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Vitreoretinal Surgery in the Digital Age

Using the NGENUITY 3D Visualization System is undeniably a different way of performing vitreoretinal surgery. It may also be a better, faster, and smarter way to perform surgery.

BY RISHI P. SINGH, MD

While the tools and instruments used to perform vitreoretinal surgery have evolved tremendously over the past few years, the basic design of the surgical microscope has remained relatively unchanged since the 1950s. The advent of the digital camera and image processing technologies offers to change that paradigm by providing surgeons a significant improvement in visualization capabilities. In turn, the improved ability to see inside the eye may enhance what we can do as surgeons.

I have been using NGENUITY 3D Visualization System (Alcon) in all of my surgeries since adopting the system 2 years ago (Figure 1). The initial installation did not require any major changes to the OR set up, and the need for staff training was minimal. I quickly discovered that rather than being an obstacle or impediment to performing delicate surgical maneuvers inside the eye, NGENUITY has actually improved my surgical abilities. In addition, as the technology has evolved over time, the various features of the system have only become more relevant for performing vitreoretinal surgery.

BETTER, FASTER, AND SMARTER SURGERY

The earlier generation NGENUITY platform that I first started using was equipped with a then state-of-the-art 1080p monitor, which has since been upgraded to a 55-inch 4K display. The technical differences are impressive—with 8 million pixels of resolution, the 4K monitor achieves

Figure 1. The NGENUITY 3D Visualization System.

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2,160 lines of resolution (1920 x 2160 pixel resolution per eye), compared to the 2 million pixel resolution (1920 x 540 pixel resolution per eye) on the previous model. Equally as important, the system uses two 1080p high dynamic range (HDR) cameras to capture the image. Essentially, HDR technology captures multiple photos or videos at different exposure levels, which are then processed to create a better picture. Anecdotally, I can say that the visual display is stunning with previously unachievable clarity.

In addition, the digital nature of the system allows for numerous adjustments to customize what the surgeon is seeing. One example is that visualization of various ocular tissues can be enhanced by using the range of color channels featured on the NGENUITY. By adjusting what colors are or are not displayed, tissue of interest can be made to appear more or less prominent (see *Practical Applications for Using Color Channels in Vitreoretinal Surgery* for additional information).

Using a microscope set-up requires numerous adjustments during surgery—moving the ocular from eye to eye and around the X-, Y-, and Z- planes to gain a view on the tissue of interest. In my experience, NGENUITY is immediately more efficient, as it provides dynamic ultrawide angle viewing and greater (five times) depth of resolution (42% finer) compared to microscope.[1] This, in turn, minimizes the need to change focus. When adjustments are necessary, they are easily done using the foot pedal of the CONSTELLATION Vision System (Alcon), keeping the surgeon's focus on the case, whereas in the past, we would have to disengage the oculars to make adjustments.

Each of these features alter how we can perform surgery—in my view, for the better. And yet, they are also synergistic. The robust digital input and output improves visualization, which can be further augmented during crucial steps of a procedure with use of a color channel to more precisely identify tissue of interest. Because of the greater depth of field and depth resolution, the ability to recognize various tissue planes is enhanced, especially with the ability to zoom down without sacrificing image quality. All the while, the surgeon is making real-time adjustments using the foot pedal, thereby maintaining focus on the screen and contributing to safer working conditions. Other features can enhance safety, including that the high-speed HDR camera provides excellent image quality even with lower illumination: surgery with NGENUITY requires only about 10% of the illumination used with a microscope.[2] In theory, the lower requirement for light should reduce the potential for phototoxicity and extend the safe working time inside the eye.

What makes NGENUITY a smarter way of performing surgery, though, is the recent addition of DATAFUSION software (Alcon), which allows the system to communicate more functionally with the CONSTELLATION. With the upgrade, key surgical parameters, including flow and aspiration rates, are integrated into the heads-up display. Preoperative and intraoperative OCT images can also be displayed for feedback and surgical planning. Navigating the display is, again, easily controlled by the foot pedal.

