Dynamic Chiropractic

UV Light, Skin Cancer and Photo-Aging: Nutritional Antioxidant Protection

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Nonmelanoma skin cancer is the most common malignancy in the United States. The estimated lifetime risk of developing malignant melanoma in the U.S. has risen from one in 250 in 1981, to one in 87 in 1996. Cumulative lifetime sun exposure and decreased protection from the earth's shrinking ozone layer are considered the primary culprits of these disquieting statistics.[1-3]

More specifically, ultraviolet (UV) light from the sun is known to induce the production of free radicals within the epidermis and dermis. These are highly aggressive, reactive molecules, known to damage skin cells and their connective tissues in various ways, leading to accelerated aging of the skin and increase in the risk of skin cancer.[4] This article outlines the biological mechanisms through which UV light creates these dangerous free radical species, and the most prudent and practical lifestyle steps individuals can employ to reduce UV-light-induced skin damage, with special emphasis on the emerging role of antioxidant supplements.

How Free Radicals Are Formed in the Skin

The presence of molecular oxygen (O_2) within skin cells in the mid-lower levels of the epidermis is a primary target for UV light waves that penetrate the skin, primarily from exposure to sunlight.[4] Molecular oxygen is a unique and volatile substance, in that its outer electron shells are not completely filled with orbiting electrons, and thus has a tendency to absorb additional electrons to fill up these two vacant orbits. Consequently, the incoming UV light can donate an electron to molecular oxygen within skin cells of the epidermis. (Electrons are negatively charged wave particles that circle the nucleus of an atom in a specific orbiting pattern. Electrons with higher energy are found in the outer orbits of the atom, whereas electrons with less energy have orbits closer to the nucleus of the atom.)

If UV light donates an electron, molecular oxygen will now have a single, unpaired electron in its outer orbit. This spells trouble, as electrons normally circle the nucleus of an atom in pairs. When molecular oxygen absorbs a single unpaired electron in this manner, it becomes an unstable, aggressive free radical known as the superoxide anion. To stabilize itself electrically, the superoxide anion will randomly steal an electron from a nearby molecule. This not only damages the molecule, but also converts it into a free radical, because it now will have an unpaired electron of its own. This sets off a chain reaction, whereby the newly formed free radical steals an electron from a neighboring molecule, turning it into a free radical, which steals an electron from another neighboring molecule, and so on.[5] This type of free radical propagation can damage many components of skin cells, such as enzymes and the cell membrane (outer skin of the cell).

Once damaged by free radicals, the cell membrane loses some of its control in determining what chemicals can enter and exit the cell (loss of a key function in the health of the cell). Fortunately, skin cells possess an antioxidant enzyme known as the superoxide dismutase, which can quench and neutralize the superoxide anion. Vitamin E within skin cells can also intercept some of the free

radicals created by the superoxide anion. However, when skin cells are exposed to a massive dosage of UV light (i.e., as from excess sun exposure), the normal antioxidant defense mechanisms within the cell cannot keep pace with the generation of free radicals, and severe free radical damage to skin cells is likely to occur, leading to accelerated aging and increased skin cancer risk.[4]

The superoxide anion is not the only free radical created by UV light. What often happens is that a second electron from the light can be added to the superoxide anion, creating a compound known as hydrogen peroxide (HOOH). This is extremely dangerous to the cell, because it can diffuse through the nuclear membrane and place itself next to the cell DNA.[1] At this point, HOOH can be easily transformed into an aggressive, damaging free radical known as the hydroxy radical(HR). This occurs when a transition metal such as ferrous iron (Fe++) donates an electron to HOOH, which splits the compound into two HRs, and converts ferrous iron to ferric iron (HO- + -OH + Fe +++). Once formed, HRs can do extensive damage to cell DNA, creating mutations linked to cancer and acceleration of the skin's aging process.

It is known that HRs do most of the damage to our cells compared to all other forms of free radicals generated from molecular oxygen. They can react with almost any compound in the body; are known to damage cellular enzymes, proteins, carbohydrates, lipids and DNA; and cause cross linking of proteins (such as collagen) in the dermis (which results in decreased elasticity of the skin). Antioxidant enzymes such as catalase and glutathione peroxidase, and vitamins E and C, work synergistically to quench and neutralize HRs. However, exposure to excessive amounts of UV light easily overwhelms these antioxidant defense mechanisms, allowing extensive DNA mutation and other significant cellular damage to occur.

