THE BRITISH JOURNAL
OF
OPHTHALMOLOGY
JULY, 1928

COMMUNICATIONS

ULTRA-VIOLET LIGHT IN THE TREATMENT OF
OPHTHALMOLOGICAL DISEASES
II.—LOCAL PHOTOTHERAPY

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IN the previous paper it has been suggested that ultra-violet radiation has a definite place in ophthalmological therapeutics; in certain diseases the local application of light has a more pronounced beneficial effect. It was also suggested that general light baths should only be given with a certain degree of care; very much more is required in local phototherapy.

The action of ultra-violet light is primarily abiotic, that is, destructive. The most readily observed effect produced in the radiation of a cell is the photo-chemical denaturation and subsequent coagulation of its proteins. This, with other reactions, leads to the production of a certain amount of trauma, involving the partial or complete destruction of the cell, an effect which is evident after radiation of the skin in the desquamation of its outermost layers. In the tissues of the eye a similar reaction takes place; with small intensities the radiated cells are injured, with great intensities they are destroyed. In many diseases of the conjunctiva and cornea this is the end which, under proper control, is desired, and the active response which the traumatism of light evokes, repairs, and more than repairs, the damage—again within limits.

In the case of the lens, however, the matter is different. This is an avascular tissue in which active repair is comparatively lacking, and here damage tends to be cumulative. Coagulation of the proteins of its cells is recognised clinically as cataract, a condition which can be produced experimentally by radiation with ultra-violet light. With radiation of such intensity as does not produce an opacity immediately, changes take place in the colloid system of this tissue with the result that the proteins are rendered more labile and their subsequent coagulation by other influences more easy. Moreover, the autoxidation system of the lens, upon which it probably depends in large measure for the maintenance and regulation of its metabolism, is damaged by ultra-violet light; while in addition, the permeability of the capsule is altered after radiation, thus further increasing the susceptibility to pathological changes (see Duke-Elder, 1926).

It has been urged that in the comparatively small doses in which it is used clinically there is little fear of such damage being caused by the radiation of the eye; but it is to be remembered that small doses such as have no apparent effect predispose to the formation of cataract, and it is further to be borne in mind that in many diseased eyes the possibility of a complicated cataract without any artificial stimulus is by no means remote. In any technique of local phototherapy, therefore, it is essential that the lens be excluded from the path of the incident rays.

Experiment has shown that the lens absorbs a large proportion of the shorter waves of the spectrum below 4,000 A.U. and all of the incident light below 3,300 A.U. Since for clinical purposes the upper limit of abiotic activity may be taken as about 3,000, it would appear that any attempt to radiate the choroid or retina through the lens, apart from the danger to this structure, is useless. Local ultra-violet light therapy is therefore only applicable to the structures in the anterior segment of the eye. A considerable amount of active radiation can pass the cornea, and it is possible to produce an abiotic effect in the iris; there is, therefore, justification for radiating the iris with a properly controlled beam in cases where it is specially indicated. Such a case would be presented by a tuberculous iritis with nodules on the anterior surface of the iris; but on the whole it may be taken that the sphere of general usefulness of this method of treatment is limited to the cornea, sclerotic, and conjunctiva.

Diseases of the Cornea and Sclerotic

In the series of 119 cases which are reviewed in this paper, 99 were infections of the cornea and sclerotic, and 20 were of varying types of conjunctivitis. The first class was as follows:

Corneal ulcers	...	...	...	56 cases.
Phlyctenular kerato-conjunctivitis				14
Acne	...	...	...	5
Herpes	...	...	...	1
Corneal opacities	...	...	...	9
Episcleritis	...	...	...	4
Sclero-keratitis	...	...	...	10

Technique

In the treatment of diseases of the cornea it is essential that the beam of light should be adequately controlled, in order that it may be limited to the diseased area and unnecessary traumatism be thus avoided, and that the lens be excluded from its path. For this purpose we employ an ophthalmic radiation lamp, which has already been described and figured in this journal (1927): in principle it is a modified Gullstrand slit-lamp fitted with a mercury vapour lamp and provided with an optical system of quartz. With such an instrument a beam of considerable intensity and any desired size can be used, and its precise incidence upon the eye can be observed through the binocular microscope. In all cases it is easy to avoid the lens by inclining the beam at a sufficient angle, the manipulation being facilitated in some cases where the pupil is very large by the previous exhibition of eserine where it is not contra-indicated.

Other methods have been proposed from time to time. Koeppe (1919) and Birch-Hirschfeld (1922) employ a carbon arc as the source of light, but this emits a very large amount of heat: infrared rays readily penetrate into the tissues of the eye and are potent for harm (Duke-Elder, 1926), while any attempt to filter them off necessarily reduces the intensity of ultra-violet rays considerably. Asher (1922) uses a quartz rod as a director along which the ultra-violet rays are guided, but although such a method is very suitable for radiating the conjunctiva, it is impossible to control the beam of light with sufficient accuracy by its use in the case of the cornea.

Dosage.—In radiating the cornea extreme care must be exercised with the dosage. The intensity of light required to produce an abiotic reaction upon this tissue is practically the same as, but very slightly less than the amount which produces an erythema upon the skin. The response, moreover, varies with different individuals just as it does in the skin. It is always best, therefore, to test the erythema dose on the skin of the arm in each individual patient, and to commence radiating the cornea with a dose slightly less than this. In those cases where treatment is required urgently, as for example in some corneal ulcers, it may be inadvisable to wait the twenty-four hours necessary for the development of the

cutaneous reaction, and it may be necessary to start immediately with an average dose. This may be taken as representing a period of radiation lasting three to three and a half minutes with the apparatus described, where the mercury vapour lamp is of the atmospheric pressure (K.B.B.) type, and runs on 220 volts, 2 to 3 ampères. Once the initial dose is obtained and its reaction observed, subsequent doses are based upon it, but the increases are to be graduated with care for it must be remembered that a small increase of a minute may make the difference between a mild and a violent photophthalmia.

