Coenzyme Q10

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Overview  
This cancer information summary provides an overview of the use of coenzyme Q10 in cancer therapy. The summary includes a history of coenzyme Q10 research, a review of laboratory studies, and data from investigations involving human subjects. Although several naturally occurring forms of coenzyme Q have been identified, Q10 is the predominant form found in humans and most mammals, and it is the form most studied for therapeutic potential. Thus, it will be the only form of coenzyme Q discussed in this summary.  
  
This summary contains the following key information:  
  
Coenzyme Q10 is made naturally by the human body.  
Coenzyme Q10 helps cells to produce energy, and it acts as an antioxidant.  
Coenzyme Q10 has shown an ability to stimulate the immune system and to protect the heart from damage caused by certain chemotherapy drugs.  
Low blood levels of coenzyme Q10 have been detected in patients with some types of cancer.  
No report of a randomized clinical trial of coenzyme Q10 as a treatment for cancer has been published in a peer-reviewed scientific journal.  
Coenzyme Q10 is marketed in the United States as a dietary supplement.  
Many of the medical and scientific terms used in the summary are hypertext linked (at first use in each section) to the NCI Dictionary of Cancer Terms, which is oriented toward nonexperts. When a linked term is clicked, a definition will appear in a separate window.  
  
Reference citations in some PDQ cancer information summaries may include links to external websites that are operated by individuals or organizations for the purpose of marketing or advocating the use of specific treatments or products. These reference citations are included for informational purposes only. Their inclusion should not be viewed as an endorsement of the content of the websites, or of any treatment or product, by the PDQ Integrative, Alternative, and Complementary Therapies Editorial Board or the National Cancer Institute.  
  
General Information  
Coenzyme Q10 (also known as CoQ10, Q10, vitamin Q10, ubiquinone, and ubidecarenone) is a benzoquinone compound synthesized naturally by the human body. The Q and the 10 in the name refer to the quinone chemical group and the 10 isoprenyl subunits that are part of this compound s structure. The term coenzyme denotes it as an organic (contains carbon atoms), nonprotein molecule necessary for the proper functioning of its protein partner (an enzyme or an enzyme complex). Coenzyme Q10 is used by cells of the body in a process known variously as:  
  
Aerobic respiration.  
Aerobic metabolism.  
Oxidative metabolism.  
Cell respiration.  
Through this process, mitochondria produce energy for cell growth and maintenance.[1-4] Coenzyme Q10 is also used by the body as an endogenous antioxidant.[1,2,4-8] An antioxidant is a substance that protects cells from free radicals, which are highly reactive chemicals, often containing oxygen atoms, capable of damaging important cellular components such as DNA and lipids. In addition, the plasma level of coenzyme Q10 has been used in studies as a measure of oxidative stress.[9,10]  
  
Coenzyme Q10 is present in most tissues, but the highest concentrations are found in the following organs:[11]  
  
Heart.  
Liver.  
Kidneys.  
Pancreas.  
The lowest concentration is found in the lungs.[11] Tissue levels of this compound decrease as people age, due to increased requirements, decreased production,[11] or insufficient intake of the chemical precursors needed for synthesis.[12] In humans, normal blood levels of coenzyme Q10 have been defined variably, with reported normal values ranging from 0.30 to 3.84 g/mL.[2,4,13,14]  
  
Given the importance of coenzyme Q10 in optimizing cellular energy production, use of this compound as a treatment for diseases other than cancer has been explored. Most of these investigations have focused on coenzyme Q10 as a treatment for cardiovascular disease.[2,4,15] In patients with cancer, coenzyme Q10 has been shown to do the following:  
  
Protect the heart from anthracycline-induced cardiotoxicity (anthracyclines are a family of chemotherapy drugs, including doxorubicin, that have the potential to damage the heart).[3,16-18]  
Stimulate the immune system.[19,20]  
Stimulation of the immune system by this compound has also been observed in animal studies and in humans without cancer.[21-27] In part because of its immunostimulatory potential, coenzyme Q10 has been used as an adjuvant therapy in patients with various types of cancer.[17,20,28-33]  
  
