Rehabilitation of lost functional vision with the Argus II retinal prosthesis

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ABSTRACT • RÉSUMÉ

The Argus II retinal prosthesis is the first commercially available device for restoration of vision in patients with Retinitis Pigmentosa or with similar retinal pathology who still have minimal residual native vision. The technology is able to restore vision with production of artificial visual percepts which usually are given adequate useful interpretation by the visual system in most implanted patients. The technology usually produces visual perception at the level of shape identification or better in some cases enabling in many less dependence on vision substitution devices and skills. There is no consensus among vision rehabilitation practitioners on single methods for assessments, outcome measures and training, yet there is constant progress in these areas of concern. Hence the current vision rehabilitation practice related to the implantation of the Argus II retinal prosthesis is a work in progress with many learning opportunities for all involved. All agree that implementation of this technology in clinical practice requires the combined work of a multi-disciplinary team which includes a specialized surgical team as well as a specialized rehabilitation team in order to obtain optimal results. Our own experience is presented in this paper and indicates so far that the Argus II technology is beneficial to patients and that it could be successfully managed within the Canadian heath care system.

La prothèse rétinienne Argus II est le premier dispositif commercial qui permette de restaurer la vision chez les patients atteints de rétinite pigmentaire ou d'autres affections rétiniennes et qui disposent d'un minimum de vision résiduelle. La technologie autorise le rétablissement de la vision et la production de préceptes visuels artificiels, qui génèrent habituellement une interprétation utile adéquate par le système visuel chez la plupart des patients. La technologie donne généralement lieu à une perception visuelle de type identification des formes, ou mieux dans certains cas, ce qui réduit la dépendance du patient envers les dispositifs et les habiletés de substitution visuelle. S'il n'existe aucun consensus au sein des praticiens de la réadaptation en déficience visuelle quant à une méthode unique en matière d'évaluations, de paramètres de mesure et de formation, il n'en demeure pas moins que l'on observe des progrès constants à ces égards. Ainsi, les techniques actuelles de réadaptation en déficience visuelle à la suite de l'implantation de la prothèse rétinienne Argus II sont appelées à évoluer, et tous les intervenants doivent profiter de ces occasions d'apprentissage. Il ne fait aucun doute que l'implantation de cette technologie en pratique clinique repose sur le travail conjoint d'une équipe multidisciplinaire qui doit comprendre une équipe chirurgicale spécialisée de même qu'une équipe de réadaptation spécialisée si l'on souhaite obtenir des résultats optimaux. Selon notre expérience à ce jour, la technologie de l'Argus II est bénéfique pour les patients et peut être prise en charge avec succès dans le cadre du système de soins de santé canadien.

Modern ophthalmology is constantly enlarging the boundaries of diagnosis and therapies for ophthalmic pathologies. Vision rehabilitation also kept abreast with the latest discoveries in visual sciences providing successful medical, surgical, and training rehabilitation to those in need of it. Rehabilitation of residual native vision in those who lost their vision after disease or injury became lately a matter of interest to many. In line with the new developments in bioengineering, software, and materials, the idea of an ocular prosthesis to replace damaged tissues evolved today to a status where it is possible to create useful physical devices aimed at restoring visual function in those who lost them. This is also the story of the Argus II retinal prosthesis (AIIRP) (SecondSight, Sylmar, Calif.).[1] The AIIRP is today at the forefront of clinical practice and research in this frontier domain of ophthalmology. The Department of Ophthalmology at the University of Toronto at the Toronto Western Hospital branch of the University Health Network (TWH) currently has experience with 11 consecutive implantation cases, the most of any centre worldwide participating in this type of program.[2] We want to share in the following pages our experience, concerns, and comments with vision rehabilitation training in this specific group of patients.

Background

AIIRP is the first commercially available implant technology that allows patients with retinitis pigmentosa (RP) regain certain amount of functional vision. In RP eyes, photoreceptors eventually stop working and die, leading to vision loss. However, the inner nerve fibre layer remains largely preserved. The implant is designed to bypass the damaged photoreceptors on the retina and

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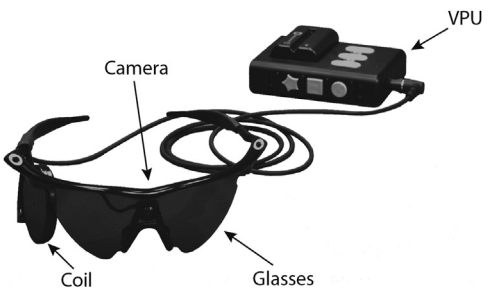

Fig. 1—External components of the Argus II prosthesis.

activate the inner retinal cells. An external component is worn by the user to capture images via a video camera and transmit artificial vision images wirelessly to the implant to induce visual perception in patients. The restored vision is composed of artificial vision images described as "somewhat pixelized" vision and comprising of spots of light requiring brain cortex interpretation.

