GlucoVision

Looking to the Future: Automated Glucose Testing

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DS1 – Design Problem & Design Brief

Design Problem

In the United States alone, 23.6 million people (roughly 7.8% of the population) have diabetes[1]. Glucose meters have become essential management devices used by these individuals on a daily basis. Amongst the 10 million elderly diabetic patients, however, approximately 50% suffer from arthritis and almost 45% also suffer from diabetic retinopathy. For these individuals with both visual and dexterity impairment, even seemingly routine procedures like pricking their fingertips and using the glucose meters may prove difficult. Furthermore, the amount of blood acquired on testing strips sometimes proves insufficient, requiring repeated attempts to extract more blood.

Design Brief

We propose an augmentation of current devices, by designing an add-on to complement existing meters. The new design will aim to provide stationary support during the testing procedure, and requires minimal dexterity for blood extraction via fingertip punctures. It should provide the means to automatically extract and detect that enough blood has been acquired for testing, without causing the patients additional discomfort. It will be easy to use, and sufficiently adapted for sterilization to prevent infective complications, as to minimize required maintenance. The device will also display information in a format accessible to a wide audience of professionals and patients.

[1] American Diabetes Association. <http://www.diabetes.org/about-diabetes.jsp>

DS2 - RESEARCH

A - Problem Summary

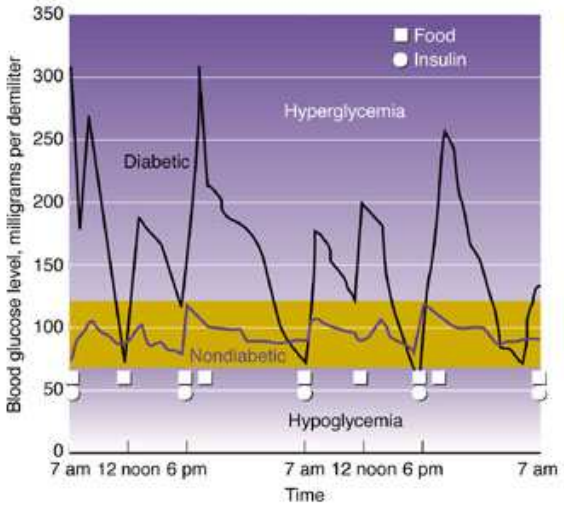
A.1 - Diabetes

Diabetes is a disorder that causes high blood sugar levels because the body does not adequately use or produce insulin, a key hormone in the regulation of blood glucose levels. Diabetes may be brought on by environmental factors or it may be hereditary. Roughly 23.6 million Americans suffer from diabetes, of which up to 5.7 million remain undiagnosed.[2] A further 57 million people are believed to have pre-diabetes, which is a less drastic form of the disease. Diabetes refers to situations in which the body fails to respond to or create insulin, which is a necessary hormone in glucose metabolism. The disease is especially common in the elderly, 23.1% of the population aged 60 and older have diabetes.[3]

Diabetes is divided into two categories, type 1 and type 2. Type 1 diabetes refers to patients whose body does not produce any insulin, whereas type 2 refers to patients who either do not produce enough insulin or whose cells do not properly respond to normal insulin levels.

Many of the symptoms of diabetes are caused directly by high blood glucose levels rather than an insulin deficiency, including increased fatigue, blurry vision, excessive thirst and hunger, and frequent urination. If high glucose levels remain untreated, severe complications can occur. Adults with diabetes have heart disease death rates 2-4 times higher than those without.[4] Long-term complications include damage to the nervous system, kidneys and eyes. For instance, diabetes is the lead cause of kidney failure, accounting for 44% of new cases in 2005.[5] Over 40% of diabetics also suffer from diabetic retinopathy, limiting their visual abilities. This can result in difficulties performing various tasks including blood glucose measurements, as existing devices include a lot of small removable parts. Furthermore, approximately 1 in 2 elderly diabetic patients also suffer from arthritis, leading to dexterity impairment that further complicates their working with existing glucose meters.

While there is no cure for diabetes, proper monitoring of blood glucose levels, along with changes to diet and lifestyle, can greatly reduce the risk of complications in diabetic patients.[6] Treatments vary depending on the severity of the disease in an individual patient. Self-monitoring of blood glucose levels and treatment with insulin is one common treatment. Approximately 40% of patients with type 1 diabetes perform blood glucose testing at least once per day. [7] It is important to monitor the patient's blood glucose closely. Extremely high blood glucose levels can result in rapid dehydration causing acute complications such as mental confusion, drowsiness, and seizures.[8] In addition, improper treatment may result in hypoglycemia, a state of abnormally low blood sugar caused by side effects of diabetes treatment that can have a rapid effect on the brain.



A.2 – Glucose Meters

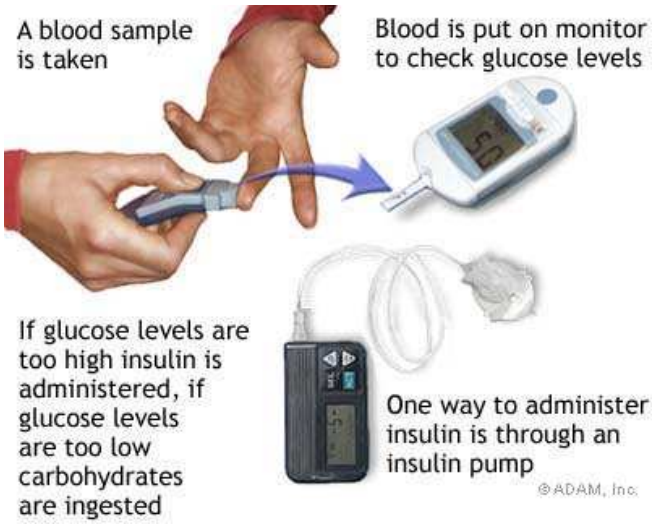
[2] American Diabetes Association. http://www.diabetes.org/about-diabetes.jsp
[3] American Diabetes Association. http://www.diabetes.org/about-diabetes.jsp
[4] American Diabetes Association. http://www.diabetes.org/about-diabetes.jsp
[5] American Diabetes Association. http://www.diabetes.org/about-diabetes.jsp
[6] Diabetes Control and Complication Trial Research Group. The effect of intensive treatment of diabetes in the development and progression of long-term complications in insulin-dependent diabetes mellitus. New England Journal of Medicine 1993;329:977
[7] Harris M, Cowie C, Howie L. Self monitoring of blood glucose by adults with diabetes in the United States population. Diabetes Care. 1993;16:1116
[8] Merck Diabetes Information http://www.merck.com/mmhe/sec13/ch165/ch165a.html

Prior to the invention of blood glucose meters, glucose levels were measured by color changing test strips. The first blood glucose meter was developed by Anton Hubert Clemens. The Ames Reflectance Meter (ARM) was primarily meant for use by physicians' offices. The test strips used by the device were also developed by Ames, Destrostix, was available since 1965 and required a "large" sample of blood.[9] The color change in the strip corresponded with a color chart of varying levels of blood glucose. The strip also required blood to be washed off one minute before inserting into the device to be measured.

The first articles in the medical literature on the home blood glucose monitoring were published in 1978.[1] These demonstrated that patients could reliably measure their blood glucose levels at home and improve control of their glucose levels. This led to the development of two dominating meters for the home market, Glucometer and Accu-Check.[10] As a result of the growing accuracy of domestic meters, color changing test strips faded from popularity.

With the American Diabetes Association, Food and Drug Administrations, and National Institutes of Health's recommendations, today's blood glucose device are designed to keep track of patient glucose levels over time, help make day-today decisions for glucose management, and to recognize emergency situations. Advanced meters today help in controlling glucose at a specific, healthy level and adjusting glucose levels in response to changes in life-style for individuals requiring medication.

Blood glucose monitoring is pivotal in the care of diabetes mellitus. American Diabetes Association (ADA) recommends that most patients with type 2 diabetes test their blood glucose levels three or more times per day.[11] A blood glucose test is performed by piercing the skin to draw blood, typically from the fingertip. This blood sample is then placed on a chemically active disposable strip which indicates the result either by a color change, or by an electrochemical change which is measured by an electronic meter.