While coenzyme Q10 may show indirect anticancer activity through its effect(s) on the immune system, there is evidence to suggest that analogs of this compound can suppress cancer growth directly. Analogs of coenzyme Q10 have been shown to inhibit the proliferation of cancer cells in vitro and the growth of cancer cells transplanted into rats and mice.[12,34] In view of these findings, it has been proposed that analogs of coenzyme Q10 may function as antimetabolites to disrupt normal biochemical reactions that are required for cell growth and/or survival and, thus, that they may be useful as chemotherapeutic agents.[12,34]  
  
Several companies distribute coenzyme Q10 as a dietary supplement. In the United States, dietary supplements are regulated as foods, not drugs. Therefore, premarket evaluation and approval by the U.S. Food and Drug Administration (FDA) are not required unless specific disease prevention or treatment claims are made. The FDA can, however, remove from the market dietary supplements that it deems unsafe. Because dietary supplements are not formally reviewed for manufacturing consistency, ingredients may vary considerably from lot to lot and there is no guarantee that ingredients claimed on product labels are present (or are present in the specified amounts). The FDA has not approved coenzyme Q10 for the treatment of cancer or any other medical condition.  
  
To conduct clinical drug research in the United States, researchers must file an Investigational New Drug (IND) application with the FDA. The IND application process is highly confidential, and IND information can be disclosed only by the applicants. No investigators have announced that they have applied for an IND to study coenzyme Q10 as a treatment for cancer.  
  
In animal studies, coenzyme Q10 has been administered by injection (intravenous, intraperitoneal, intramuscular, or subcutaneous). In humans, it is usually taken orally as a pill (gel bead or capsule), but intravenous infusions have been given.[4] Coenzyme Q10 is absorbed best with fat; therefore, lipid preparations are better absorbed than the purified compound.[2,4] In human studies, supplementation doses and administration schedules have varied, but usually have been in the range of 90 to 390 mg/day.  
  
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History  
Coenzyme Q10 was first isolated in 1957, and its chemical structure (benzoquinone compound) was determined in 1958.[1,2] Interest in coenzyme Q10 as a therapeutic agent in cancer began in 1961, when a deficiency was noted in the blood of both Swedish and American cancer patients, especially in the blood of patients with breast cancer.[2-4] A subsequent study showed a statistically significant relationship between the level of plasma coenzyme Q10 deficiency and breast cancer prognosis.[5] Low blood levels of this compound have been reported in patients with malignancies other than breast cancer, including myeloma, lymphoma, and cancers of the lung, prostate, pancreas, colon, kidney, and head and neck.[2,6,7] Furthermore, decreased levels of coenzyme Q10 have been detected in malignant human tissue,[8-12] but increased levels have been reported as well.[8]  
  
A large amount of laboratory and animal data on coenzyme Q10 have accumulated since 1962.[2] Research into cellular energy-producing mechanisms that involve this compound was awarded the Nobel Prize in Chemistry in 1978. Some of the accumulated data show that coenzyme Q10 stimulates animal immune systems, leading to higher antibody levels,[13] greater numbers and/or activities of macrophages and T cells (T lymphocytes),[13,14] and increased resistance to infection.[15-17] Coenzyme Q10 has also been reported to increase IgG (immunoglobulin G) antibody levels and to increase the CD4 to CD8 T-cell ratio in humans.[18-20] CD4 and CD8 are proteins found on the surface of T cells, with CD4 and CD8 identifying helper T cells and cytotoxic T cells, respectively; decreased CD4 to CD8 T-cell ratios have been reported for cancer patients.[21,22] Research subsequently delineated the antioxidant properties of coenzyme Q10.[23-27]  
  
Proposed mechanisms of action for coenzyme Q10 that are relevant to cancer include its essential function in cellular energy production and its stimulation of the immune system (which may both be related), as well as its role as an antioxidant. Coenzyme Q10 is essential to aerobic energy production,[1,25,28] and it has been suggested that increased cellular energy leads to increased antibody synthesis in B cells (B lymphocytes).[6,18] As noted previously (General Information section), coenzyme Q10 can also behave as an antioxidant.[1,25-27,29-32] In this capacity, coenzyme Q10 is thought to stabilize cell membranes (lipid-containing structures essential to maintaining cell integrity) and to prevent free radical damage to other important cellular components.[1,25,27,32] Free radical damage to DNA (and possibly to other cellular molecules) may be a factor in cancer development.[11,23,30,33-36]  
  
