COVER STORY

Transition from optical to digital opens opportunities in the operating room

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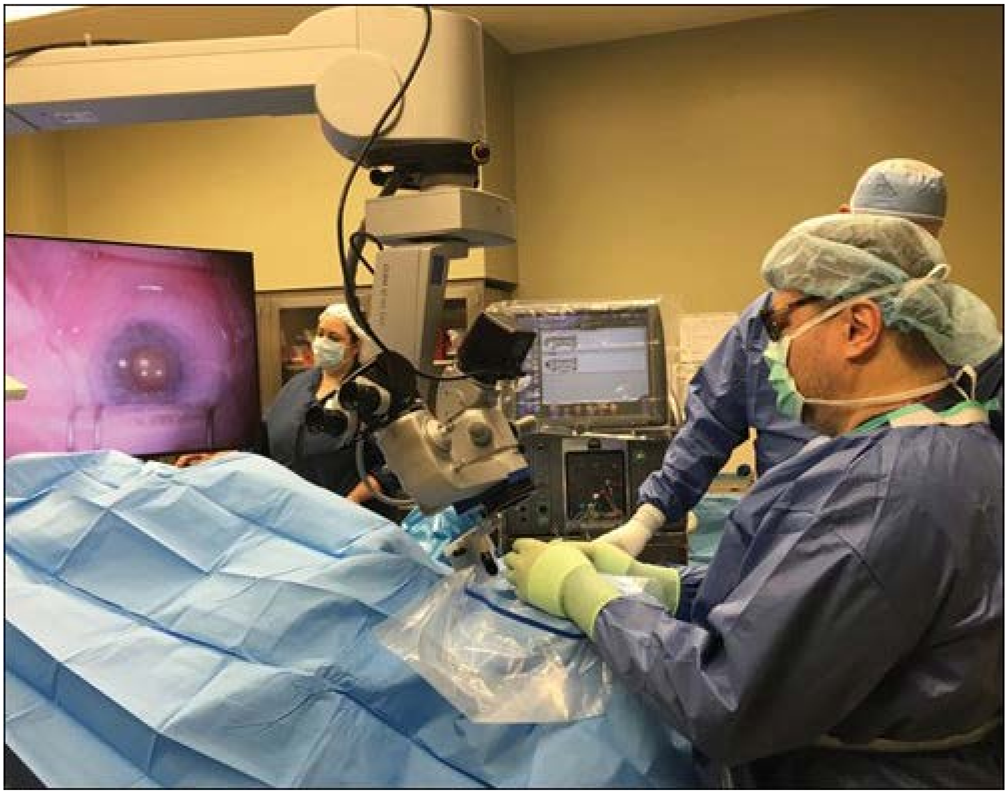
Digitally assisted surgery may be the next revolutionary step that makes surgeons move away from the oculars of the operating microscope, opening up a world of new opportunities.

“The next two decades will see 3-D digital imaging replace the optical microscope completely, giving us beautiful, high-grade depth perception and a quality of visualization that is better than human vision,” **Christopher D. Riemann, MD,** said.

In 2010, Riemann presented at the American Academy of Ophthalmology meeting the first scientific poster of a series of heads-up 3-D digitally assisted vitrectomy surgery procedures with both an early iteration of the TrueVision system and a self-built 3-D system, showing that this technology provided adequate visualization, superior surgeon ergonomics, acceptable OR times and no complications.

“We established the idea of the equivalency and the validity of doing this heads-up 3-D vision primary viewing for retinal surgery,” he said.

Further developments over the following years led to the launch, by Alcon and TrueVision together, of the Ngenuity 3-D visualization system, the first available platform for digitally assisted vitrectomy surgery. An HDR camera, extensive signal processing and extremely low latency allow retina surgeons to operate looking at a high-definition OLED 3-D screen.



According to Christopher D. Riemann, MD, the next two decades will see 3-D digital imaging replace the optical microscope completely, giving high-grade depth and a quality of vision that is better than human vision.

Source: Christopher D. Riemann, MD

"It is a game changer," Riemann said. "It allows for better ergonomics, better teaching, improved depth of field, lower light intensity, intraoperative auxiliary video handling, digital red-free settings and digital overlays."