There are several key characteristics of modern blood glucose meters. These include: size, test strips, volume of blood sample, testing speed, display, and memory/data storage. These testing devices are typically small, hand held, and battery powered with a liquid crystal display screen. The electrochemistry of the testing strip is essential to the operation of the glucose monitor. Test strips are the consumable, one-time use elements of these meters, and a typical test trip is composed of the following: ~29% w/w glucose oxidase, ~32% potassium ferricyanide, and ~39% w/w non-reactive ingredients. [12] Each strip contains a capillary, to draw up blood from the patient, and an enzyme electrode containing glucose oxidase, which can be reoxidized with an excess of ferricyanide ion. The concentration of glucose in the blood sample can be measured milligrams per deciliter (mg/dl) since it is proportional to the total charge passing through the electrode.[13] Different models vary the amount of blood needed for accurate blood glucose measurements. These can range from 0.3µl, all the way to 10µl.[1]

[9] http://www.fda.gov/Diabetes/glucose.html#16
[10] http://www.mendosa.com/history.htm
[11] http://www.fda.gov/Diabetes/glucose.html#7
[12] Bayer Ascensia Elite blood glucose test strips package insert, 2002.
[13] http://en.wikipedia.org/wiki/Glucose_meter

A3. – Fingertip vasculature and alternate site testing.

There has been a growing trend amongst modern blood glucose meters to allow for testing blood from alternative sites, such as the upper arm, forearm, base of the thumb, and thigh. Alternate site testing is possible only with newer blood glucose meters that require a significantly small quantity of blood (0.6µl – 1.0 µl) to generate accurate blood glucose measurements. Among the alternate-site meters currently available are the Accu-Chek Active and Compact (marketed by Roche Diagnostics); the Ascencia Breeze, Contour, DEX2, Elite, and Elite XL (Bayer); the FreeStyle Freedom and FreeStyle Flash (Abbott); and the InDuo, One-Touch Ultra, One-Touch Ultra 2, and OneTouch UltraSmart (LifeScan).[14] Each meter's user manual specifies what parts of the body can be used to obtain the blood sample. Sampling blood from alternative site may be desirable, but it has some limitations. Glucose concentrations change rapidly after every meal, injection of insulin, or exercise. The measured levels at alternate sites appear to change more slowly than in the fingertips due to their vasculature. The fingertips are source of arterial blood whereas alternative site testing usually test venuous blood. After one has a meal, their glucose levels change rapidly. Arterial blood is the fastest indicator of blood since glucose is directly absorbed into the blood stream and pumped toward the extremities. This means that alternative site test results may be different from fingertip test results not because of the meter's ability to test accurately, but because the actual glucose concentration can be different.[15]

Recent studies over the past few years have compared the accuracy of alternate-site testing results with results from fingertip blood glucose monitoring. The studies have generally shown that during routine blood glucose monitoring, such as before meals or two or more hours after meals or exercise, the results from alternate sites correspond well with results from fingertip monitoring. However, because glucose utilization in the fingertips is faster than in the arms or other sites, when blood glucose level is falling rapidly (e.g. immediately after exercise) or rising rapidly (e.g. right after a meal), alternate-site readings lag behind fingertip readings.[16] This could result in delayed detection of hypoglycemia or sharp changes in blood glucose level. Therefore, alternate-site testing should not be performed directly after a meal or exercise or when blood glucose level is low or falling. It is also recommended that users confirm low readings from alternate-sites with a fingerstick check before treating hypoglycemia.

A4. - Who is the customer?

While the patient who uses the device is usually the primary customer, many of them seek reimbursement from insurance companies. To ensure our product is readily received into the market we should design it assuming the customer to be an insurance company.

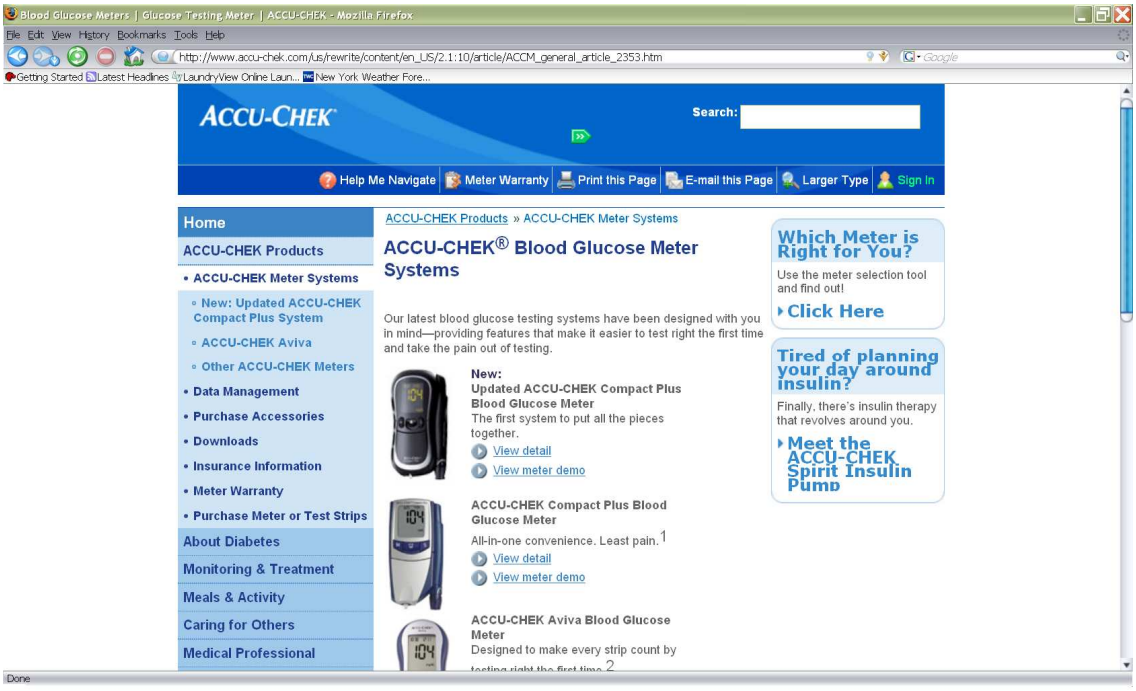
A5. - Who is the user?

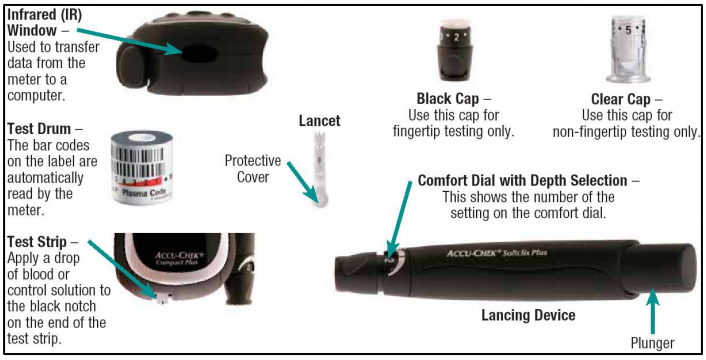
Our target user is the elderly population living with diabetes that currently use conventional blood glucose monitors. Specifically, we hope users with visual and/or dexterity impairments will prefer our device over currently distributed monitors.

[14] http://www.diabetesselfmanagement.com/articles/Diabetes_Definitions/Alternate_Site_Testing
[15] http://www.fda.gov/diabetes/glucose.html#12
[16] http://americandiabetes.com/AlternateSite.htm

B - Existing Products

B.1





http://www.accu-chek.com/us/rewrite/content/en_US/2.1:10/article/ACCM_general_article_2353.htm