The AIIRP consists of 2 major components. The first is an epiretinal implant that is surgically implanted and positioned on the retina by a vitreoretinal surgeon. The internal retinal implant consists of a receiving coil for receiving information and power from the external components of the Argus II system and an electrode array relaying artificial vision images to the existing visual pathways. The second component is an external patient-worn system that supplies power to the system electronics and also collects, processes, and converts camera-captured images to artificial images, which are transmitted wireless to the internal implant. The external components include the Argus II Telemetry Camera Glasses and the Argus II Video Processing Unit (VPU) (Fig. 1).

The AIIRP is surgically implanted usually in one eye. A miniature camera positioned on the front of a pair of the glasses worn by the patient captures video images, which are sent to the VPU, where they are converted into electrical stimulation pulses fitting a processed artificial vision image. These pulses are transmitted wirelessly via an antenna to the artificial retinal implant inside the eye. The array emits small pulses of electricity that bypass the damaged photoreceptors and stimulate the retina's remaining "undamaged" inner cells. The induced visual stimulation travelling via the optic nerve results in corresponding perception of patterns of light in the brain describing an artificial vision image. By learning to interpret these visual patterns of artificial vision images, the patient regains some functional vision.[3]

Vision Rehabilitation Protocol

The rehabilitation process for AIIRP users follows the traditional approach of assessment, establishment of rehabilitation goals, vision rehabilitation intervention, progress notes, and discharge summary. We adopted and followed the protocols described in the SecondSight Vision rehabilitation guide prepared specifically for the users of the AIIRP[1] as well as established general principles of LVR.[4,5] Established guidelines for the Argus II retinal prosthesis suggest that all rehabilitation sessions for LVR postsurgery take place within 8 weeks after the surgery.

Intake

Intake takes place before surgery involving the entire surgical and rehabilitation team. It has 2 main components: functional vision assessment and visual functions assessment, 2 different entities.

Performing an assessment of the patient is an important first step in this rehabilitation program. Assessment is multifaceted. Before surgery the patient and the significant others are given an opportunity for a thorough conversation with the members of the team where questions can be asked, technology can be discussed, expectations can be evaluated, and counseling can be provided.

It is imperative that a comprehensive assessment of the patient profile is completed before beginning of rehabilitation so that one understands clearly the patient's functional abilities with and without the AIIRP. After this assessment, one would be able to establish rehabilitation goals that will benefit from the use of the AIIRP System. It is critical to explain to the patient and the patient's significant others that the AIIRP does not restore normal vision. Even in an ideal case, the system would produce a 10×6 grid of spots of light, with a central visual field of approximately 20°. Furthermore, the images produced by the system produce highly variable perception impressions between patients. Motivation, expectations, and involvement need to be assessed into details. Questions along these lines can help form a more complete picture of the patient and his/her prospective satisfaction with the Argus II. It is possible that patients with greater independence and those who have shown high motivation to seek out and learn from blind rehabilitation may be more satisfied with vision from the AIIRP. Conversely, those with very high expectations of the system are more likely to be disappointed. Patients who live very far from the clinic and/or who do not understand the requirement for follow-up visits may be more likely to be dissatisfied with the AIIRP after implant. This section is intended to gain an understanding of the patient's availability for and commitment to the requirements for fitting and rehabilitation.

