

The Next Generation of Artificial Vision

Current technologies, although remarkable in their abilities to restore function, are only the first steps in curing blindness.

BY PAUL HAHN, MD, PhD

For blind individuals, a bionic eye could be the solution they are seeking. Enter the Argus II Retinal Prosthesis System (Second Sight Medical Products Inc.), the only retinal implant approved by the US Food and Drug Administration (FDA). It is currently available for use in blind individuals with severe to profound retinitis pigmentosa (RP), a rare genetic disorder affecting an estimated 1.5 million people worldwide.¹

Although its FDA approval was groundbreaking, the so-called bionic eye has been under development for more than 25 years since its conception by Mark Humayun, MD, PhD, and in human use for more than 10 years—a well-established technology far beyond exploratory stages.

The Argus II works by converting video images captured by a miniature camera housed in the patient's glasses into a series of small electrical pulses, which are transmitted wirelessly to an array of 60 electrodes on an implant surgically placed on the surface of the retina (Figures 1 and 2). The stimulation of remaining undamaged retinal cells is intended to result in the corresponding perception of patterns of light in the brain. The patient learns to interpret these visual patterns by correlating the grayscale images with additional sensory perceptions, such as sound and touch, thereby regaining some visual function and improving societal interaction.

IMPROVING FOCUS

Blindness is frequently isolating. Users of the Argus II have reported significant improvement in mobility and increased confidence and safety while navigating the world. Patients once in darkness can now see where other people are in relation to themselves, and a seemingly small improvement in their ability to greet others without bumping into them is quite profound in allowing them to feel more socially connected. Patients report the ability to eat more gracefully by locating their

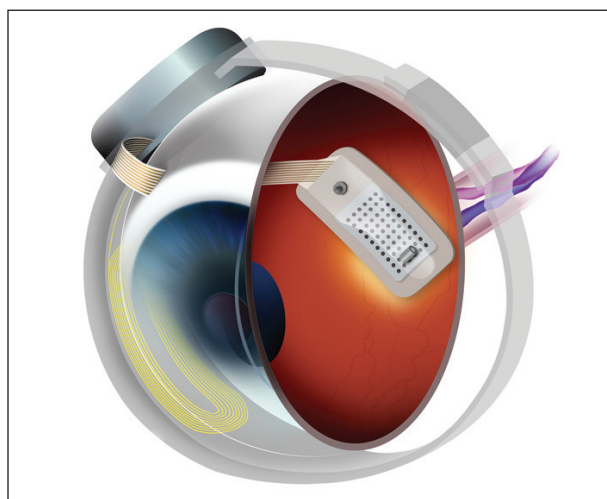


Figure 1. Schematic of the Argus II Retina Prosthesis System, depicting the placement of the electrode on the retina.

utensils more easily; they say they can navigate without bumping into walls and obstacles. Engaging in a more natural interaction with their environment provides patients joy as they see and experience things as they have not been able to for years. Many patients have described the excitement of again seeing the brightness of the moon in the night sky, the flashes of fireworks, lights on a Christmas tree, or even their grandchildren and other loved ones. Many even report the ability to detect motion or changing scenes on the television—which seems to be particularly gratifying with sports programming—enabling them to better appreciate what they have for a long time only heard.

Polling of the 100+ patients implanted with the device indicates that navigation and orientation are among the major benefits of the Argus II. In efforts to maximize further improvements, Second Sight, in partnership with the Johns Hopkins University Applied Physics Laboratory,

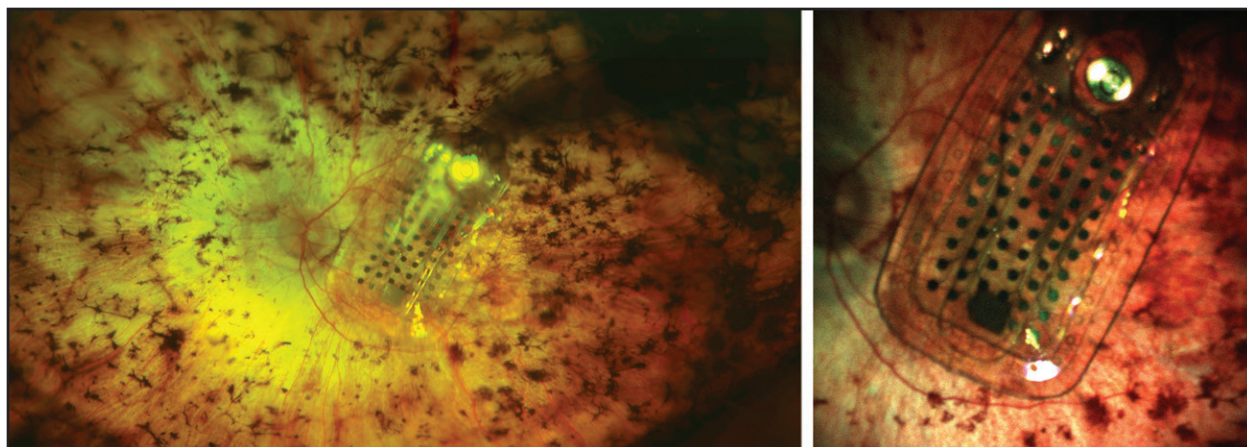


Figure 2. Fundus photographs of an electrode that has been surgically implanted in a patient's eye.

has launched a project to develop the next generation of glasses, which will likely include embedded vision and eye tracking sensors to identify potential obstacles.