Since the beam is always kept at a focus upon the cornea, the distance of the lamp must be kept constant, and dosage is altered only by time. Allowance must be made, however, for the obliquity of the rays, for it is evident that if the rays are not falling normally upon the cornea, account must be taken of the resulting diminution of their intensity per unit area. In this case the energy varies quantitatively as the cosine of the angle of incidence, this angle being that which the incident ray makes with the normal to the tangential plane. The following table gives the factor by which the time of exposure determined for a normal ray should be multiplied to give an equivalent exposure with oblique rays :

Angle of incidence.					Cosine.	Factor.
0°	(i.e. normal)	...	...	...	1.000	× 0.00
15°	...	...	...	...	0.966	× 1.03
30°	...	...	...	...	0.866	× 1.16
40°	...	...	...	...	0.766	× 1.30
45°	...	...	...	...	0.707	× 1.40
60°	...	...	...	...	0.500	× 2.00

Biological Action upon the Cornea

The biological reaction to light as seen in the cornea of radiated subjects and experimental animals has already been described at some length (1926), and it is only necessary here to note some of the essential characteristics. The reaction starts after a latent period, usually of six to eight hours, which varies directly with the length and intensity of the exposure. During this time no changes can be made out macroscopically or microscopically. Thereafter with mild degrees of radiation, there is a stippling of the cornea with irregularity of its reflex and sometimes vesicular formation accompanied by hyperaemia of the conjunctiva. After more intense exposures the corneal epithelium is desquamated, and bright staining can be obtained with fluorescein. Greater intensities of radiation produce in the more anterior layers of the substantia propria a diffuse interstitial haze which tends to disappear

rapidly; more intense exposures still (as may be seen in experimental animals) leave an opacity, which in a few week's time, becomes highly vascularized and very largely tends to clear up. The changes are at their height in 48 hours, and thereafter gradually subside, the rate of subsidence varying directly with the intensity of radiation. In three days after a moderately severe exposure the epithelium has reformed and the eye appears normal.

Histological examination in experimentally radiated animals conducted 48 hours after a moderate exposure shows that the surface epithelium is completely absent; with a less severe exposure the surface cells only are exfoliated, and the basal cells are spread out and spaced apart. The lamellae near the affected area in the more severely radiated cases are swollen, and stain less readily with eosine, while the corpuscles show nuclear fragmentation and granular formation in the cytoplasm. Meantime there is a marked infiltration round the limbus, the capillaries are greatly dilated, and eosinophile cells are seen in large numbers in the substance of the cornea. These changes are accompanied by the characteristic symptoms of photophthalmia: after small doses there is merely a sensation of pricking as of a foreign body in the eye; after intense doses a considerable disturbance occurs, involving much pain, accompanied by marked photophobia, lacrymation and blepharospasm.

In the treatment of the cornea, in the great majority of cases a mild reaction is the end desired. In most cases any severe after-effects are contra-indicated, and within three days the reaction should have completely subsided. The pain of the photophthalmia is due to the exposure of the corneal nerve endings after the desquamation of the epithelium, and in such conditions as corneal ulcers where the epithelium is already gone, provided the rays are allowed to play on the ulcerated area only, the subsequent irritation is almost negligible. The latent period which elapses before the reaction starts is about eight hours, and it is the practice to conduct most of the treatments during the afternoon. In this way the symptoms occur during the night, and if the patient has the eye bandaged up so that the lids do not abrade the radiated area, he frequently experiences no subjective symptoms at all, especially if a small dose of aspirin be given before going to bed to ensure a sound sleep.

Corneal Ulcers

Corneal ulcers respond remarkably well to radiation with ultra-violet light. This seems to apply, within limits, to any form of ulcer, but inasmuch as a mild case of acute ulceration tends to heal up in any case with the usual methods of treatment, it is in the chronic and recurrent forms where ulceration has been active

and an eye injected over long periods of time, that the beneficial effect of treatment is seen to the best advantage.

This action appears to depend on several factors. First, the question arises of the direct killing by radiation of the organisms responsible for the ulceration. This certainly occurs in the superficial layers, but the absorption of the abiotically active rays in traversing the substance of the cornea is so great that little of this effect can remain in the deeper layers. The freshly excised cornea of the rabbit, for example, protects colonies of staphylococci sown on agar plates from the lethal action of light, and if the anterior chamber of the same animal be injected with a culture of this organism, and thereafter the animal be exposed to radiation of such intensity as produces a corneal opacity, the aqueous shows on culture a growth no less abundant than that obtained from unirradiated controls (Duke-Elder, 1926). Within the limits of intensity of radiation which are justifiable clinically, therefore, it would seem impossible to sterilize the whole thickness of the cornea (Verhoeff and Bell, 1916), although it would appear that a lesser inhibitory effect on the growth and activity of micro-organisms may possibly be obtained: thus Hertel (1907) demonstrated that bacteria suspended in a quartz cell in the anterior chamber could be rendered immobile by ultra-violet light. On the other hand the whole of the infected area of epithelium with its contained organisms can be destroyed and exfoliated, and a milder abiotic action can be exerted with perfect safety extending into the superficial layers of the corneal lamellae. In this connection if a sensitizer could be found which would attach itself to bacterial protein in preference to that of the corneal tissue, it would be of great utility.

A second factor which enters into the question is the great vascular reaction which radiation excites. Especially is this evident in chronic ulcers of long standing which have remained in a torpid condition; after several applications of light they can be seen by the slit-lamp to become traversed by innumerable small vessels of new formation. It is possible that the abiotic reaction, involving the production and absorption of photo-chemical products from the injured corneal cells may have a therapeutic influence also; but about this little is at present known. Lastly, and of considerable importance, the stimulus of ultra-violet light to epithelial growth cannot fail to exert a definite influence on the sound healing of an ulcer. This effect of radiation whereby the basal cells of the skin are stimulated to active mitosis and growth was noted in the previous paper; the same occurs in the cornea, and the fact that a recurrent ulceration which has constantly given trouble despite ordinary treatment for several years, may be epithelialized over after light treatment in such a

manner that no recurrence has occurred over periods of observation extending to eighteen months, speaks for itself.

The types of ulcers which were treated are these (70 cases) ;

Acute simple ulcer	...	...	...	14 cases.
Hypopyon ulcer	...	...	...	3
Chronic ulcer	...	...	...	14
Dendritic ulcer	...	...	...	2
Recurrent ulcer	...	...	...	23
Phlyctenular ulcer	...	...	...	14

In every case a cure was obtained, in that the ulcerative process healed and the eye became quiet. No other treatment was given except atropine, and, in some cases, heat.

