

Digital Viewing Systems Bring Benefits to the OR



The ability to manipulate color value and saturation may be only the beginning.

BY THOMAS M. AABERG, MD, MSPH

The ophthalmic surgical microscope dates to 1946, the brainchild of Richard Perritt, MD, of Chicago. The microscope technology significantly advanced over the next 2 decades: By the 1960s, the operating microscope had x-y-z movement, a side scope, improved optics, and, for some models, even video capabilities.

But in the ensuing 5 decades, beyond the introduction of wide-field viewing for retina surgery, there have been no dramatic advances in ophthalmic microscope technology because, ultimately, any analog system has limitations.

Digital technology, however, now allows advances beyond the limitations of analog. Consider the analog versus the digital telephone. The rotary telephone reliably allowed the user to talk to people anywhere in the world, connecting one person to another by voice but with no other application. Today, with digital technology, our phones are not only communication devices, but also cameras, computers, internet web portals, and much more.

Another example more relevant to this discussion is the analog camera. An analog photograph—a product

of film exposure—can be manually manipulated in a photo lab via tedious work. The advent of digital cameras now provides instantaneous images that can be easily manipulated in endless ways.

BENEFITS OF DIGITAL IMAGING

There are clear benefits of using a digital ophthalmic surgical imaging platform (DOSIP), including ergonomics. The importance of this benefit should not be underestimated. Several studies have documented the deleterious effects of surgery on the surgeon.¹⁻³ Back, neck, and shoulder pain are the most commonly reported issues, and in some cases they can be severe enough to prematurely end a

surgeon's career.

Even with the advent of ergonomically friendly surgical microscopes, there is still a significant toll on surgeons' bodies. In part, this is because it is unnatural for a human to maintain a specific head position for long periods of time. With an operating microscope in ophthalmic surgery, our eyes look through oculars with less than a square inch of surface area, allowing the surgeon's head to move only a few degrees up and down or side to side.

With a large surgical viewing platform such as the 56-inch OLED monitor on the Ngenuity 3D Visualization System (Alcon), by contrast, the surgeon can shift from one position to another, move his or her body, and

AT A GLANCE

- ▶ The use of digital ophthalmic surgical imaging platforms brings advantages in ergonomics and training to the vitreoretinal OR.
- ▶ Beyond these basic advantages, these systems allow manipulation of color and can display additional information beside the surgical image.
- ▶ For full use of current systems' capabilities, expert operation is required, but with future advances the systems should become more user-friendly.

move freely around the patient's head without having to move the oculars.

A DOSIP is also an unparalleled advantage for surgeons involved in training programs. When the faculty surgeon operates, more than one trainee can observe the techniques and nuances of surgery in high definition and with stereopsis. Moreover, when a trainee is operating under the guidance of the faculty surgeon, the trainer can direct the trainee using a laser pointer in a sterile baggy or can physically point to areas in the surgical field.

THE TECHNOLOGY

The issue most pressing for surgeons and patients is whether a DOSIP can improve surgical safety and outcomes. To understand how digitizing the surgical image can help to meet this challenge, one must understand high dynamic range (HDR) technology and color technology.

HDR video technology was a dramatic advance toward reproducing what the naked eye sees in colors and in contrast between the brightest whites and the darkest blacks. HDR is about recreating image realism from camera to processor to display. This technology is now present in nearly every digital camera, including those in our phones.

The *dynamic range* of an imaging device refers to the difference between the brightness of whites and the darkness of blacks and the color depth that can be maintained across this range. HDR video surpasses that of standard dynamic range (SDR) video, as the whites are brighter, the blacks are deeper, and the color palette is wider. Compared with SDR, HDR provides greater transfer functions, greater bit depth, and static and/or dynamic metadata.

How does the dynamic range of current digital microscopes compare with that of the human eye? The human eye has the equivalent of 10 to 20 f-stops of dynamic range, depending on pupil size and the ability to dark-adapt. However, practically speaking (because we do not have 30 minutes to dark-adapt), under normal surgical conditions the surgeon's eye has a dynamic range of 6 to 7 f-stops. The Ngenuity digital system has 85 db (equivalent to 15 f-stops) of dynamic range.

HDR technology conveys a multitude of benefits. HDR and computational imaging processing can optimize 3D image exposure in real time, producing brighter whites, deeper blacks, and a wider color palette. The digital camera combined with HDR technology also produces 19% greater magnification, increases depth of field by 2.7 times, and allows real-time image manipulation. This type of processing brings up the intensity of the imagery, adding new levels of contrast, sharpness, and color.⁴

The advantages of a DOSIP also depend on color, light, and the technology of the sensors and the OLED monitor (see *The Vocabulary of Color*). There are three integral components of color: hue, value, and saturation (or chroma).

THE VOCABULARY OF COLOR



Most of us can tell red from green and dark from light, but few of us know the language of color. Here's a cheat sheet.



HUE: Our most common understanding of color. Hue is the frequency of light to which we ascribe a name—red, blue, orange, violet. It tells us that a plum is purple and a banana is yellow.



VALUE: A hue's lightness or darkness, which is to say, the amount of light reflected from a hue. Adding black to a hue provides a *shade*. Adding white to a hue provides a *tint*. It's how we can tell the difference between two objects of similar hues—say, a lighter (tinted) flamingo and a darker (shaded) flamingo, both of which are pink.



SATURATION/CHROMA: The grayscale of color. The more saturated a hue, the purer the reflection. Turning the saturation to 0% on your television settings turns the color palate into a series of grays.