However, none of these questions should determine eligibility on their own; they should be considered in the context of other aspects of this evaluation. The following ideas are just a sample of possible lines for questioning: Has the patient had previous O&M rehab? What kind? Does he or she use a cane? Does he or she have a guide dog? Is the patient working? Is he or she active? Does he or she do sports or have hobbies? Does he or she use a computer? What would the patient like to be able to do

with the system? What is he or she expecting, hoping? Does the patient understand the difference between artificial vision and his/her former vision? Does the patient understand that his/her residual vision could get worse? Is the patient aware of the follow-up visit requirements? Is he or she willing and able to come to the hospital several times for fitting and rehab? How difficult would transportation be? Would he or she be accompanied or travelling alone? Does he or she live far? Is it possible to stay overnight in a hotel? Is the patient aware of the needed commitment into rehabilitation process? Is he or she willing and able to commit to the rehabilitation process (i.e., in-clinic and at-home sessions)?

A formal functional vision assessment is the next step. The Functional Low-vision Observer Rated Assessment (FLORA) customized for the unique population of AIIRP is used in most cases. FLORA has been developed to serve as a template for assessing AIIRP user's functional vision and the impact of this vision on activities of daily living and quality of life. It involves both self-report by the client and observer-rated visual skills and tasks. Any assessment done as well as the entire rehabilitation program can and should be customized for the goals, abilities, and interests of each particular client. For example, if the client is an independent traveller (with mobility aids such as a cane or dog), the avoidance of objects that might be missed by the aids, like tree branches or other head-high obstacles, may be of importance to him or her. On the other hand, if the client spends most of his or her time at home or in a single room, adding the ability to transfer some tasks from tactile to partly visual within the home might be more important. The FLORA program can be used also as a guide to supplement own approach to functional vision assessment in ultra-low-vision clients.

Finally, it is helpful to let the patient examine and wear the external equipment to ensure she/he understands what the equipment will look and feel like. In some rare cases, the style or fit of the glasses could be a source of patient dissatisfaction post-implant if she/he was not introduced to them before surgery.

The second core aspect of the rehabilitation protocol is *evaluation of visual functions*, pre- and postsurgery. The goal of the visual functions evaluation is to determine whether the patient's residual native vision exceeds the likely benefit from the amount of artificial vision produced by the AIIRP on the one hand and to ensure that the patient has a functioning visual system (i.e., optic nerve and visual cortex) on the other.

Performance when using standard clinical measures of low vision such as ETDRS charts and counting fingers may point to the fact that residual native vision is better than optimal results expected with the AIIRP system and will disqualify the patient from having surgery. Patients who have residual native vision at the level of hand movements tested at 1 foot and light perception may benefit from the Argus II technology. Yet hand movements and light perception methodology for visual acuity assessments are unrefined methods and offer little details on the level of residual vision. This was recognized early not only by clinicians working with low-vision patients but also by commercial entities developing retinal prostheses devices. For this purpose, SecondSight Inc developed proprietary methods for assessment of visual acuity pre- and postsurgery in cases where the AIIRP is considered. In our practice we used the following 3 different high-contrast, objective, computer-based outcome measures developed by SecondSight: square localization (SL), moving grating visual acuity (MGVA), and grating visual acuity (GVA). Visual function tests were performed at baseline, 3 months, 6 months, and 1 year.

SL measures the ability to locate and touch a target (white square on a black touchscreen monitor). Forty trials were performed, and response error (the distance between the subject's response and the centre of the target square in centimetres) was recorded and averaged.

MGVA measures the ability to perceive the direction/trajectory of a moving object (white bar on a black touchscreen), and the subjects were asked to draw the direction of the bar movement. Eighty trials were performed, and response error (the difference between the subject's response angle and the target bar's angle in degrees) was recorded and averaged. GVA measured visual acuity in the range of 1.6 to 2.9 logMAR using black-and-white gratings displayed for 5 seconds. Four alternative answers were given (horizontal, vertical, diagonal left/right), and the program adaptively reduced or increased the spatial frequency of the gratings on the basis of the number of correct and incorrect answers.

Technical System Setup (System Customization)

Once patients are implanted, their system settings must be customized and they must receive adequate training in handling the device before they can take it home. During the first office rehabilitation session, testing takes place to ascertain whether sending electrical current through the electrodes produces a visual percept. A percept is a single spot of light. "Percepts" as the plural would imply that there are multiple yet separate spots of light. The next step is measuring thresholds—the amount of electrical current necessary to produce a percept—for each electrode on the array. The testing setup in the clinic is done with a computer that can directly control the implant without camera information. Once the basic measurements are taken, the clinician creates customized settings and loads them to the patient's VPU. After this is done the patient's camera is turned on for the first time, allowing stimulation according to the real-time video image of the world around him or her. Additional tests are used to determine how effective the customized settings are, and whether they are comfortable for the patient. If the settings cause the stimulation to be too bright, too dim, or create any

physical sensation (sometimes a mild vibration near the eye), the settings are readjusted until the stimulation is comfortable for the patient.

