JDDG
Journal of the German Society of Dermato
CME Article
DOI: 10.1111/ddg.13646
Submitted: 28.11.2017
Accepted: 19.6.2018
Conflict of interest
None.

Phototherapy

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Section Editor
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Summary

The efficacy of phototherapy is based on the interaction between ultraviolet (UV) radiation and the skin. The photobiological effects thus achieved depend on the wavelengths used. Targeted use of UVA and UVB, where indicated in combination with a photosensitizer such as psoralen, provides the dermatologist with a broad armamentarium for the treatment of a multitude of skin diseases. The spectrum of indications ranges from superficial dermatitis, psoriasis, and malignancies, such as cutaneous T-cell lymphoma, to deep sclerosing conditions such as morphea. The objective of the present review is to highlight the photobiological effects of the various types of UV radiation as well as the resultant clinical indications for phototherapy.

Introduction

The effects of ultraviolet radiation on the human body have been used to treat dermatological conditions since antiquity.

The effects of ultraviolet radiation on the human body have been used to treat dermatological conditions since antiquity. The Greek physician Galen instructed patients with skin diseases to spend more time in the sun. During the period of colonial rule, British doctors observed that patients with psoriasis experienced marked improvement in disease activity during their sojourn in India. However, it took many more years before phototherapy was first used in a more structured fashion. In 1903, the Faroese dermatologist Niels Ryberg Finsen was awarded the Nobel Prize in Medicine "*in recognition of his contribution to the treatment of diseases, especially lupus vulgaris, with concentrated light radiation, whereby he has opened a new avenue for medical science*" [1]. The use of modern UV lamps subsequently paved the way from heliotherapy to modern phototherapy, a development that is still ongoing. For example, UVA1 therapy has only become possible with the use of innovative high-pressure UVA lamps. In the future, this treatment option might be further simplified by the incorporation of LED technology. Modern phototherapy continues to be an effective, quick, and simple treatment modality that is virtually indispensable for the management of numerous dermatological disorders.

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Physical principles

Ultraviolet radiation (UV radiation) is part of the electromagnetic spectrum. The sun is the most important source of UV radiation, providing us with heat and energy and thereby making life possible on our planet. There are other artificial sources of radiation such as mercury vapor lamps and arc welding devices. Exposure to UV radiation is associated with the transmission of energy. The transmitted energy

UV radiation has more energy than visible light and ranges from 100 to 380 nm.

and wavelength are inversely proportional: the shorter the wavelength, the greater the frequency as well as the transmitted energy. That part of the electromagnetic spectrum that we perceive with our eyes is generally referred to as "light", with wavelengths ranging from 380 (violet) to 700 nm (red). UV radiation has more energy than visible light and ranges from 100 to 380 nm. From a functional perspective, UV radiation is further divided into UVA (320–380 nm), UVB (280–320 nm), and UVC (100–280 nm). The UVA range can be further subdivided into UVA1 (340–400 nm) and UVA2 (320–340 nm). Based on said physical principles, it becomes clear that the term "light therapy" is not correct, given that dermatologists use UV radiation rather than visible light for phototherapy. The term "radiation therapy" should likewise be avoided as it may stoke fear by suggesting a resemblance with oncological radiation therapy. In principle, however, dermatological phototherapy constitutes a form of radiation therapy.

UV radiation can be divided into UVA (320–380 nm), UVB (280–320 nm), and UVC (100–280 nm).

Interactions between tissue and UV radiation

The effects of phototherapy on the body largely depends on the wavelength of the UV radiation the skin is exposed to.