Summary

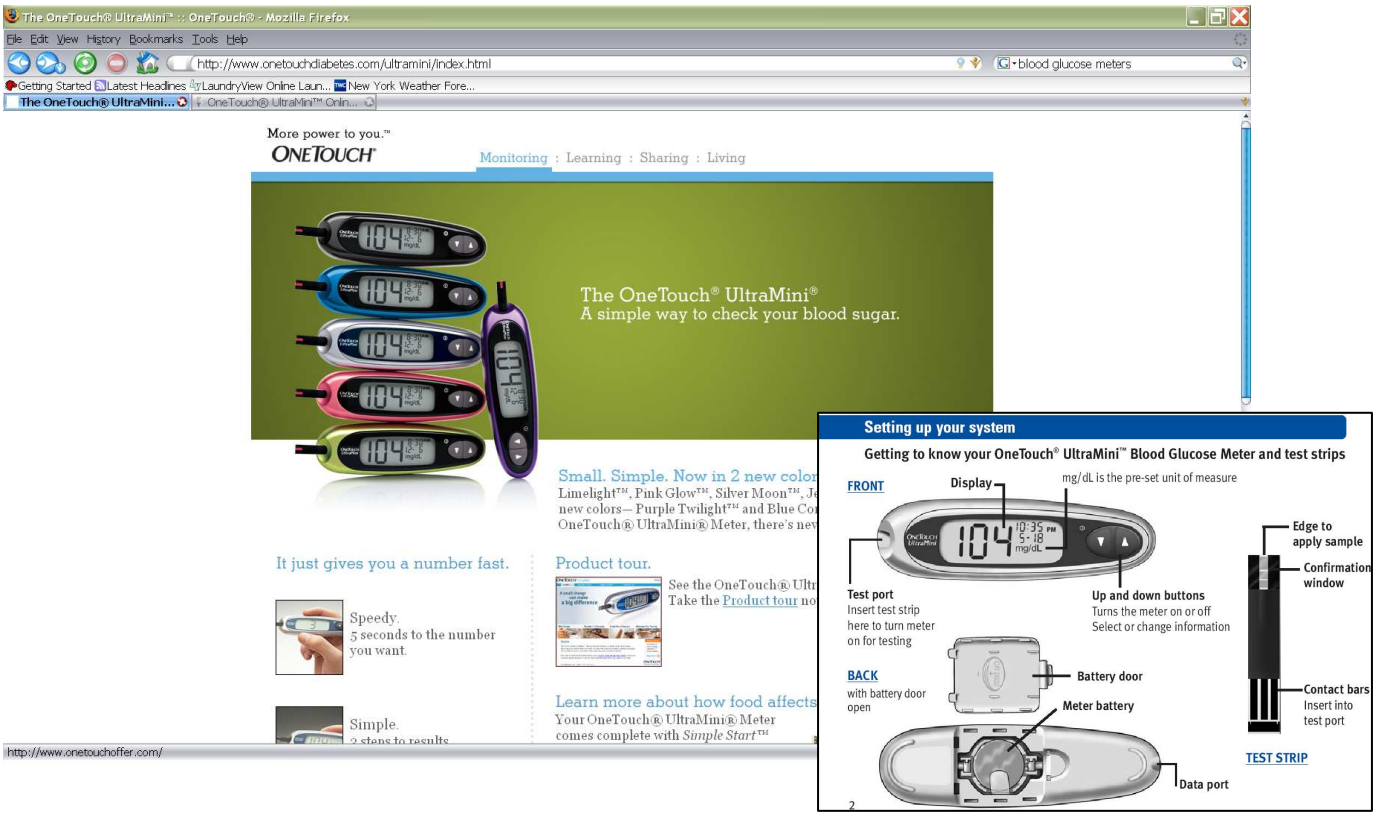
ACCU-CHEK® diabetic meter systems: Portable blood glucose meter that utilizes a pre-loaded drum of 17 diabetes test strips to eliminate individual strip handling. Disposable test drums are sold separately. Device can be used to test from patient's fingertip, palm, forearm, upper arm, thigh, or calf. ACCU-CHEK Compact Plust Bood Glucose Meter requires only a 0.6 microliter sample volume and results appear in 5 seconds. Test results can be stored into a 300-value memory and downloaded to a PC via infrared with proprietary ACCU-CHEK software. Device features a detachable lancet which can be used attached or detached from the blood glucose meter. User is asked to press a plunger on the lancing device (like a pen) one the test site. Audible alarms can be programmed to remind the user up to 3 times a day to check blood glucose levels. MSRP: $85.00

Comments

This product utilizes a rotating "drum" of test strips as a means to eliminate individual strip handling. It's similar to our idea of loading multiple strips onto a rotating disk or a conveyor belt. However, each individual strip still needs to be discarded with this device, and the lances still need to be individually

loaded and replaced during each test. Our product will be advantageous because after loading a whole disk or conveyor belt, no further action needs to be done in terms of replacement until the entire disk/belt runs out. The device also includes a lot of removable parts, including the lancing device (very rapidly launches and then retracts the lances) and various caps, which may not be convenient for the elderly population our add-on will target. Although, the alternate sites (palm, forearm, upper arm and thigh) testing capability of the device is worth considering.

B.2



http://www.onetouchdiabetes.com/ultramini/index.html

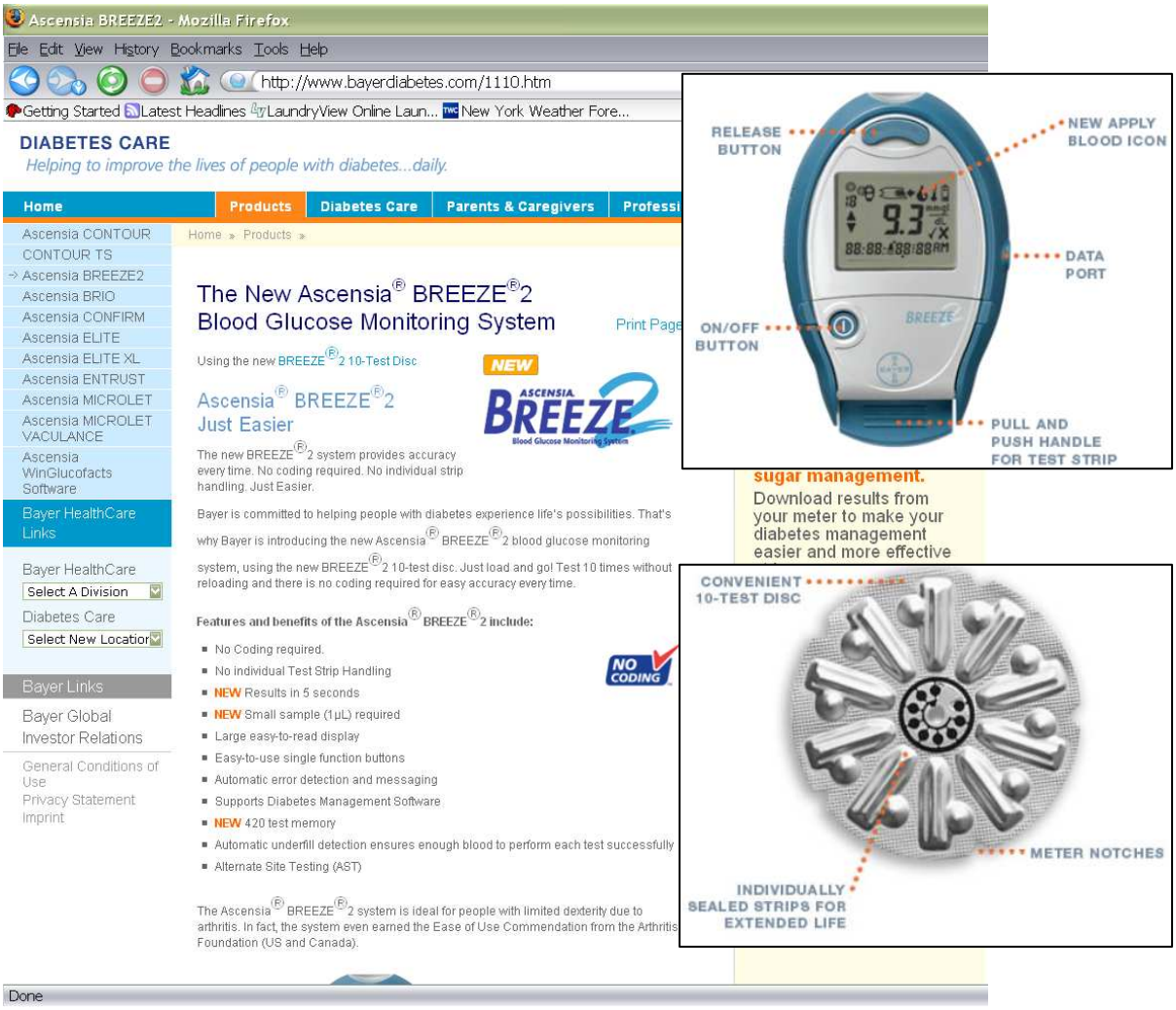
Summary

OneTouch® UltraMini™ Blood Glucose Meter: Device offers a low-cost, highly portable, sleek design which allows for testing at the fingertip, forearm, or palm. Requiring a 1 microliter sample of blood from the user, the meter stores a maximum of 500 blood glucose test results. Individual results are processed within 5 seconds of testing. Users are asked to either puncture at the fingertip or at alternate sites. This meter employs a unique feature that eases the testing at these alternate sites. When puncturing at the forearm or palm, the user is asked to firmly press and hold the lancing device until the OneTouch® AST™ Clear Cap changes color (as blood collects beneath the skin). This indicates to the user that there is sufficient blood for a good sample. The OneTouch disposable lancing device has nine puncture depth settings to use for children and adults. Proprietary disposable test strips are sold separately. MSRP: $19.99

Comments

This is a small, portable device. This could be advantageous in terms of accessibility, but may pose a problem to use for the elderly, being so small. We're not sure if it comes with its own lancing device, as the webpage makes no mention of it. Similar to the Accu-Chek, this device is also capable of alternate sites testing at the base of the thumb, the forearm, the upper arm, and at the thigh. Alternate site testing is definitely worth considering in our add-on, as it's less painful than at the fingertip. This existing device also utilizes color change to indicate that enough blood has been loaded onto the test strip, which is a reminder that our add-on should have some sort of similar visual/audio queue to serve the same function.