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Laboratory/Animal/Preclinical Studies  
Laboratory work on coenzyme Q10 has focused primarily on its structure and its function in cell respiration. Studies in animals have demonstrated that coenzyme Q10 is capable of stimulating the immune system, with treated animals showing increased resistance to protozoal infections [1,2] and to viral and chemically-induced neoplasia.[1-4] Early studies of coenzyme Q10 showed increased hematopoiesis (the formation of new blood cells) in monkeys,[4,5] rabbits,[6] and poultry.[5] Coenzyme Q10 demonstrated a protective effect on the heart muscle of mice, rats, and rabbits given the anthracycline anticancer drug doxorubicin.[7-12] Although another study confirmed this protective effect with intraperitoneal administration of doxorubicin in mice, it failed to demonstrate a protective effect when the anthracycline was given intravenously, which is the route of administration in humans.[13]  
  
Researchers in one study sounded a cautionary note when they found that coadministration of coenzyme Q10 and radiation therapy decreased the effectiveness of the radiation therapy.[14] In this study, mice inoculated with human small cell lung cancer cells (a xenograft study), and then given coenzyme Q10 and single-dose radiation therapy, showed substantially less inhibition of tumor growth than mice in the control group that were treated with radiation therapy alone. Since radiation leads to the production of free radicals, and since antioxidants protect against free radical damage, the effect in this study might be explained by coenzyme Q10 acting as an antioxidant. As noted previously, there is some evidence from laboratory and animal studies that analogs of coenzyme Q10 may have direct anticancer activity.[15,16] See the General Information section.  
  
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Human/Clinical Studies  
In This Section  
Symptom and Side Effect Management  
Cardiac toxicity  
Fatigue  
Cancer Treatment  
Current Clinical Trials  
Clinical studies on the use of coenzyme Q10 to prevent side effects of cancer treatment, treat side effects of cancer treatment, and/or as a treatment for cancer are very limited. Importantly, clinical trials that examined the use of coenzyme Q10 during cancer treatment to prevent toxicities have not followed patients for long-term outcomes to determine whether coenzyme Q10 decreased the efficacy of cancer treatments (e.g., chemotherapy and radiation therapy). A recent observational study conducted with 1,134 patients with breast cancer enrolled in an National Cancer Institute multi-institution clinical trial (SWOG S0221) suggested that the use of antioxidant supplements, including coenzyme Q10, prior to and during cancer treatment may be associated with increased recurrence rates and decreased survival.[1]  
  
Symptom and Side Effect Management  
Cardiac toxicity  
In view of promising results from animal studies, coenzyme Q10 was tested as a protective agent against cardiac toxicity that was observed in cancer patients treated with the anthracycline drug doxorubicin. It has been postulated that doxorubicin interferes with energy-generating biochemical reactions that involve coenzyme Q10 in heart muscle mitochondria and that this interference can be overcome by coenzyme Q10 supplementation.[2-4] Studies with adults and children, including the aforementioned randomized trial, have confirmed the decrease in cardiac toxicity observed in animal studies.[2,5-7] A randomized trial [7] of 20 patients tested the ability of coenzyme Q10 to reduce cardiotoxicity caused by anthracycline drugs.  
  