The earth's atmosphere and the gases contained therein act as a filter for solar radiation. Part of the UV radiation is absorbed or reflected. The UVC component in the solar spectrum is virtually completely filtered out by the ozone layer and will not be further addressed herein. A large part of UVB rays are filtered by the atmosphere, too. Only some of them reach the skin surface. The effects of phototherapy on the body largely depends on the wavelength of the UV radiation the skin is exposed to. Short-wave UVB radiation is rapidly absorbed in the epidermis. Only a small percentage penetrates the superficial dermis. The filtering effect of the earth's atmosphere is much less pronounced in terms UVA (longer wavelength). Following penetration of the atmosphere, its intensity is 1,000 times higher than that of UVB. The energy of UVA is also absorbed much more slowly as it passes through the skin; it therefore penetrates into deeper layers of the dermis, where it can exert its effects. The different depths of penetration of UV rays determine their applications in phototherapy. UVB is predominantly used for superficial dermatoses that primarily affect the epidermis. Skin disorders that also involve the deeper dermis, such as morphea, tend to require treatment with UVA. Given the lower energy of UVA radiation and thus lower efficacy of UVA phototherapy, its action can be enhanced by a photosensitizer such as psoralen. This form of treatment is referred to as PUVA (psoralen plus UVA).

UVA radiation has less energy but penetrates into deeper layers of the dermis, whereas UVB exerts its biological effects only in the epidermis and superficial dermis.

Mechanism of action of UVB

Exposure to UVB primarily leads to direct DNA damage.

A large part of UVB rays emitted by the sun is filtered out in the earth's atmosphere. Only about 5 to 10 % reach the skin surface. As it penetrates the skin's layers, the energy of UVB is almost completely absorbed by the epidermis. Only about 15 % of UVB rays the skin is actually exposed to reach the superficial dermis [2]. Exposure to UVB primarily leads to direct DNA damage. Absorption of UVB energy by DNA can result in covalent bonds between two adjacent pyrimidine (cytosine and thymine) bases in the DNA strand, thus resulting in pyrimidine dimers. The most important pyrimidine dimers in terms of sheer numbers are the cyclobutane pyrimidine dimers (CPDs) and the pyrimidine-(6-4)-pyrimidone photoproducts (6-4PPs) (Figure 1). Such photoproducts affect the DNA structure and interfere with the physiological function of the enzymes involved in replication and transcription. In addition, such photoproducts may give rise to mutations. C→T- and CC→TT transitions are particularly important. Given that they are characteristic of UV damage, they are referred to as signature mutations.

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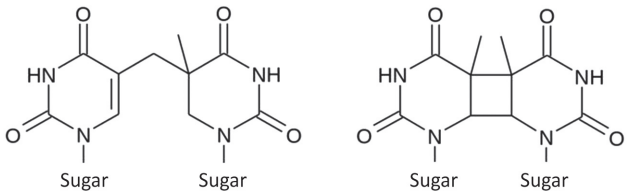

Figure 1 Example of a pyrimidine-(6-4)-pyrimidone photoproduct (left) and a cyclobutane pyrimidine dimer (right) consisting of two thymine bases.

Induction of apoptosis as well as necrosis is a key mechanism of action of UVB.

The cell is equipped with a number of repair mechanisms to eliminate UV-triggered DNA damage prior to the next replication. A mutation arises only when a given DNA damage is transcribed in the following replication phase. If the damage is too substantial and cannot be eliminated by the various repair mechanisms such as nucleotide excision repair and translesion DNA synthesis, the last resort available to the cell to avoid a mutation is initiation of apoptosis. Induction of apoptosis as well as necrosis is a key mechanism of action of UVB. In addition, exposure to UVB is associated with immunomodulatory effects, including inhibition of Th1 and Th17 cells and simultaneous upregulation of regulatory T cells (Tregs) [3]. In particular, there is an increase in Foxp3$^+$ Tregs, which play a role in immune tolerance and prevention of autoimmune processes: Foxp3 stabilizes Tregs, thereby contributing to decreased production of Th17 cells and their key cytokines IL-17, IL-22, and IL-23 [4]. A lower number of such Foxp3$^+$ Tregs is found in psoriasis lesions, which helps explain the efficacy of UVB treatment in these patients. There is strong evidence from studies showing an immune shift from a Th1/Th17 to a Th2 immune response, which is associated with reduced expression of IL-12, IL-18, IL-23, TNF-α, and (the proinflammatory) IFN-γ, as well as upregulation of anti-inflammatory cytokines such as IL-4 and IL-10 [5, 6].