B.3



http://www.bayerdiabetes.com/1110.htm

Summary

Ascensia® CONTOUR® BREEZE®2 Glucose Monitoring System: Device offers 5 second test time and is capable of storing 420 test entries. Unique rotating 10-test disc and automatic strip filling action allows for easier handling for people with limited dexterity due to arthritis. Meter automatically checks for errors and calibrates each time a new lot of test strips is used. Device is cleared for multiple-site testing including the finger, forearm, palm, abdomen and thigh. One microliter sample size required. MSRP: $59.99

Comment

This new meter by Ascensia can be served to a similar audience as our add-on. It utilizes a rotating disk for loading of test strips as to increase convenience. Again, though, once the disk is loaded, the strips still need to be discarded individually after usage. Neither dexterity nor visual impairment is very well targeted, since the patient still needs to manually bring the small exposed tip of the test strip to the test site. Our add-on, instead, will eliminate the small steps. Furthermore, the lances and the lancing device are also separate from the body of the meter, unlike what we've envisioned for our add-on. Nonetheless, the disk design warrants further observation and can be used in our finalizing our design.

B.4

OneTouch® Ping™ is the intelligent glucose management system with one thing on its mind: working together to help you perform at your best.

Like other insulin pump systems, OneTouch® Ping™ frees you from multiple daily injections and gives you the ability to quickly and easily adjust your insulin based on your body's immediate needs.

But unlike other systems, OneTouch Ping delivers the double whammy in terms of smarts. The pump is packed with unique capabilities that may be accessed both wirelessly (by using the meter-remote) and manually. And the meter-remote, with its full set of functions, is designed to make your life with diabetes easier and more discreet. In fact, you can even dose your insulin from it.

It matches your body's needs like no other pump system.

OneTouch Ping gives you the smallest basal increment available (0.025 U/hr) for more precise basal dosing. So if you need 0.025, 0.675 or 1.075 U/hr to perform at your best, we can deliver. Talk about fine-tuned control.

It has serious communication skills.

The OneTouch Ping meter-remote and the OneTouch Ping insulin pump communicate and share information wirelessly. In addition to testing blood glucose, the meter-remote can actually control pump functions. This means that the meter-remote can calculate a bolus, then tell the pump to deliver it. It also lets you view things like your basal rate without having to look at your pump.

It's smart about your carbs.

The meter-remote can store the nutritional values of 500 of your favorite foods, via CalorieKing®, for easy and accurate carb counting on the go. Using ezManager® Max software, you can even customize the database or enter your own favorites (like Mom's chicken soup). That means you can rest assured you're giving yourself the most precise insulin dose, wherever, whenever.

It's got beauty as well as brains.

The OneTouch Ping insulin pump has a flat panel color screen that uses the same screen technology as the latest televisions and digital cameras. The screen is also self-illuminating and high contrast for readability and viewable from a wide angle. Plus it comes in five brilliant colors.

http://www.animascorp.com/animas-onetouch-ping-insulin-pump.aspx

Summary

OneTouch® Ping™: An insulin pump that also detects glucose levels. Wireless information shared between the OneTouch meter and the OneTouch pump. The pump is capable of calculating and delivering necessary bolus. It's also capable of giving very small dosages, down to 0.025U/hr for basal dosing. Detects and stores information about carb. content in consumed food, and then delivers necessary amount of insulin. It's also waterproof up to 12 meters for 24 hours, and therefore works while the patient's in the pool or caught in the rain. MSRP: To be determined.

Comment

This device was something that we came across and thought was very neat. Not only is it capable of detecting blood sugar levels, it can relay the information wirelessly to an insulin pump, and have that pump deliver the appropriate amount of insulin. This requires a needle to be subcutaneously imbedded in the patient for extended periods of time, which is something we thought we'd steer away from. The water-proof aspect, however, was a protective aspect of the device maybe our add-on can incorporate as well, assuming it's not too complicated to implement.

B.5

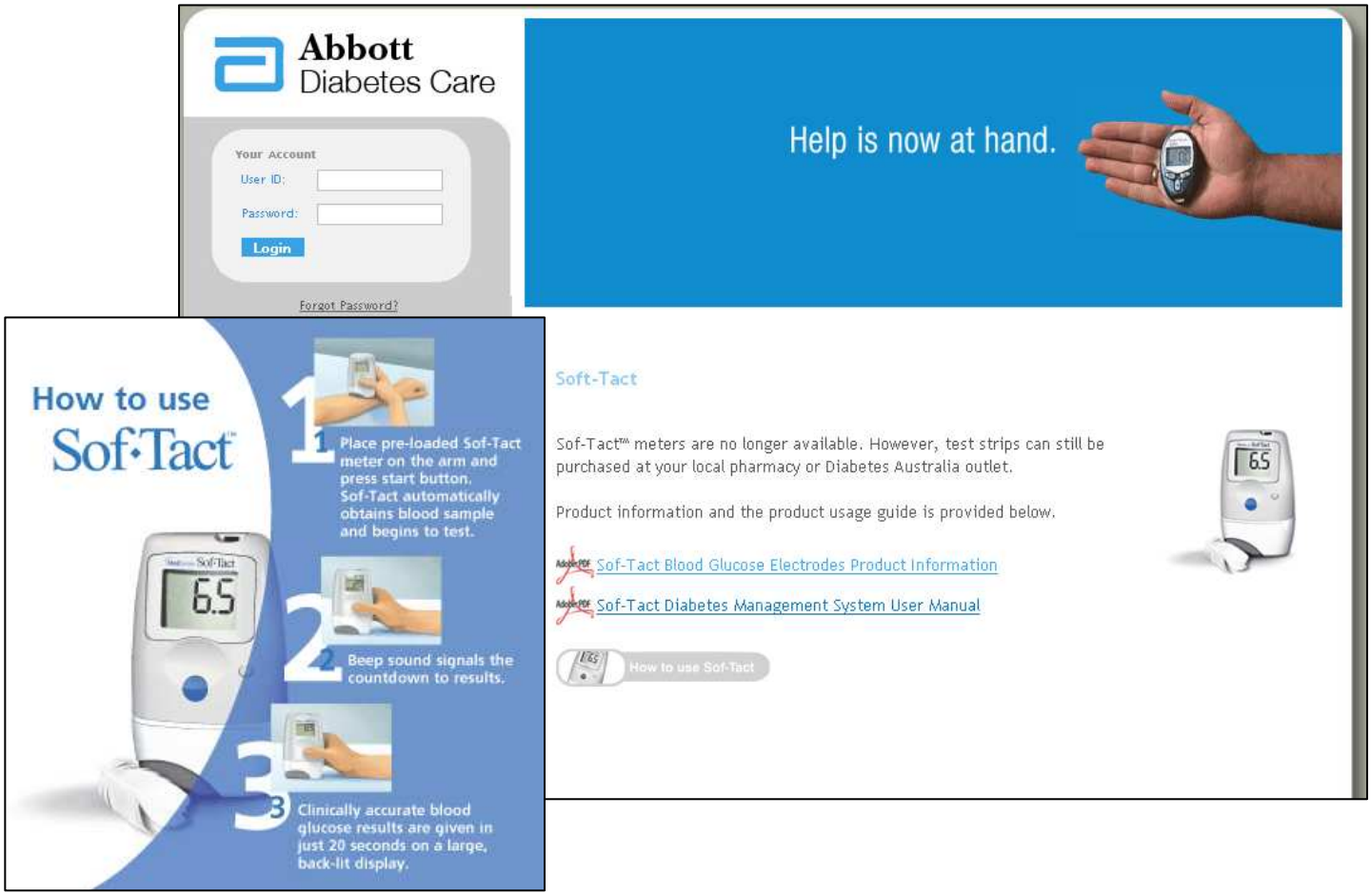
http://www.accu-chek.com/us/rewrite/generalContent/en_US/article/ACCM_general_article_2542.htm

Summary
ACCU-CHEK® Comfort Curve Test Strips: These test strips are curved to fit around your finger. You don't need to put the blood on the test strip, and users are instructed not to do this. By simply placing the curved area next to the drop of blood on your finger, the blood will be pulled into the yellow testing window. MSRP: $33.69

Comment
These test strips are ideal in our design to draw the user's blood directly into the capillary situated in the middle of the test strip. Our current design is implemented with the rotating disk of lances that comes up below where the test strip is positioned. We're thinking by implementing these grooved test strips, the lances can puncture through right by the capillary without the need to break through the strip itself.

