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How safe is the light during ophthalmic diagnosis and surgery

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Abstract

The light used when undertaking ophthalmic diagnosis or ophthalmic surgery can be hazardous and the need to address this from a clinical and practicable point of view is discussed. Not all patients are equally at risk. Age and health are risk factors that need to be taken into account, the aged eye being more at risk as is the eye with existing disease. The risk of photochemical damage to the retina is increased as a result of patients being examined with different ophthalmic instruments during a 24-h period. The ways in which the clinician needs to address these safety issues is discussed bearing in mind the guidelines that are being developed.
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It is well-known that sunlight is hazardous and can damage the eye; eclipse burns are very real and can result in severe visual impairment. It is also known that light at lower intensities can be hazardous and this applies to the sources of light that are used in ophthalmic instruments. To what extent does the light we use to examine the eye when attempting a diagnosis and when undertaking surgery put the eye itself at risk? This is the 60 000 dollar question. It has been known for a long time that the light used does present a risk of damage, which may be transient or may be permanent. Indeed 'How safe is light' could have been the title of a paper when Helmholtz produced his own ophthalmoscope in 1850 in which the light source was a flickering candle, later to be replaced with a gravity fed oil lamp, then a gas lamp, and then finally in 1885 with the first, unstable, tungsten filament lamp. The risks then were of setting fire to the clinic rather than specifically of damage to the eye.

With modern light sources, the extent of the risk of damage is related to how long the examination or surgery takes; the shorter the exposure, the smaller the risk. So time is a factor in determining safety. If the eye could be completely examined in a second and an operation completed likewise, there would be little risk and this topic would be superfluous. However, therein lies the rub; attempting to make a diagnosis takes time as does surgery and frequently involves the use of a number of different ophthalmic instruments.

We need to examine the eye to determine not only its state of health but also, as it is a window into the body, what might be taking place elsewhere. We have a virtual armoury of diagnostic ophthalmic instruments, not all of which present a light hazard to the eye. For example, the perimeter, which enables the visual field to be fully investigated, utilises an intensity of light that is not hazardous even if used for very long periods. On the other hand, the emissions from instruments such as the ophthalmoscope, slit lamp, operation microscope, or endoilluminator are potentially hazardous and can damage the eye, in particular the retina.

Not all eyes are equally at risk. Those with disease are more at risk of being damaged by light exposure than healthy eyes. However, even for those with healthy eyes, age on its own is a risk factor due to physiological changes in the vascular system. Bearing in mind that we are attempting to detect the earliest signs of the disease or once diagnosed, indicators that show whether the disease is progressing, the search for such features frequently involves a longer examination time than would be the case if the eye is shown to be healthy.

Recognising that the light being emitted from ophthalmic instruments can be hazardous to the eye, work started in 1989 on producing an International Light Hazard Safety Standard for the manufacture of ophthalmic instruments. It was recognised that the increasing use of new light sources meant that in the absence of any limits on the amount of energy exiting such

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instruments, it would be possible to seriously damage the eye being examined.[1] As a result, the International, Standards Organisation (ISO) set up a Light Hazards Task Group involving international experts to identify the hazards involved, define, and review the limits and guidelines for manufacturers and provide information to end users about best practice in relation to the nature of the hazards and the ways in which they can be kept to a minimum. A very detailed International safety standard entitled 'Light hazard protection' (ISO 15004-2) was subsequently published and is reviewed and updated on an ongoing basis. It specifies the fundamental requirements for optical radiation safety for ophthalmic instruments that direct optical radiation into or at the eye.

Getting a clear view of the retina with these ophthalmic instruments is not always straight forward due to the presence of a number of obstacles, in particular the pupil size and the clarity of the media especially the crystalline lens. The older the patient, the smaller the pupil becomes. To overcome this, the pupil is usually dilated as a result of which more light reaches the retina. To complicate matters, the older examiner also has a smaller pupil than his younger colleague and this reduces the apparent brightness of the retinal image, as a result of which he or she will increase the intensity of the illuminating beam to compensate. Thus the dilated patient, whose pupillary reflex has been paralysed, is subjected to a higher intensity when examined by an older clinician, than would otherwise be the case.

Most ophthalmic instruments moved from using tungsten filament lamps to halogen lamps many years ago. These lamps are capable of delivering a relatively high level of ultra violet radiation. Within the visible spectrum they also deliver a significant level of blue light, which represents a potential photochemical hazard to the retina. Elimination of the ultra violet and the blue light is possible with appropriate filters. While eliminating the ultra violet does not present a problem, elimination of all the blue light results in a change of colour of the emerging light; this in turn, changes the appearance of the retina. This was found to be totally unacceptable to the majority of clinicians because under such conditions the fundus no longer has its typical red appearance, as a result of which diagnostic clues need to be reinterpreted. It was clear that most clinicians would not use such a filter. From a practical point-of-view therefore, the blue light hazard cannot be eliminated completely.

Photochemical damage to the retina is a dose-related phenomenon. In addition to the magnitude of the retinal irradiance, the length of the exposure must be taken into account in assessing the risk of damage to the eye. To enable clinicians to assess this risk in practice, a safe time for each instrument could be derived, which would define how long the instrument can be used before the risk of producing photochemical damage to the retina would arise. This approach, however, is unrealistic for a number of reasons. In an examination situation, there are many variables that complicate the issue of safe times. The eye is frequently examined with a number of different instruments which use intense light sources. The effects of such repeated exposure to light during the course of a single 24 h period are considered to be cumulative. If for example, ophthalmoscopy is followed by a slit lamp examination, the safe time on the slit lamp will be reduced by the prior exposure to ophthalmoscopy and this would be further reduced if the eye has been exposed to retinal photography.