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Besides its effects on the adaptive immune system, UVB also affects the innate component of our immune system. In 2009, Gläser et al. showed that various antimicrobial peptides – such as defensins (ß-defensin 2 and 3), RNases (ribonuclease 7), and S100 proteins (psoriasin) – were secreted by keratinocytes following UVB irradiation [7]. It is safe to assume that this mechanism of action is involved in the prevention of bacterial infections during phototherapy.

Narrowband UVB therapy can be combined with salt water baths (balneo-phototherapy). The high concentration of salts contained in the water produces synergistic effects with the actual phototherapy. Such treatment generally has keratolytic effects (for example, on psoriasis plaques), thus facilitating the penetration of UV radiation into the dermis. In addition, there is a drop in the activity of human leukocyte elastase and in the number and activity of Langerhans cells [8].

Indications for UVB therapy

Two different UVB modalities are available. Either the entire UVB range between 280 and 320 nm can be utilized (broadband UVB therapy) or merely a small segment at 311 nm (narrowband UVB therapy or UVB 311). The latter is intended to increase the tolerability of UVB treatment by avoiding lower wavelengths, which are thought to be associated with more adverse effects due to their higher energy content. As UVB311 is similarly effective, it has been shown to be superior in the treatment of psoriasis, atopic dermatitis, and vitiligo, as well as for the prevention of polymorphic light eruption [9].

Narrowband UVB therapy has been shown to be superior to broadband UVB in the treatment of psoriasis, atopic dermatitis, and vitiligo, as well as for the prevention of polymorphic light eruption.

While narrowband UVB is the phototherapy of choice in psoriasis, PUVA therapy appears to be superior to UVB in severe cases.

Psoriasis is a chronic inflammatory disease characterized by the predominance of Th1/Th17 cells. The outstanding efficacy of UVB phototherapy in patients with psoriasis can be explained, on the one hand, by the shift from Th1/Th17- to Th2-mediated immune responses, which is associated with a drop in key psoriasis cytokines such as IL-17, IL-22, and IL-23. In addition, upregulation of IL-10, a key Th2 cytokine and an inhibitor of macrophage function, helps correct the IL-10 deficiency in psoriasis lesions. On the other hand, UVB induces apoptosis of inflammatory cells in the psoriatic infiltrate (especially T lymphocytes but also keratinocytes and Langerhans cells). PUVA is an alternative to UVB in the treatment of psoriasis and appears to be superior, especially in severe cases. Studies indicate that the combination of biologics with narrowband UVB therapy is a safe treatment option [10]. As assessment of the carcinogenic potential requires long-term follow-up, there should be a clear indication for such treatment and it should only be used in the absence of alternatives [9]. While the combination of UV therapy with cyclosporine must absolutely be avoided, combining UVB therapy with systemic retinoids is an adequate option [11].

Patients with atopic dermatitis also benefit from narrowband UVB therapy, which is equally effective as UVA1 treatment.

Patients with atopic dermatitis also benefit from narrowband UVB therapy, which is equally effective as UVA1 treatment. The outstanding efficacy of narrowband UVB therapy involves the chromophore urocanic acid. Found in the stratum corneum, it exerts its photoprotective effect by absorbing UVB in particular. The production of urocanic acid requires filaggrin, whose expression is decreased or entirely absent in patients with atopic dermatitis. It has been shown that the resultant deficiency in urocanic acid in the stratum corneum of atopic dermatitis patients leads to an increase in efficacy of narrowband UVB therapy, an uptick in vitamin D production, as well as upregulation of antimicrobial peptides, involucrin, and other cytokines that promote the epidermal barrier function [12].

