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# Engineering new weapons in the fight against juvenile diabetes

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Engineering researchers at Rensselaer Polytechnic Institute are combining automation techniques from oil refining and other diverse areas to help create a closed-loop artificial pancreas. The device will automatically monitor blood sugar levels and administer insulin to patients with Type 1 diabetes, and aims to remove much of the guesswork for those living with the chronic disease.

For six years, Professor B. Wayne Bequette, a member of the Department of Chemical and Biological Engineering at Rensselaer, has been creating progressively more advanced computer control systems for a closed-loop artificial pancreas. His work stands to benefit the 15,000 children and 15,000 adults who are diagnosed with Type 1 diabetes, also known as juvenile diabetes, every year in the United States.

"Every single person with Type 1 diabetes has a different response to insulin and a different response to meals," Bequette said. "These responses also vary with the time of day, type of meal, stress level, and exercise. A successful automated system must be safe and reliable in spite of these widely varying responses."

For Bequette, the fight against Type 1 diabetes is also personal. His younger sister developed the disease early in life, when the state of diabetes care was not nearly as advanced as today.

Bequette's work is funded by the Juvenile Diabetes Research Foundation (JDRF), along with the National Institutes of Health (NIH). He frequently publishes research findings in the journals Diabetes Technology and Therapeutics, and *Journal of Diabetes Science and Technology*, of which he is a founding member of the editorial board. His most recent study, titled "A Closed-Loop Artificial Pancreas Based on Risk Management," may be viewed online.

In Type 1 diabetes, an individual's pancreas produces little or no insulin. As a result, they must inject insulin several times every day, or use an insulin pump that continually administers small amounts of rapid-acting insulin. Additionally, they must test their blood sugar several times every day. Failure to maintain proper insulin and blood sugar levels could result in serious, potentially life-threatening hypoglycemic (low blood sugar) and hyperglycemic (high blood sugar) reactions. Type 1 diabetes can occur at any age, but is most commonly diagnosed from infancy to the late 30s, according to the JDRF.

A key challenge for people living with Type 1 diabetes, Bequette said, is the constant monitoring of their blood sugar level. Blood glucose levels are generally measured from a tiny blood sample captured from a finger stick test, prior to eating or sleeping. Another critical challenge, he said, is accurately estimating how many carbohydrates they eat. These blood sugar readings, along with the amount of carbs eaten, must be interpreted to decide how much insulin the individual needs to inject. Exercise and fitness also impact the amount of insulin required. Continuous blood glucose monitors are available on the market, but are not yet as accurate as finger sticks tests, he said.

All in all, Bequette said, there are many judgment calls and best guesses being made on a daily basis by individuals with Type 1 diabetes. And though medical technology for diabetes is very advanced and reliable, he is working on an artificial pancreas that would remove the need for most of this guesswork.

The device marries an insulin pump with a continuous blood glucose monitor, which work in conjunction with a feedback controller – forming a "closed-loop." A diabetic would wear this device at all times, with a needle inserted just under the skin, in order to regulate his or her glucose levels. When the device senses the blood sugar getting high, it automatically administers insulin. Inversely, the device cuts off the insulin pump to avoid hypoglycemia.

The newest incarnation of this device includes options for users to input their carbohydrate intake. Bequette said this should greatly boost the accuracy, reliability, and predictive capability of the device. Importantly, the device will still function if users forget to input their meal information.

At the heart of this closed-loop artificial pancreas are Bequette's carefully engineered algorithms. The sophisticated computer code makes predictions based on data inputs, including blood glucose levels and eaten carbohydrates. Bequette employs model predictive control and state estimation techniques, which he used in his research in controlling traditional chemical processes, such as oil refining. These methods are able to extract more meaningful, predictive data from blood glucose monitoring, and other critical aspects of the artificial pancreas.

Provided by Rensselaer Polytechnic Institute