Acute ulcers.—As a rule a single exposure to ultra-violet light is sufficient to cause an acute ulcer to heal; three out of the fourteen treated were of a widespread nature and required a second application four days later, three required a third. The procedure adopted is to instil cocaine into the eye, which is followed by fluorescein, which again is washed out by cocaine. The ulcer is then examined through the ultra-violet slit-lamp, a uviol filter being interposed. A remarkably beautiful and well pronounced fluorescent effect is obtained in this way, and the extent of ulceration is clearly defined. The beam is accurately focused so that it plays upon the ulcerated area and, if possible, on no other part of the cornea; the uviol filter is then turned off and the unfiltered light allowed to fall upon the eye. If in spite of the cocaine the patient is unable to keep his eye open during the whole of the time necessary for treatment, there is no disadvantage in interrupting the treatment for some time, for intermittent exposures are additive in their effects and have the same cumulative action as a single long exposure so long as the interval between them does not exceed twenty-four hours.

No scar is left in the majority of cases, the usual sequela being a shallow transparent facet.

Female, aged 29 years. Three weeks after confinement, looked ill. Large staining ulcer of about 4 mm. diameter right eye. Intense congestion and much pain. Conjunctival swab showed pneumococci. Three light treatments with atropine. Two days following the first much of the pain away, and ulcer showed general diffuse staining. After the second a few staining points centrally. After the third, ulcer healed, eye quiet, with a faint hazy nebula, vascularized.

Female, aged 12 years. Ulcer of three weeks duration. Still staining after two carbolicizations. Two treatments: eye quiet, ulcer healed.

Hypopyon Ulcer.—Here again the results are extremely satisfactory.

Male, aged 56 years. Central traumatic ulcer with hypopyon; much dental sepsis. Three treatments: after the first, eye much less painful and hypopyon diminished; after the third, eye quiet, hypopyon away, leaving an opaque scar.

Female, aged 30 years. Irido-cyclitis right, three months. Much k.p. with deep injection. One course of twenty general treatments; eye better, a few pigmented k.p. remaining. Three weeks later, traumatic ulcer right, with large hypopyon. Three local treatments: eye white and hypopyon away, opaque corneal scar. A further course of twenty general baths given.

The results of the treatment of hypopyon ulcer recorded in this paper are, unfortunately, comparatively few; but Hoffman (1927) from the clinic of Birch-Hirschfeld at Königsberg, where direct radiation has been practised in the treatment of this form of ulcer for several years, gives extremely favourable statistics covering a series of 190 cases. These he divides into three classes: mild cases where the hypopyon was merely visible (65 cases), severe cases, where the hypopyon filled from a quarter to one-third of the anterior chamber (63 cases), and grave cases where the hypopyon was larger and other infections were present in the eye (62 cases). Under ultra-violet light treatment, all of the first two series recovered, and of the third series nine eyes were lost. This, a loss of 4.6 per cent. only, over a large series of hypopyon ulcers including all cases as they arrived at the clinic, is a remarkable result. Before the method was introduced as a routine, the incidence of excisions in such cases at Königsberg was 32 per cent. Judging from the dissatisfaction expressed regarding the usual methods of treatment at the symposium on hypopyon ulcer at the meeting of the Ophthalmological Society of the United Kingdom at Liverpool in 1927, this would appear to be the method of choice in these cases.

Chronic Ulcer.—Under this heading are classed those ulcers of the cornea which have progressed over a long period in spite of treatment; most of them were associated with a varying degree of deep keratitis and corneal opacity, and many with iritis and irido-cyclitis. The aetiology of many was considered infective, while some appeared to be tuberculous. In the majority of these cases the patient was an unhealthy subject, and the eye had reached a torpid and sluggish state. The usual treatment given was a course of general light baths, with in addition, three, four, six or more local treatments as seemed indicated. As a result they all cleared up eventually, the eye becoming quiet and comfortable, but with the opacity which had been present before the commencement of treatment unaltered.

Female, aged 16 years. Cyclitis and keratitis with a chronic ulcer in the right eye, twelve months. No obvious infective focus, von Pirquet positive; considered tuberculous. Carbolized on acute exacerbations in Jan., Nov., and Dec., 1925, with little or no improvement. Tuberculin treatment without effect. One course of twenty general baths; very slow improvement in the corneal condition, with continued irritability. Four local treatments: eye quiet and comfortable, no injection, ulcer covered by epithelium leaving an opacity. A further course of general treatment; since which time the eye has remained quiet until the patient passed out of observation (15 months). This occurrence is typical where general light treatment makes little impression; local radiation clears up the condition with great rapidity.

The most chronic case (of unknown aetiology) which had been active for several years, and which had been carbolized on numerous occasions and had a peritomy performed twice with little beneficial result, required twelve local treatments in addition to sixty general baths before the condition subsided.

The two cases of *Dendritic Ulcer* radiated healed over after two applications of light.

Recurrent Ulcer.—Recurrent ulcers, especially those marginal ones associated with a continually relapsing conjunctivitis respond particularly well to light treatment. The ulcer itself clears up, which, of course, is usually easily brought about, but after the epithelium round the ulcer has been desquamated in the photophthalmic reaction following exposure to ultra-violet light, the new layer seems healthy and resistant so as to withstand the liability to break down on future occasions. As a general rule the ulcer heals up after the first or second exposure, and in the milder cases heals up leaving a transparent facet; but it is the custom in most of these cases to give them a third or fourth exposure bringing about a mild reaction each time involving a traumatism and renewal of the epithelium in order to render the possibility of recurrences more remote.

Female, aged 37 years. Recurrent corneal ulcer four years with intermittent conjunctivitis, with an attack of ulceration as a rule about every eight weeks. Treatment started in the course of an exacerbation. Eye quiet after first treatment; four treatments given; eye has remained quiet from March, 1926 to December, 1927, and this in spite of two attacks of acute conjunctivitis, an occurrence which surprised the patient to an amusing extent.

Phlyctenular Ulcers.—Acute phlyctenular ulcers respond so well to general light treatment that it is not worth while as a rule to coax a child affected with this disease to submit to keeping its eye open in the beam of the slit-lamp. It is in the chronic cases which have gone on for years, leaving an ulcerated, opaque, and vascularized cornea, and involving continued irritation frequently with acute exacerbations, that the method has its greatest use. Here again it is best employed along with general light baths. In these cases the eye quiets down and becomes white and comfortable, but the extensive opacities which are already present with the resulting diminution of vision, remain.