It can be seen that because of the large number of variables involved in the examination, not least of which are those associated with the patients themselves, defining a 'safe time' for each instrument is not feasible. An alternative approach has however been used in which hazard exposure guidelines have been developed. These guidelines are intended to inform the clinician about potential optical radiation hazards that may be associated with the use of their instruments, thus enabling them to make balanced clinical judgements in terms of the length of the examination and the level of light to be used.

Photochemical retinal damage, if not too severe, is repairable by the body. Were it not, even minor damage would build up relatively quickly making the retina non functional. So while the effects of repeated radiation over the day are considered to be additive, the irradiation of one day is not added to that of the next day since it is assumed that the previous day's damage has been repaired. All of this assumes a normal repair mechanism is in place, which is a good assumption for a normal healthy retina. This, however, cannot be assumed to be the case for unhealthy and diseased retinae. Such retinal tissue may not be able to repair itself in a normal way and so a normal level of photochemically induced actinic insult may be more serious than would be the case for the healthy retina. The eye with disease is therefore more vulnerable as a result of the examination procedure itself to developing photoretinitis in a shorter time than would be the case for a healthy eye. Ironically, it is diseased eyes that require the longest exposure times.

There are a number of other aspects which affect the level of risk. If the light source remains focussed on stationary point on the retina, the risk of damage will be greater than if the light is moving. Eye movements consequently will have the effect of reducing the risk of damage. If the eye is immobilised as is often the case during an operation, the risk of photochemical damage is increased significantly.

Involuntary user movement of the ophthalmic instrument during the examination will have the effect of reducing the potential light hazards to the eye. Although

such involuntary movements can be significant, the results of studies, however, do not indicate that the risk of damage overall can be regarded as being reduced, bearing in mind that not all users are prone to being unsteady in using such instruments.[2]

Of all the instruments used to examine and treat the eye, the greatest risks arise when using operation microscopes and endoilluminators. Ophthalmic surgery, which frequently takes place on immobilised eyes, generally takes much longer than a diagnostic examination and involves the use of intense levels of light, which present a potential hazard. There are, however, a number of factors which reduce the risk here. For example, in a cataract extraction, during the first part of the operation the lack of clarity in the crystalline lens reduces the amount of light that can reach the retina. Once the lens has been removed, although the light pathway to the retina is now unobstructed, the period in which the light is unimpeded is reduced considerably by the surgical instruments that are positioned from time to time within the visual pathway.

Endoilluminators present the greatest risk for photochemical damage to the retina. The risk is associated with the fact they expose the retina to intense light for extended periods of time, the light source effectively being positioned within the eye itself and consequently much closer physically to the retina than is the case with any other ophthalmic instrument.

To reduce the risk of retinal damage from intense light, safety guidelines for endoilluminators have been developed. The risk, based on a worst case scenario, is represented by the time it takes to reach the safety guideline and, as such, gives a measure of the potential hazard that exists for a beam of light to cause photochemical damage to the retina.

The distance of the endoilluminator light guide from the retina will significantly affect the risk factor. Reducing the distance from say 15 to 5 mm can increase the risk and decrease the time to reach the safety guideline by as much as a factor of nine times. On the other hand, increasing the distance from 5 to 10 mm can decrease the risk and increase the time to reach the safety guideline by as much as a factor of 4. In addition, maximum exposure times may be significantly related to field angles of the exiting light. For example, the time to reach the safety guideline for a field angle of 20° is five times shorter than that for a field angle of 40° for the same intensity level.

There are a number of other factors that can increase the time to reach the safety guideline. Reducing the light intensity increases the maximum exposure time in direct proportion to the decrease in intensities. Movement of the light guide prevents the light from exposing the same point on the retina and increases the time to reach the safety guideline in direct proportion to the time the light beam is not on the same point on the retina. Instruments and blood in the in the eye within the light path to the retina will attenuate the light and therefore also increase the time to reach the safety guideline. If blood in the eye only transmits 50% of the light, then the time to increase the safety guideline will also increase by a factor of 2. The use of imaging agents such as indocyanine green (ICG) will increase the risk of phototoxic injury since ICG is a known photosensitizer.

So at the end of the day, how should the clinician respond? A clinical judgement has to be made. It is the practitioner who must decide what to do and what not to do. The decisions have to be made on a case-by-case basis. There are certain fundamental points that must always be borne in mind: the brighter the light and the longer the examination time, the greater the risk. On the other hand, insufficient light intensity may make adequate visualisation impossible and the effect of this and inadequate examination time may be regarded as a more serious risk than any photopic injury that may be produced. Such a judgement must be balanced taking into account all the risks that exist.

So how safe is the light that is used in clinical settings? It is clear that it has the potential to be hazardous and that must always be borne in mind. While the experts can provide the most up-to-date information about the hazards that exist and guidance on best practice, they cannot provide a black and white set of guidelines. What they can say is that as our knowledge increases the advice that we give today may well have to be revised tomorrow.

Conflict of interest

The author declares no conflict of interest.

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