Better ergonomics

Sitting at the microscope for 30 minutes to 2 hours, with the neck bent and the eyes moving no more than 5° in one way or the other, is an abnormal position for a human being, leading to back, neck and shoulder problems, **Thomas M. Aaberg Jr., MD,** said.

In a study on self-reported musculoskeletal disorders in ophthalmologists, Dhimitri and colleagues found a 52% self-reported prevalence of neck, upper body or lower back pain. Approximately 15% of the ophthalmologists were limited in their work by these symptoms.

In 2012, another study by Kitzmann and colleagues compared musculoskeletal disorders among eye care physicians and family doctors. Neck pain was reported by 46% vs. 21%, and low back pain by 26% vs. 9%. Surgeons in the age group of 46 to 55 years who perform more than 70 microscope surgeries per month are the most exposed to injuries,

Thomas M. Aaberg Jr.

according to further studies.

“Some people have argued that the new microscopes have better ergonomics, but when you compare studies from 1994 with older microscopes to those from the current century, you still have high rates of neck and back pain,” Aaberg said.

“If you look at me sitting at the microscope, you can see how I am bending my neck forward. Conversely, when I skip the oculars and look at the monitor during surgery, my neck is straight, my back is straight and I have excellent lumbar support,” Riemann said.

“You have a much better sitting position, and there is nothing you need to adjust. You put your patient in the height you like and can sit back comfortably because you don’t have to bend, which means less strain on your back and your neck,”**Anastasios Nikolakopoulos, MD,** said.

Effective teaching, easy transition

These open surgical settings create the perfect situation for teaching and learning.

“It is not easy for trainees to learn through a microscope when they are not used to it, and videos are not always clear — details are very limited. Here you are sitting in front of a big monitor and seeing exactly what your trainees are seeing. It is easier to talk to them, make them discuss and ask questions. Your surgery can be projected to an auditorium with thousands of people, so there is no limit to how many people can see exactly what you are doing and exactly what you are seeing,” Nikolakopoulos said.

He called the feeling of using a wide-angle viewing system and a “huge” magnification with “excellent” resolution a “surgical dream come true.”

“I found it especially rewarding in macula surgery and with the use of 27-gauge systems. Inserting 27-gauge valved trocars and especially soft-tip cannulas can become difficult with a vertical introduction. Using the high magnification and a high resolution, it is not a problem anymore,” he said.

Nikolakopoulos is director of the Thessaloniki International Vitreo-Retinal Summer School in Greece, which offers, in the last week of May each year, lessons and wet labs on vitreoretinal surgery.

“We have 4 to 5 hours of wet labs every day, 10 positions with microscopes and three positions with Ngenuity. Students train on artificial reusable eyes specially made in Miami to teach surgery heads-up with the Ngenuity system. Our course is unique in this respect; it is the only place where you can learn 3-D surgery with the new technique as well as classic surgery through the microscope. We enroll 30 to 40 people each year, coming from all over the world, and have 20 teachers who are the best international experts in our field," he said.

Jean-Antoine Pournaras, MD, tried the TrueVision prototype some years ago and was surprised by how fast he was able to adjust to the new system.

"I did not have a learning curve, which surprised me a lot because it was something totally new — the position, the viewing system and the spatial relationships. And yet I tuned with it immediately. Now I use the upgraded version in all my cases, and I know I can improve and reduce my time of surgery. I feel as if I had always used this system now," he said.


Jean-Antoine Pournaras

He observed that beginner surgeons find this system easier to handle than a microscope.

"They can see more clearly and therefore understand the situation better and learn faster how to manage it," he said. "It is easier also for the training surgeon because even when you are not doing the surgery yourself, you can help the trainee by showing exactly what you want to do and share exactly the same vision. At a microscope, the teacher or the assistant cannot see as well as the surgeon. Here you both see well, and you drive the treatment smoothly and securely."

Depth perception

"When you talk to surgeons who have tried 3-D surgery, they often describe it as having a 'hyperstereo' effect. They feel like they are in a really deep 3-D experience, giving them a depth perception they have never felt before," **David R. Chow, MD, FRCS,** said.