The first rehab session is usually booked on the same day as a Technical System Setup session to minimize the number of clinic visits for and travel burden on the patient. After the setup training, most patients will have the basic skills to activate their Argus II device. Patients must now learn to interpret the light patterns as meaningful images and be able to use the visual information in their everyday life. After years of blindness, patients lose their hand–eye coordination and have to relearn to transition from tactile to visual performance of activities of daily living and orientation and mobility (O&M) tasks.

Functional Vision Rehabilitation

The general goal of this program is to help the client maximize the use of the visual information available through the AIIRP System in order to improve the client's quality of life. This program can take place over the span of approximately 8–10 sessions, ideally indoors and outdoors. The central focus of any vision rehabilitation program is to maximize visual ability and to foster meaningful use of vision throughout the day at work and at home. Visual ability encompasses a person's amount of access to visual information combined with his or her lifetime of visual experience. Training provided by the rehabilitation team reinforces existing abilities and introduces new ones. The intervention begins with simple tasks in isolation (the "building blocks") and moves toward more challenging functional tasks. Clients may benefit from transition activities that use targets such as bright lights for the purpose of isolating developmental skills and increasing the chances of success with the skill. As the client demonstrates success with each skill, more challenging functional tasks will be introduced. The SecondSight Instructional Kit contains tools (lights, high-contrast objects, etc.) designed to be used with this program. As the lessons progress, one can use the early experiences with objects as a reinforcement strategy. Showing the patients how much progress they are making will encourage more practice and effort. The following training sessions are anticipated and planned.

Fig. 2—Magnet board for scanning training.

Skill 1: Eye, Head, and Camera Position Awareness and Movement. For the Argus II System to maintain its connection and provide accurate visual information, it is vital that clients' eyes remain in line with their head (always pointed straight with respect to their head position, analogous to viewing through a hand-held telescope) while using their system. Because of the importance of head and eye position, the first skill that the clients must learn is awareness of their eye position relative to their head. Because Argus II clients have often been blind for many years and have no visual feedback, they are often unaware of how their eyes are positioned and have trouble controlling their eye position or movements. Therefore, clients who present with this problem can be taught to fixate on an audio cue and become aware of their eye position. One has to keep in mind that they are trained on these skills in the clinic, but their mastery of head and eye position awareness and control should be assessed and reinforced as part of the rehabilitation program.

Skill 2: Small-Scale Light Localization/Microscanning. The goal of this training is to enhance the client's small-scale head scanning technique for efficiency and thoroughness. Small-scale scanning is probably the most important skill for an Argus II client, and its importance cannot be overstated. The stimulation pattern on the retina will adapt the cells after a few seconds, and the percept will fade if the image remains stationary. Clients must learn to make these small scanning movements to refresh the image, in most situations.

One has to use the magnet system included in the Instructional Kit to evaluate the client's scanning strategy (Fig. 2). By positioning the magnet in different locations and observing the client's strategy and success rate, object localization ability and scanning efficiency can be evaluated. Practice this technique by asking the client to find and touch white magnets of different sizes on the black background.

Skill 3: Large-Scale Light Localization/Macroscanning. The goals of this section are to administer a baseline assessment of the client's ability to localize light sources on a large-scale (to integrate macro- and microscanning), and to provide intervention if necessary. The purpose of this concept and skill area is to encourage clients to scan a wide area quickly to identify the potential location of the object they wish to view (macroscan). This assessment is performed in a darkened room. Position one flashlight from the instructional kit in one of these different locations: horizontal location of left, centre, right; vertical location of head height, waist height, feet; and at varying distances from 2 to 5 m at the various locations. One usually begins with the brightest setting and closest distance (2 m) and

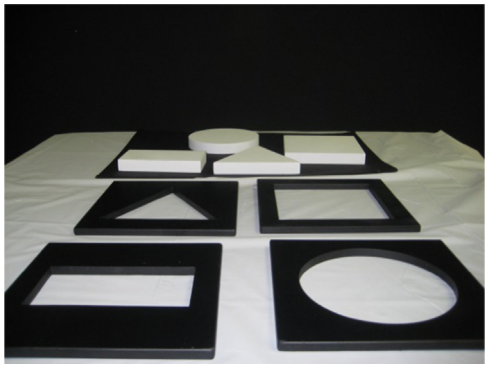

Fig. 3—2D and 3D shapes used for combined tactile and visual training.

gradually increases the distance until the client cannot complete the task. The client has to find the light and point to its location.

