ANTIOXIDANTS AND OTHER NUTRIENTS DO NOT INTERFERE WITH CHEMOTHERAPY OR RADIATION THERAPY AND CAN INCREASE KILL AND INCREASE SURVIVAL, PART 1
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Purpose • Some in the oncology community contend that patients undergoing chemotherapy and/or radiation therapy should not use food supplement antioxidants and other nutrients. Oncologists at an influential oncology institution contend that antioxidants interfere with radiation and some chemotherapies because those modalities kill by generating free radicals that are neutralized by antioxidants, and that folic acid interferes with methotrexate. This is despite the common use of amifostine and dexrazoxane, 2 prescription antioxidants, during chemotherapy and/or radiation therapy.

Design • To assess all evidence concerning antioxidant and other nutrients used concomitantly with chemotherapy and/or radiation therapy, the MEDLINE® and CANCERLIT® databases were searched from 1965 to November 2003 using the words vitamins, antioxidants, chemotherapy, and radiation therapy. Bibliographies of articles were searched. All studies reporting concomitant nutrient use with chemotherapy and/or radiation therapy (280 peer-reviewed articles including 62 in vitro and 218 in vivo) were indiscriminately included.

Results • Fifty human clinical randomized or observational trials have been conducted, involving 8,521 patients using beta-carotene; vitamins A, C, and E; selenium; cysteine; B vitamins; vitamin D3; vitamin K3; and glutathione as single agents or in combination.

Conclusions • Since the 1970s, 280 peer-reviewed in vitro and in vivo studies, including 50 human studies involving 8,521 patients, 5,081 of whom were given nutrients, have consistently shown that non-prescription antioxidants and other nutrients do not interfere with therapeutic modalities for cancer. Furthermore, they enhance the killing of therapeutic modalities for cancer, decrease their side effects, and protect normal tissue. In 15 human studies, 3,738 patients who took non-prescription antioxidants and other nutrients actually had increased survival. (Altern Ther Health Med. 2007;13(1):22-28.)
many patients have been told not to use food supplement antioxi-
dants and other nutrients while undergoing chemotherapy and/or
radiation therapy because there is an erroneous but seemingly log-
ical belief that antioxidants interfere with radiation and some
chemotherapies because those modalities kill by generating free
radicals that are neutralized by antioxidants, and another errone-
ous belief that folic acid interferes with methotrexate.27-29

In an article that appeared on the front page of The New
York Times on October 26, 1997, Larry Norton, MD, of Memorial
Sloan Kettering Cancer Center, New York, was quoted as saying,
"Research at [Memorial Sloan Kettering] showed that large
doses of vitamin C could blunt the beneficial effects of
chemotherapy for breast cancer. . . . It is also known that folic
acid can negate the effects of methotrexate, a drug used to treat
cancer."27 The research referred to was finally published almost 2
years later and demonstrated only the mechanism by which can-
cer cells obtain vitamin C and that more vitamin C was found in
mice cancer cells compared to normal mice cells.29 However, the
senior author of that paper stated in a news release on the day of
publication (September 15, 1999), "It's possible that taking large
amounts of vitamin C could interfere with the effects of
chemotherapy or even radiation therapy."30 So a single interview
in The New York Times in 1997 that was not based on published
scientific work and a single research paper involving mice, along
with a press release by its author in 1999, led to the erroneous
notion that vitamin C interferes with chemotherapy and radi-
ation in humans. This notion soon applied to all antioxidants as
physicians, patients, the media, the American Cancer Society,31,32
and scores of websites took the same position without reviewing
the scientific evidence.

This 2-part article presents the scientific data that antioxi-
dants do not interfere with chemotherapy and/or radiation ther-
apy. Furthermore, it is not folic acid that interferes with the action
of methotrexate, but rather folinic acid, a prescription drug that is
not a vitamin nor an antioxidant.33-35 This article reviews data
about vitamin A, beta-carotene, and vitamin E. Part 2 will review
data about antioxidant combinations, B vitamins, vitamins D3
and K3, and the glutathione-selenium complex.

METHODS
MEDLINE® and CANCERLIT® searches were done using
key words: vitamins, antioxidants, chemotherapy, and radiation
therapy. All studies reporting food supplement nutrients used
concomitantly with chemotherapy and/or radiation therapy were
indiscriminately included; however, in cases in which an
author had published his or her findings in multiple sources,
only the most recently published paper was used as it usually
contained the greatest number of patients.