IMPROVED DEPTH OF FIELD

The improved depth of field on NGENUITY compared to ocular viewing is one of the more impressive features of the system. Vitreoretinal surgery often requires working at various depths along the Z-plane. Moving from the peripheral

Practical Applications for Using Color Channels in Vitreoretinal Surgery

The ability to toggle color settings on the display monitor of the NGENUITY 3D Visualization System (Alcon) offers a novel mechanism for identifying different tissue in the eye. There may be several scenarios in which the array of digital filters offered on the platform, combined with adjustments to other settings, might aid with visualization. For instance, the red-free filter can be engaged to identify a hemorrhage; it may also help visualize a tissue plane during internal limiting membrane (ILM) peeling. Other tissues are more discernable with other color filters: epiretinal membrane is easier to visualize with a green filter, and vitreous may be more noticeable with a blue filter.

In certain situations, I have found the use of color filters to be extremely helpful:

- **Extrascleral hemorrhage.** Localizing the area for placing a port is greatly facilitated by use of the red-free filter.
- **Dense vitreous hemorrhage.** The presence of a hemorrhage results in a red hue being cast against an orange background, often making it difficult to distinguish the retina. Reducing the red in the display output therefore obscures the hemorrhage, permitting direct visualization of the retina.
- **ILM peeling.** Adjusting the hues and gains in the picture helps to highlight the ILM. In our surgeries, we have found that we can often gain an edge and peel the membrane with very little dye.

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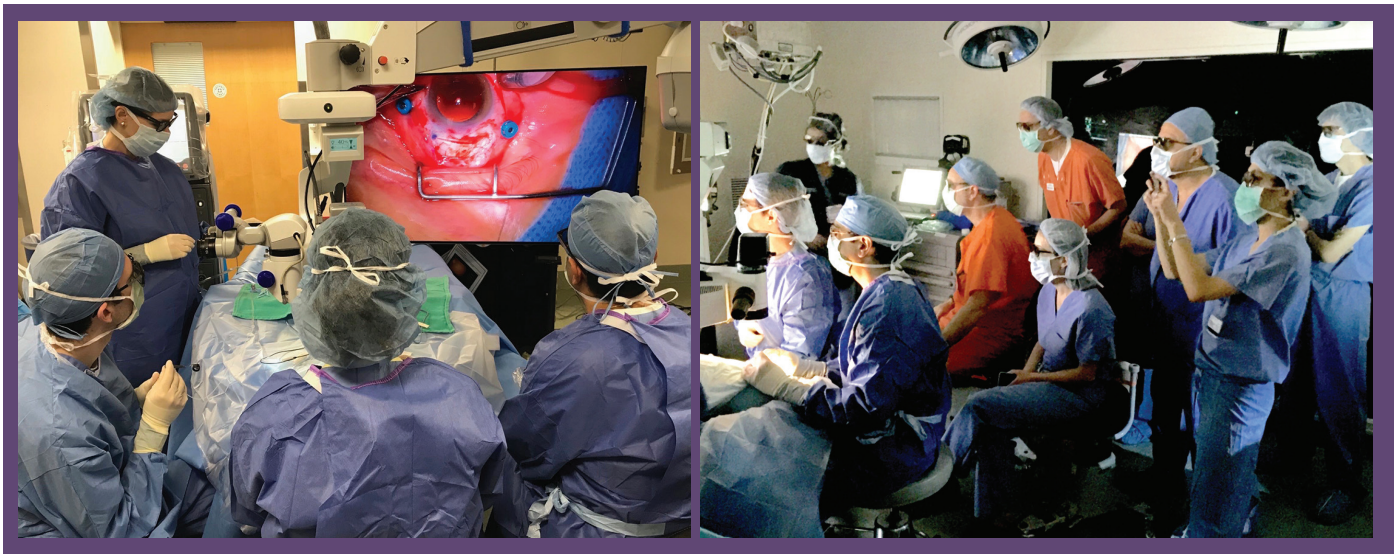
TABLE. MATHEMATICAL MODELING COMPARING THE TOTAL DEPTH OF FIELD FOR DIGITAL ASSISTED VITREORETINAL SURGERY (DAVS) AND OCULAR VIEWING.