Female, aged 21 years. Phlyctenular kerato-conjunctivitis "since ever she could remember." Both eyes showed active scars with staining areas and many new vessels; photophobia and constant lacrymation. Sixteen general treatments; eyes still active, but less so. R.V. 6/60; L.V. less than 6/60. One local treatment; photophobia and lacrymation away. Five local treatments given at intervals of one week along with general treatment. Eye quiet "for the first time she can remember." R.V. 6/36, L.V. 6/60.

Male, aged 26 years. Phlyctenular kerato-conjunctivitis "for many years." Deep ulcers, R. and L., blepharitis and conjunctivitis, corneae opaque. Six general baths, eye less irritable and general health much improved. One local treatment, local condition relieved. Four local treatments given with forty general: eye white with corneal opacities unchanged. Three weeks later, a cold and a relapse with a small ulcer in the right eye. Three local treatments and a course of general treatment: eye quiet, and remained so nine months.

Acne.—The corneal lesions of acne usually tend to subside rapidly after three or four local applications of light along with general baths directed especially to the regions of the skin most affected. After the first two treatments the intense photophobia and pain usually subside. Three of the series of five cases were very chronic ones having gone on for 4, 6, and 12 years; in each the irritation subsided and the eye became quiet, the extensive corneal opacities, however, being unaffected. One, a man, aged 42 years, had a pustule forming an interstitial abscess in the cornea; after six applications this had cleared up leaving a small opaque scar, and the eye was white and quiet six months later.

The one case of *Herpes febrilis* which was treated received little or no benefit.

Corneal Opacities.—In order to investigate claims in the literature, a series of nine cases of old corneal opacities were given a fair trial with local radiation. No results justifying the continuation of the treatment were seen anywhere. It is certainly the case, however, that recent opacities, such as those following ulceration, may be improved, and the prophylactic action of the treatment of ulceration by light in the prevention of opacity formation is very marked. Two factors seem to enter into this: the rapidity of healing with new-formed epithelial cells, and the large amount of vascularization which the photophthalmic response excites. To this extent its action would seem to be comparable to that of an irritant, such as dionine.

Episcleritis and Sclero-keratitis

Four cases of episcleritis were treated by local radiation, all with good results; but as this termination is not unusual in any case, more importance should be attached to the cases of deep sclero-keratitis. Each of the ten cases treated was in a chronic and serious condition; but they all eventually yielded to prolonged treatment. It was found that general radiation alone was unable to arrest the disease satisfactorily in some cases, but so far as experience has gone, the combination of the two methods has resulted in the establishment of a quiet eye, although, in some, an eye of little use for visual purposes from corneal damage due to the process of the disease. If the cases were got earlier under the influence of treatment, very good results would probably have been obtained.

Female, aged 35 years. Sclero-keratitis right, two years: dental sepsis. Sclera deeply injected, thinned, and bluish three-quarters of the way round the limbus. Invasion of the cornea over the corresponding area, the opacity extending well over the pupillary aperture. Eye painful and irritable, iritis with posterior synechiae. R.V. counts fingers at three feet. General light baths—9 mercury vapour lamp followed by 19 carbon arc exposures. Iritis seemed less, pupil dilating, but eye still injected and irritable. A further course of 18 general baths: eye still injected although quieter. Five local treatments: eye quiet and comfortable, corneal opacity

receded to well past the central area. A further course of 15 general treatments: eye still quiet, R.V. 6/36.

Female, aged 28 years. Sclero-keratitis, presumed to be tuberculous, nine months. Scleritis extending three-quarters round the limbus on the inner side, with corneal invasion at the upper and lower quadrants. Twenty general light-baths; eye painless but still considerably injected. A further course of 18 treatments; eye still injected, with intermittent exacerbations of pain and irritability. Seven local treatments: eye quiet and comfortable, corneal opacity largely receded.

Diseases of the Conjunctiva and Lids

The following cases of diseases of the conjunctiva and lids were treated:

Chronic conjunctivitis (simple) ...	6 cases.
Trachoma	6
Vernal catarrh	3
Chronic blepharitis	5

On the conjunctiva ultra-violet light has the same reaction as it has upon the skin. The superficial cells are traumatized, killed, and exfoliated, and the mucous membrane underneath receives a stimulus which rapidly renews the desquamated layer. Any pathological organisms in the superficial layers are thus killed and cast off. The reaction is not nearly so easy to produce as in the skin, and, especially in a vascularized and chronically inflamed conjunctiva, exposures of ten to fifteen minutes to the mercury vapour lamp may sometimes be required. With severe exposures the eye has the appearance of an intense conjunctivitis; it is red and

FIG. 1.

Lid-everting forceps. When the forceps has gripped the lashes and the lid has been everted, the guard is attached to the holder on the forceps, so that the everted lid is opposite the aperture. The size of the aperture can be varied to correspond with that of the lid by approximating the slides seen in the figure, which are controlled by a two-way screw. (Made by Montague, Bond Street, London).

FIG. 2.

Mercury vapour lamp as used for general radiation fitted with an aluminium housing into which can be inserted a metal tube director (Fig. 5), or a quartz director (Fig. 6).

inflamed with a swollen conjunctiva, and there is always a certain amount of secretion, which contains large numbers of eosinophile cells. In the more intense degrees of the reaction, this may become frankly purulent. The reaction is at its height in about 48 hours, and usually lasts two or three days, the duration varying with the intensity of the exposure. It is not accompanied by any pain and with very little discomfort, so long as the cornea is protected from the light during the radiation; it is the desquamation of its epithelium and exposure of its free nerve endings which cause the intense pain and photophobia of a typical photophthalmic reaction.

Technique.—The technique employed varies with the area of the conjunctiva to be radiated. If the palpebral surface of the lids is to be exposed, these are everted with the lid evertor seen in Fig 1. The lashes are gripped in the forceps in such a way that

the flange attached to the posterior blade lies upon the skin surface of the upper lid pointing upwards; the lids are then everted by rotating the forceps round so that the flange fully everts the tarsal plate, and then the shield is fixed on so that the everted lid appears

FIGS. 3 and 4.