Comparing the depth perception between a traditional microscope and the Ngenuity system requires a complex set of mathematical formulas that incorporate optical, geometric and wave components. In addition, one of the unrecognized contributions to depth perception at a traditional microscope is the surgeon's own accommodation. Not many people realize that the depth of field they experience on a traditional microscope depends on their ability to accommodate, Chow said.

"The depth perception perceived on the Ngenuity system, on the other hand, is independent of a surgeon's own accommodation. Our recent mathematical modeling has shown that the depth of field experienced with the Ngenuity system is always superior to that available on a microscope when the Ngenuity camera aperture is set at 30%," Chow said. "Older surgeons will experience a depth of field with Ngenuity almost three to four times more than what they are getting on a traditional microscope whereas younger surgeons will experience a gain of about 60% to 70% depth of field. This explains why older surgeons have frequently noticed a greater 'wow' effect with Ngenuity than younger surgeons."

Not only does the Ngenuity system have more depth of field, but it also provides more magnification and better depth resolution than a traditional microscope, he said. These variables, however, vary inversely with changes in microscope zoom or TV viewing distance.

"We can make use of this knowledge intraoperatively to optimize our surgical performance. For instance, when we are trimming the vitreous skirt in a retinal detachment surgery, depth resolution is probably not as important as depth of field because we are trying not to bang into the tissues surrounding our cutter. As a result, we should zoom out and maybe move the TV further away from us to increase our depth of field. When we are doing ILM peeling, on the other hand, it is more important to have great depth resolution. So, we should zoom up on the microscope and maybe pull the TV closer to increase magnification and increase depth resolution while reducing depth of field," he said.

Light exposure, color modulation

The ability to use lower light levels on Ngenuity is another important advantage for surgeons, and probably the one from which patients benefit the most.

"You can cut your endoillumination levels down to 10% without any perceived loss of brightness on the TV screen, which is a real testament to the capability of the Ngenuity camera to function at lower light levels," Chow said.

Cutting the light pipe power to 10% means cutting the brightness from 7 lumens to 8 lumens down to 1.5 lumens to 2 lumens, a tiny amount of light that was traditionally felt to be inadequate to operate. When 25-gauge vitrectomy first came out, the 25-gauge light pipes were only capable of 4 lumens to 6 lumens, and it was a big problem, Chow remembered.

"Now we have a situation where we can operate with such a low level of light and still create on the monitor a level of light that is comfortable. In terms of preventing phototoxicity, if you use 10% light you have the ability to work five times as long without having to worry," he said.

Aaberg calls "videochromatography" the possibility to selectively enhance or eliminate frequencies of light intraoperatively thanks to a proprietary software of the CPU.

"In the operating arena, we can use it in a number of ways: We can lower our light exposure or we can enhance visualization of dyes using a less concentrated dye. So in many cases, particularly for macular hole, I want to use a lower concentration of ICG dye and a lower light setting. I boost the green pixels, use a 5% illumination, keep the aperture of the camera open and increase the gain. You can adjust your green, red and blue frequencies, and play around to how you can potentially optimize your visualization," Aaberg said.

Retina GPS

The revolution of this surgery is not about 3-D and heads-up, but instead about informatics and the transition from optical to digital imaging, according to OSN Retina/Vitreous Board Member **Pravin U. Dugel, MD.**

"We have the opportunity to become more efficient and better surgeons by getting more information appropriately, and we have the technology to do that now. It is a matter of repurposing the technology we already have to our field," he said.

The mechanics of surgery have developed extensively over the last 10 years, but the visualization has not developed nearly as rapidly, he said. Using the microscope nowadays is akin to using a Polaroid camera in the era of digital cameras, missing the possibility to manipulate the pictures in any way you want.

"This new modality of visualization is not so much about seeing more beautiful pictures or bigger pictures or brighter pictures. It is really about getting all the information you want in the appropriate sequence at the appropriate time," he said.


Pravin U. Dugel

From this perspective, calling this surgical modality "heads-up" or "3-D" takes its scope away from the point, and he prefers to call it "retina GPS."

"In many ways, it is like the GPS of your car as opposed to a roadmap. The GPS does not represent the road and the buildings accurately, but provides the information you need as you need it: the traffic, the actual time and the way to get from one place to the other as efficiently as possible. That's what we are going to have with the new informatics applied to surgery," Dugel said.

