Optimal Illumination
Key to Safe, Effective Surgery

Characteristics of different light sources can guide selection of the best option.

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As the use of smaller-gauge instrumentation and wide-angle viewing systems for vitreoretinal surgery has become standard practice in recent years, numerous new illumination options have entered the market. These higher intensity light sources, including metal halide, xenon, mercury vapor, and LED, have been introduced to compensate for the reduced transmission of light through smaller gauge instruments and to accommodate the broad diffusion of light needed for wide-angle viewing and chandelier-type illumination.

With so many illumination options now available, it is worthwhile for the vitreoretinal surgeon to consider the factors that contribute to making a light source safe and effective for its intended purpose. This article reviews some of these considerations and offers an overview of some of the options currently available. Much of the information below is adapted from a book chapter on this topic that I recently authored.

MODES OF ENDOILLUMINATION

There are many ways of getting illumination to the posterior pole for vitreoretinal surgery, the most commonly used being the fiber optic “light pipe,” chandelier lighting, and illuminated instruments. Each mode of illumination has its own advantages and tradeoffs.

The light pipe is perhaps the most common means of endoillumination. Light pipes can provide safe and efficient illumination, leaving most of the heat at the light source and conveying the light to the posterior segment through a fiber optic. Traditionally, light pipes provided focal illumination—a cone of light with a relatively small angle of divergence. With the advent of wide-angle viewing systems, the small cone of light provided by focal light pipes left most of the visible surgical field in relative darkness. As a result, wide-angle light pipes that spread illumination over a wider area have become more popular. The rounded or conical tips of these light pipes spread the output of the optical fiber and provide a more uniform delivery of light in all directions, unlike the spotlight-type illumination from flat-tipped, focal light pipes. On the downside, the diffuse nature of the illumination provided by wide-angle light pipes may make visualization of some structures less satisfactory. In particular, it can be more difficult to see the vitreous under diffuse lighting.

Chandelier illumination is designed to allow truly bimanual surgical techniques, with an instrument in each hand, while providing the surgeon in essence a “third hand” to hold the light. Despite the obvious advantages of bimanual capability for certain surgical situations, there are a number of tradeoffs with the use of chandelier illumination. Although excellent overall illumination is provided, chandeliers may provide insufficient illumination in any particular spot. That is, at the point of surgical dissection, the more distant, diffuse illumination from the chandelier may not be as helpful as a nearby light pipe would be. Shadows cast by instruments may also impede visualization, and the potential for thermal buildup in the steadily illuminated chandelier tip may be a cause for concern.

Chandeliers are available in single- and dual-fiber configurations. Early multiple-point chandelier systems required large sclerotomies, but now, with brighter light sources available (see next section), 25-gauge and even 27-gauge chandelier fiber optics have become feasible and are widely available. The principal advantage of dual-
fiber configurations is the reduction or elimination of shadows from the surgical field.

A variety of illuminated instruments is currently available, including illuminated vitrectors, forceps, scissors, picks, and laser probes. The chief tradeoff with these instruments is that they never seem to provide enough light in the right place. Nevertheless, the light is very bright, resulting in considerable glare. One exception may be the 3-function tissue manipulator combining light, aspiration, and cautery. This tool can be useful in complex surgery, such as repair of traction or combined traction-rhegmatogenous retinal detachments in diabetic patients.

LIGHT SOURCES

Although the introduction of minimally invasive surgery with 23- and 25-gauge (and, increasingly, 27-gauge) instruments has resulted in reduction of surgical trauma and patient discomfort, it has also presented a challenge regarding achieving adequate illumination. There is reduced transmission through 25-gauge and 23-gauge endoilluminators due to the reduced surface area of the fiber optic—40% and 50% compared to 20-gauge, respectively.2 Thus, more light is needed at the source to “pump” it through the fiber optic into the eye to provide sufficient illumination.