C - Similar Applications

C.1



http://www.abbottdiabetescare.com.au/sof-tac.php

Summary & Comments

MediSense Sof-Tact™ Meters: The Sof-Tact Diabetes Management System is designed for *in vitro* diagnostic use (use outside of the body). It is for use only with fresh capillary whole blood from sites such as your forearm, upper arm, or the base of your thumb. To use, both test strip and standard lancet are placed within the unit. Holding the Sof-Tact against your skin, you press a button that generates a slight vacuum, lances the skin, and applies the blood to the test strip. This happens in about five to ten seconds and is completely automatic. Once the test strip has a sample, the unit generates a reading in 20 seconds. Even though testing was relatively painless, the Sof-Tact is not the ideal alternative site monitor because of its relatively large blood volume requirement. Obtaining the required 2-3 microliters from the forearm was not always easy. (Other alternative site meters require from one-third to one-tenth the volume of blood as the Sof-Tact.) One reader who uses the Sof-Tact reports that changing the lancet each time is essential to getting the correct blood volume. Though the meter automates the process of blood glucose testing, the user is still required to change individual test strips and lances between testings. The meter is also much larger than other meters and somewhat awkward to handle for very small hands. The internal lancing and blood application also means that the meter requires cleaning. This device has been discontinued as of 2005.

C.2

Importance of Glucose Monitoring

While diabetes is a chronic disease that has no known cure, self-monitoring of sugar levels by patients has transformed the management of diabetes over the last several years, allowing diabetics to achieve and maintain specific glycemic goals. Why is self-monitoring so critical? Without proper management of diabetes, the disease can cause severe long-term health complications, including blindness, kidney disease, heart disease, and nerve damage, potentially leading to amputation or death. Results of blood glucose monitoring are used to asses efficacy of therapy and to guide modifications in nutrition therapy, exercise, and medications to achieve the best possible blood glucose control. By keeping the concentration of glucose in blood inside a defined range (100-120 mg/dL), diabetics can lead normal lives. Shown above at left are the daily accouterments of a diabetic: glucose monitor, lancet, alcohol swabs, syri needles, insulin, and emergency sugar for over-injection of insulin.

Enter the GlucoWatch® Monitor

As previously described, monitoring blood glucose levels all day is no small ordeal. The GlucoWatch monitor, a newly developed product of Cygnus, Inc., is a wrist-worn device that provides automatic, non-invasive measurement of glucose levels for adults with diabetes. It has a disposable sensor that adheres to the wearer's wrist, allowing measurement of sugar levels in the interstitial fluids on the outermost layers of the skin of the wrist. Although it is not yet FDA-approved for use by diabetics, and is still being tested and considered an investigative device, diabetics around the world anxiously await its release.

How the GlucoWatch® Monitor Works

Before use, the GlucoWatch monitor must first be calibrated. The wearer may do this by taking an initial glucose measurement using the traditional finger-pri calibrated, the monitor can provide up to three glucose readings each hour for 12 hours. The GlucoWatch monitor uses reverse iontophoresis to collect gluc intact skin. Similar to the transdermal medication patches used for smoking cessation and hormone therapy, iontophoresis is a non-invasive, needle-free m controlling the transport of water-soluble ionic (electrically charged) drugs out of the skin and surrounding tissues using a low level of electrical current.

A single-use sensor containing gel collection discs gathers glucose samples. The gel collection discs contain the enzyme glucose oxidase. As glucose ente the glucose oxidase in the gel to form hydrogen peroxide. A biosensor in contact with each gel collection disc detects the hydrogen peroxide and issues an e monitor uses the calibration value initially entered by the wearer to translate the signal into a glucose measurement. The monitor then displays the glucose r memory. In addition to taking glucose readings, the GlucoWatch monitor can sound alarms in response to results outside of high and low values selected fo feature can provide a method to reduce the risk of hyperglycemia (abnormal increase of sugar in the blood) and hypoglycemia (abnormal decrease of sugar

The GlucoWatch monitor should prove to be an excellent alternative to the painful pricking of traditional glucose reading methods. For many concerned diabe

Update on the GlucoWatch

The U.S. Food and Drug Administration (FDA) approved the use of the GlucoWatch as a prescription device for adults with diabetes on March 22, 2001. This glucose-monitoring device of its kind currently approved by the FDA.

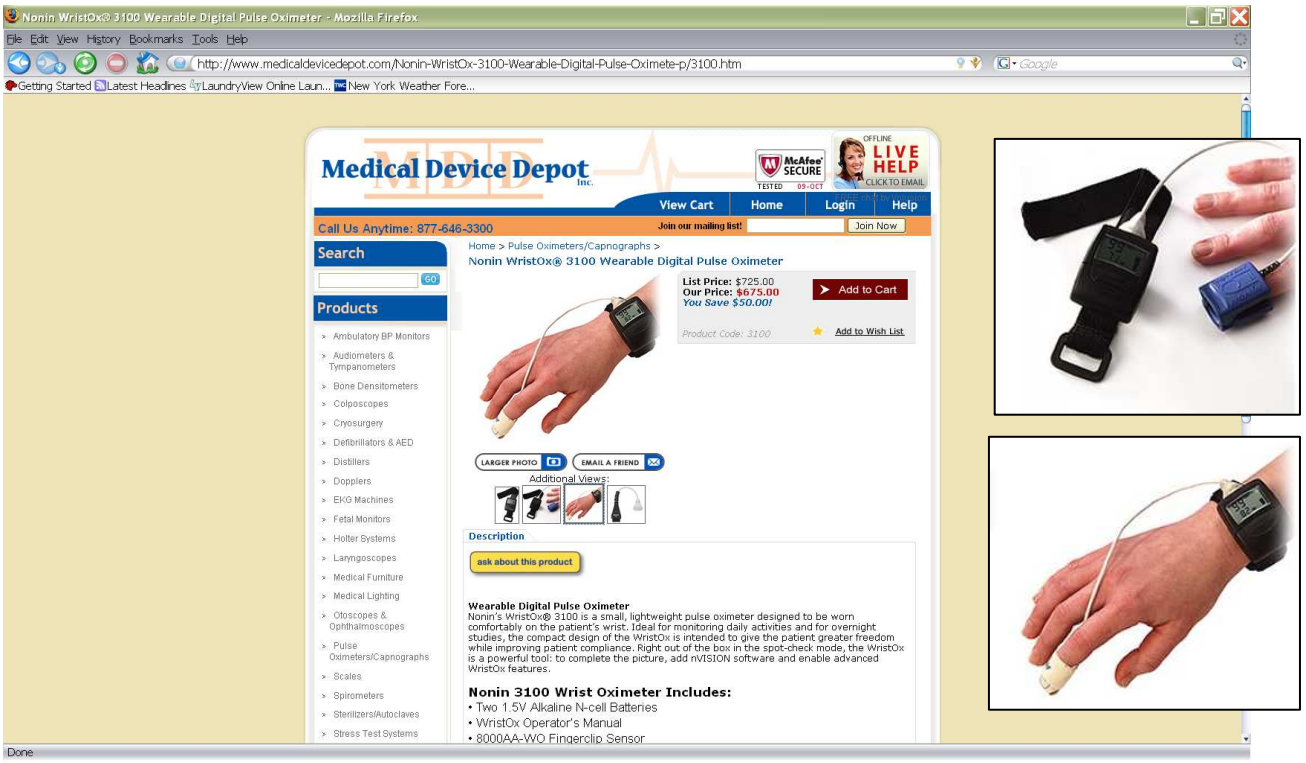
Diabetes and Glucose-Monitoring Web Site Links

http://www.brookscole.com/chemistry_d/templates/student_resources/0030223180_garrettgrisham/HotTopics/GlucoWatch.html

Summary & Comments

Animas GlucoWatch ® G2 Biographer system: The glucowatch was an attempt at a non-invasive glucose measuring device for patients who test their blood sugar levels multiple times per day. The device used small electrical currents to draw glucose out of the arm, and because of this caused mild to moderate skin irritation. The wrist watch design is a good attempt to make the device convenient to use. The device still required daily calibration using a conventional finger-prick measurement, and therefore did not eliminate the necessity for invasive measurements on a regular basis. Suffering from inaccuracies in measurement, especially at low glucose levels, and expensive costs (the sensor needs to be replaced every 13 hours and they cost approximately $5.00 each, which is very expensive compared with test strips) the glucowatch has been discontinued. Since the glucowatch did not rely on finger-prick measurements it did not need to address the manual dexterity impairments we are focusing on.