Narrowband UVB therapy should also be the phototherapy of choice in patients with vitiligo.

Narrowband UVB therapy should also be the phototherapy of choice in patients with vitiligo. Compared with PUVA treatment, narrowband UVB has been shown to be associated with higher response rates in patients with vitiligo [13]. However, treatment should continue for a sufficiently long period of at least six, ideally twelve months. Topical application of calcineurin inhibitors or vitamin D3 analogues during phototherapy significantly enhances the response to treatment. For a long time, the combination of topical calcineurin inhibitors and UV radiation had been viewed with caution because of its potentially increased carcinogenicity. However, several studies in humans and animals have provided no evidence of an increase in adverse effects [14]. In one study, application of topical calcineurin inhibitors even led to a reduction in UV-mediated thymine dimers. It should be pointed out, though, that such findings must be interpreted with caution, given the long latency period between UV exposure and tumor development.

Table 1 provides an overview of the indications for UVB phototherapy.

Mechanism of action of UVA

The photobiological effects of UVA are predominantly based on indirect effects.

The epidermis is exposed to roughly 80 % of solar UVA radiation; about 60 % reach the dermis and can be utilized to treat skin disorders located deep within the dermis [2]. The photobiological effects of UVA are predominantly based on indirect effects. The energy of UVA is absorbed by chromophores. These are molecules that – based on their chemical structures – are capable of absorbing electromagnetic energy. Chromophores can occur naturally in the body (for example, flavins, porphyrins, melanin, and various vitamins) or may be introduced from outside (for example, psoralen as part of PUVA). The chromophores "pass on the energy thus absorbed" and transfer it, for instance, to molecular oxygen. The resultant singlet oxygen ($^1O_2$) then attacks

Table 1 Important indications for UVB phototherapy.

Indication	UVB broadband	UVB 311 nm
Atopic dermatitis	+	++
Pruritus	+(+)*	+
Prurigo	+	+
Plaque parapsoriasis	+	+
Mycosis fungoides (patch stage)	+	+
Prophylaxis of polymorphic light eruption	+	++
Vitiligo	–	++
Lichenoid pityriasis	+	o
Lymphomatoid papulosis	+	o
Seborrheic dermatitis	+	+
HIV-associated pruritic eruptions	+	o
Cutaneous graft-versus-host disease	+	+
Pigmented purpura	o	+
Chronic spontaneous urticaria	o	+
Solar urticaria	o	+

*In the treatment of pruritus, especially if caused by uremia, broadband UVB may be superior to narrowband UVB [9].

guanine bases in the DNA, which results in the formation of 8-oxoguanine. Apart from singlet oxygen, other reactive oxygen species such as superoxide anions ($^{\bullet}O_2^-$) may occur. These react to form hydrogen peroxide (H_2O_2) and subsequently hydroxyl radicals ($^{\bullet}OH$). Hydroxyl radicals are capable of damaging all DNA components. Chromophores excited by the absorption of UVA can transfer their energy not only to oxygen, thus contributing to the formation of reactive oxygen species, they are also able to transfer energy directly to DNA in the form of single-electron oxidation. Oxidized purine bases, such as 8-oxoguanine in particular, are the main products of UVA-mediated oxidative cell damage. 8-oxoguanine is even a bioindicator for exposure to UVA. Besides oxidation of purine and pyrimidine bases, UVA exposure also leads to single-strand breaks and C→T transitions, like those observed following UVB irradiation. UVA-induced oxidative and direct cell damage results in apoptosis of proinflammatory cells, especially T cells, thus causing an anti-inflammatory effect.

Oxidized purine bases, such as 8-oxoguanine in particular, are the main products of UVA-mediated oxidative cell damage.

