REMOTELY CONTROLLED ARTIFICIAL PANCREAS (2ND REVISION)
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TelCheck: A Real-Time Multi-Mode Wireless Glucose Meter and Artificial Pancreas Communication Hub

The problem with diabetes care is, simply stated, huge medical costs & poor health outcomes which are only getting worse. For insulin dependent diabetics, the promise of living a more normal life, improving overall health and containing costs is currently restrained by the inability to safely monitor artificial pancreas function, hampering future development and clinical approval. For all diabetics who monitor blood glucose levels, the lack of testing compliance is directly linked to increases in complications and higher resulting medical costs. Use of wireless technologies has been suggested as a promising means to improve diabetes outcomes. Current wireless communication between patient, glucose meter, insulin pump and physician normally use only one type of wireless transmission, each type with its' own abilities and limitations. For example, a cellular connection between glucose meter and physician, or an infra-red connection between glucose meter and insulin pump. Unfortunately, there is no single form of wireless data transmission that allows for both the short-range control between insulin pump and glucose monitor, while at the same time affords long-range, real-time, remote monitoring required for artificial pancreas function and testing compliance. Additionally, current patient interfaces are complex and confusing, requiring the use of multiple sub-menus and manipulating many buttons (Medtronic and OmniPod).

TelCheck is an advanced, wireless glucose meter with both long-range and short-range wireless communication capabilities to both enable artificial pancreas development and provide a real-time monitoring solution for all diabetics who manually check their glucose level with a finger-stick meter. The TelCheck is comprised of a cell phone (long-range wireless) built inside a blood glucose meter along with Bluetooth capabilities (short-range wireless), called multi-mode technology. A visual representation of the multi-mode TelCheck is shown below, indicating the ability to communicate in real-time, simultaneously to connect insulin pump, continuous glucose monitor (CGM not shown), TelCheck glucose meter and care-management server.

Simply connecting a glucose meter to a cellular network is not new. TelCheck is a novel wireless communications hub built inside a glucose meter, generating a powerful process change with seamless automation of multi-mode data exchange. The JDRF has stated that the lack of wireless monitoring of artificial pancreas development is currently hampering clinical progress. TelCheck provides the answer by seamlessly streaming data and information, from the patient to clinician and back again, providing a safety net for artificial pancreas development. An additional benefit of the multi-mode enablement allows TelCheck to transform and simplify the patient interface by removing all function buttons and offering color-coded cues to show patient status and provide real-time feedback. The cellular enablement will not require an expensive data plan, important in these hard economic times, nor break Stark laws which prohibit financial inducements to patients. The $3 per month cost of the wireless data plan will be covered by the company out of the sale of test strips, reimbursed by Medicare and private insurance. Increased monitoring, leads to increased testing, which by definition will require a higher number of test strips to be used, hence greater profitability. The real world relevance of the TelCheck multi-mode technology is the fact that up to 40% of the cost of running clinical trials is data collection. The TelCheck will enable the ability to seamlessly monitor, collect and transfer recorded data directly to a clinical studies database. This could lower overall costs of data collection through direct capture and transfer of data in an Electronic Medical Record (EMR), HiPAA compliant format. Use of the TelCheck could also potentially increase patient enrollment and retention rates in clinical trials by reducing manual logging of glucose levels, reducing protocol deviations and data collection errors, thereby increasing data accuracy, integrity and validity. The TelCheck is a powerful communication tool, built on the two ideas of ***simplicity*** and ***safety***.

The TelCheck Glucose Meter

Clinical Efficacy: TelCheck is the culmination and integration of two proven existing wireless technologies, each having been clinically tested separately. It is expected that the TelCheck will capture the positive outcomes experienced by each form of wireless technology and overcome the limitations that single-mode communication strategies have had in the past. Once the TelCheck prototype is completed in summer 2009, a quality testing program to ensure that multi-mode enablement does not compromise glucose meter function will be undertaken, comparing day to day variation to meet the 10% maximum change per ADA recommended allowances. Completion and validation of the TelCheck will culminate in a double blind controlled study to determine whether the TelCheck can affect health care outcomes such as reduction of HbA1c and increased testing compliance. The following two pilot studies were completed with each of the two wireless technologies used separately, prior to building them into a single multi-mode TelCheck unit.