BACKGROUND
Radiation and certain chemotherapies produce cellular kill by
generating free radicals; antioxidants neutralize free radicals and
the oxidative reactions that are caused by free radicals (Table 1).

Other nutrients are included in this review. B vitamins

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<th>TABLE 1 Agents That Generate or Neutralize Free Radicals</th>
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<td>Generate Free Radicals</td>
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<td>Alkylating Agents</td>
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Antioxidants (Neutralize
Free Radicals)

Glutathione-selenium complex
N-acetyl cysteine
Selenium
Vitamin C
Vitamin E

enhance the immune system and protect normal cells from the
harm of radiation and other destructive mechanisms. Glutathione
peroxidase, a selenium-containing antioxidant enzyme complex,
protects the cell from free-radical injury. Glutathione peroxidase
easier to measure than selenium and has the advantage of assess-
ing only biologically active selenium. Vitamin A and retinoids have anti-cancer effects, repair normal
cells, and modulate the growth and differentiation of malignant
cells. Vitamin D3 inhibits cancer cell proliferation and replica-
tion, induces differentiation of leukemia cells, inhibits the onc-
gene c-myc, and enhances the immune system. Vitamin K3
(menaiondione) inhibits cell growth, cell proliferation, DNA synthe-
sis, and the cell cycle. Vitamin K3 acts on apoptosis through
expression of c-myc and c-fos proto-oncogenes and lowers intra-
cellular pools of reduced glutathione.

Effects of Chemotherapy and Radiation Therapy on Serum
Nutrient Levels
Cancer patients suffer from caloric and nutritional malnutri-
tion and have vitamin deficiencies, particularly of folic acid, vita-
m in C, pyridoxine, and other nutrients because of poor nutrition
and treatment.38 Chemotherapy and radiation therapy reduce
serum levels of antioxidant vitamins and minerals due to lipid per-
oxidation and thus produce higher levels of oxidative stress.28-29
Iron could be the intermediate cause of this oxidative stress.28-29
Therefore, supplemental iron should not be recommended to can-
cer patients who have anemia unless it is an iron-deficiency anemia.
Early Studies

Five early studies showed that N-acetyl cysteine, an antioxidant, protects the heart from the cardiac toxicity of adriamycin without interfering with the tumor-killing capability of adriamycin. 113 Seven cellular studies, 116-118 22 animal studies, 119,120 and human studies 121-128 have demonstrated that vitamins A, E, C, and K, as well as beta-carotene and selenium—as single agents or in combination—all protect against the toxicity of adriamycin and actually enhance its cancer-killing effects.

Cellular and Animal Studies

Fifty-one cellular 129-138 and 81 animal studies 139-150 using nutrients that include vitamins A, B 6, B 12, C, D, E, and K, beta-carotene, other retinoids, selenium, or cysteine as single agents or in combination given concomitantly with chemotherapy, radiation, or combinations of these modalities show the same effect—no interference, increased protection of normal tissues, increased tumor killing, and, in some studies, increased animal survival.

Observational Versus Randomized Clinical Studies

Compared to randomized studies, observational studies are less costly, can be done more quickly, and have a broader range of patients. Observational studies provide valid information and virtually the same results as randomized studies, a finding that differs from previous conclusions. 111,112 Furthermore, “Observational studies do not overestimate the magnitude of the effects of treatment compared with those in randomized trials on the same topic.” 151 In this 2-part article, we will summarize 50 human studies, 36 observational and 14 randomized, that reported concomitant nutrient use with chemotherapy and/or radiation therapy.

Review of Human Studies

Fifty human studies, involving 8,521 patients, have been conducted using single or multiple nutrients in combination with systemic treatment and/or radiation treatment and demonstrate that nutrients do not interfere with treatment. In fact, 47 of these 50 studies indicated that nutrients decrease side effects of treatment, and the other 3 studies showed no difference. In addition, many of the studies reported that nutrients produce higher response rates and higher survival rates when administered concomitantly with chemotherapy and/or radiation therapy. This part of the 2-part article reviews data about vitamin A, beta-carotene, and vitamin E. 114-118

VITAMIN A (RETINYL PALMITATE)

In an observational study of 275 patients with head and neck cancer, patients were treated with 5-fluorouracil and cobalt-60 radiation, as well as vitamin A. Vitamin A enhanced the cellular sensitivity to irradiation, increased treatment response rate, and lowered toxic side effects. 115