To answer this challenge, more powerful light sources have been introduced. In order of increasing light output, the available light sources commonly used for vitreoretinal surgery are halogen, metal halide, xenon, LED, and mercury vapor.1

Of prime concern in vitreoretinal surgery is the spectral content of the light source, in terms of both tissue visualization and phototoxicity. Phototoxicity can be caused by either thermal damage or photochemical injury. Thermal damage is the mechanism of injury that is employed in retinal photocoagulation; photochemical injury causes tissue damage without a thermal effect.1

Risk of phototoxicity is influenced by 3 factors: the wavelength of the light being used, the intensity of light exposure, and the duration of exposure. Shorter wavelength photons—toward the blue or violet end of the visible spectrum, and into the ultraviolet—contain more energy, and are therefore more damaging at a given power level, than longer wavelength photons. Ham et al3 analyzed the relative risk for retinal damage from exposure to these longer wavelengths and developed an “aphakic hazard curve” (Figure 1), which illustrates that at shorter wavelengths, at a given exposure level, the risk of phototoxicity increases.3

The risk of phototoxic damage can be reduced by the use of filters to eliminate shorter wavelengths. Ultraviolet and blue wavelengths are more dangerous than longer wavelengths, and most of these wavelengths are not necessary for tissue identification2; therefore, filters are commonly used to block these wavelengths, generally at a cutoff of about 420 to 435 nm.

Each light source used in vitreoretinal surgery has its own characteristic spectral output distribution pattern (Figure 1)—xenon has a peak in the low end, for example, and mercury vapor has a dual peak in the midrange—and therefore each requires adjustment of filters to eliminate damaging wavelengths or unnatural color balance. LED light color is dependent on the design and can vary considerably. Additionally, multiple LEDs can be blended to produce favorable spectral outputs. The eye’s response curve is a bell curve, centered around 550 nm and extending from about 400 nm to 700 nm (Figure 1).1

The human eye likes white light, or some version of white light, which can be achieved by various mixtures of
the colors of the visible spectrum. Therefore, efforts must be made to preserve for the surgeon a tolerable and natural light that is capable of safely but clearly illuminating the structures of interest in the posterior segment. In other words, compromises must be made to achieve safety along with sufficient brightness and an acceptable color temperature, or mixture of colors.

Missing from Figure 1 is the output curve for a relatively new light source, the LED, as used in the LEDStar (Dutch Ophthalmmic). Figure 2 shows the unfiltered white light output of the LED light source. The peak in the phototoxic range at 450 nm can be filtered out almost entirely with the LEDStar’s built-in adjustable yellow filter (Figure 3). When the filter is set to its maximum of 20 (on an arbitrary scale of 0 to 20), phototoxicity is minimal, but the filtering results in a distinctly yellow light. My personal preference is to use a setting of approximately 10 to 15 (Figure 4), which minimizes photochemical toxicity and provides an only faintly yellow light. On this setting, the light would appear yellow if compared directly to unfiltered white light, but after a few minutes in surgery it is quite comfortable and natural.

The light provided by the LED, with up to 40 lumen output, is sufficient to provide chandelier illumination through even the smallest gauges currently in use. The LED technology is robust, with durable “bulb” life lasting up to 10 000 hours, as compared with approximately 400 hours for metal halide bulbs.

**CONCLUSIONS**

Light toxicity is uncommon or rare, but ideally it should never occur. Sometimes it can be caused by extrinsic factors the surgeon is not aware of, such as a patient’s use of a photosensitizing drug, but generally speaking light toxicity is caused by too much light or light with unfavorable spectral characteristics used during surgery. The technology exists to perform safe vitreoretinal surgery, and surgeons should strive to achieve this standard in every case.

It should be noted that there is considerable subjectivity in regard to acceptance of light color. People perceive colors differently, and taste is also a factor—what we like and what we don’t. With light color in surgery, as in many other things in life, there is probably a range of preferences. With the available illuminating choices, it is a matter of calibrating one’s senses—our eyes, in this case—to the environment, and learning to recognize the structures we are targeting with our surgeries.

There have been numerous recent advances in the availability of options for illumination in vitreoretinal surgery. High-intensity light sources—made necessary by the move to smaller-gauge instruments and wide-field viewing systems—offer benefits but also present increased risks. In using these newer light sources, it is important to remember that they are powerful and capable of causing retinal photochemical toxicity and associated loss of vision. The surgeon must be careful to use the minimum amount of light possible to safely accomplish the tasks at hand during surgical intervention.

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