C.3

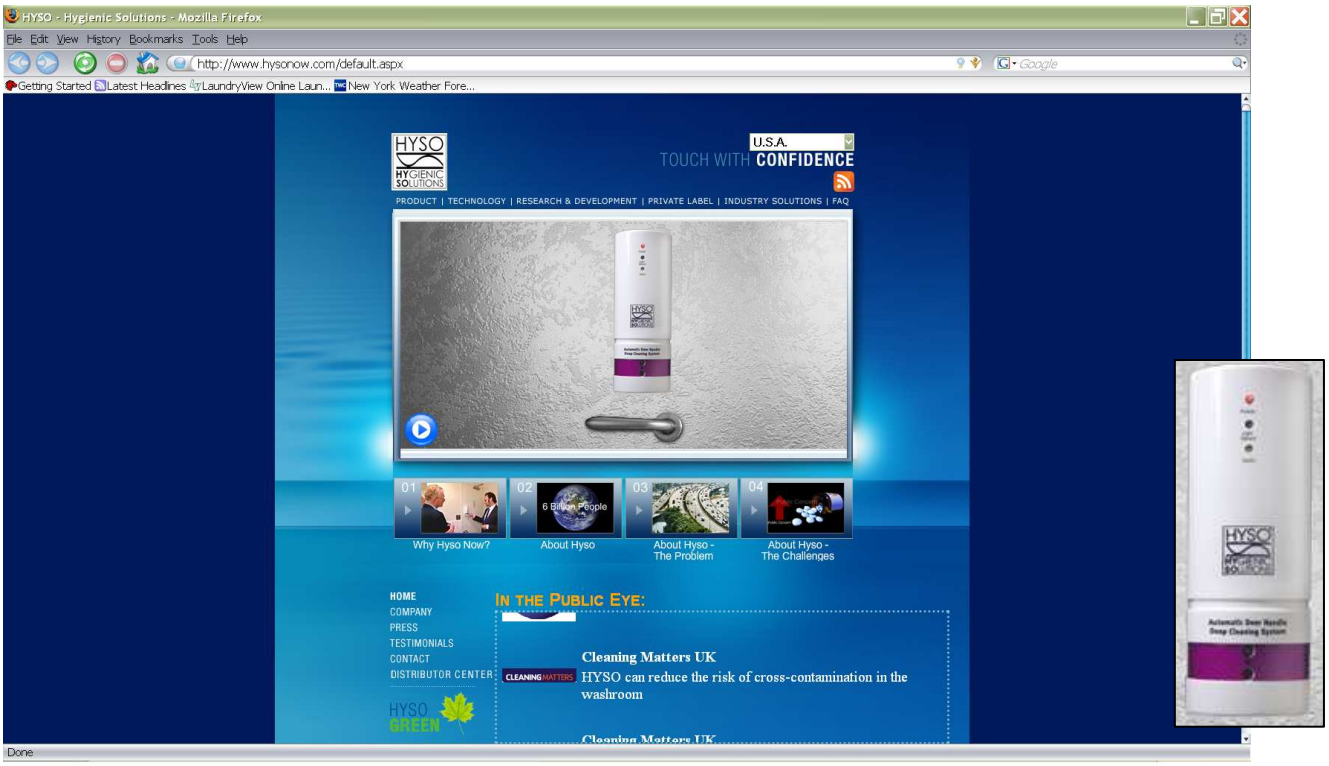


http://www.medicaldevicedepot.com/Nonin-WristOx-3100-Wearable-Digital-Pulse-Oximete-p/3100.htm

Summary & Comments

Nonin WristOx® 3100 Wearable Digital Pulse Oximeter: Device is a small, lightweight pulse oximeter designed to be worn comfortably on the patient's wrist. Ideal for monitoring daily activities and for overnight studies, the compact design of the WristOx is intended to give the patient greater freedom while improving patient compliance. The concept of a wearable device can be incorporated into our design ideas. We like the automatic monitoring and ease of use this device offers. MSRP: $725.00

C.4

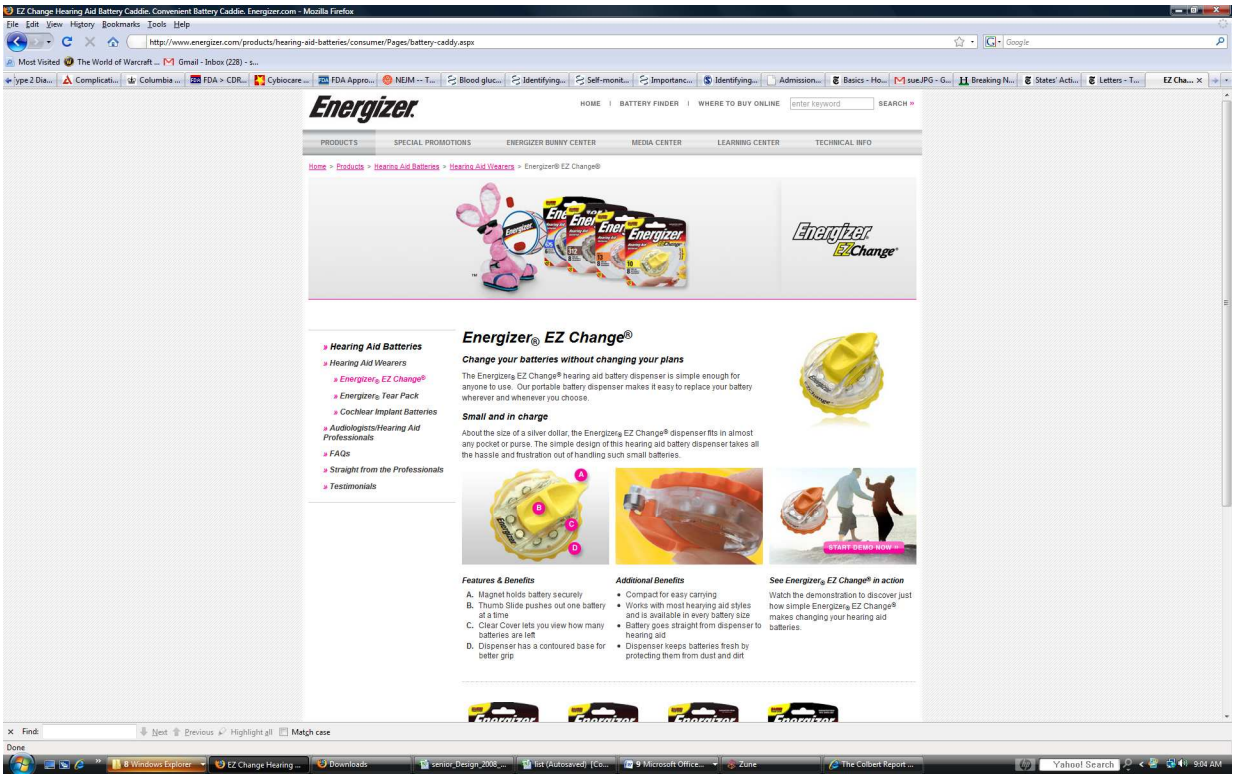


http://www.hysonow.com/default.aspx

Summary & Comments

HYSO Automatic Door Handle Sanitizer: The HYSO device contains a replaceable can of specially formulated "QUAT based" ULTRA CLEANER that depending on the selected interval setting, can last for up to 3 months. At the cusp of intervals a system of gears engages the patented stem pipe, which releases a measured mist of the formula. A proximity sensor detects motion within one meter of the unit ensuring the cessation of delivery, thus eliminating the inadvertent spraying of a hand. Also containing a light sensor, the HYSO unit will power down if no ambient light is present. Powered by 4 AA batteries, the HYSO unit does not require special wiring into the main electric source, making it easy to install and inexpensive to operate. We're thinking of implementing something similar in our add-on, as to provide sterilization for the patients. MSRP: $59.95

C.5



http://www.energizer.com/products/hearing-aid-batteries/consumer/Pages/battery-caddy.aspx

Summary & Comments

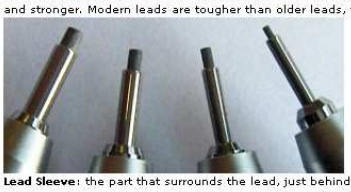
The Energizer EZ Change: is a patented device that aids the elderly in the replacement of batteries for their hearing aids. We expect our customers to suffer from similar dexterity and visual impairments. The intuitive design that eliminates the need for elderly users to interact with very small parts is something we wish to incorporate into our design. It is also very well marketed and described. Price: ~$15.

C.6

Features

So, what should you look for in a mechanical pencil? There are a surprising variety of features to consider, even sticking with only the most common variations.

