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Team Increases Understanding of Two Types of Blindness, Bolsters Simple Prevention Strategy, and Develops Gene Therapy Option

By Mark Schrope and Mika Ono

A collaborative team of scientists from the Scripps Research Institute and other institutions has shed light on the causes of and potential treatment for two blinding conditions known as macular telangiectasia (MacTel) and retinal angiomatous proliferation (RAP), types of macular degeneration. Though based on mouse studies, the research bolsters the idea that humans suffering from these and other eye conditions may be able to help preserve function by adding antioxidants to their diet, and explains why this would work. The team also devised a new cell-based gene therapy technique that could eventually offer another option for arresting vision loss from these diseases.

The work, led by Scripps Research Professor Martin Friedlander was reported in an advance, online edition of the *Journal of Clinical Investigation* on February 2, 2009. The research is also likely to apply to a range of other neurodegenerative conditions, including vision loss from Huntington's and Alzheimer's diseases and inherited retinal degenerations, such as retinitis pigmentosa.

Many forms of blinding degenerative eye conditions are tied to the abnormal proliferation of new blood vessels in the eyes, or neovascularization. Treatment of these conditions has generally focused on blocking continued neovascularization, but this typically only slows disease progression because new growth eventually wins out, leading to continued damage and vision loss.

For many of these conditions, vision loss has been definitively attributed to the blinding effect of fluid leakage and hemorrhage from newly grown blood vessels. But the cause of vision loss in certain diseases such as MacTel has been more elusive.

To better understand these eye diseases, and to develop new and better treatments, the research team examined a mouse model of these human diseases. The particular "knockout" mouse the team focused on has been used by other researchers for studying fat metabolism. The mouse model, however, also has a genetic alteration that leads to increased blood vessel growth in the eyes—a fact that Friedlander and colleagues had pointed out in a previous publication. In this model, neovascularization occurs in the back of the eyes in an area of the retina that is normally avascular. This is also a defining characteristic of MacTel, a somewhat rare though probably underdiagnosed form of macular degeneration, and RAP.

In the current study, the team found that debilitating eye damage in these mice is caused by increased oxidative chemical activity sparked by the new blood



Scripps Research authors of the new study include (left to right) Research Associate Michael Dorrell, Professor Martin Friedlander, and Scientific Associate Edith Aguilar.

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vessel growth, rather than simply by the new blood vessel growth itself. Even properly functioning eyes create an extremely stressful environment because oxidants are produced as neurons fire all day in response to light stimuli, and as a result of neuronal tissue being bombarded by light. A small increase in oxidative chemical activity from neovascularization can be enough to kill certain types of neurons, leading to vision loss from the mouse equivalent of MacTel and RAP, and possibly other conditions. Such oxidative damage had been suspected of playing a role in these conditions but had never before been proven.

In the process of showing how the conditions cause damage, the team was able to identify two remarkably effective treatments. One of these options is simply giving the mice doses of antioxidants orally. "People have thought before that antioxidants could have benefits for these conditions, but these data demonstrate clear proof of concept for this treatment approach," says Michael Dorrell, a research associate in the Friedlander lab.

The researchers showed that antioxidants counterbalance the oxidative damage to neurons, blocking further deterioration in the eyes of treated mice. "This implies that something as simple as changing your diet may in fact maintain visual functioning for long periods of time even if the underlying abnormality hasn't been fixed," says Friedlander, who in addition to his position at Scripps Research is a staff member at Scripps Clinic and Green Hospital in La Jolla, California. "That was quite surprising to us. Others have already shown that such alternations in diet can reduce the risk of developing bleeding from the more common type of neovascular macular degeneration in humans, but the concept of maintaining functioning photoreceptors in the face of continuing vascular abnormalities has not been shown previously."

An Attractive Alternative

The second option the group explored is more complex but has proven equally successful. Using a novel twist to standard gene therapy techniques, the researchers were able to deliver directly to the neurons in question a protein that protects neurons, effectively fortifying them against the onslaught of oxidants.