Reactive oxygen species not only damage DNA, thus inducing apoptosis and necrosis, they also lead to oxidation of membrane lipids. The latter then act as intermediate signaling molecules and affect gene expression. One such example is heme oxygenase 1 (HO-1), which is upregulated following UVA exposure and has cytoprotective and antiapoptotic effects [15]. Heme oxygenase 1 can be understood as a cellular protective mechanism against oxidative stress. Its impact on collagen metabolism is also particularly important for understanding the effects of UVA. UVA exerts an antifibrotic effect through the expression of HO-1, the induction of matrix metalloproteinases (such as MMP-1), and the inhibition of fibroblasts. Degradation of dermal collagen plays an important role in the treatment of sclerosing disorders in particular.

UVA affects gene expression through oxidation of membrane lipids.

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The importance of UVA1

The photobiological reactions following UV exposure described above are usually not specific for UVA and UVB. The effects of UV radiation on the human body do not change abruptly from one wave spectrum to the next but rather change continuously with the wavelength. Hence, direct DNA damage may also be caused by UVA, and reactive oxygen species by UVB. However, this generally happens to a much lesser degree. An exception to this rule is 8-oxoguanine formed as a result of purine base oxidation, which is observed exclusively after exposure to UVA.

The photobiological effects of UVA1 are primarily based on the induction of apoptosis of lymphocytes, mast cells, and Langerhans cells, on inhibition of the expression of Th2-associated cytokines such as IL-5, IL-13 and IL-31, and on the degradation of dermal collagen by activation of collagenases.

With the goal of developing a form of phototherapy with as few adverse effects as possible, treatment with UVA1 was first introduced in the early 1990s. UVA1 has the lowest energy within the UV spectrum and is supposed to largely avoid direct DNA damage. Given its low energy content, treatment requires special high-pressure UVA1 lamps as well as a relatively long exposure time. The photobiological effects of UVA1 are primarily based on the induction of apoptosis of lymphocytes, mast cells, and Langerhans cells, on inhibition of the expression of Th2-associated cytokines such as IL-5, IL-13 and IL-31, and on the degradation of dermal collagen by activation of collagenases.

Indications for UVA therapy

The main indications for UVA1 phototherapy are atopic dermatitis and sclerosing skin disorders.

The main indications for UVA1 phototherapy are atopic dermatitis and sclerosing skin disorders. In the treatment of atopic dermatitis, the efficacy and tolerability of high-dose UVA1 and narrowband UVB therapy are equivalent. Oral PUVA therapy is superior to both in terms of efficacy [9]. As regards sclerosing disorders, UVA1 phototherapy has been shown to be effective in the treatment of morphea, acrosclerosis caused by systemic sclerosis, extragenital lichen sclerosus et atrophicus, and scleroderma-like graft-versus-host disease [9]. In addition, there have been reports of its efficacy in patients with necrobiosis lipoidica and systemic lupus erythematosus [16]. Table 2 provides a synopsis of indications for which there is good evidence and those suggested by pilot studies and case reports.

Mechanism of action of PUVA

In PUVA therapy, psoralen is used as an artificial chromophore to enhance the effect of UVA radiation.

As described above, the presence of a chromophore is key to effective UVA therapy. This can be a molecule naturally occurring in the body or one introduced from outside. In PUVA therapy, psoralen is used as an artificial chromophore to enhance the effect of UVA radiation. The furocoumarin 8-methoxypsoralen (8-MOP) is typically used in Germany. It is inserted in the DNA of keratinocytes and – following UVA exposure – binds covalently to a nucleobase, which gives rise to a monoadduct. After another photonic excitation, 8-MOP can then bind to a second nucleobase on the opposite DNA strand, resulting in a DNA interstrand crosslink (ICL). Damage repair requires the cell to delay replication by arresting the cell cycle, so that repair mechanisms have more time to act. However, if the DNA damage is too extensive, the cell initiates apoptosis. PUVA therapy results in cell cycle arrest and apoptosis, especially of lymphocytes. PUVA also has an immunomodulatory effect: there is an increase in IL-2 and IFN-γ and a decrease in IL-4, IL-5, and IL-10, which suggests a Th2→Th1 shift [5]. In addition, there is upregulation of MHC-I following PUVA treatment. By forming photoadducts with membrane lipids, PUVA can also affect gene expression: known mechanisms include upregulation of the transcription factor NF-κB and of *p53*.