Type of mercury vapour lamp with vertical arc used both in the ultra-violet slit-lamp and in the lamp of Fig. 2. It consists essentially of a U tube filled with mercury, one end of which (B, Fig. 4) is sealed, and the other (A, Fig. 4) is closed by a stopper. There is a small branch tube (E, Fig. 4) surrounded by a heating coil. This the current raises to a red heat, and thus the mercury in E is boiled to a vapour. The expansion thus caused drives the mercury up the other end of the U tube from its original position (C D), thus making contact with the electrode at A. A cut-out device then diverts the current through the mercury vapour, making an arc in the vertical tube.

through the hole cut near its centre. An aluminium cone (Fig. 5) is fitted on to the housing of the mercury vapour lamp, its end being shaped to correspond with the conjunctival surface of the everted lid, and this is brought to within half an inch of the patient, who remains with his head on a head-rest during the treatment. The cornea and the skin of the face are thus efficiently covered, and the lid is easily steadied, while it is fully exposed to the unfiltered rays of the mercury lamp at a short distance, thus receiving a powerful radiation. The mercury lamp is used since its emanations contain little or no heat rays; if the carbon arc were

FIG. 5.

Cone-shaped director tube for radiating the conjunctival surface of the everted lids.

employed in such treatment, it would be necessary to interpose a cooling cell of quartz containing cold circulating water in the path of the light.

When the recesses of the fornices are radiated, the light is guided into them through a quartz director. Initially in the practice of the clinic a solid rod of quartz was used, but, since the absorption of energy in passing through six inches or thereabouts of quartz is by no means inconsiderable, this has now been replaced by a hollow cone of polished aluminium upon whose tip is attached a small point of quartz, shaped to correspond with the extent of the superior fornix and so bent as to insinuate itself up into it. Some freedom of movement is obtained by fixing the quartz point to the aluminium tube by a spring joint (Fig. 6). The under surface of the quartz point, that is the surface which rests upon the upper part of the cornea and the sclerotic is silvered and blackened, so that the rays are reflected up into the fornix and

are effectually prevented from reaching the eye, and thus, the light being led along the quartz point by internal reflection, this inaccessible part can be radiated with comparative ease.

Chronic Conjunctivitis.—Six cases of conjunctivitis of very long standing were treated; in each of them considerable improvement was seen. Two were in children, and the local treatment combined with general light baths brought about a rapid change for the better, and they were considered cured after four applications. Four adults were treated before the technique outlined above was adopted; three were so considerably benefited after eight treat-

FIG. 6.

Quartz director for radiating fornices. The quartz tip is attached to a hollow aluminium tube by a spring joint which allows of movement in all directions. The under surface of the tip is blackened and silvered.

ments as to warrant cessation of treatment, and one did not persist in the treatment beyond the third application.

Trachoma.—Six cases of trachoma come under this review. Four appeared to be so much benefited as to warrant the cessation of treatment, and have remained in a comfortable condition for periods ranging from nine to fifteen months. Both of the others cleared up considerably at first; they were both young adult girls, both with very active disease, with large fleshy follicles on the conjunctiva, an immense amount of pannus vascularizing the entire cornea, both with frequently breaking down ulcers, and suffering continuously from photophobia and profuse lacrymation. Visual acuity could not be elicited in either. After bi-weekly treatments for four weeks both cleared up immensely, so that the photophobia and the greater part of the subjective symptoms had disappeared and the visual acuity reached 6/36 in both. Thereafter both had relapses in spite of treatment. One was put back on silver treatment, and was lost sight of. The other continued with the light treatment, and again improved, until after three months treatment, during which time another small relapse occurred; the eyes were comfortable, the conjunctival follicles had subsided, the pannus was in great measure cured and inactive, and the visual acuity had reached 6/60 and 6/18.

Since the period covered by this paper, which was restricted up to July, 1927, in order to obtain end-results of some value, a considerable number of additional trachoma cases have been treated. The majority of these have responded extremely well, better, indeed than the earlier ones. The improvement is probably due to increased efficiency in technique. No case seems too bad to be benefited; most show a response much more satisfactory than is obtained by silver or copper, and the absence of excessive scarring and cicatricial deformity is especially notable.

It is difficult to get a good photophthalmic reaction with an inflamed and fleshy conjunctiva, and very long doses up to ten or fifteen minutes must be given. The cases which did well did remarkably well, the follicles disappearing rapidly, and the cornea especially showing a marked change for the better. The ideal to be aimed at is to get, where possible, a reaction sufficient to exfoliate the superficial layers of the mucous membrane, and to repeat this process as soon as a new one has formed until the final conjunctiva seems healthy. Such a reaction causes little inconvenience to the patient, who as a rule merely appreciates a lessening of the distressing symptoms of the disease.

Vernal Catarrh.—The position in regard to vernal catarrh is that we feel that more extended experience is necessary. Of the three cases treated, one recovered after six weeks' treatment, one showed a marked improvement and then was lost sight of, and the third, after improving at first, relapsed and persisted having relapses over a period of treatment lasting fifteen weeks. At the end of this time the irritation was much less, but follicles were still present, and the treatment was discontinued.

Chronic Blepharitis.—Five cases of chronic blepharitis were treated by direct radiation. They were all of the chronic ulcerative type occurring in children which had resisted the usual treatment, and which was progressing to the loss of the lashes. The closed lids were radiated through a slit-aperture for periods varying from ten to twenty minutes, thus giving a severe reaction. After a few exposures, combined with the ordinary routine of general light baths, all of them cleared up, and in two, the lashes which were reduced to a meagre quantity, grew again to a considerable extent.

To summarize, it would appear that the clinical use of local radiation with ultra-violet light should be limited to the treatment of diseases of the cornea, the sclera, the conjunctiva, and the lids. In selected cases of these its effect is often dramatic. Particularly is this so in the case of corneal ulcers of all kinds, ranging in severity from a hypopyon ulcer to the small recurrent and marginal ulcers which are often so troublesome. In these cases ultra-violet light therapy would undoubtedly seem to be the treatment of choice. The treatment is also decidedly indicated in cases of sclero-keratitis, and in many chronic affections of the conjunctiva, including the most severe cases of trachoma. In all of these where the aetiology is tuberculous the results of treatment are the

most satisfactory. Two further conditions of which no case has appeared up to the present at the clinic, may be added: tuberculous conjunctivitis, and lupus. These have both been treated with somewhat similar methods with very good results on the Continent (see Bibliography, Lundsgaard, etc.), while many cases of the cure of the latter have been obtained at the Clinic at Alton under the care of Sir Henry Gauvain.