- **Lead Size**: may well be your first consideration. For drawing and sketching, you may want quite thick lead, and some mechanical pencils are available with 4mm or thicker lead. For writing, many people prefer 0.9mm or 0.7mm, with 0.5mm and 0.3mm becoming more popular for writing and drawing, and certainly leading the way for technical drawing. The thicker the lead, the more likely it is to need sharpening, but the thicker the line you can get from it, and the easier it is to shade large areas. If you like especially soft or hard lead grades, you may be limited by the thicknesses your preferred grade of lead is available in. 0.5mm usually has the widest choice, and softer grades are more common in thicker leads. If you write or draw 'aggressively', thinner leads can be prone to snapping, so you may prefer something thicker and stronger. Modern leads are tougher than older leads, though, so if you used to find 0.5mm leads snapped for you years ago, it might be worth another try with a modern lead like Pentel's AIN.



- **Lead Sleeve**: the part that surrounds the lead, just behind the writing tip. Either thin and round, or conical...
  - **Thin round sleeves** are used in drafting pencils. They give an easier view of the drawing area, and allow the pencil to be used more accurately and easily with rules and templates. Sometimes, the sleeve can slide back, so it gets pushed out of the way by the paper if you run low on lead. If you use rules and templates a lot, you may prefer a fixed sleeve, but otherwise, a sliding sleeve can be convenient.
  - Pencils for writing usually have a **conical sleeve**, which is less prone to getting bent or broken, and less likely to poke through pockets (and accidentally stab your own leg!)

- **Retractable Tip**: often referred to as "Pocket Safe". If you are going to carry a pencil in your pocket, being able to retract the tip part inside the pencil can save your pocket and your leg from damage. This is less important with conical sleeves than with thin sleeves.

- **Lead Grade Indicator**: some pencils have an indicator you can set to show which grade of lead you have loaded in that pencil. If you use a number of different pencils, with different hardnesses of leads, this could be very useful. The indicator will usually only have a limited range of hardnesses listed, so if you use unusually hard or soft leads, you may not be covered by all pencils.
- **Grip**: you need to be able to hold the pencil comfortably and without it slipping in your fingers, so you need to get a grip that suits your fingers. Many people now like rubber grips, and they are fast becoming the most common type available. Some people still prefer the old-fashioned knurled metal style, and such grips do still exist - especially in drafting pencils. If you have trouble holding a thin pencil, you may want to look for one with a wider grip - like the Faber-Castell Grip Plus. Don't always assume, though, that rubber will be the most non-slip surface - some plastic or metal grips can be very *grippy*.
  - **Triangular Grips**: some people find a triangular grip section more comfortable, and it can give you a bit more contact area with the pencil. See the Faber-Castell Grip range, and Staedtler's Triplus pencils, for some nice examples.

- **Clip**: if you like to carry your pencil(s) in a shirt pocket, a pocket clip may be important to you. Most pencils come with a clip of some sort, and in some cases it can be removed. A clip will also stop the pencil from rolling off the desk when you put it down for a moment.
- **Lead Advance**: all mechanical pencils have some way of moving the lead forward. The most common is a button at the top of the pencil, but there are other options available now...
  - **Top Button**: still the most common, and many pencils with other mechanisms *also* have a button on the top.
  - **Side Button**: a few pencils are available with a button on the side as well as or instead of the top. This lets you advance the lead without moving the pencil as much, usually using your thumb.

http://www.cultpens.com/acatalog/Mechanical_Pencils.html

Summary & Comments

Mechanical pencil constructs are similar in design to the lance loading mechanism in current devices. We are identifying the best lance advancement mechanism and found an assortment of current mechanical pencil designs. In considering for an optimal lance loading mechanism, we are geared to finding one that is a one step snap loading in addition to being relatively easy to release. These layouts are fitting for our design because they all entail simple clicks to advance the lead. If we would expand upon these constructs and adapt them to a single, rapid release along the entire length of the lance, it would be advantageous for the user and us.

D - Interviews

D.1

(Grandmother-Had to be translated from another language, so the answers are not direct quotes.)
Q: How long have you had diabetes?
A: I've had diabetes since you were born, in 1987, so it's been a bit over two decades.

Q: What is the most difficult part of having diabetes?
A: I think the most difficult part came when I was first diagnosed with diabetes. In China at the time, the medicines weren't that great and didn't help much to manage glucose levels. It really came down to self-management, and having to restrain myself from eating a lot of the foods that I've been eating all my life. The insulin was also not perfect, whereupon it can lower the patient's blood glucose level to such an extent that it became dangerous to the patients.

Q: What is the most challenging aspect of managing your diabetes?
A: Up to the present day, it would still be the dietary constraints. Don't get me wrong, it's not that I love food, but it's quite a burden to have to be careful about everything you eat. Also, you can't eat a lot per meal, and have to divide your regular meals into multiple servings.

Q: How many times a day do you have to check your glucose level?
A: Once every 2 days or so when properly managed, and I inject insulin once daily. If I see that my glucose reading is too high on a particular day, I would watch my diet even more closely and may do additional tests during the day.

What device are you currently using?
A: I'm not too sure. It's in English, and I can't read it.

Q: Are you content with your current device, and what do you think can be improved about it?
A: Well, I've been using this device for almost a decade now, and have gotten used to it. I did get a new device about a year or two ago, but I'm not really using it because of all the pre-programming and setup required. I suppose it can be made more user-friendly, especially for people who have a language barrier. Also, cleaning the current device is problematic, because it's difficult to open and expose the inside of the detector where the measurement strips are inserted. I suppose in that regard, sterilization can be improved.

Q: How much did your device cost?
A: I don't remember the exact cost, but it should have been over $100 back then.

Q: What do you think about our proposed device?
A: I think it'll be an improvement. With the current device I'm using, I've gotten so used to it that testing doesn't provide much of a problem for me, and I can tell how much blood I need to have extracted. However, I can certainly see the advantage of having something that provides more stationary support and sterilization.

Q: What do you dislike about our proposed device?
A: Well, it's not something that I dislike about it, but for people like your grandfather who has a psychological fear of needles and getting injections, can it be made less invasive or less painful? Although your proposed device will provide better support and sterilization, he'll still feel pain and knows that a needle is involved.

D.2

(Interview with Djalil Macki)
To further our understanding of how patients cope with their disease and use currently distributed blood glucose monitors we interviewed Djalil Macki, a 62 year old male who has type II diabetes.

We first asked him a number of questions regarding how he uses his blood glucose monitor. Since he uses the device multiple times per day, he prefers using different fingers throughout the week so as not to bother one finger too much. He also prefers using his device while seated at a table, which he feels makes it easier to prick his finger and get a proper amount of blood onto the strip with relative ease. Djalil is frequently frustrated with the occasional need to acquire a second sample when the first sample is insufficient. He will occasionally reuse the lance but always ensures that he wipes it and washes his hands before taking a measurement.

When informed about the function of our device, Djalil initially felt it not applicable to him since he does not have trouble pricking his finger for measurements. However, after further discussion, he did say that it would be convenient to have a device in a stable location to automate his measurements. He also felt a record of previous measurements would be beneficial. He also said that since the device isn't readily portable he would still feel the need to have his current glucose monitor. When asked if he would prefer a device that incorporates his existing glucose monitor, he responded enthusiastically, saying it would be useful to have all the results stored on one device overtime so he does not need to combine the data if he wanted to track his glucose level for a prolonged period (for example when testing a new diet).

D.3

Patricia Kringas, RN, BSN, MA
Research Coordinator

We interviewed Patricia Kringas, RN at the Naomi Berrie Diabetes Center. She was ecstatic over the comfort and ease of use plans we had detailed. Along with agreeing that current devices needed preloaded drums or cartridges for extended testing, she also liked our idea of improving lancing device comfort and handling through automation. Additionally, she liked our idea of pre-loaded lances in the form of a drum or cartridge which would have superior handling compared to the current individual lances. Nurse Kringas suggested by providing these lances in a compact, user friendly container it would free the user from the high dexterity required to handles single lances.

Nurse Kringas also approved the finger guiding system of our add-on and its universal appeal to patients with movement impairments and younger users. She suggested that with a form of stationary support such as a table clamp, patients with these dexterity impairments or weaker hands would be better able to test without losing their grip on the machine. As she often deals with patients that have movement disorders, she realized the importance that a firm, stationary support would have high appeal to patients looking to be independent from assisted care.

Nurse Kringas also noted the need to allow the patient to rotate the finger within the machine so that the same exact site is used no more than a few times a week. Often patients with diabetes rotate testing sites to avoid sores and infection to the testing area. With the tight spacing and motorized components, Nurse

Kringas was concerned with excess blood from elderly or younger users preventing efficient cleaning of the device. She mentioned a possible open air compartment would be better suited for maintenance and replacement of parts.