In a randomized study of 153 patients with chronic myelogenous leukemia (CML), patients were randomized to receive pulse oral busulfan with or without the daily administration of oral vitamin A (50,000 IU). Patients receiving only busulfan had a shorter survival, with a 42% greater risk of death. In addition to increasing survival, vitamin A decreased side effects and increased treatment response rate. 116

In an observational study of 40 patients with stage IIIIB or stage IV non-small cell lung cancer, patients were treated with cisplatin (120 mg/m 2 divided into 5 days), vindesine (3 mg/m 2 on days 1 and 5), 5-fluorouracil (500 mg/m 2 on days 1 and 5), beta-interferon (1 million IU 3 times a week), and retinyl palmitate (50,000 IU twice a day). Vitamin A produced fewer side effects, a higher response rate, and increased survival compared to historical controls. 117

In an observational study, 23 patients with unresectable or recurrent advanced oral cavity cancer were treated with 5-fluorouracil (1,000 mg/m 2) and cisplatin (20 mg/m 2) for 5 days. Vitamin A (15,000 IU twice a day) was also given throughout the treatment. Vitamin A decreased side effects, increased response rate, and slightly increased survival. 118

In an observational study of 36 patients with stage IV breast cancer, patients were treated with cyclophosphamide, 5-fluorouracil, 4-epidoxorubicin, vincristine, and prednisone every 3 weeks for 6 courses, followed by 2 courses of methotrexate, mitomycin-C, and mitoxantrone. Treatment continued with tamoxifen and vitamin A. Sixty-four percent of patients had a clinical response, 19% had stable disease, and side effects were minimal. Median overall survival was 32 months. These results compare favorably with historical controls. 119

In an observational study of 22 patients with unresectable and/or metastatic pancreatic cancer, patients were treated with folinic acid (200 mg/m 2), 5-fluorouracil (370 mg/m 2), epirubicin (60 mg/m 2), mitomycin-C (10 mg/m 2), interferon (1 million IU/m 2 3 times a week), and vitamin A (50,000 IU twice a day). Response rates and survival were similar to historical controls. 120

In an observational study of 49 patients with metastatic breast cancer, 33 were treated with tamoxifen (30 mg/d), interferon (1 million IU 3 times a week), and vitamin A (15,000 IU twice a day). Sixteen patients were treated with tamoxifen (30 mg/d), interferon (3 million IU 3 times a week), and vitamin A (50,000 IU twice a day). There was no statistically significant difference in the response rate, response duration, or survival in the 2 groups treated with different dose levels of vitamin A and interferon. Compared to the Surveillance, Epidemiology, and End Results (SEER) Program data of the National Cancer Institute, however, these patients had a higher response rate and longer survival with fewer side effects. 121
**BETA-CAROTENE**

In an observational study of 20 patients with advanced squamous carcinoma of the mouth, patients were given 60 Gy cobalt radiation therapy in 30 fractions. The week before and after radiation, and also during the third and sixth weeks of radiation, patients were given synchronous injections of chemotherapy consisting of vincristine (2 mg), methotrexate (200 mg), and bleomycin (30 mg). Patients were randomized to receive supplemental beta-carotene (250 mg for days 1-21; 75 mg daily thereafter). No toxic side effects of beta-carotene were observed. Patients who received supplemental beta-carotene had less severe acute mucosal reactions.122

In an observational study of 15 patients treated with chemotherapy for various advanced cancers, patients were given chemotherapy/radiation therapy and beta-carotene. Beta-carotene decreased side effects and allowed for a longer than expected disease-free interval in all surviving patients.123

**VITAMIN E (ALPHA-TOCOPHEROL)**

In an observational study of 66 patients with transfusion-dependent myelodysplastic syndrome, patients received either high-dose 13-cis-retinoic acid only or high-dose 13-cis-retinoic acid with alpha-tocopherol. Patients who received alpha-tocopherol had decreased measures of skin and constitutional toxicities and were able to achieve longer treatment continuation with 13-cis-retinoic acid. As a result, fewer of these patients experienced progression to acute leukemia (28%) when compared to patients who received 13-cis-retinoic acid only (60%). A 2-fold increase in median survival also was observed in the group treated with vitamin E.124

In an observational study of 39 patients with head and neck cancer, study participants were treated with high-dose 13-cis-retinoic acid (100 mg/m² orally per day) and alpha-tocopherol administered in escalating dose schedules of 800, 1200, 1600, and 2000 IU per day for each subsequent 4-week treatment cycle. Over a 3-month period, patients experienced fewer grade 2 and grade 3 toxicities from high-dose 13-cis-retinoic acid without altering its plasma concentration.125