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BIBLIOGRAPHY OF PHOTOTHERAPY

Although light has not been used scientifically as a therapeutic agent for many years, the bibliography which has accumulated around it is already enormous. Some of the more important references have already been alluded to in the text of the present two papers, from which others can be obtained. A very brief sketch of the development of the subject, however, may not be without interest.

Primitive people have worshipped the sun and its light from the earliest times of which we have record (the Arabians, the Egyptians, the Persians, the Greeks, the Druids, and so on), more, it would appear, from its power of driving away the spirits of darkness and disease than for its actual power of healing. The first practitioner to advise and practise heliotherapy of whom we have record was **Hippocrates** (c. 400 B.C.), and the Asklepieion, the Temple of Æsculapius, the son of Phoebus Apollo, in the island of Cos in the Greek Archipelago, appears to have been the first Light Clinic. The value of the sun as a therapeutic and restorative agent was also known to the Romans, and the solarium of the patrician palaces testify to the popularity of the sun-bath. **Celsus** and **Galen** both used and advised treatment by sunlight; but after their time the practice seems to have fallen into disuse and to have been forgotten.

In 1774, **Faure** seems to have rediscovered the value of exposures to sun-light in the healing of suppurating wounds and ulcers, and later workers developed the practice of *photocauterization*, using glass lenses to concentrate the light. In 1845, **Bonnet** drew attention to the great value of heliotherapy in tuberculosis, applying both general and local treatment especially to tuberculous bones and joints. The therapeutic agencies appear to have been regarded as light and heat, but **Charcot**, in 1859, demonstrated that there was an action quite independent of the heating properties. In 1877, **Downes** and **Blunt** proved the bactericidal power of light; and **Widmar**, in 1889, showed that the ultra-violet region of the spectrum was responsible for the abiotic action.

The scientific application of light to the cure of disease may be said to date from the work of **Niels Ryberg Finsen**, of Copenhagen, whose first experiments were published in 1893. Of delicate constitution himself, he noticed that his vitality increased in the sunny weather, and his suspicions were confirmed by the behaviour of his cat, which made a habit of basking in the sun and following it round the courtyard through the day; the matter was clinched by the very definite improvement which his patients with lupus showed during the summer months,

and he began experimental work and clinical observations on a large scale. At the commencement he treated lupus with sun-light, concentrating it through lenses, first of glass, and later of quartz; finally he employed the carbon arc. His world-famous Institute was opened in Copenhagen in 1896. In 1899, Queen Alexandra, then Princess of Wales and President of the London Hospital, urged upon this hospital the advisability of adopting the methods of her countryman, and established there the first light-clinic for lupus in this country. In 1903, the year in which Finsen was presented with the Nobel Prize, **Rollier** started his sun clinic for tuberculosis in Leysin in the Vaudois Alps; and in 1908, **Gauvain** commenced his work on tuberculous children at Alton and Hayling Island.

From this time onwards the treatment of tuberculosis by light was well recognised; but in 1918, the observations of **Huldschinsky** on the beneficial effect of light in rickets, coming as they did in the period of war and distress in Central Europe, gave a new and economically important aspect to the subject. Since that time much attention has been given to the biological action of light, work which in this country has been largely directed by the Medical Research Council, which instituted a Committee for the purpose in 1922 under the chairmanship of Bayliss.

The application of light treatment to ophthalmic diseases seems to have begun with the practice of the photocoagulation. **Antonino Sciascia** described to the Italian Ophthalmological Congress at Palermo in 1892 how he treated wounds, lupus and trachoma by concentrating the sun's rays by a convex lens. The next year, **Tayer** of America, in 1894, **De Renzi** of Naples, and in 1895, **Kellog** of America, carried on the same practice. Meantime the Finsen treatment of lupus at Copenhagen was being directed to lupus of the lids, and for the last twenty years **Lundsgaard** has been extending the same principles to other ocular diseases. In Germany, in the early years of the century, **Birch-Hirschfeld** investigated experimentally the effects of light upon the eye, and since that time has employed it widely therapeutically. His work and that of others, are noted in the bibliography.

Albrich.—*Klin. Monatsbl. f. Augenheilk.*, Bd. LXXVII, S. 227, 1926.

Treated trachoma with an arc lamp cooled by a water filter; used bengal rose as a sensitizer as a subconjunctival injection; good results.

Angstein.—*Vide* Koeppe, S. 206, 1919.

Treated tuberculous disease with general light-baths (choroiditis, etc.); good results.

Arnold.—*Klin. Monatsbl. f. Augenheilk.*, Bd. LXXI, S. 219, 1923.

Used Birch-Hirschfeld's technique (q.v.) Treated ulcus serpens, rodent ulcer, catarrhal ulcer, tuberculous ulcer, keratitis filiformis, keratitis disciformis, and herpes corneae; results not uniform.

Ascher.—*Klin. Monatsbl. f. Augenheilk.*, Bd. LXVII, S. 622, 1921.

Used a mercury vapour lamp with a quartz director for local applications.

Aulamo.—*Acta Ophthal.*, Vol. IV, p. 480, 1926.

Treated ulcus serpens locally; good results.

Axmann.—*Deutsch. med. Wochenschr.*, Bd. XXXIII, Nr. 5, 1907.

General use in ophthalmology.

Bentzen.—*Acta Ophthal.*, Vol. V, p. 29, 1927.

General baths in irido-cyclitis (especially tuberculous), phlyctenular disease, tuberculous scleritis, sclerosing keratitis, etc.; Finsen's technique.

Birch-Hirschfeld.—100 *Versamm. deutsch. Naturforsch. u. Aerzte*, September, 1922; *Heidelberg, Ber.*, 1924; *Zeitschr. f. Augenheilk.*, Bd. LIII, S. 151, 1924; *Klin. Monatsbl. f. Augenheilk.*, Bd. LXXVII, S. 184, 1926.