The other free radical generated from the interaction of UV light with molecular oxygen within skin cells is singlet oxygen. In this instance, an electron in a lower orbit is bumped to a higher orbiting shell by the incoming energy from the UV light wave. This is known as an excited state of oxygen, which is also created in the body upon exposure to X-rays. The antioxidant betacarotene is a powerful quencher of singlet oxygen, as is one of its sister carotenoid compounds, lycopene, a red carotenoid that provides tomatoes with their distinctive color.[4,5]

The P53 Tumor Suppressor Gene and Pheomelanin

Free radicals generated by UV light within the skin also can damage the P53 tumor suppressor gene, which normally acts to prevent mutated cells from proliferating and initiating skin cancer development. When the P53 is intact within cell DNA, it identifies any serious mutations that have occurred to the genetic structure. If the damage to the DNA is severe, the P53 prevents the cell from dividing and replicating. As a result, the mutated, potentially cancerous cell eventually undergoes programmed cell death, or apoptosis. This is a safeguard mechanism the body uses to encourage newly formed cancer cells to commit suicide, preventing them from replicating and spreading through the body.

Unfortunately, free radicals can damage the P53 within our DNA, increasing the risk that mutated and cancerous cells will continue to divide and spread. Damage to the P53 tumor suppressor gene has been shown to occur in more than 50 percent of all human malignancies. It has been shown that this also applies to skin cells, as the free radicals induced by UV light have been shown to cause mutations to the P53 in epidermal cells. Thus, free radicals in the skin can cause direct damage to cellular structures within skin cells, and can increase cancer risk by disabling other protective mechanisms such as the P53.[4]

Note that those with fair skin and red hair tend to have the red-brown or yellow pigment

pheomelanin, a melanin molecule. Brown or black melanin (eumelanin) normally acts like a protective sunscreen (antioxidant), absorbing electrons from UV light to help reduce skin inflammation and free radical damage to skin cells, and the connective tissues within the dermis. However, in fair-skinned and redheaded individuals, pheomelanin is altered in such a way as to allow it to easily become converted into a free radical upon exposure to UV light, generating the superoxide anion, which, can damage nearby skin cells, including the DNA of melanocytes.

Free radical damage to melanocytes is thought to give rise to melanomas - the most lethal form of skin cancer. Individuals with red-brown or yellow pigment (pheomelanin versus eumelanin, which is brown or black in color) in their skin are known to be at higher risk for skin cancer, because the type of melanin in their epidermis can be converted easily into a cancer-causing free radical upon exposure to sunlight.[5-7]

Normal Skin Aging Versus UV-Light-Induced Skin Aging

Free radical damage to the skin from UV light is known to produce accelerated aging of the skin. In fact, all changes due to normal aging of the skin can be distinguished from those caused by UV-light-induced skin damage, as this causes dermatoheliosis: distinctive changes to five parts of the skin (epidermis: actinic keratosis; dermis: solar elastosis; blood vessels: telangiectasia; sebaceous glands: solar comedones; and melanocytes: diffuse or mottled brown patches).

Solar elastosis accounts for much of the skin wrinkling, the result of exposure to UV light. In solar elastosis, the free radicals generated in the skin from UV light cause "up-regulation" of the elastin promoter gene, which increases synthesis and accumulation of elastin and fibrin in the upper dermis. This produces the characteristic "deep-wrinkle" appearance of the skin. On the face, solar elastosis is visible as yellowish skin, crisscrossed by deep wrinkles, and on the neck and extended surfaces of the limbs, as atrophied and dyschromic skin.[8]

Free radicals reaching the dermis also cause translocation of glycosaminoglycans and alter their main dissacharide units. As a result, dermal glycosaminoglycans are repositioned from between collagen fibers (where they belong) to be deposited on the elastic material of the superficial dermis. As the correct structure and location of glycosaminoglycans within the skin is responsible for retaining water molecules and moisture, the repositioning and re-structuring of glycosaminoglycans results in less hydration and suppleness of the skin, further contributing to acceleration of skin aging.[9-12]

Protection From UV Light-Induced Free-Radical Skin Damage

There are four primary ways to reduce free radical damage generated from UV light: Avoid excess exposure to sunlight; wear protective clothing; use antioxidant-containing sun block creams and lotions; and ingest antioxidant supplements at levels beyond that which food alone can provide.[13,14] Taking these supplements is a lesser-known, but sound strategy to help defend the skin against free radical damage. Studies demonstrate that skin cells show rapid depletion of antioxidant enzymes and antioxidant nutrients (vitamins E and C, betacarotene and coenzyme Q10) upon exposure to UV light. This indicates that these antioxidant defenses are being used up rapidly to protect skin cells and related structures from free radical damage.[15,16] The same is true for skin surface lipids (a mixture of sebum and lipids secreted by epidermal cells), which represent the outermost protective layer of the skin.