In an observational study of 17 patients with myelodysplasia, patients were treated with all-trans-retinoic acid (45 mg/m² in 2 divided doses), granulocyte colony-stimulating factor (started at 1 microgram/kg per day), erythropoietin (5,000 IU per day starting on day 2), and vitamin E (400 IU per day). Vitamin E reduced the toxicity and increased the response rate without affecting the performance of all-trans-retinoic acid.126

In an observational study involving 1 patient, the patient developed a skin carcinoma in a chest wall scar from having a mastectomy and radiation therapy 17 years earlier. After surgical excision of the carcinoma, she was treated with radiation therapy to the site. She also was given a vasodilator (pentoxifylline 1,200 mg/d) and vitamin E (400 IU per day) in an attempt to reduce the new scar formation. The authors concluded that vitamin E decreased the side effects of radiation, and the skin condition began to improve by the fourth month.127

In an observational study of 21 patients with metastatic breast cancer, patients had endomyocardial biopsies and were given alpha-tocopherol orally at 2 g/m² daily starting 7 days before cyclophosphamide, Adriamycin, and 5-fluorouracil administration. Vitamin E did not compromise the antitumor activity of the chemotherapy. Fifteen of 21 achieved an objective response—similar to the authors’ previous experience. Vitamin E allowed for an additional 100 mg/m² of Adriamycin to be given, but the authors stated that vitamin E did not protect the heart.128

In a randomized study of 12 patients with metastatic breast cancer, patients were treated with doxorubicin as an intravenous bolus infusion (60 mg/m²), and 6 were randomized to receive 200 mg alpha-tocopherol given intramuscularly 6 hours before infusion and 60 mg nifedipine given orally each day for 2 days before treatment. A higher response rate was achieved and cardiac toxicity was prevented in those who received vitamin E and nifedipine.129

In a randomized study of 20 patients with acute myelogenous leukemia, patients were given vitamin E daily and treated with induction chemotherapy (10 patients) and intensive chemotherapy followed by bone marrow transplantation (10 patients). Vitamin E increased treatment response rate and prevented mucositis—an inflammatory response of the oral cavity caused by radiation therapy—especially during induction therapy for acute myelogenous leukemia.130

In a randomized study of 18 patients with various cancers, patients received chemotherapy appropriate for their cancer site and were randomized to receive either placebo oil or topical vitamin E (400 IU/cc) to control mucositis. For the 16 patients with head and neck cancer, 5-fluorouracil (1,000 mg/m² as a continuous infusion for 5 days) and cisplatin (100 mg/m² on day 2) were given. For the patient with hepatocellular carcinoma, doxorubicin (45 mg/m² every 3 weeks) was given. The patient with acute myelogenous leukemia (AML) received Ara-C (100 mg/m²/d for 7 days) and doxorubicin (45 mg/m² on days 1-3). Oral mucositis lesions were observed daily before and 5 days after the application of either vitamin E or placebo oil. Vitamin E prevented chemotherapy-induced mucositis. In fact, whereas only 1 of 9 patients receiving placebo achieved complete resolution of their oral lesion, 6 of 9 patients receiving vitamin E achieved complete resolution.131

In a randomized study of 16 patients with various cancers, all participants were treated with a regimen containing Adriamycin appropriate for the cancer site. Seven were randomized to receive 1,800 IU tocopherol daily starting 24 hours after Adriamycin administration and continuing for at least 1 week after Adriamycin administration. Vitamin E did not interfere with chemotherapy but also did not protect against cardiac toxicity.132

Sixteen evaluable cancer patients in an observational study of 18 patients receiving Adriamycin were given dl-alpha-tocopherol acetate (1,600 IU a day) to determine whether vitamin E would protect against alopecia (hair loss), which occurs in virtually all patients receiving Adriamycin. Sixty-nine percent of patients given Adriamycin and vitamin E did not have alopecia.
Furthermore, a correlation was found between the time vitamin E was taken and the degree of alopecia. Most patients who began taking tocopherol more than 72 hours before chemotherapy treatment did not have alopecia.\(^{139}\)

**SUMMARY**

These studies show that vitamin A, beta-carotene, and vitamin E do not interfere with and actually can enhance the killing capabilities of therapeutic modalities for cancer, decrease their side effects, protect normal tissues, and, in some studies, prolong survival. Part 2 will review antioxidant combinations, B vitamins, vitamins D\(_3\) and K\(_3\), and the glutathione-selenium complex. A summary and discussion will then be presented.

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