Used a Zeiss carbon arc with filtered light on a focusing apparatus locally. Treated ulcus serpens (190 cases), pannus ulcer (16 cases), eczematous ulcer (26 cases), episcleritis (6 cases), tuberculous iritis (2 cases), tuberculous keratitis (1 case), marginal ulcer (11 cases), rodent ulcer (1 case), herpes corneae (9 cases), parenchymatous keratitis (10 cases), traumatic infections (17 cases), late infections after trephine (2 cases). The results on the whole were good, and markedly so in ulcus serpens; here the percentage of failures was only 8.5.

- Castresana.**—*Anal. de Oftal.*, p. 555, 1925; *Siglo Med.*, Vol. LXXVII, p. 509, 1926.
Treated tuberculosis of the anterior segment; good results.
- Chotzen u. Kuznitzky.**—*Klin. Monatsbl. f. Augenheilk.*, Bd. LX, S. 198, 1918.
Local treatment of trachoma. Also parenchymatous keratitis, corneal infiltrates, blepharitis, conjunctivitis, and iritis. Also experimental work on the effects of local radiation in rabbits.
- Darier.**—*La Clin. Ophtal.*, T. XIV, p. 325, 1908.
Treatment of ulcus serpens.
- Denman.**—*Jl. Ophtal., Otol. and Laryngol.*, Vol. XXX, p. 208, 1926.
Good results in trachoma, tuberculous conjunctivitis, corneal ulcers.
- Duke-Elder.**—*Brit. Med. Jl.*, Vol. I, p. 891, 1926; *Lancet*, Vol. I, pp. 1137, 1188, 1250; Vol. II, p. 16, 1926; *Trans. Ophtal. Soc. U.K.*, Vol. XLVI, p. 213, 1926; *Brit. Jl. of Ophtal.*, Vol. XI, p. 67, 1927.
- Flaschenträger.**—*Arch. f. Augenheilk.*, Bd. XCVI, S. 170, 1925.
Local treatment of ulcus serpens and episcleritis; good results.
- Fleming u. Krusius.**—*Deutsch. med. Wochenschr.*, S. 1600, 1911.
Treatment of tuberculosis, iritis, and irido-cyclitis.
- Franke.**—*Wiener. med. Wochenschr.*, May 11, 1907.
Good results in corneal lesions.
- Gilbert.**—*Klin. Monatsbl. f. Augenheilk.*, Bd. LXXIV, S. 781, 1925.
Using Birch-Hirschfeld's technique. Good results in tuberculous keratitis and scleritis, clearing of corneal opacities with improvement of vision, little good in parenchymatous keratitis, best in suppurative inflammation of the cornea, abolishing operative procedures and the use of caustics in ulcus serpens.
- Goulden.**—*Trans. Ophtal. Soc. U.K.*, Vol. XLVI, p. 207, 1926.
General treatment good in tuberculous irido-cyclitis and phlyctenular disease; not in episcleritis, sclerosing keratitis, or infective irido-cyclitis.
- Grönholm.**—*Arch. f. Ophtal.*, Bd. LXXX, S. 1, 1911; *Arch. f. Augenheilk.*, Bd. LXVII, S. 4, 1910; *Vortag in medicinsk Selskab* in Copenhagen, January, 1910; *Finska Läkars. Handlingar*, Bd. LIII, 1911.
Local treatment of trachoma, with histological study of conjunctival changes. 89 eyes treated, with 79 cures.
- Hegner u. Bauermann.**—*Berl. klin. Wochenschr.*, Nr. 29, 1910.
Good results in trachoma.
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- Hertel.**—*XXXI Versamm. deutsch. ophtal., Gesell.*, Heidelberg, S. 144, 1903. *Arch. f. Ophtal.*, Bd. LXVI, S. 275, 1907; *Zeitschr. f. Augenheilk.*, Bd. XXVI, S. 5, 1911.
Good results in ulcus serpens. Experiments on bactericidal action of light.
- v. Hippel.**—*Vide Thedering: Das Quartzlicht*, Oldenberg, 1923, S. 127.
Mercury vapour lamp gave good results in phlyctenular disease, irido-cyclitis, and tuberculous infection.
- Hoffman.**—*Klin. Monatsbl. f. Augenheilk.*, Bd. LXXVIII, S. 489, 1927.
Birch-Hirschfeld's local technique with carbon arc. Extremely good results with ulcus serpens; only 9 eyes lost in a series of 190 cases of all types. Also tuberculous keratitis, episcleritis, and herpes corneae.
- Hunsel.**—*Geneeskund. Tijdschr. v. Nederl.*, Nr. 6, 1911.
Good results in trachoma.
- Isaak.**—*Westnik. Ophtal.*, Bd. XXX, S. 988, 1913-14.
Good results in trachoma.

Koeppé.—*Arch. f. Ophthal.*, Bd. XCII, S. 115, 1916; *Diathermie u. Lichtbehandlung des Auges*, Leipzig, 1919, Vogel; *Münch. med. Wochenschr.*, Bd. LXVI, S. 743, 1920.

General baths to tuberculous patients. Local treatment by carbon arc heavily filtered down to employ rays from 3,500 to 5,000 A.U.: the so-called "blue light." Koeppé and others report good results with this, especially in tuberculous iritis, etc., which, however, are not borne out by all who have used the method. It is difficult to imagine that rays so long could have any great beneficial effect. It is also employed for the interior of the eye, that is, through the lens. This has already been commented upon as being dangerous, and (since the lens absorbs all the abiotically active elements) useless.

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Tuberculous iritis treated by mercury vapour lamp.

Lewkojewa.—*Russ. Arch. Festschr. f. Averbach*, Moskau, S. 201, 1926.

Good results in ulcus serpens.

Lombold.—*Brit. Jl. Dermatol.*, Vol. XXXVI, p. 112, 1924.

Good results in local treatment of xanthelasma.

Lottrut-Andersen.—*Hospit. Tid.*, Copenhagen, Bd. LXII, SS. 1217, 1242, 1263, 1289, 1316, 1919.

Good results in ulcus serpens.

Löwenstein.—*Die Tuberculose des Auges*, Berlin, S. 30, 1924.

Good results with Koeppé's methods in tuberculous infections, especially irido-cyclitis. Sensitizers, such as fluorescein used.

