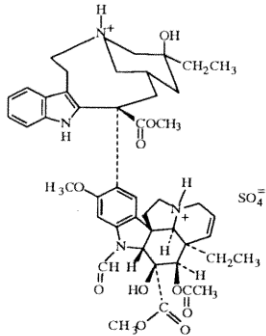


## Lecture 4: Antimitotic agents –cell cycle specific (M phase)

### 1. Vinca alkaloids

#### Vincristine (Oncovin):



Uses: Acute leukemia, Hodgkin's lymphoma (MOPP, COPP, BEACOPP regimens); non-Hodgkin's lymphoma (CHOP: cyclophosphamide/hydroxydaunorubicin/**oncovin**/prednisone); neurosarcoma, Wilm's tumor (nephroblastoma). Administration by IV only; intrathecal administration can be fatal. Vinca alkaloids are light sensitive.

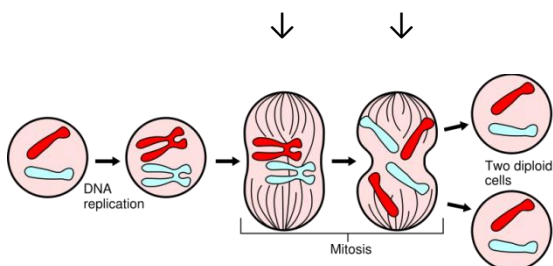
Mechanism: Binds to microtubules in the spindle apparatus and prevents their proper function (see Figure 1). Specifically, it binds at interface of  $\alpha$  and  $\beta$  tubulin heterodimers and inhibits tubulin polymerization. Opposite mechanism of taxanes but similar end result.

Toxicity: Peripheral neuropathy\*, constipation, paresthesia, alopecia; but myelosuppression not severe. Avoid extravasation as it can be very painful. \*Peripheral neuropathy can be severe and a reason to stop or avoid use of vincristine. A person with a family history of Charcot-Marie-Tooth disease (CMT) may benefit from genetic testing for CMT before taking vincristine.

ADME: Tri-phasic elimination with very long terminal t<sub>1/2</sub> being ~100 hrs; clearance mainly hepatic with involvement of CYP3A4. Use of strong inhibitors of CYP3A4 can increase peripheral neuropathy.

Note(s): A natural product (di-alkaloid) initially isolated from the common Periwinkle plant.

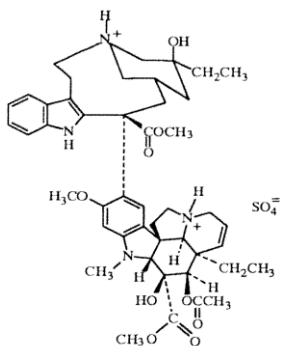
Figure 1. The cell cycle showing the role of the spindle apparatus in cell division.



**Vincristine sulfate liposomal (Marqibo):** approved Aug 2012

A liposomal formulation (sphingomyelin/cholesterol) of vincristine. It is used in the relapse setting in adults with acute lymphocytic leukemia that is Philadelphia chromosome negative (Ph<sup>-</sup>).

**Vinblastine (Velbe):**



**Uses:** Hodgkin's lymphoma, non-small cell lung cancer, breast cancer. A component of **VBM** (vinblastine/bleomycin/methotrexate) or **ABVD** regimens for Hodgkin's lymphoma. Administration by IV only; intrathecal administration can be fatal. Vinca alkaloids are light sensitive.

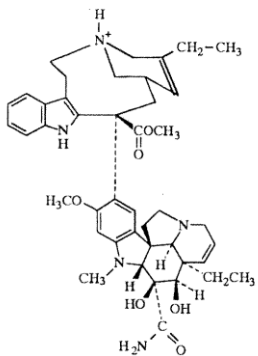
**Mechanism:** Similar to vincristine (inhibits tubulin polymerization); but also causes changes in amino acid metabolism principally involving glutamic acid and tryptophan.

**Toxicity:** Like vincristine but more myelosuppression (especially leukopenia). Leukopenia can be dose limiting and leukocyte counts are used to guide dosing of this agent.

**ADME:** Tri-phasic elimination with long terminal t<sub>1/2</sub> being ~24 hrs but this is shorter than vincristine; clearance mainly hepatic with involvement of CYP3A4. Use of strong inhibitors of CYP3A4 can increase peripheral neuropathy and myelosuppression.

**Note(s):** A natural product (di-alkaloid) initially isolated from the common Periwinkle plant.

**Vinorelbine (Navelbine):**



Uses: Non-small cell lung cancer, often with cisplatin. Administered IV only; intrathecal administration can be fatal. Vinca alkaloids are light sensitive.

Mechanism: Similar to vincristine but may also interfere with amino acid and glutathione metabolism, calmodulin-dependent  $\text{Ca}^{++}$ -transport, cellular respiration, nucleic acid biosynthesis and lipid biosynthesis.