Source of Depth of Field	DAVS		Ocular Viewing	
	Full Scope	1/4 Iris Diameter	Young Eye (4D)	Prebyopia (2D)
Depth of focus of physician eye	2.3 mm	13.5	2.1 mm	2.1 mm
Accommodation of the eye			10 mm	5 mm
Depth of field of the scope to the objective lens			0.3 mm	
Total Depth of Field	2.6 mm	13.8 mm	12.4 mm	7.4 mm

retina to the macula might require an adjustment of about 7 to 10 mm. In cases of IOL exchange or removing a lens that has fallen to the macula, the surgeon may have to perform maneuvers along the entire 20- to 22-mm length of the eye. Inherently, these situations present challenges for adjusting the view so that the focus is at the correct plane.

As noted above, mathematical modeling suggests that NGENUITY provides up to five times the depth of field as a standard microscope set-up.[1] Specifically, aperture adjustments change the depth of focus, with a larger aperture providing less depth of field and a smaller aperture providing greater depth of field. However, there is an interesting caveat—the gain in depth of field at any aperture setting is greater for individuals with more profound loss of accommodative amplitude. In practical terms, this means that the greater depth of field compared to ocular viewing and ability to magnify images without sacrificing clarity helps control the effects of presbyopia (Table).

Although the depth of field with NGENUITY is improved compared to ocular viewing, how the system is set up and used in the OR has an impact. For instance, the accommodative effect that would normally occur when looking at a picture on a screen is greatly diminished by zooming all the way in and adjusting the gross focus to get the picture in the correct plane. Most surgeons will be familiar with this step (ie, establishing parfocality) from previous experience with a surgical microscope, yet it is essential for ensuring the image is within the actual frame. Second, it is recommended that the monitor display be set up 1.2 m away from the surgeon. Using the screen at closer distances may result in the image appearing to "come off the page." A good rule of thumb is that you can never go wrong by having the screen too far away, but you can only have problems if the machine is too close. Lastly, there is a slight learning curve associated with using NGENUITY. In my experience, it took about four to five



Courtesy of Rishi P. Singh, MD.

Figure 2. Dr. Singh uses NGENUITY as a teaching tool with his staff.

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cases on my first surgical day before I felt fully comfortable with the different way of looking at surgery. To counter this, I scheduled more routine surgeries while I was navigating the learning curve and saved more difficult cases for later.

CONCLUSION

The benefits of NGENUITY extend beyond the system itself. One of the unexpected things I have come to appreciate about this visualization system is that it helps to involve the entire surgical team in the case (Figure 2). With the case displayed on a large monitor, my nurses know when I am getting close to finishing a case. Without even asking, they can start our protocols for closing a case and prepare the next patient for surgery. The resulting efficiency is certainly one benefit; in addition, the anesthesia team can monitor the patient's excursion to see if any movement is affecting the surgery.

NGENUITY is also an amazing teaching tool. The large prominent display is the most obvious reason, yet there are more subtle aspects to this, as well. Using the color channels, for example, helps demonstrate the different ocular tissues. In a similar vein, keeping track of the infusion and flow rates on the screen lets us and our trainees know if the cutter is engaging vitreous. In my OR, I also use a wireless mouse to point out pathologic markers or where to start a membrane peel. Overall, I have been impressed with how it helps with the development of training surgeons.

As surgeons, we continually seek to expand our skills and capabilities to improve outcomes, enhance safety, and be more efficient. In this regard, NGENUITY has proven an important addition to my OR. Digital assisted vitreoretinal surgery is not just a tool for performing surgery in a different way; instead, I have found it is a way to perform better, faster, and smarter vitreoretinal surgery. ■

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1. Data on File. Alcon Laboratories Inc; December 2017.
2. Adam MK, Thorton S, Regillo C, et al. Minimal endoillumination levels and display luminous emittance during three-dimensional heads-up vitreoretinal surgery. *Retina*. 2017;37(9):1746-1749.