Lundsgaard.—*Hospitalende*, 1905; *Klin. Monatsbl. f. Augenheilk.*, Bd. XLIV, S. 191, 1906; *Arch. f. Ophthal.*, Bd. LXVI, S. 578, 1907; *Klin. Monatsbl. f. Augenheilk.*, Bd. XLVI (ii), S. 602, 1908; Bd. XLVII (i), S. 386, 1909; Bd. XLIX (ii), S. 763, 1911; Bd. LXI (ii), S. 369, 1918; Bd. LXVIII, S. 103, 1922; Bd. LXVI, S. 861; *Acta. Ophthal.*, Bd. I, S. 39, 1923.

General baths and local treatment, with the Finsen technique. Especially good results in local treatment of lupus and tuberculosis of the conjunctiva, all cases of which were eventually cured. General treatment especially in tuberculous subjects—keratitis, scleritis, dacryocystitis, iritis, and irido-cyclitis.

Lundsgaard and Nielson.—*Trans. Dansk. Oft. Selskab.*, p. 43, 1921-22.

Finsen therapy, as above.

Macbeth.—*Pacific Coast Oto-Ophthal. Soc.*, p. 44, 1925.

Treatment of trachoma, vernal catarrh, and follicular conjunctivitis.

Mayer and Dworski.—*Amer. Review of Tuberculosis*, Vol. X, p. 146, 1924.

Experimental tuberculosis of rabbits; results of radiation.

Menacho.—*Ann. d'Ocul.*, T. CXL, p. 150, 1908.

Good results in vitreous haemorrhages; no useful results in corneal opacities.

Mohr u. Baumm.—*Klin. Monatsbl. f. Augenheilk.*, Bd. XLIX, S. 629, 1911.

Good results in trachoma treated locally by a Kromayer mercury vapour lamp and a prism compressor. Radiation pushed to the formation of a pseudo-membrane.

Narog.—*Polska Gaz. lekarska*, Bd. III, S. 776, 1924.

Local treatment of trachoma, blepharitis, tuberculous iritis and uveitis.

Nesnamoff.—*Westnik. Ophthal.*, Bd. XVIII, 1901.

Treated 7 cases hypopyon ulcer with good results.

Nutt.—*Brit. Jl. of Ophthal.*, Vol. X, p. 138, 1926.

Phlyctenular disease treated with general baths by mercury vapour lamp; good results.

Passow.—*Heidelberger Ber.*, S. 243, 1920; *Med. Klin.*, Nr. 57, S. 1307, 1919; *Strahlenther.*, Bd. XII, S. 441, 1921; *Arch. f. Augenheilk.*, Bd. XCIII, S. 95, 1923; Bd. XCIV, S. 1, 1924; Bd. XCVII, S. 74, 1925; *Münch. med. Wochenschr.*, Bd. LXXI, S. 733, 1924.

General and local treatment. Good in phlyctenular disease, blepharitis, conjunctivitis, and ulcus serpens. Used sensitizers, as bengal rose. Experimental work on the action of bacteria and the effect of radiation with sensitizers.

Poyales.—*Arch. de Oftal. Hisp.-Amer.*, Vol. XXV, p. 555, 1925.

Used Koeppe's technique. Reports good results in phlyctenular disease, corneal ulcers, iritis, irido-cyclitis, and choroiditis and chronic glaucoma. Little benefit in spring catarrh, trachoma, and interstitial keratitis.

Russo.—*Ann. di Ottal. e Ciin. Ocul.*, Vol. LIV., p. 406, 1926.

Good results in trachoma.

Sanguinetti.—*Lettura Oftal.*, Vol. III, p. 59, 1926.

Corneal and conjunctival conditions treated.

Schanz.—*Arch. f. Ophthal.*, Bd. LXXXVI, SS. 549, 568, 1913; *Münch. med. Wochenschr.*, Bd. LIV, S. 525, 1917; *Zeitschr. f. Augenheilk.*, Bd. XXXVI, S. 101, 1918; *Klin. Wochenschr.*, S. 2568, 1922; *Deutsch. Ophthal. Gesell.*, Jena, S. 229, 1922; *Münch. med. Wochenschr.*, Bd. LXIX, S. 1341, 1922.

Local treatment. Good results in corneal ulcers, especially pneumococcal, old opacities and deep infiltrates. Also eczema of lids and tuberculous iritis.

Schenck.—*Homeopath. Eye, Ear, and Throat Jl.*, October, 1907.

Good results in iritis and chronic glaucoma.

Schinck.—*Ver. d. Augenaerzte v. Ost. u. Westpreussen in Königsberg*, November, 1921; *Zeitschr. f. Augenheilk.*, Bd. LXVIII, S. 292, 1922.

Local treatment of 42 cases of ulcus serpens: 19 very good, 24 good, 9 unsatisfactory.

Schwarzkopf.—*Zeitschr. f. Augenheilk.*, Bd. XLVIII, S. 77, 1922.

Local treatment using optochin as sensitizer against pneumococcus.

Seefelder.—*Heidelberger Ber.*, S. 243, 1920.

Treatment of conjunctivitis.

Seidel.—*Arch. f. Ophthal.*, Bd. XCIII, S. 357, 1917.

Used direct sunlight through a small hole in a card with good results in tuberculous iritis, episcleritis and parenchymatous keratitis.

Stein.—*Klin. Monatsbl. f. Augenheilk.*, Bd. LXXVII, S. 203, 1926.

General sun-baths for tuberculous infections and their sequelae.

Stock.—*Klin. Monatsbl. f. Augenheilk.*, Bd. LXXVI, S. 542, 1926; *Med. Klin.*, S. 1834, 1926.

Used Koeppe's technique without particular success in ulcus serpens, iritis, irido-cyclitis, disciform keratitis, etc.

Strebel.—*LXXXV Versamm. deut. Naturfors. in Kassel.*, 1903; *Klin. therap. Wochenschr.*, Wien, Bd. X, SS. 1281, 1287, 1903. *Vide* Bach: Kunsliche Höhen-sonne, IX ed., p. 123, 1922.

Treatment of lupus, conjunctivitis, chalazion, etc.

Strebel u. v. Ammon.—*Deutsch. med. Wochenschr.*, Bd. XXIX, S. 409, 1903.

As above.

Sulzer.—*XVII Internat. Med. Congress*, London, 1913. Sect. IX, pt. ii, p. 71.

Corneal infiltrates and opacities treated with iron arc and quartz lens.

Werther.—*Münch. med. Wochenschr.*, Bd. LXIV, p. 527, 1917.

Tuberculous conjunctivitis and lupus treated locally with good results.