Fatigue  
Two randomized, controlled trials have explored the potential of coenzyme Q10-containing supplements to prevent or treat fatigue in patients who received cancer therapy. A randomized, placebo-controlled trial of 236 patients with breast cancer who received adjuvant chemotherapy with or without radiation therapy concluded that coenzyme Q10 at a daily dose of 300 mg combined with 300 IU of vitamin E, divided into three doses, did not prevent treatment-induced worsening of mean fatigue levels or quality of life after 24 weeks of supplementation.[8] Another smaller trial (N = 59) used a daily administration of a different supplement that contained coenzyme Q10 (30 mg) along with branched-chain amino acids (2,500 mg) and L-carnitine (50 mg). All patients received adjuvant chemotherapy, but none received radiation therapy during the 21 days of the trial. The results of this trial also failed to show a significant difference in the mean fatigue levels between the treatment group and the control group, though a statistically significant benefit was seen for the study s primary endpoint (worst level of fatigue during the past 24 hours).[9]  
  
Cancer Treatment  
The use of coenzyme Q10 as a treatment for cancer in humans has been investigated in only a limited manner. In view of observations that blood levels of coenzyme Q10 are frequently reduced in cancer patients,[10-14] supplementation with this compound has been tested in patients undergoing conventional treatment. An open-label, nonblinded, uncontrolled clinical study in Denmark followed 32 patients with breast cancer for 18 months.[15] The disease had spread to the axillary lymph nodes, and an unreported number of patients had distant metastases. Patients received antioxidant supplementation (vitamin C, vitamin E, and beta carotene), other vitamins and trace minerals, essential fatty acids, and coenzyme Q10 (at a dose of 90 mg/day), in addition to standard therapy (surgery, radiation therapy, and chemotherapy, with or without tamoxifen). Patients were seen every 3 months to monitor disease status (progressive disease or recurrence), and if there was a suspicion of recurrence, mammography, bone scan, x-ray, or biopsy was performed. The survival rate for the study period was 100% (four deaths were expected). Six patients were reported to show some evidence of remission; however, incomplete clinical data were provided and information suggestive of remission was presented for only three of six patients. None of the six patients had evidence of further metastases. For all 32 patients, decreased use of painkillers, improved quality of life, and an absence of weight loss were reported. Whether painkiller use and quality of life were measured objectively (e.g., from pharmacy records and validated questionnaires, respectively) or subjectively (from patient self-reports) was not specified.  
  
In a follow-up study, one of six patients with a reported remission and one new patient were treated for several months with higher doses of coenzyme Q10 (390 mg/day and 300 mg/day, respectively).[16] Surgical removal of the primary breast tumor in both patients had been incomplete. After 3 to 4 months of high-level coenzyme Q10 supplementation, both patients appeared to experience complete regression of their residual breast tumors (assessed by clinical examination and mammography). It should be noted that a different patient identifier was used in the follow-up study for the patient who had participated in the original study. Therefore, it is impossible to determine which of the six patients with a reported remission took part in the follow-up study. In the follow-up study report, the researchers noted that all 32 patients from the original study remained alive at 24 months of observation, whereas six deaths had been expected.[16]  
  
In another report by the same investigators, three patients with breast cancer who received high-dose coenzyme Q10 (390 mg/day) were followed for a total of 3 to 5 years.[11] One patient had complete remission of liver metastases (determined by clinical examination and ultrasonography), one patient had remission of a tumor that had spread to the chest wall (determined by clinical examination and chest x-ray), and one patient had no microscopic evidence of remaining tumor after a mastectomy (determined by biopsy of the tumor bed).  
  
All three of the above-mentioned human studies [11,15,16] had important design flaws that could have influenced their outcome. Study weaknesses include the absence of a control group (i.e., all patients received coenzyme Q10), possible selection bias in the follow-up investigations, and multiple confounding variables (i.e., patients received a variety of supplements in addition to coenzyme Q10 and received standard therapy either during or immediately before supplementation with coenzyme Q10). Thus, it is impossible to determine whether any of the beneficial results was directly related to coenzyme Q10 therapy.  
  
Anecdotal reports of coenzyme Q10 lengthening the survival of patients with pancreatic, lung, rectal, laryngeal, colon, and prostate cancers also exist in the peer-reviewed scientific literature.[6] The patients described in these reports also received therapies other than coenzyme Q10, including chemotherapy, radiation therapy, and surgery.  
  
Current Clinical Trials  
Use our advanced clinical trial search to find NCI-supported cancer clinical trials that are now enrolling patients. The search can be narrowed by location of the trial, type of treatment, name of the drug, and other criteria. General information about clinical trials is also available.  
  