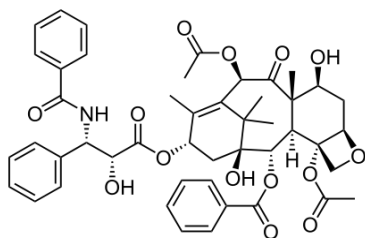
ADME: Tri-phasic elimination with long terminal  $t_{1/2}$  being ~30 hrs; clearance mainly hepatic with involvement of CYP3A4. Use of strong inhibitors of CYP3A4 can increase myelosuppression and peripheral neuropathy.

Toxicity: Myelosuppression (especially granulocytopenia), peripheral neuropathy, constipation, paresthesia, alopecia; rare but cases of interstitial pulmonary disease.

Note(s): A natural product (di-alkaloid) initially isolated from the common Periwinkle plant.

## 2. Taxanes

### Paclitaxel (Taxol):



Uses: Non-small cell lung cancer and ovarian cancer (with cisplatin), breast cancer (with doxorubicin and cyclophosphamide), prostate cancer (with prednisone). Administered IV only. Due to its low aqueous solubility, this agent is formulated in a Cremophor/ethanol emulsion. Cremophor is polyethoxylated castor oil. However, these components add complications (infusion reactions and unpredictable pharmacokinetics) to use of this agent. Patients often premedicated to reduce infusion reactions. See Abraxane below.

Mechanism: Binds to microtubules in the spindle apparatus and prevents their proper function. Specifically, it binds to microtubules and over-stabilizes them. Opposite of vinca alkaloids.

Toxicity: Myelosuppression, peripheral neuropathy, alopecia. Myelosuppression can be increased when given with cisplatin.

**ADME:** Bi-phasic elimination with terminal  $t_{1/2}$  being ~10-20 hrs but dependent on dose\*; clearance mainly hepatic with involvement of CYP2C8 mainly (CYP3A4 minor). Use of strong inhibitors (gemfibrozil) of CYP2C8 or inducers (rifampin) can increase myelosuppression and peripheral neuropathy. High binding to serum albumin.

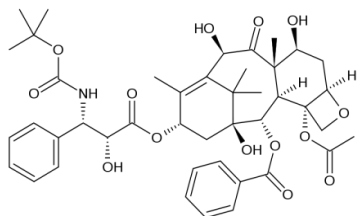
**Note(s):** \*PK is complicated in part by the components of the formulation. Initially isolated from the Pacific Yew tree found in the Pacific Northwest. The molecule is also a potent antifungal against certain fungi – of value in damp, dark forests.

### **Nab-Paclitaxel (Abraxane):**

This is a relatively new formulation of paclitaxel. Nab stands for nanoparticle-albumin bound. This formulation utilizes human serum albumin to which paclitaxel (in nanoparticle form) is bound.

**Uses:** Primarily breast cancer, but probably no good reason it could not be used for everything that Taxol is used for. Cost is relatively high compared to Taxol however.

### **Docetaxel (Taxotere):**



**Uses:** Non-small cell lung cancer (with cisplatin), breast cancer (with doxorubicin and cyclophosphamide), prostate cancer (with prednisone), gastric cancer (with cisplatin and 5-FU), head and neck cancer squamous cell (with cisplatin and 5-FU). Due to its low aqueous solubility, this agent is formulated in a polysorbate-80/ethanol solution. These components can add complications (infusion reactions or hypersensitivity) when using this agent, similar to paclitaxel.

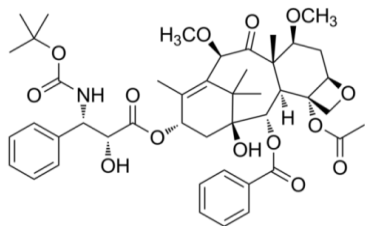
**Mechanism:** Binds to microtubules similar to paclitaxel but somewhat different binding sites. Also, the agent is more potent and toxic than paclitaxel. Because the binding differs from that of paclitaxel, some patients can benefit after response to paclitaxel fails.

**Toxicity:** Myelosuppression, hepatotoxicity, peripheral neuropathy, hypersensitivity, alopecia.

**ADME:** Tri-phasic elimination with terminal  $t_{1/2}$  being ~10-15 hrs; clearance mainly hepatic and mainly by CYP3A4. Use of strong inhibitors of CYP3A4 can increase myelosuppression and peripheral neuropathy.

**Note(s):** Not a natural product – purely synthetic.

**Cabazitaxel (Jevtana):** approved June 2010



Uses: Prostate cancer (with prednisone) for patients that have been previously treated with docetaxel. Due to its low aqueous solubility, this agent is formulated in a polysorbate-80/ethanol solution. These components can add complications (infusion reactions or hypersensitivity) when using this agent.