TIPS FOR NEW USERS OF DIGITAL OPHTHALMIC SURGICAL IMAGING PLATFORMS

► Positioning

Position the monitor appropriately. There is a cone of stereopsis specific to the type of monitor you have. Outside that cone, there will be shadowing or frank double images. Know the specifications of your monitor.

► Orientation

When you begin a case, make sure you are parfocal on the anterior segment. During retina surgery, once you are in the posterior segment, make sure to be parfocal either in the midvitreal or on the macular surface. There is such good depth of field on these systems that it is easy to get out of focus, and the surgeon may perceive this as a microscope resolution issue.

► The Patient

Always remember that the patient and his or her surgical outcome are of utmost importance. If you do not feel comfortable with your visualization, have a low threshold to remove the camera and go back to traditional oculars.

Hue is the frequency of light we see and name; for example, a stoplight is red. It is the first item of color we refer to and the dimension of color we readily experience. There are three primary hues: red, green, and blue. This is why televisions, computer monitors, and other full-range electronic color visual displays use a triad of red, green, and blue phosphors to produce all electronically communicated color. To produce white light, the three primary hues are added together at full strength, and black is the absence of all three.

The *value* of a color refers to the dimension of lightness or darkness of that color, or the quantity of light reflected. In terms of a spectral definition of color, value is the overall intensity or strength of the light. When we speak about pigments, dark values with black added are called *shades* of the given hue name. Lighter values with white pigment added are called *tints* of the hue name.

Saturation or *chroma* defines a range, from pure color (100%) to gray (0%), at a constant light level. A pure color is fully saturated.

THE VALUE OF CHANGING VALUES

With digital technology we can change all three components of color: hue, value, and saturation. Hue shifting in digital microscopy has not been useful, as it involves only reassigning a detected frequency of light to a different displayed frequency of light. However, the ability to change values and saturation levels has been very useful. The ability to eliminate specific color channels provides an opportunity to enhance surgical visualization.

The human eye has the best perception in the green frequencies. There is a good explanation for this. Red cones comprise 64% of the total number of cones in the retina; green cones make up 32%, and blue cones make up only 2%. Nonetheless, the rods in the eye play an important role in vision resolution. The rods provide sensitivity to light brightness, but they respond only at limited wavelengths, peaking at 550 nm (within the yellow-green color wavelengths). This sensitivity was understood by ophthalmologists years ago, and it led to the inclusion of red-free light on most slit-lamp microscopes.

Red-free examination of the macula can, for example, highlight epiretinal membranes.

Digital imaging circumvents the need to use a specific type of light source or to physically insert or remove filters. Instead, the system can be programmed to suppress the red channels. I have found this filtering to be useful in complex dissections of diabetic fibrovascular proliferation.

I have also explored changing saturation levels. Looking at OCT images, I realized that it is easier for me to detect pathology when I view with a grayscale as opposed to a colorized image. Changing the surgical image to zero or near-zero saturation creates a similar grayscale. Although it initially seems odd to see the surgical field in black and white, I find that there is better resolution and definition with this setting.

It is hoped that the use of DOSIPs can expand our capabilities beyond simply visualizing the surgical field. The use of multimodal imaging, integrating and bringing all the incredible tools we use daily in our clinics into the OR, is rapidly becoming a reality. The Ngenuity system allows multimodal imaging in anterior segment ophthalmic surgery. With this capability, cataract surgeons can import preoperative vector analysis to allow precise placement of astigmatic corneal incisions or toric IOLs.

In retina, meanwhile, surgeons can import preoperative images—OCT and angiography, for example—into the Ngenuity and display those images adjacent to the surgical field. In the future, integrated with endoscopy, a digital surgical viewing system would allow simultaneous en face and en plane visualization. With intraoperative OCT, it would be possible to display both the surgical field and live intraoperative OCT side by side.

AREAS FOR IMPROVEMENT

As with any new technology, there are areas to improve and weaknesses

to address. Image lag is and will continue to be the most notable hurdle. The goal is to maintain a lag of less than 100 ms. NASA engineers have studied this matter and determined that a 100 ms lag is the limit at which a human can accurately perform tasks.

Posterior segment surgery proceeds slowly enough that this degree of lag is more than acceptable and, frankly, imperceptible. I have performed hundreds of surgeries with the Ngenuity system, and I do not perceive any lag. Anterior segment surgery, however, has larger and faster movements. Consequently, depending on the speed of the surgeon's movement, lag may be noticed. As more programming and software capabilities are added to these systems, it will be the engineers' challenge to maintain a short lag time. I expect that the lag hurdle will be lowered as processor capabilities improve.

System lockup is also a concern. All of us have used computers that freeze just at the inopportune time. The muscle of digital imaging systems is a sophisticated processor and computer. There is a legitimate concern that the computer could crash in the middle of surgery. Rebooting a system during a critical part of surgery requires time that may affect a surgical outcome. Consequently, current systems and any updates and upgrades must be tested thoroughly before being released for clinical use.

For new users seeking pearls on DOSIP implementation, see *Tips for New Users of Digital Ophthalmic Surgical Imaging Platforms*.

THE FUTURE OF OPHTHALMIC SURGERY

Although the Ngenuity viewing system is gradually being integrated into the Constellation Vision System (Alcon), full use of the system's capabilities requires an operator (eg, a circulating nurse) to change filters, channels, gain, etc. As these systems evolve, I expect them to become more user-friendly.

It is my belief that DOSIPs are not only the future of imaging in ophthalmic surgery; they will be necessary tools for ophthalmologists to make the next quantum advances in ophthalmic surgery. ■

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