Multimodal imaging and feedback

Multimodal imaging will no longer be a purely diagnostic tool but will enter the operating room, Riemann said.

"We will apply digital overlays to the surgical field, like OCT, angiograms, fundus autofluorescence, as well as capsulorrhexis templates, LRI templates, toric IOL alignment templates — all this worked out and optimized to the current optical aberrometry systems. You can also have an auxiliary video feed for the endoscope to couple the endoscopic view and the primary surgical view in 3-D on the same screen. You can generate an information-handling cockpit, like for airplanes," he said.

Potentially, the surgical instruments themselves could provide information, according to Dugel.

"Right now our instruments don't talk to us. We can't feel what it is that we are pulling. We can't know how close we are to the retina. Our instruments are entirely passive, and the reason for it is that we are still using optical visualization. Once we step into digital systems, then we can incorporate feedback from many other systems, including instruments. Again, it is all about informatics. If we have the motivation to do it and get the companies interested, it can be done today," he said.

Preplanned surgery

Dugel envisages an entirely new approach in which surgery is preplanned before entering the OR, the plan uploaded into the system and the surgeon executing what is planned.

"Pilots are not going in the air and deciding there where they are going to go. A lot of time is spent preplanning the flight, and the flight is only executing that plan. That is exactly what we are going to do, preplan our surgery and the surgery will be executing what we have planned," he said. "As an example, you can navigate your laser treatment; you may want to selectively treat some areas so you can preplan where you want the laser and be precisely where you want to be."

He said that all of this is not far in the future because some of it is already happening right now with the technology we use in our everyday lives.

"A lot of what I have described can already be done with our iPhone, and video games require a much higher level of technology than I am talking about for surgery. Picking exactly what we want to see prior to surgery or during surgery, selectively and in an individualized way, is augmented reality, and that exists today in the gaming industry. It is just a matter of repurposing that technology," he said.

Augmented reality

An augmented reality HD head wearable display is pushing the frontier of digital imaging-assisted surgery even further. This system is a new application of a technology developed by BeyeOnics, a medical venture out of Elbit Systems, an Israeli company that uses similar technologies for combat and commercial aviation pilots. Following preclinical studies, it is now being tested in humans by **Anat Loewenstein, MD,** and Adiel Barak, MD.

"The original idea was that pilots, rather than having all the data displayed in front of them, could have them inside the helmet they wear on their

Anat Loewenstein

head. This happened already 30 years ago, and since then it has developed to be a very common technology used by major aircraft pilots all over the world. Inspired by this technology, we had the idea to apply it to the surgical field," Loewenstein said.

Three-D video images are transmitted from the operating field directly to the surgeon's eyes as high-resolution augmented reality, with up to a 30-fold magnification.

"You can receive at the same time all kinds of other information, such as OCT and angiography maps, the patient's pulse, pressure, vital signs, everything. And you can do image enhancement, playing around with contrast, color and illumination," Loewenstein said.

Ergonomically, this system may be better than both the surgical microscope and the Alcon monitor because the head and neck are not constricted into a fixed position. The head can be moved around without losing contact with the image and the head-mounted piece is "lighter than an indirect ophthalmoscope," Loewenstein said.

"You can also see in transparency the background of the surgical theater. You can see the nurses and whoever is around you," she said.

One major difference from the 3-D monitor systems is that image latency is close to zero, 16 milliseconds as compared with hundreds.

Loewenstein and Barak performed with this technology five procedures of silicone oil removal, have already scheduled 15 cases of membrane peeling and will then go on to more complex vitreoretinal surgery.

"It is very promising. At present, the image quality is comparable to that of the microscope, not better and not worse and certainly good enough for me. The manufacturers have 30 years of experience with this technology for pilots, and I can foresee that improvements will be fast," Loewenstein said.

She also expects that this new platform, once launched into the market, will not be more expensive than an operating microscope. *–by Michela Cimberle*

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Disclosures: Aaberg, Chow, Dugel and Riemann report they are consultants for Alcon. Loewenstein, Nikolakopoulos and Pournaras report no relevant financial disclosures.

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