Mechanism: Similar to paclitaxel and docetaxel. Note the extreme similarity to docetaxel. This agent is also called dimethyl-docetaxel. More potent than either paclitaxel (P) or docetaxel (D). For example, doses: (P) 135-175 mg/m<sup>2</sup>, (D) 60-100 mg/m<sup>2</sup>, (C) 25 mg/m<sup>2</sup> all every 3 weeks (q3w). Binds somewhat different to microtubules and helps overcome some drug resistance to P and D.

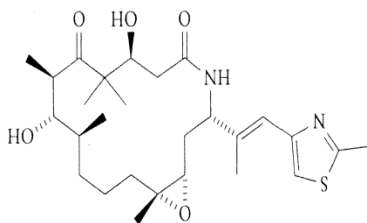
Toxicity: Myelosuppression, peripheral neuropathy, hypersensitivity, alopecia.

ADME: Tri-phasic elimination with very long terminal t<sub>1/2</sub> being ~95 hrs; clearance is hepatic and mainly by CYP3A4. Use of strong inhibitors of CYP3A4 can increase myelosuppression and peripheral neuropathy. Poorer substrate for P-gp compared to P and D.

Note(s): Not a natural product – purely synthetic. Like docetaxel, substrate of CYP3A4.

### 3. Epothilones and halichondrins

**Ixabepilone (Ixempra):** approved 2007



Uses: Breast cancer (commonly with capecitabine) for patients who have been previously treated with anthracyclines or who cannot tolerate additional anthracyclines. Or as monotherapy if a patient's tumor is resistant to anthracyclines, taxanes, or 5-FU. Administration is IV only. This drug is formulated

similar to that of paclitaxel (Cremophor/ethanol). Therefore, infusion reactions and unpredictable pharmacokinetics can occur.\* Patients should be premedicated.

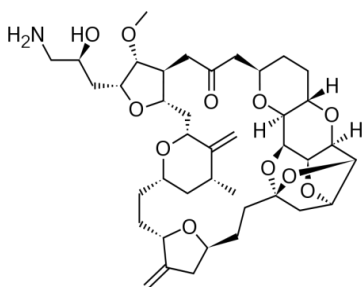
**Mechanism:** Similar to the taxanes in that it binds microtubules. Data indicate that the binding site(s) are quite different. Therefore, some patients can benefit after response to taxanes fail. Data indicate that ixabepilone is active in xenografts that are resistant to multiple agents including taxanes, anthracyclines, and vinca alkaloids. Ixabepilone has demonstrated synergistic antitumor activity in combination with capecitabine in vivo. In addition to direct antitumor activity, ixabepilone has antiangiogenic activity.

**Toxicity:** Peripheral neuropathy, myelosuppression, liver toxicity; \*infusion and allergic reactions.

**ADME:** Long terminal t<sub>1/2</sub> being ~50 hrs; clearance is hepatic and mainly by CYP3A4. Use of strong inhibitors of CYP3A4 can increase myelosuppression and peripheral neuropathy.

**Note(s):** Originally discovered in a bacterium that resides in soil.

**Halichondrin (Eribulin, Halaven):** approved Nov 2010



**Uses:** Breast cancer in patients who have previously received at least two chemotherapeutic regimens for the treatment of metastatic disease. Prior therapy should have included an anthracycline and a taxane in either the adjuvant or metastatic setting. Formulated as the mesylate salt.

**Mechanism:** Inhibits the growth phase (early phase) of microtubules leading to G<sub>2</sub>/M cell-cycle block.

**Toxicity:** Myelosuppression (especially neutropenia), peripheral neuropathy, alopecia, nausea, constipation. Some evidence of QT prolongation (see below).

**ADME:** Elimination t<sub>1/2</sub> of about 40 hrs; Eribulin is minimally metabolized and is excreted in the feces and urine mainly unchanged. Drug interactions with CYP enzymes are not an issue. Dosage adjustment guided by blood cell counts and degree of peripheral neuropathy.

**Note(s):** Eribulin is a synthetic analogue of halichondrin B, a product isolated from the marine sponge *Halichondria okada*.

**QT prolongation:** The QT interval is a measure of the time between the start of the Q wave and the end of the T wave in the heart's electrical cycle. In general, the QT interval represents electrical depolarization and repolarization of the left and right ventricles. A lengthened QT interval is a biomarker for ventricular tachyarrhythmias like torsades de pointes and a risk factor for sudden death.

Starting in 2005, FDA and European regulators have required that nearly all new molecular entities are evaluated in a Thorough QT (TQT) study to determine a drug's effect on the QT interval. The TQT study serves to assess the potential arrhythmia liability of a drug.

The QT interval is intrinsically longer in women than men.

**Neutrophil nadir:** Myelosuppression is a common side effect of many anticancer agents, including the antimetabolic agents. The specific loss of neutrophils is part of this suppression. Neutrophils are very important for fighting infections and recovery of neutrophil counts can have an impact on dosing frequency. The nadir (low point) often occurs 7-14 days after dosing a chemotherapeutic. It can take from 2-3 weeks for neutrophil counts to return to normal. Hence, dosing of anticancer agents that cause severe myelosuppression is often q3w.

