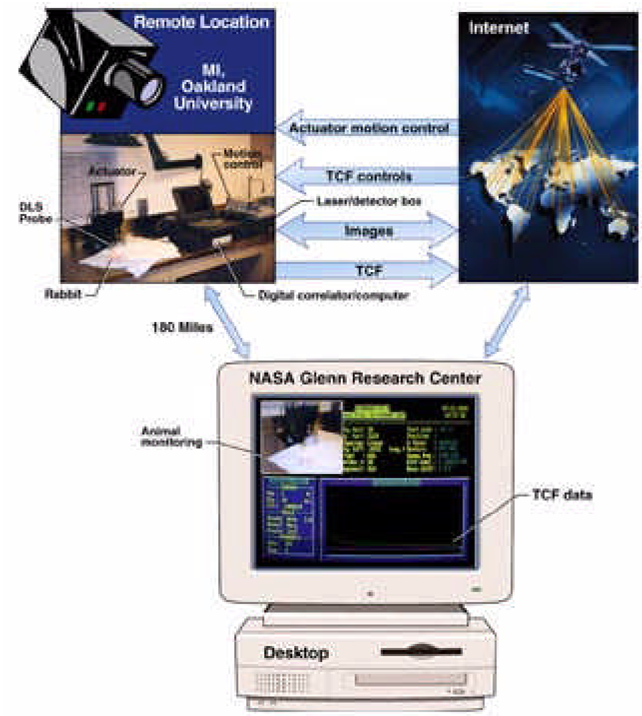
Applications in Bioastronautics and Bioinformatics: Early Radiation Cataracts Detected by Noninvasive, Quantitative, and Remote Means

Human exploration of Mars is a key goal in NASA's exploration planning in the next 20 years. Maintaining crew health and good vision is certainly an important aspect of achieving a successful mission. Continuous radiation exposure is a risk factor for radiation-induced cataracts in astronauts because radiation exposure in space travel has the potential of accelerating the aging process (ref. 1). A patented compact device (ref. 2) based on the technique of dynamic light scattering (DLS) was designed for monitoring an astronaut's ocular health during long-duration space travel. This capability of early diagnosis, unmatched by any other clinical technique in use today, may enable prompt initiation of preventive/curative therapy. An Internet web-based system integrating photon correlation data and controlling the hardware to monitor cataract development in vivo at a remote site in real time (teleophthalmology) is currently being developed. The new technology detects cataracts very early (at the molecular level). Cataract studies onboard the International Space Station will be helpful in quantifying any adverse effect of radiation to ocular health.

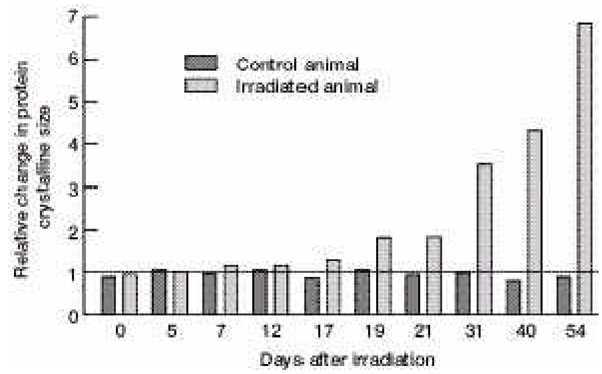
The normal lens in a human eye, situated behind the cornea, is a transparent tissue. It contains 35 wt % protein and 65 wt % water. Aging, disease (e.g., diabetes), smoking, dehydration, malnutrition, and exposure to ultraviolet light and ionizing radiation can cause agglomeration of the lens proteins. Protein aggregation can take place anywhere in the lens, causing lens opacity. The aggregation and opacification could produce nuclear (central portion of the lens) or cortical (peripheral) cataracts. Nuclear and posterior subcapsular (the membrane's capsule surrounds the whole lens) cataracts, being on the visual optical axis of the eye, cause visual impairment that can finally lead to blindness. The lens proteins, in their native state, are small in size. As a cataract develops, this size grows from a few nanometers (transparent) to several micrometers (cloudy). Ansari and Datiles have shown that DLS can detect cataracts at least two to three orders of magnitude earlier noninvasively and quantitatively than the best imaging (Scheimpflug) techniques in clinical use today (ref. 3).



Bioinformatics system currently under development. TCF, time correlation function.

One important aspect of monitoring an astronaut's ocular health is the ability to collect data noninvasively, frequently, easily, and quickly, and to send it to Earth for examination by expert ophthalmologists in real time. Here on Earth such a device will make it easy to monitor human health in remote and underserved areas of the world (e.g., Polynesia, Africa, etc.) and to monitor defense personnel (naval ships, army battalions) at remote combat locations. As shown in the preceding figure, we are setting up a system in cyberspace to conduct DLS/cataract evaluation measurements. The system has two components. First, a digital camera, microphone/speaker, a fiber-optic probe equipped with actuators, detector, and a digital correlator are located at the testing site (an animal facility in this case). The output of the digital correlator and the camera is connected to an Internet site via the telephone lines. The second component consists of an operator at a desktop at another location (the NASA Glenn Research Center in this case) controlling the experiment and collecting data. The functional keys on the computer keypad are used to direct the fiber-optic probe at a desired location in the animal eye to collect data in 2 to 5 sec.

Recently, we conducted experiments to test our technology in collaboration with Dr. Frank Giblin at Oakland University in Michigan on his animal-radiation model. X-ray exposure accelerated the aging process. DLS can detect radiation cataract much earlier noninvasively and quantitatively. Our approach provides good reproducibility and single endpoint measurements in terms of lens protein crystalline size. We see changes in the lens nucleus as early as 1 week after the radiation exposure. However, traditional methods still show the lens nucleus to be transparent until 9 to 10 weeks after the x-ray irradiation. The DLS method would be very useful to monitor early damage to ocular tissues in a space environment so that countermeasures could be taken. It can be a useful tool for guaranteeing astronauts' and cosmonauts' safety onboard the International Space Station, in transit to and from Mars, and during Mars exploration. A DLS-bioinformatics system presently under development has the potential to provide online monitoring of an astronaut's ocular health noninvasively, quantitatively, and remotely, perhaps beginning a new era of celestial teleophthalmology.



Environmental ocular toxicity: effects of x-ray irradiation.

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