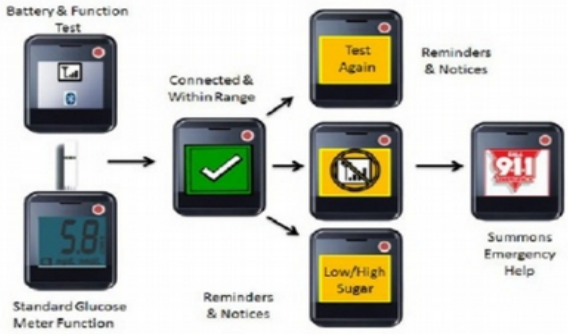
1) **Effect on HbA1c Levels of Adults from Short-Range Wireless Pilot:** A non-randomized trial was conducted with 15 Type II diabetes patients with a Bluetooth-enabled glucose meter paired to a cell phone and diabetes care was performed by a pharmacist/diabetes educator using an FDA cleared care-management server. Over the course of an 8 week study, testing performance increased 25%, compared to historical performance for the same group of patients. Over that same 8 week period, HbA1c was observed to decrease from a cohort average of 7.63% to 6.92% ($p = .02$ by paired t-test). Given the non-randomized nature of the study, a Hawthorne effect cannot be ruled out. The study did demonstrate an increase in compliance and feasibility of using short-range wireless communications in patients who were previously only moderately compliant.
2) **Effect on HbA1c Levels of Children from Long-Range Wireless Monitoring Pilot:** In a randomized, controlled pilot study, 34 Type I diabetic children completed a 3 month open-label study using GPRS long-range wireless transmission of blood glucose data. Subjects were children with an avg. age of 14 who had had Type 1 diabetes for an avg. of 6 years with an avg. HbA1c of 11.0 ± 1.5 %. The control group used manual logging of data, while the intervention group used the long-range wireless transmission of blood glucose data. At the beginning of the trial, HbA1c was comparable in the control and intervention group (11.2 ± 1.3 % vs. 10.8 ± 1.6 %, $p = 0.56$). After 3 months the HbA1c in the control group was unchanged (11.2 ± 1.3 % vs. 11.5 ± 1.7 %, $p = 0.40$), while HbA1c in the wireless-enabled intervention group went from 10.8 ± 1.6 % to 9.2 ± 1.1% ($p < 0.0001$) over 3 months. These findings indicate that long range wireless-enabled blood glucose monitoring can significantly improve HbA1c levels in children with poorly controlled T1D.

Aesthetics: Current patient interfaces for finger-prick glucose meters, CGM's and insulin pumps and indeed many cell phones are complex and confusing, especially to children and the elderly. The use of multiple interfaces and buttons currently needed to monitor and control insulin regulation is daunting, bordering on the ridiculous. Simplification, optimization and automation are clearly required, yet are sorely lacking. It must be stressed that improving diabetic health is as much about changing human behavior as it is about developing new technology solutions. Practical solutions must be designed with a single focus in mind of solving the problem of the patient, by encouraging behavioral changes, while keeping things ***simple*** and ***safe***.