Skill 4: Tracking. Using a flashlight on the brightest setting (in a room where illumination can be controlled), ask the client to track the light as you move slowly in a horizontal direction. If the client can successfully track the light, try moving it in different directions and at different speeds.

Once the client is comfortable tracking the light along the horizontal meridian, one moves to vertical tracking. As proficiency improves, the client is asked to track the light with no auditory cue—using only visual information. Then the contrast is decreased by gradually increasing room illumination. When the client demonstrates the ability to successfully track the light, one moves to more functional targets, like a person in the room.

Skill 5: Luminance Discrimination. Two flashlights at the 2 different brightness settings are placed in a row against a contrasting background and the client is asked to determine the relative intensities of both lights When the client demonstrates the ability to identify different light intensities, one moves to more functional targets, such as clothing of different colours, lights around the house, and parked cars outside.

Skill 6: Shape Recognition. Having described the learning activities for basic visual skills, it is now time to consider more advanced perceptual skills of shape recognition. Argus II users can learn to use their new vision by connecting tactile information with visual information. Clients can feel the 2D and 3D shapes on the board and practice visually identifying them as well (Fig. 3). One can proceed after to training recognition of contrasting placemats and dinnerware, including having the client discriminate black from white objects, locate and differentiate large and small plates and bowls, and set matching (or contrasting) place settings from the available options.

Meaningful Visual Integration. The underlying goal of any vision curriculum is to cultivate *meaningful vision integration*—to nurture the client's abilities to make meaningful use of vision as it naturally occurs throughout the day in a wide range of real-life situations. It may seem surprising that clients who once had excellent visual skills may have trouble integrating their prosthetic vision with other senses and creating new visual memories with artificial vision. However, the artificial vision provided by the Argus II System can be integrated meaningfully into clients' lives.

Orientation and Mobility. Vision provided by the AIIRP System can improve a client's orientation skills. Instruction should focus on integrating the visual information from the system with the client's normal mobility aids (or, in some cases, ignoring the visual input in favour of the mobility aids). It is important to stress that they should not use the Argus II System as their primary mobility aid.

Because this is a new type of vision, clients may need an initial period of adjustment as they concentrate on the new information the system provides. Walking more slowly and attending to the visual information more than auditory information are normal events.

Our Observations

This is a retrospective review of our experience. We provided rehabilitation training to all 11 cases implanted at TWH. The rehabilitation and training protocol we followed was approved by the University Health Network Ethics Board. The number of in-clinic rehabilitation sessions per patient ranged from 3 to 9. Each rehabilitation session lasted approximately 1 hour. The time frame between in-clinic sessions was approximately 2 weeks.

Training sessions to improve various eye-related skills as listed in the previous paragraph were planned and implemented.

Head–eye position awareness and control was the first skill reinforced. One method used for training involved patients to look through a clear large tube as they held it against their face. The goal of this exercise was to practice moving the head, neck, and shoulders as a unit while at the same time reinforcing eye position looking through the tube forward during head scanning. Another method used for training to reinforce this skill was using auditory feedback from the VPU. When the eyes and head are not aligned for the same direction, the internal and external portions of the Argus system move apart from each other; the relay of radio frequencies between the 2 is disturbed, and the VPU begins to beep. This is a reminder to the patient that his or her eyes are not aligned with his or her head and the external Argus II part needs to be readjusted on the head.

To master the microscanning skill, a magnetic board is used in conjunction with various 2-dimensional shapes (i.e., circle, square, triangle) that can be placed on the board. The patient sits at arms-length distance in front of

the board and uses microscanning skills to locate 1, 2, or even more shapes on the board. One side of the magnetic board is black, whereas the other side is white. The magnetic shapes come in both white and black colours. The white shapes are placed on the black side of the board, and the black shapes are placed on the white side of the board.