Following exposure to UV light, the antioxidant defenses within skin surface lipids have been

shown to be rapidly depleted (such as with vitamin E and coenzyme Q10) with the concurrent accumulation of lipid peroxides (free radical damaged fats) and other dangerous end-products of free radical damage to cholesterol and unsaturated fats found within skin surface lipids.[17] Studies show, however, that when individuals take antioxidant supplements prior to exposure to UV light, there is less free radical damage to skin cells and related structures (e.g. collagen, elastin, blood vessels, melanocytes and sebaceous glands), and fewer free radicals created within skin surface lipids (suggesting that skin surface lipids should be viewed as the outermost antioxidant shield against free radicals from UV light).

It also is known that individuals can increase the concentration of antioxidant nutrients within their skin (epidermal) cells and skin surface lipids by taking antioxidant supplements at levels beyond what can be obtained from food alone.[17-20] In addition to vitamins E, C and betacarotene, the studies of Professor J.C. Beani[21] indicate that selenium and zinc are also important to boosting the antioxidant defense of skin cells. Selenium is required to activate the antioxidant enzyme glutathione peroxidase, and zinc has been shown to protect against cytotoxicity of UV-A and UV-B light, and against UV-B-induced DNA damage. Zinc also is required to activate the antioxidant enzyme superoxide dismutase within certain parts of the cell, a function it shares with the minerals magnesium and manganese.

Beani showed that better nutritional status of selenium and zinc within skin cells (and higher intracellular glutathione levels) resulted in significantly less free radical damage to these cells upon exposure to UV radiation than occurred in skin cells that displayed lower concentrations of these nutrients prior to UV radiation exposure. He concluded, "As DNA damage has a main place in photocarcinogenesis, our results point out the potential interest of photoprotection based on the support of endogenous antioxidants (food and supplement sources of antioxidants).... The research is indeed a necessity because sunscreens did not give convincing evidence of efficacy in preventing skin cancers."[21]

Thus, it is prudent that all patients and clients fortify the antioxidant defense mechanisms of the skin by choosing an antioxidant-rich diet (fruits, vegetables, legumes) and using an antioxidant-enriched multivitamin and mineral supplement each day. I would suggest the following levels of supplemental nutrients from high-potency multivitamins and minerals to help protect the skin from UV-light-induced skin damage:

Nutrient	Volume
Vitamin A	2,500- 3,000 IU
Beta-carotene	7,500 -15,000 IU
Vitamin C	500-1,000 mg
Vitamin E	200-400 IU
Selenium	100-200 mcg
Zinc	10-20 mg
Magnesium	100-300 mg
Manganese	5 mg
Copper	1-2 mg

In conclusion, intensive investigation into this area of research indicates that free radicals produced in the skin from the interaction between UV-light and molecular oxygen (within skin cells), and from the interaction of UV-light and pheomelanin, are primary factors in accelerated skin aging and increased risk of skin cancer. The biological mechanisms through which free radicals are created within the skin are largely understood, as are their deleterious effects on skin cells and related skin structures, and the ensuing depletion of skin antioxidant enzymes and nutrients that result from their presence.

Recent evidence indicates that nutritional antioxidants (from diet and supplements) are critically important to optimizing the defenses of skin cells and related skin structures and secretions (i.e., skin surface lipids), in addition to other standard lifestyle strategies commonly recommended to reduce risk of UV-light-induced skin damage. As such, health practitioners and skin care professionals should encourage their patients and clients to consume a diet rich in fruits, vegetables and legumes, and to ingest an antioxidant-enriched multivitamin and mineral each day that includes the above-noted levels of nutrients, as an integral part of lifelong protection against skin photo-aging and skin cancer.

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