To provide higher resolution vision, Second Sight will be exploring the concept of current steering, which employs electric field and current shaping to create virtual electrodes between physical ones, thereby increasing the effective number of "pixels" users can perceive.

Video processing that employs object detection and depth perception is yet another potential means of enhancing visual input for Argus II users. For example, new algorithms are being developed to detect, preprocess, and highlight an object—for example, a ball on the ground—so that it "pops" in the patient's vision. This may prove particularly important in everyday situations. A patient walking down a street, for example, may encounter a sidewalk curb that is of similar color and luminosity to the street. The algorithm is designed to employ advanced image processing to electronically identify and enhance salient objects in the environment. Such paradigms are intended to effectively combine computer vision, autonomous manipulation, and a user interface to unclutter visual information, thereby creating a more natural visual experience.²

A WORLD IN COLOR

Processing images in color, although not essential to completing most tasks, may augment a patient's visual experience. Color stimulation with the Argus II is still in the early experimental stages, but initial experiments are encouraging in their capability to produce multiple colors on different electrodes in a repeatable manner. Implementing color vision in the Argus II will require additional research. However, as with most of these algorithm improvements, this is a software or external update, and patients with existing implants will likely

benefit from this upgrade once it is available via a simple reprogramming of the external computer.

FILTERING

After an image is preprocessed by the Argus II, it is encoded. The success of an encoding process relies on the ability of a system to mimic the neurophysiology of natural retinal stimulation. These neurophysiologic processes are poorly understood; however, several groups are engaged in research of various encoding strategies that may be considered for integration into the Argus II in the future.

As with early versions of cochlear implant devices, the Argus II currently uses a very simple but highly effective encoding strategy of increasing current to the threshold point at which a precept is generated. This coding method assumes that there is a uniform retinotopic layout of the same cell type devoid of richness or variety in the cell types and does not account for variations in ganglion, amacrine, and other retinal cell types. As this field matures and understanding grows, different processing and encoding strategies can be tested. Patients now using the Argus II should be eligible for these additional benefits via future software updates.

AGE-RELATED MACULAR DEGENERATION

The success of initial and long-term trials with the Argus I and II has paved the way for clinical trials in additional patient populations. Age-related macular degeneration (AMD) is the leading cause of blindness in the Western world. Estimated to affect 20 to 25 million people worldwide,³ this disease results in the degeneration of the outer, photoreceptor layer of the retina, similar to RP. However, RP degeneration typically first affects peripheral vision and progresses toward the center, whereas AMD degeneration typically affects central vision.

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Trials are currently under way to establish the feasibility of expansion of the Argus II indication to patients who have total central vision loss due to dry AMD. If successful, these investigations will likely evolve to include patients with wet AMD without active angiogenesis as well as other retinal diseases.

THE GAME-CHANGER

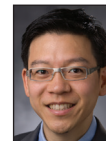
The capacity to treat nearly any form of blindness is no longer science fiction. Potential applications of this technology continue to grow with the development of the Orion Cortical Prosthesis (Second Sight Medical Products Inc.). Implanted on the surface of the visual cortex located within the occipital lobe of the brain, the Orion will bypass the optic nerve, optic tract, and optic radiations all together. The Orion technology emerged from the Argus II, but the electrode array has been changed from a retinal array to a cortical array.

Bypassing the optic nerve potentially offers hope for treating patients with optic nerve damage, as in glaucoma and other optic neuropathies; patients with inner retinal dysfunction, as in retinal artery occlusions; and patients with panretinal dysfunctions, as in retinal detachments, trauma, and infection. Cortical stimulation is not a new approach; it was originally demonstrated as early as 1929.⁴ Because of inadequate technology at the time, clinical devices were not pursued. Over the past 15 years, however, Second Sight has developed reliable long-term implant technology, which will be drawn upon to develop the Orion Cortical Prosthesis with the potential to aid individuals who are blind from nearly any cause.

CONCLUSION

Investigators in the ongoing quest to cure blindness have made tremendous progress, offering hope to a significant population. New advances in technology and expansions of clinical trial inclusion criteria offer hope for a world in which the chance for second sight is attainable and realistic. ■

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1. Berson EL. Retinitis pigmentosa: unfolding its mystery. *Proc Natl Acad Sci U S A*. 1996;93:4526-4528.
2. Johns Hopkins Applied Physics Lab Receives \$4 Million to Develop a Retinal Prosthesis [press release]. Johns Hopkins APL. January 14, 2015. <http://jhuapl.edu/newscenter/pressreleases/2015/150114.asp>. Accessed January 29, 2015.
3. Chopdar A, Chakravarthy U, Verma D. Age related macular degeneration. *BMJ*. 2003;326(7387):485. doi: 10.1136/bmj.326.7387.485.
4. Foerster, O. Beitrage zur Pathophysiologie der Sehbahn und der Sehsphäre. *J Psychol Neural (Leipzig)*. 1929;39:463-485.