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Adverse Effects  
No serious toxicity associated with the use of coenzyme Q10 has been reported.[1-4] Doses of 100 mg/day or higher have caused mild insomnia in some individuals. Liver enzyme elevation has been detected in patients taking doses of 300 mg/day for extended periods of time, but no liver toxicity has been reported.[1] Researchers in one cardiovascular study reported that coenzyme Q10 caused rashes, nausea, and epigastric (upper abdominal) pain that required withdrawal of a small number of patients from the study.[5] Other reported side effects have included dizziness, photophobia (abnormal visual sensitivity to light), irritability,[5] headache, heartburn, and fatigue.[6]  
  
In a prospective study that explored the association between supplement use and breast cancer outcomes (SWOG S0221), the use of any antioxidant supplement before and during treatment including coenzyme Q10, vitamin A, vitamin C, vitamin E, and carotenoids was associated with a trend showing an increased hazard of recurrence (adjusted hazard ratio, 1.41; confidence interval, 0.98 2.04, P = .06).[7]  
  
Certain lipid-lowering drugs, such as the statins (lovastatin, pravastatin, and simvastatin) and gemfibrozil, as well as oral agents that lower blood sugar, such as glyburide and tolazamide, cause a decrease in serum levels of coenzyme Q10 and reduce the effects of coenzyme Q10 supplementation.[1,8-10] Beta-blockers (drugs that slow the heart rate and lower blood pressure) can inhibit coenzyme Q10-dependent enzyme reactions. The contractile force of the heart in patients with high blood pressure can be increased by coenzyme Q10 administration.[1] Coenzyme Q10 can reduce the body s response to the anticoagulant drug warfarin.[10] Finally, coenzyme Q10 can decrease insulin requirements in individuals with diabetes.  
  
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Summary of the Evidence for Coenzyme Q10  
To assist readers in evaluating the results of human studies of integrative, alternative, and complementary therapies for cancer, the strength of the evidence (i.e., the levels of evidence ) associated with each type of treatment is provided whenever possible. To qualify for a level of evidence analysis, a study must:  
  
Be published in a peer-reviewed scientific journal.  
Report on a therapeutic outcome or outcomes, such as tumor response, improvement in survival, or measured improvement in quality of life.  
Describe clinical findings in sufficient detail that a meaningful evaluation can be made.  
Separate levels of evidence scores are assigned to qualifying human studies on the basis of statistical strength of the study design and scientific strength of the treatment outcomes (i.e., endpoints) measured. The resulting two scores are then combined to produce an overall score. A table showing the levels of evidence scores for qualifying human studies cited in this summary is presented below. For an explanation of the scores and additional information about levels of evidence analysis for cancer, see Levels of Evidence for Human Studies of Integrative, Alternative, and Complementary Therapies.  
  
Coenzyme Q10 Summary: Reference Numbers and the Corresponding Levels of Evidence  
Reference Number Statistical Strength of Study Design Strength of Endpoints Measured Combined Score  
[1] 3iii Nonconsecutive case series Diii Indirect surrogates -- tumor response rate 3iiiDiii  
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Latest Updates to This Summary (06/07/2022)  
The PDQ cancer information summaries are reviewed regularly and updated as new information becomes available. This section describes the latest changes made to this summary as of the date above.  
  
Editorial changes were made to this summary.  
  
This summary is written and maintained by the PDQ Integrative, Alternative, and Complementary Therapies Editorial Board, which is editorially independent of NCI. The summary reflects an independent review of the literature and does not represent a policy statement of NCI or NIH. More information about summary policies and the role of the PDQ Editorial Boards in maintaining the PDQ summaries can be found on the About This PDQ Summary and PDQ Cancer Information for Health Professionals pages.  
  
About This PDQ Summary  
Purpose of This Summary  
This PDQ cancer information summary for health professionals provides comprehensive, peer-reviewed, evidence-based information about the use of coenzyme Q10 in the treatment of people with cancer. It is intended as a resource to inform and assist clinicians in the care of their patients. It does not provide formal guidelines or recommendations for making health care decisions.  
  
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be cited with text, or  
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