PUVA therapy results in cell cycle arrest and apoptosis, especially of lymphocytes.

Table 2 Indications for UVA1 phototherapy [9].

Indications confirmed by studies	Pilot studies and case reports
– topic dermatitis – Dyshidrotic hand eczema – Morphea – Chronic scleroderma-like GvHD	– Lichen sclerosus et atrophicus – Disabling pansclerotic morphea – Acrosclerosis caused by systemic sclerosis – Mycosis fungoides – Lymphomatoid papulosis – Follicular mucinosis (idiopathic) – Plaque psoriasis – Pityriasis rubra pilaris – Lichenoid pityriasis – Reticular erythematous mucinosis – Urticaria pigmentosa – Cutaneous sarcoidosis – Granuloma annulare – Lichen planus – Scleredema – Grover's disease – Netherton syndrome – Systemic lupus erythematosus

Indications for PUVA therapy

A distinction is made between cream PUVA, bath PUVA, and systemic PUVA.

A distinction is made between cream, bath, or systemic PUVA, depending on whether 8-MOP is applied topically, in the form of a cream or bath additive, or used systemically (per os). In hand/foot PUVA, only the hands and feet are bathed in psoralen solution. When performing PUVA therapy, it is important to bear in mind that PUVA is not only an enormously effective treatment option due to the deep penetration of UVA radiation and the significant increase in potency due to the use of an artificially inserted chromophore. Compared to other forms of phototherapy, it is also associated with the most adverse effects and complications. PUVA should therefore only be used if there is a clear indication, especially in children and patients with mild disease.

Apart from its outstanding efficacy, the disadvantage of PUVA therapy is that it causes the most DNA damage among all forms of phototherapy and thus harbors the greatest carcinogenic potential.

PUVA demonstrates outstanding efficacy in the treatment of patients with psoriasis.

PUVA demonstrates outstanding efficacy in the treatment of patients with psoriasis. In severe psoriasis, it is superior to other types of phototherapy. Both plaque and pustular forms of psoriasis can be treated. PUVA also has an excellent effect in atopic dermatitis, which is largely based on the aforementioned Th2→Th1 shift in the immune response and to the proapoptotic effect on lymphocytes. Along with the upregulation of MHC-I and the increase in IFN-γ production, the latter effect suggests good efficacy in the treatment of mycosis fungoides and lymphomatoid papulosis [17]. Systemic PUVA is generally preferred as this is the only way to treat the face as well; moreover, it is the only option that allows for whole-body treatment, which is required in most cases of mycosis fungoides. Unlike vitiligo, in which narrowband UVB therapy is given over a period of six to twelve months, PUVA therapy in mycosis fungoides should not be continued once complete clinical remission has been achieved. While treatment continuation would not prolong the disease-free interval, it would be associated with an increase in adverse effects and complications. Furthermore, PUVA therapy can be combined with systemic retinoids (Re-PUVA). Such combination treatment has been described in severe forms

Given its risk-benefit profile, the main indication for PUVA therapy is mycosis fungoides and lymphomatoid papulosis.

Table 3 Common indications for PUVA.