Simplicity: Many attempts have been made to re-purpose cell phones to become medical devices, a function they were never designed for. TelCheck begins at the opposite end of the spectrum, by taking a mission-critical medical device, necessary for calibration and safe operation of an artificial pancreas as well as every day monitoring of blood glucose levels and building in both cellular and Bluetooth function. The TelCheck has been designed starting with the conceptualization of what the patient sees and does from sun up to sun down. First, because of the multi-mode seamless communication, all of the confusing sub-menus, buttons and up and down arrows have been removed. This information can still be seen on any internet webpage through a Diabetes Dashboard that is FDA cleared. The TelCheck has only a single power on / power off button. The goal of ***simplifying*** device function is to increase the chance that the patient will use the TelCheck more often, especially if the patient is given visual cues and immediate reinforcement. A device that will be widely accepted must be able to be used by diabetics of all ages. All current glucose meters to date have monochrome screens and depend on text to relay information because of the trade-offs with battery life and connectivity. Due to the multi-mode power requirements, TelCheck will come with a rechargeable Lithium Ion battery and recharging base which can be placed at the patient's bedside. This will

reduce cost to the patient needing to replace batteries every month and remind them to recharge the TelCheck each night and to test regularly before bed and upon waking. By utilizing a rechargeable battery, TelCheck has been upgraded with a color screen. If the color screen was only for vanity, it could not justify the extra battery draw. The TelCheck color screen serves the purpose of reassuring the user that by simply looking at the color of the screen, they can know if things are ok, or need greater attention. This color scheme is designed to work for diabetics of all ages, without the need to read text. For those diabetics who are using a wireless CGM as part of an artificial pancreas there are even more safety benefits described below. The figure above shows the TelCheck's different colors and associated functions that each screen represents. The dimensions of the TelCheck are anticipated to be 3" X 2.5" X .5" with a black matte finished OLED, or TFT color screen with beveled edges and a mini-USB port to connect to a recharging stand and for manual download if required.

Safety: Enhanced safety will be enabled by validating the proper data communication transfer between insulin pump, CGM and TelCheck with a care-management server. Remote monitoring without the ability to impact change does not by itself enhance safety. The ability to actively change operation remotely demonstrates TelCheck's ability to enhance patient ***safety*** and promote artificial pancreas development. An illustrative example of the type of monitoring envisioned to occur is shown below (original figure by Abbott). The goal is to manage blood glucose levels between 80 and 180 mg/dL. The following graph and figure show how the different TelCheck color-coded screens would be displayed given varying glucose levels, providing the user with immediately recognizable feedback. If the glucose levels are within the anticipated range, the green color of the screen would give immediate peace of mind. If the patient saw yellow and resulting insulin pump function did not adjust the requisite levels through bolus delivery, the patient would receive a warning. If the range surpassed a physician-initiated, pre-established level, a red indicator would both alert the patient and call an emergency professional (shown at noon with a 350 mg/dL hyperglycemic level). The multi-mode enablement also allows emergency providers to remotely control insulin pump function, providing an additional remote safety shield for both clinical testing and every day use of the artificial pancreas. For non-insulin diabetics who monitor their glucose only a few times a day, the blue and green light functions would be the same, while the yellow light would remind the patient that they haven't tested enough times per day, or that their glucose level was low, or high. While the red screen would still alert emergency help, no remote control of other devices would be possible. The TelCheck through its innovative, simplified design fills the need for a safe and effective communications hub that allows for clinical testing of the artificial pancreas as well as increased compliance for all glucose monitoring diabetics.



Illustrative depiction
A target range of 80-180 mg/dL is used in the above examples

Summary: TelCheck is more than just a cell phone and glucose meter combination. The integration of two different types of wireless communications is an enabling multi-mode technology solution that allows for real-time, validated data transfer and the remote ability to monitor and control proper and improper artificial pancreas function. In achieving this safety feature, the patient experience has been dramatically simplified by eliminating buttons and creating a color-coded interface, giving immediate feedback to users of all ages that things are ok, need attention, or require emergency help. The practical outcomes of using the TelCheck are expected to be lower costs to conduct clinical trials more quickly, while having fewer adverse events occur and the ability to shut down function in cases of un-anticipated overdosing. Outside of the clinic, diabetics of all ages will be able to live a more normal life and feel secure knowing there is an extra layer of ***safety***, while enjoying the ***simplified*** patient interface and that with a glance at the color **green** knowing that their diabetes is under control.