Once the patient was able to accurately locate the shapes the next step was to identify the shape of interest. This was a more difficult task and many patients used their tactile touch in conjunction with their Argus vision to identify the shape. Over time the goal was to reduce the tactile input as much as possible.

As patients became more proficient with this task they worked on identifying large single letters on the board. The letters were either black or white depending on the colour of the board being used, and they comprised magnetic properties so that they could be placed on the board. With one patient, we were successfully able to play a game of tic-tac-toe that was created from magnetic strips.

To scan a wide area quickly so that an object of interest can be identified, macroscanning skills were reviewed. The patients were instructed to imagine a line running up and down the centre of their body separating their world into a left and right field. They were also instructed to imagine a horizontal line running across their body from one shoulder to the other. This separates their world into an upper and lower field. Also to facilitate training, during the clinic sessions a flashlight was used to shine a light on one of the viewed image quadrants. Using an organized scanning pattern, the patient identified which quadrant the light was in. Once the quadrant was identified the patient used his or her microscanning skills to make a more precise identification of the location of the light. For viewing the inferior field, patients were reminded to rotate their head and eyes downward when scanning. Since the camera lies at the bridge of the glasses, in order to locate objects lower down, full vertical head rotations in the downward direction were found to be important.

To practice tracking skills we used a flashlight. A bright light source placed closer to the patient was used initially. Both horizontal and vertical motions were used while teaching this skill. As the clinic sessions progressed, the tracking light was made more difficult by decreasing the brightness of the light, retracting the light farther away from the patient as well as altering the direction the light was moving. For example, moving the light in circles or zig zags was a more difficult task. For homework, patients were encouraged to track family members and moving cars, among other things.

Luminance discrimination was the fifth skill taught. This skill posed difficulty to most of the patients when it was introduced. After 2 flashlights were placed in front of a patient, the patient was asked to identify which light source is brighter. With a big discrepancy between the flashlights, most patients were able to identify the brighter source. As the discrepancy in brightness between flashlights weakened, this skill became much more difficult. Functionally, patients were encouraged to practice this skill at home by sorting their laundry into whites and darks.

Shape recognition was the most challenging skill to be learned. Patients worked on touching the 2-dimensional magnet shapes on the board while visually identifying them with their Argus II vision. We then moved onto 3-dimensional shapes and their 2-dimensional templates. Patients developed their visual memory by relearning these shapes. Tactile sensation and Argus vision were both used to identify these shapes. By the end of the clinic sessions, some patients were able to identify the shapes with Argus vision only.

Once a fundamental skill was taught and practiced during the clinic session, patients were then given homework instructions on how to practice that skill. The homework instructions also included suggestions on how to modify the task to best fit the patient's needs. Patients could increase or decrease the difficulty of the task based on their ability. The instructions also included recommendations on how to functionally apply these skills in daily life.

The primary factor for assessment of performance was how quickly the patient was able to progress through the fundamental skills for Argus II Prosthesis use as outlined in Second Sight's vision rehabilitation manual.[1] It was important that patients practiced these newly acquired skills between clinic sessions. The amount of time allocated by the patients contributed to how quickly they were able to master these fundamental skills and ultimately how many in-clinic sessions were needed. The patient's level of comfort in moving on to the community-based portion of the rehabilitation program was also an important consideration.

The variation in number of in-clinic sessions can be attributed to a few factors. The primary factor for variation in the number of clinic sessions was how quickly the patient was able to progress through the fundamental skills for Argus II Prosthesis use as outlined in the Second Sight's vision rehabilitation manual. It was important that patients practiced these newly acquired skills between clinic sessions. The amount of time allocated by the patients contributed to how quickly they were able to master these fundamental skills and ultimately how many in-clinic sessions were needed.

A 1-hour rehabilitation session was found to be ideal as it enabled a realistic amount of time for the patient to practice the fundamental skills learned in clinic and it also allowed the patient to check in with the rehabilitation team in a timely manner if additional feedback or instruction were needed. The sessions at times would end earlier if the patient became saturated while using the Argus II prosthesis and required a rest period of certain length. As tolerances built up, longer sessions could be endured. The 2-week interval period was found to be ideal as it enabled a realistic amount of time for the patient to

practice the fundamental skills learned in clinic and it also allowed the patient to check in with the rehabilitation team in a timely manner if additional feedback or instruction were needed. There was a longer time frame between sessions that occurred later in the rehabilitation process. It was found that patients required more time out of the clinic to practice the multiple fundamental skills as well as to incorporate them into daily life. The patient's level of comfort in moving on to the community-based portion of the rehabilitation program was also an important consideration.