Indication	Systemic PUVA	Bath PUVA	Hand/foot PUVA
Psoriasis	+	+	
Palmoplantar psoriasis			+
Atopic dermatitis	+	+	
Dyshidrotic and hyperkeratotic hand and foot eczema			+
Plaque parapsoriasis	+	+	
Mycosis fungoides	+	+*	
Lymphomatoid papulosis	+	+	
Morphea	+	+	
Acute and chronic (scleroderma-like) graft-versus-host disease	+	+	
Lichen planus	+	+	+
Polymorphic light eruption, solar urticaria, chronic actinic dermatitis, hydroa vacciniforme, actinic prurigo	+		

*This type of phototherapy does not include the face and therefore does not allow for whole-body treatment, which is required in most cases of mycosis fungoides; modified after [9].

of plaque and pustular psoriasis, as well as in the treatment of cutaneous T-cell lymphoma, graft-versus-host disease, hand and foot eczema, and lichen planus. Other indications for the various forms of PUVA can be found in Table 3.

Phototherapy and carcinogenesis

However, several large studies have shown even longer-term treatment with broadband and narrowband UVB to be very safe [18].

From the mechanisms of action discussed above, it is readily understandable that UV radiation, on principle, has mutagenic potential. This notion is underscored by the increased incidence in melanoma and nonmelanoma skin cancer as a consequence of high UV exposure, for example among outdoor workers. However, several large studies have shown even longer-term treatment with broadband and narrowband UVB to be very safe [18]. The situation is different with PUVA therapy, which has the greatest carcinogenic risk among all forms of phototherapy.

However, the combination of phototherapy and cyclosporine (including a history of cyclosporine use) should be avoided, given the markedly increased carcinogenic potential.

Summary

The efficacy of phototherapy is essentially based on three mechanisms of action: apoptosis, immunomodulation, and modification of collagen metabolism.

The efficacy of phototherapy is essentially based on three mechanisms. First, exposure to UV radiation causes various forms of cell death, including apoptosis and necrosis. This affects not only cells of the inflammatory infiltrate but also keratinocytes. Secondly, there is modulation of the immune response, which differs considerably depending on the wavelengths used. UVB treatment tends to be associated with a shift from a Th1 to Th2 immune response. By contrast, PUVA therapy brings about an increase in IL-2 and IFN-γ, key Th1 cytokines. Thirdly, there is modulation of collagen metabolism, primarily due to the deep penetration of UVA. This has therapeutic implications in the treatment of sclerosing skin

disorders such as morphea or forms of graft-versus-host disease. In addition, phototherapy is an extremely cost-effective alternative, especially compared to biologics; and the dosage can easily be adjusted. The therapeutic range, on the one hand, and the relatively simple, quick, and cost-efficient implementation, on the other hand, make phototherapy an indispensable treatment option in dermatology.

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Fragen zur Zertifizierung durch die DDA

1. Welche Aussage zur UV-Strahlung ist richtig?

a) UV-Strahlung kann vom menschlichen Auge wahrgenommen werden.
b) Die Begriffe UV-Licht und UV-Strahlung können synonym verwendet werden.
c) Der UV-Bereich kann weiter in UV-A, UV-B und UV-C aufgeteilt werden.
d) Die Frequenz der UV-Strahlung ist geringer als die von rotem Licht.
e) Die Sonne ist die einzige Quelle für UV-Strahlung.

2. Welche der folgenden Aussagen ist korrekt? UV-A ...

a) wird fast vollständig in der Erdatmosphäre absorbiert.
b) dringt nur oberflächlich in die Haut ein.
c) ruft vorwiegend Doppelstrangbrüche in der DNS hervor.
d) ist der energieärmste Teil des UV-Spektrums.
e) sollte auf keinen Fall in der Behandlung von Kindern Anwendung finden.

3. Welche Behauptung zu UV-B ist falsch?

a) UV-B entfaltet seine gesamte Wirkung fast ausschließlich in der Dermis.
b) UV-B überträgt mehr Energie als UV-A.
c) UV-B hat eine kleinere Wellenlänge als UV-A.
d) Ein Großteil des solaren UV-B wird in der Erdatmosphäre durch Absorption und Reflexion herausgefiltert.
e) UV-B findet Anwendung in der Medizin.

