Eye is window for blood-chemical monitoring

Lori Howe

Rather than drawing blood to measure blood-chemical levels, it may one day be possible for diabetic patients to scan their own eyes at home to monitor their glucose levels, for doctors to scan patients' eyes to monitor drug levels in the brain, or for a patrol officer to scan the eyes of a driver to determine blood-alcohol level.

James Lambert, a researcher at the Jet Propulsion Laboratory (Pasadena, CA), and Mark Borchert from the Children's Hospital Los Angeles have developed a prototype sensor that uses Raman spectroscopy to measure blood-sugar levels though the eye (see figure). The instrument collects light scattered from the front of the eye and analyzes it to determine a blood-glucose level as accurately as conventional finger-stick-based home glucometers.

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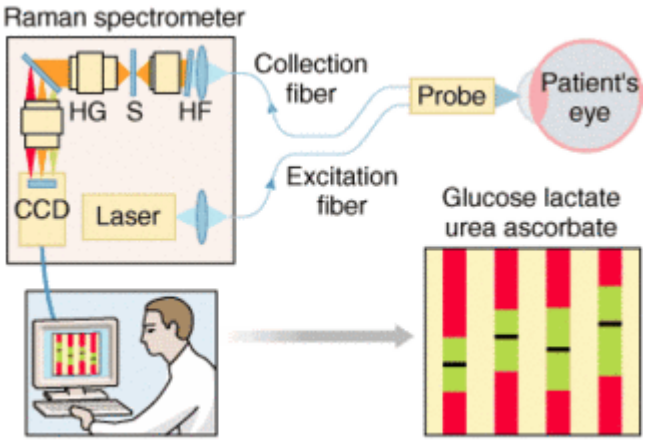

Blood-sugar levels are measured through the eye with a Raman spectrometer.

The front of the eye is an ideal location for such measurements because aqueous humor—the clear fluid that nourishes the transparent cornea and lens of the eye with glucose and oxygen—is filtered blood product. Most chemicals found in blood are too large to pass through the filter, located behind the iris, making spectral measurements of the concentration of the few types of molecules within the aqueous humor (such as glucose) much simpler. The team also has been able to determine the concentration of other small molecules, such as ethanol, that pass from the blood into the aqueous humor.

Raman photons typically convert optical energy received by the target molecules into increased vibrational-bond energy. As a result, optical energy is lost and therefore longer-wavelength, lower-

energy photons are scattered. Because each molecule has a unique set of vibrational modes, the resulting Raman spectral signature serves as a "fingerprint" that can be used to identify the compound.

The Raman spectral signature of any mixture is simply a linear combination of the signatures of its individual constituents weighted by their concentrations. Upon measuring the spectrum of various mixtures of these constituents in buffered solutions, a partial-least-squares algorithm is used to determine the concentration of glucose from a spectrum acquired from the patient's eye.

Enough laser power must be focused into the eye to generate spectral signatures from the aqueous humor with a high enough signal-to-noise ratio to produce clinically useful results. An exposure of 15 mW of near-IR (785-nm) light for 30 seconds is sufficient. The instrument is eye-safe because it is designed to focus optical power into the aqueous humor of the eye. As the beam travels through the eye, it diverges, forming a rather large spot on the retina with relatively low power density. The retinal power density is actually below the ANSI eye-safety limits, and therefore risk to the retina is minimal. Infrared light is used because it is nearly invisible to the patient, it does not cause photochemical changes in the eye, and it produces Raman-scattered light that is unencumbered by fluorescence from the aqueous humor, cornea, and lens.

Borchert has established the safety of the device via animal-threshold testing and will soon begin human trials. Testing with human subjects is expected to be completed within a year and half.

The current prototype is not miniaturized or inexpensive (the CCD is a large part of the cost). Yet Lambert believes his technology will be competitive in the diabetic-monitoring market, in part because it is so simple to use. "Future developments in detectors will allow mass production of less-expensive systems," Lambert says. "Patients with diabetes may have to stick themselves four to six times a day. This is not only uncomfortable, but each glucose test strip costs about a dollar. Diabetics would happily pay $2000 to $3000 for a system that over their lifetime would allow them to monitor their blood glucose painlessly."

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