Toward the end of the in-clinic sessions, most patients described abilities they were able to master with their Argus vision that previously were not possible. Examples included being able to see shelves in the fridge and bottles on a dressing table; identifying food on a plate; seeing a glass of water on a table as well as the water in the glass moving; seeing people walking and cars moving; and seeing people in stationary positions who were very close in proximity. One patient was able to determine whether unfamiliar people in the room had dark hair compared to another person in the room (who was familiar) with light-coloured hair. Within the home, patients reported that door frames were more distinct.

After the second or third in-clinic session, if the patient was progressing well in mastering the fundamental skills and was confident in his or her ability, an introduction was initiated between the patient and orientation mobility instructor.

The O&M specialist takes the visual skills that the AIIRP recipient has developed during clinic training and adapts them to accomplish rehabilitation goals within the community. The complexity of the outdoor environment with fluctuating levels of illumination and the presence of glare requires that the user has a high degree of comfort manipulating the device settings. The O&M will focus first on training the patients to become more adept at manipulating contrast and polarity. The edge detection setting is typically introduced during O&M training to allow users to visually find edges of paths and take direction from their environment. The user is guided through experiences finding visual targets and exploring settings to see what produces the best visual image. With practice, users get a sense of what setting is likely to produce the best results in different environments such as reverse polarity in very bright surroundings or enhanced contrast under low-light conditions.

The in-clinic training has the advantage of practice tasks where a visual target can be confirmed tactually by reaching out to it. In the community, this is not always the case, so it is good to start training in a familiar setting where the visual targets can be anticipated and more readily recognized. AIIRP users tend to make good progress identifying things around their home or place of work, such as cups and plates on a table, a phone or computer on a desk, or an empty seat at a table.

Tasks that have applications for independent mobility and are good initial goals for training include indoor tasks in familiar environments, such as visually identifying windows, doors, or overhead lights. Identifying contrasting rugs, tiles, and mouldings is a common next step. Our AIIRP users have had success moving on to visually identifying concrete and gravel paths on their property as well as fencing, decks, and buildings, where there is sufficient contrast to the surrounding environment.

After sufficient community training, our AIIRP users have been able to progress to visually identify contrasting edging on stairs and Tactile Walking Surface Indicators along drop offs such as subway platforms. Intersecting sidewalk paths, zebra stripes at pedestrian crossings, and curbs are all objects that, when detected using the device, have improved the safety and efficiency of the user's mobility.

Experienced users among our cases have had success using it to avoid obstacles in their path of travel such as posts, poles, or newspaper boxes. Some have been able to identify unique or iconic signs to help orient themselves on familiar routes—the best example of this being an user who could consistently recognize the golden arches of a McDonald's in her neighbourhood.

Despite these examples of the impact of the AIIRP, the user who already possesses strong rehabilitation or blindness skills may struggle to recognize its impact on his or her independence as the device is not sufficient on its own to replace these traditional skills. AIIRP users will still make use of the tactile information a cane provides and the auditory information they have long been accustomed to using. It can therefore be a useful exercise to attempt tasks with and without the device to demonstrate its effect. To this end, timing routes completed with and without the device with our patients has shown that the device increases the speed and efficiency of travel. This is due to user's visual input allowing them to choose more efficient cane techniques at appropriate areas. Observations of street crossings have demonstrated that its use can reduce the degree of veering experienced during street crossings compared to using the auditory information provided by parallel traffic.

The community rehabilitation experience of providing O&M training to AIIRP users has been rewarding and educational for both the recipient and training providers. Our experiences in Toronto have shown the importance of coordination between the initial rehabilitation provider in the clinic and the community-based provider. Delivering a seamless rehabilitation experience increases the likelihood of a positive impact on the Argus II user's independence.