4. Die Wirkung der Phototherapie beruht auf ...

a) Nekrose, Veränderung der Genexpression, Abtöten aller Bakterien auf der Haut.
b) Apoptose, Modulation des Zytokinmilieus, Beeinflussung des Kollagenstoffwechsels.
c) Beeinflussung des Kollagenstoffwechsels, selektive Zerstörung maligner Zellen, Veränderung der Genexpression.
d) Modulation des Zytokinmilieus, Abtöten aller Bakterien auf der Haut, Induktion verschiedener Formen des Zelluntergangs.
e) selektive Zerstörung maligner Zellen, Induktion von Apoptose, Veränderung der Genexpression.

5. Welche Zuordnung von Strahlungstyp und vorrangigem Wirkmechanismus ist falsch?

a) UV-A: indirekte Schädigung der DNS
b) UV-B: Entwicklung von Cyclobutan-Dipyrimidin-Dimeren
c) UV-A: Entstehung von oxidierten Purinbasen
d) UV-B: direkte Schädigung der DNS
e) UV-B: Entstehung von reaktiven Sauerstoffspezies

6. Welche der folgenden Erkrankungen sollte nicht mit einer Schmalspektrum-UV-B-Therapie behandelt werden?

a) Scleroedema adultorum Buschke
b) Psoriasis vulgaris
c) atopisches Ekzem
d) Vitiligo
e) Mycosis fungoides

7. Die Psoriasis kann behandelt werden mit ...

a) UV-B 311
b) Bade-PUVA
c) UV-A1
d) Breitband-UV-B
e) Creme-PUVA

a) Nur b, c und e sind richtig.
b) Nur a und d sind richtig.
c) Keine der Aussagen ist korrekt.
d) Alle Aussagen sind korrekt.
e) Nur Antwort a trifft zu.

8. Welche Behauptung zur PUVA-Therapie trifft nicht zu?

a) Psoralen interkaliert in die DNS.
b) Durch kovalente Verknüpfung von Psoralen mit Nukleobasen können Mono- und Biaddukte entstehen.
c) In Folge einer PUVA-Behandlung können Mutationen in Zellen beobachtet werden.
d) Durch die PUVA-Therapie können auch maligne Zellen entstehen.
e) PUVA ist unter den verschiedenen Formen der Phototherapie diejenige mit dem geringsten Risiko von Langzeitschäden.

9. Welche Therapiekombination sollte in jedem Fall vermieden werden?

a) Retinoide und UV-B
b) UV-A1 und Protopic-Salbe
c) PUVA und Ciclosporin
d) Retinoide und PUVA
e) Biologika und UV-B 311

10. Welche Aussage zur Phototherapie ist falsch?

a) Die verschiedenen Formen der Phototherapie können die Genexpression beeinflussen.
b) Durch UV-A angeregte Chromophore können die Energie auf molekularen Sauerstoff aber auch direkt auf die DNS übertragen.
c) Bei Chromophoren handelt es sich stets um künstliche Moleküle, die in der Lage sind die Energie von Photonen zu absorbieren.
d) Bestimmte Formen der Phototherapie sind sogar zur Behandlung von Photodermatosen geeignet.
e) C→T-Transitionen sind charakteristische Schäden einer Therapie mit UV-Strahlung.

Liebe Leserinnen und Leser,
der Einsendeschluss an die DDA für diese Ausgabe ist der 31. Oktober 2018. Die richtige Lösung zum Thema „Tumoren der Kopfhaut“ in Heft 6 (Juni 2018) ist: (1e, 2b, 3c, 4d, 5b, 6d, 7a, 8a, 9d, 10c).

Bitte verwenden Sie für Ihre Einsendung das aktuelle Formblatt auf der folgenden Seite oder aber geben Sie Ihre Lösung online unter http://jddg.akademie-dda.de ein.