy.

Examples include **prednisone, methylprednisolone (Solumedrol®), and dexamethasone (Decadron®)**.

## Category 8) Differentiating agents:

These drugs act on the cancer cells to make them mature into normal cells.

Examples include :

**tretinoin (ATRA or Atralin<sup>®</sup>)**

**M3 AML**

**bexarotene (Targretin<sup>®</sup>)**

**T cell Lymphoma**

**arsenic trioxide (Arsenox<sup>®</sup>)**

**M3 AML**

## Category 9) Hormone therapy

Drugs in this category are sex hormones, or hormone-like drugs, that change the action or production of female or male hormones. They are used to slow the growth of **breast, prostate, and endometrial (uterine) cancers**, which normally grow in response to natural hormones in the body. These cancer treatment hormones do not work in the same ways as standard chemotherapy drugs, but rather by preventing the cancer cell from using the hormone it needs to grow, or by preventing the body from making the hormones.



Examples include:

The **anti-estrogens** for **Breast Cancer**:

**fulvestrant (Faslodex<sup>®</sup>)**

**tamoxifen**

**toremifene (Fareston<sup>®</sup>)**

**Aromatase inhibitors:**

**anastrozole (Arimidex<sup>®</sup>)**

**exemestane (Aromasin<sup>®</sup>)**

**letrozole (Femara<sup>®</sup>)**

**Progestins: megestrol acetate (Megace<sup>®</sup>)**

## **Anti-androgens for Prostate Cancer:**

**bicalutamide (Casodex<sup>®</sup>)**

**flutamide (Eulexin<sup>®</sup>)**

**nilutamide (Nilandron<sup>®</sup>)**

**abiraterone (Zytiga)**

**enzalutamide (Xtandi)**

**Gonadotropin-releasing hormone (GnRH)**, also known as luteinizing hormone-releasing hormone (**LHRH**) agonists or analogs:

**leuprolide (Lupron<sup>®</sup>)**

**goserelin (Zoladex<sup>®</sup>)**

**Triptorelin (Trelstar)**

## Category 10) Immunotherapy

Some drugs are given to people with cancer to stimulate their natural immune systems to recognize and attack cancer cells. These drugs offer a unique method of treatment, and are often considered to be separate from chemotherapy.

There are different types of immunotherapy.

***Active immunotherapies*** stimulate the body's own immune system to fight the disease.

***Passive immunotherapies*** do not rely on the body to attack the disease; instead, they use immune system components (such as antibodies) created outside the body.

Types of immunotherapies and some examples include:

**Monoclonal antibody therapy** (passive immunotherapies), such as:

<b>rituximab (Rituxan<sup>®</sup>)</b>	<b>Lymphoma</b>
<b>alemtuzumab (Campath<sup>®</sup>)</b>	<b>Leukemia</b>
<b>Arzerra</b>	<b>Leukemia</b>
<b>Actemra</b>	<b>Hodgkins Disease</b>

Non-specific immunotherapies and adjuvants (other substances or cells that boost the immune response), such as BCG, interleukin-2 (IL-2), and interferon-alfa

***Cancer vaccines*** (active specific immunotherapies).

In 2010, the FDA approved the **first vaccine** to treat cancer (the **Provenge<sup>®</sup>** vaccine for **advanced prostate cancer**);

## **Yervoy (Ipilimumab) Melanoma**

MDX-101 is a monoclonal antibody that turns off the inhibition of circulating cytotoxic T lymphocytes

Tositumomab (Bexxar)

Ibritumomab tiuxetan (Zevalin)

Monoclonal antibodies used to deliver **radiation in the form of Yttrium-90** to the **lymphoma**.

**Monoclonal antibodies** are substances that are made in the laboratory by hybridoma technology to block a specific target on the outside of cancer cells. These drugs are usually given intravenously (IV) because they are large compounds that are not absorbed well by the body. Examples include:

<b>bevacizumab (Avastin)</b>	<b>Colon Cancer</b>
<b>ziv-aflibercept (Zaltrap)</b>	<b>Colon Ca</b>
<b>cetuximab (Erbix)</b>	<b>Colon Ca</b>
<b>panitumumab (Vectibix)</b>	<b>Colon Ca</b>
<b>pertuzumab (Perjeta)</b>	<b>Breast Ca</b>
<b>trastuzumab (Herceptin)</b>	<b>Breast Ca</b>
<b>Trastuzumab emtansine (Kadcyla)</b>	<b>Breast Ca</b>

Oral small molecules are given in the form of a pill that a patient takes by mouth because the body absorbs them better than monoclonal antibodies. These drugs usually block cancer processes in the inside of a cancer cell. Examples include **Tyrosine Kinase Inhibitors:**

<b>dasatinib (Sprycel)</b>	<b>CML</b>
<b>erlotinib (Tarceva)</b>	<b>Lung Ca</b>
<b>gefitinib (Iressa)</b>	<b>Lung Ca</b>
<b>imatinib (Gleevec)</b>	<b>CML</b>
<b>nilotinib (Tasigna)</b>	<b>CML</b>
<b>sorafenib (Nexavar)</b>	<b>Kidney Ca</b>
<b>sunitinib (Sutent)</b>	<b>Kidney Ca</b>
<b>bosutinib (Bosulif)</b>	<b>CML</b>
<b>axitinib (Inlyta)</b>	<b>Kidney Ca</b>
<b>regorafenib (Stivarga)</b>	<b>Colon Ca</b>
<b>pazopanib (Votrient)</b>	<b>Kidney Ca</b>
<b>crizotinib (Xalkori)</b>	<b>Lung Ca</b>
<b>Vemurafenib(Zelboraf)</b>	<b>Melanoma</b>



MTOR inhibitor/Mammalian target of rapamycin a  
Serine threonine kinase inhibitor

everolimus (Afinitor)

Kidney Cancer

Temsirolimus (Torisel)

Kidney Cancer

**Proteasome inhibitors** interfere with specialized proteins called enzymes that break down other proteins in the cell. Used primarily in **Multiple Myeloma**:

**bortezomib (Velcade)**

**carfilzomib (Kyprolis)**

Inhibition of DNA methyltransferase:

**Decitabine (Dacogen)**

**Myelodysplasia**

**Azacitidine (Vidaza)**

**Myelodysplasia**

Immunomodulator/Anti-angiogenesis used primarily in  
Multiple Myeloma

Thalidomide (Thalomid)

Lenalidomide (Revlimid)

Pamolidomide (Pomalyst)

## **Into the impossible with a father of string theory**

*After abandoning family plans to go into the heating business, he went on to become a founder of string theory. Now **Leonard Susskind** is teaching physics to people in their 90s.*

***Physics is a very human enterprise, and the process of going from the human, the contentious, to the objective kernel of truth - textbook science - requires input from experiment. What's going to happen when that becomes prohibitive?***