Discussion

The AIIRP is currently available for general use in cases with RP, and the first cases were implanted in Canada with the device in 2014. Up-to-date, 11 cases were

implanted, all with vision less than 20/2000. The Low Vision Team at UHN TWH worked with patients to reinforce proper techniques and provide assistance with problem-solving to maximize the benefit of the AIIRP in the patients' daily life. The program is delivered over ten 1-hour sessions with some sessions delivered in the patient's home or work environment as deemed necessary. Before rehabilitation begins, the Low Vision Rehabilitation Specialists complete a comprehensive assessment of the patient to understand his/her functional abilities with and without the AIIRP system. The assessments will help foster the customization of the program to the goals, abilities, and interest of the patient. The specialist then works with the patient to develop visual skills and meaningful visual integration skills.

The most major challenge faced today by all involved in restoration vision therapy such as with the AIIRP is that current levels of artificial vision produced by the devices are still in the range of ultra-low vision. Therefore, in clinical practice one may encounter a variety of responses from those whom we consider suitable surgical candidates for this new technology. Some patients have totally adapted to complete blindness and efficiently use vision substitution modalities for activities of daily living. Such patients will find the benefits from using the AIIRP insufficient and to a certain degree counterproductive. Some patients who still retain residual native vision and use it efficiently in conjunction with vision substitution modalities for activities of daily living. Such patients may have difficulties to adapt to the artificial vision images produced by the AIIRP and their integration with vision substitution modalities. They may regret postsurgery the loss of the minimal residual native vision they had and used before the surgery. Finally there are patients who may retain some amount of residual native vision postsurgery and may find very difficult to convert to users of artificial vision images provided by the implant. Incidental comments along those lines were noticed also among our patients. All those situations described above are very important in assessing patients before and after surgery. Unfortunately we still do not have full proof assessment methods to clarify the variety of situations described above, and more research is needed in this context.[6]

The introduction of prosthetic devices for vision rehabilitation in cases with minimal residual native vision brought to the fore the issue of the usage of suitable outcome measures for assessment of such cases. In general, outcome measures for low vision are divided into 3 groups: physiological measures such as mfERG; visual function measures such as visual acuity, contrast sensitivity, and fields of vision; and skill-based functional measures such as reading or activity of daily living estimates.[4] Because of the complexity of the cortical vision processing, subjective measures such as visual function and functional vision measures are viewed as the preferred outcome measures in low-vision rehabilitation. Although such outcome measures are currently defined, standardized, and validated for mainstream low-vision cases, most if not all are not suitable for assessment of cases with minimal residual native vision. The SecondSight set of tests for SL, MGVA, and GVA that we used in our cases is a proprietary approach to provide a measure of utility in such cases with regard to visual functions. Other similar proprietary measures with other devices were publicized as well. From our results, we see that SL and MGVA were significantly better with the device turned ON, yet these results did not correlate accurately in some cases with the initial impressions we collected on actual functional vision obtained. Also, these results cannot be compared for equivalency with results from other studies using different technologies because other studies use also proprietary-specific outcome measures. This is probably the biggest challenge MRNV rehabilitation faces today. We still need to define, standardize, and validate outcome measures for assessment of visual functions and of functional vision in cases with minimal residual native vision. Technological and research efforts need to be directed by our community to solve this conundrum sooner rather than later.

Assessment of functional abilities also is an issue in need of clarifications. Currently various questionnaires are used by various researchers and clinicians, none directed specifically to the cases with minimal residual native vision. Recently, a new questionnaire was developed specifically for this group of patients, and it is hoped that its usage will standardize collection of data in this aspect of practice.[7]

In summary, the surgical remedies available today for those with minimal residual native vision are truly revolutionary in scope and practice, and vision rehabilitation after surgery is an indispensable part of the process required to ensure a successful outcome. We can also state that to a certain extent the successful outcomes witnessed with some of our patients are a direct result from the availability of a comprehensive team of specialists, surgical and rehabilitation, involved with the patient.

Object recognition happens when the concept of an object as it is stored in memory matches the sensory input from our sense organs. The sensory input from a retinal prosthesis is very different from the native visual input, and the patient cannot simply apply past visual memories to recognize an object. The patient using a retinal prosthesis will have to develop new or modified memories to identify a prosthesis input image. Also, detail, contrast, and colour are not processed with prostheses as they are with retinal cells. Finally with native vision, central and peripheral information is processed simultaneously. Prosthesis-generated vision requires sequential processing through scanning. The natural scanning with eye movements has to be replaced by scanning with head movements.

All those and more are challenges we face with this new therapy; however, with a unified team of specialists, chances for success and better results in the future will be higher.

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Footnotes and Disclosure:

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