The virus used in the technique—adeno-associated virus (AAV)—is a common component of gene therapies, but the Friedlander team's work included some major advances. Current studies exploring the potential of gene therapy with this particular viral vector to treat a number of eye conditions are limited by the need for potentially dangerous subretinal injections. But, the Friedlander team devised a new method that circumvented many of the problems associated with such injections.

Eye neurons are supported and nourished by glial cells, which surround them. One type of these cells, known as Müller glia, extends from the front to the back of the retina and produce glial fibrillary acidic protein (GFAP) in response to a variety of disease conditions. The team recognized the potential to exploit the unique characteristics of Müller glia to develop a better form of gene therapy delivery.

The researchers were able to safely inject into the vitreous cavity, rather than the retina itself, viral particles loaded with the genetic sequence that codes for a protein called neurotrophin 4, which promotes the growth and survival of neurons. These viral particles crossed into the Müller glial cells, which allowed neurotrophin 4 protein encoded by the virus to travel to the back of the eye and to the areas of neovascularization. To ensure that the AAV-delivered gene was only turned on where needed, the group also added a genetic sequence known as a promoter that signals the starting point for the transcription of GFAP. As a result,

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the same cellular components in the glial cells that would normally attach to this promoter on DNA and then begin production of GFAP, were tricked into also attaching to the genetic sequence introduced by the virus to produce the neurotrophin 4. The same basic technique could be used to trigger production of other beneficial proteins as well.

This process induced neurotrophin production and successfully fortified neurons around the neovascularization.

"You're not really getting rid of the oxidative stress," says Dorrell, "you're helping specific neurons cope with it, which allows them to survive." As with the antioxidant method, the gene therapy arrested further deterioration of neurons.

Neither the antioxidant nor gene therapy option caused regeneration of lost neurons, but if similar results are found in humans, either treatment option could prevent the onset or continued progression of MacTel and RAP. Either treatment would be most effective before extensive cell death occurred. Because of similar causes, it's also likely that other related neurodegenerative conditions, such as Alzheimer's, Huntington's, and inherited retinal degeneration, might also be effectively treated using the same or related methods. In fact, the group is already studying the latter using a different mouse model.

Because antioxidants are already widely used, testing their efficacy against MacTel and RAP should be a simple matter of assembling an appropriate group of patients to study their response to treatment. But, Dorrell says, one of the beauties of the findings is that antioxidant availability from food (such as vegetables, fruits, grains, legumes, and nuts) and over the counter supplements means those at risk for or suffering from these conditions can take antioxidants to see if they help. Friedlander points out that some of the impacts of over the counter supplements are still not known, so people should consult their physicians and may need to avoid high doses.

The researchers say the effectiveness of antioxidants is likely to vary from person to person, meaning the neurotrophin 4 technique could also prove to be a critical treatment. Because the AAV vector used to deliver the neurotrophin gene has been widely used in other applications, it is already approved for use in humans. Ceregene, a San Diego-based pharmaceutical company and collaborator on the project, already has developed the needed techniques for producing the virus in quantities sufficient for human trials.

"It's conceivably a much shorter step to the clinic than would otherwise be faced," says Friedlander.

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In addition to Dorrell and Friedlander, other authors on the paper, titled "Treatment with antioxidants or neurotrophic factors preserves function in neurons damaged by neovascularization-associated oxidative stress," were Edith Aguilar, Ruth Jacobson, Oscar Yanes, Ray Gariano, and Gary Suizdak, from Scripps Research, John Heckenlively, from the University of Michigan, Ann Arbor, Eyal Banin, from Hadassah-Hebrew University Medical Center, G. Anthony Ramirez and Mehdi Gasmi, from Ceregene, and Alan Bird, from University College London. For more information, see <http://www.jci.org/articles/view/35977>.

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