D.4

Dr. Lauren Golden
Endocrinologist

We also interviewed Dr. Lauren Golden at the Naomi Berrie Diabetes Center. Dr. Golden liked our ideas for a meter add-on and applauded our idea to eliminate the individual placement of strips. She suggested pre-loading strips in the form of cartridges ranging from 15-20 to allow users easy loading. As for the overall design, she found our initial combination of automation and comfort to be unique and innovative, since many current companies have not demonstrated a device to encompass an all-in-one system.

Dr. Golden works with middle aged and older patients experiencing diabetes and found that our proposed device would be especially appealing to all people because of its simplicity and automation. In regards to our finger massaging portion, Dr. Golden recommended massaging to occur before the procedure, since massaging during blood extraction may create complications. Taking her suggestion into practice, we proposed the idea of a rough, automated area that would produce a massaging area when the finger is placed on it.

When asked the question of when to sterilize or if to sterilize, Dr. Golden mentioned that repeated sterilization via alcohol pads actually dries the finger and causes long term issues with the patient skin. Instead of sterilizing the finger, she proposes that patients engage in active, daily hand washing to maintain sanitary conditions.

E – Safety Considerations and FDA

U.S. Food and Drug Administration — Department of Health and Human Services

CENTER FOR DEVICES AND RADIOLOGICAL HEALTH

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FDA > CDRH > Guidance Documents > Review Criteria Assessment of Portable Blood Glucose Monitoring In Vitro Diagnostic Devices Using Glucose Oxidase, Dehydrogenase or Hexokinase Methodology

Review Criteria Assessment of Portable Blood Glucose Monitoring In Vitro Diagnostic Devices Using Glucose Oxidase, Dehydrogenase or Hexokinase Methodology

DRAFT DOCUMENT

This guidance document is being distributed for comment purposes only.
Clinical Chemistry and Toxicology Devices Branch
Division of Clinical Laboratory Devices
Office of Device Evaluation
Draft released for comment on 2/28/97

Comments and suggestions regarding this draft document should be submitted within 60 days of the above release date to: Joseph Hackett, Ph.D., Associate Director, Divisi Clinical Laboratory Devices, HFZ-440, 2098 Gaither Road. Rockville, MD 20850. Comments and suggestions received after this may not be acted upon by the Agency until th document is next revised or updated. For questions regarding the draft document, contact Dr. Kaiser Aziz or Dr. Joseph Hackett via phone (301) 594-3084 or fax (301) 594-5

U. S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Food and Drug Administration
Center for Devices and Radiological Health

REVIEW CRITERIA FOR ASSESSMENT OF PORTABLE BLOOD GLUCOSE MONITORING IN VITRO DIAGNOSTIC DEVICES USING GLUCOSE OXIDASE, DEHYDROGENASE, OR HEXOKINASE METHODOLOGY

VERSION 02/14/96

This is a flexible document presenting current guidance on the preparation of premarket notifications (510(k)s) for glucose in vitro diagnostics devices employing enzymatic methodologies. It is based on l) current technology, 2) clinical experience, 3) previous submissions by manufacturers to the Food and Drug Administration (FDA), and 4) Safe Medical Devices Act of 1990 and regulations in the Code of Federal Regulations (CFR). So that we may revise the draft as necessary, please send your comments to the add given below.

Joseph Hackett, Ph.D.
Associate Director

http://www.fda.gov/Diabetes/glucose.html

"(a) Identification.

A glucose test system is a device intended to measure glucose quantitatively in blood and other body fluids. Glucose measurements are used in the diagnosis and treatment of carbohydrate metabolism disorders including diabetes mellitus, neonatal hypoglycemia, and idiopathic hypoglycemia, and of pancreatic islet cell tumors.

(b) Classification. II"

FDA:

- -all devices require testing and accuracy check before marketing
- -the FDA has approved one minimally invasive and one noninvasive device
  - -both devices, however, are not meant to serve as replacements for standard devices
  - -they're meant to provide additional information on top of standard measurements
  - -both also need to be re-calibrated frequently

Safety Considerations:

- -the movement of the lance/needle needs to be restricted beyond a certain threshold, as to prevent puncturing the patients too deeply
- -the restricting ring for inducing blood extraction needs to be capped at a maximum amount of force applied, as to prevent causing the patients additional discomfort
- -perhaps some sort of safety mechanism should be included, as to prevent small children from insertion their fingers into the detector
- -small removable parts are involved in the construction of the device, and warrant further consideration (i.e. how to prevent a small child from removing one of the pieces and ends up choking on it)

DS3 – Constraints and Specifications

Constraints

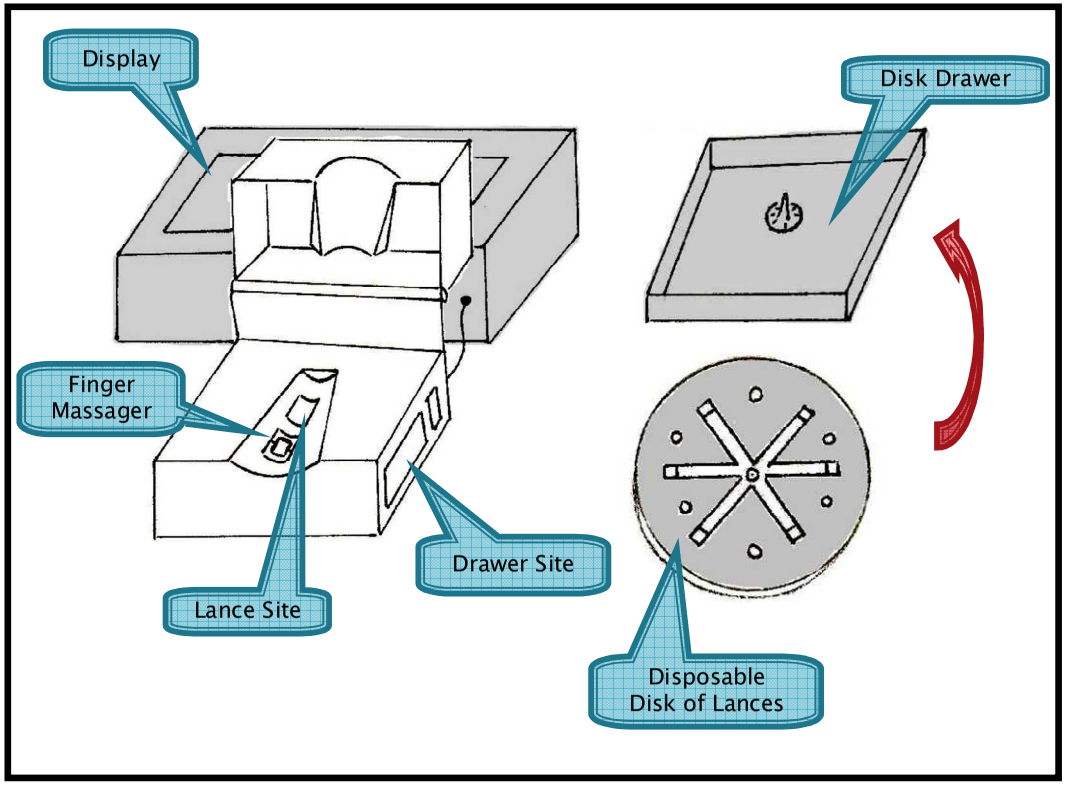
- Must be usable by dexterity and/or visually impaired patients
- Must not cause unnecessary pain to patients
- Must not be so large as to prohibit portability (i.e. transport between home and work should not be inhibited)
- Must reliably and accurately detect glucose levels
- Must be readily able to be sterilized
- Should be adjustable for use on different fingers
- Should be adjustable to allow for different pressures necessary to puncture skin of varying thickness
- Must be easily maintained and cleaned
- Must be priced competitively compared to existing glucose monitors

Specifications

- Device must be testable using materials of varying toughness
- Device will be AC powered from wall outlet (includes necessary transformers)
- Ergonomics are a very important consideration since target users are dexterity and/or visually impaired
- Device must be accessible since elderly population has difficulty programming complex devices
- Device should be relatively small and rectangular to allow for easy transport
- Minimal training should be required, since currently special nurses teach patients how to use glucose monitors prior to treatment plans
- Should cost less than $150 to manufacture, and less than $200 to sell
- Reliability of data is essential since inaccurate measurements can result in patient mortality
- Life of product for user is approximately 5-10 years
- Life of product for company is approximately 2 years
- Data acquired should be saved over time and readily uploaded to computers
- Device should take less than 1 year to design since market is susceptible to new innovations in non-invasive measurement techniques
- Device must not harm patients unnecessarily (i.e. stab them to deep)
- Device must deliver necessary volume of blood (between 1 and 10 microliters depending on glucose monitor)
- Device must add-on to an existing glucose monitor and be separable to allow for portability

DS4 – Design Ideas

Design Idea – 1

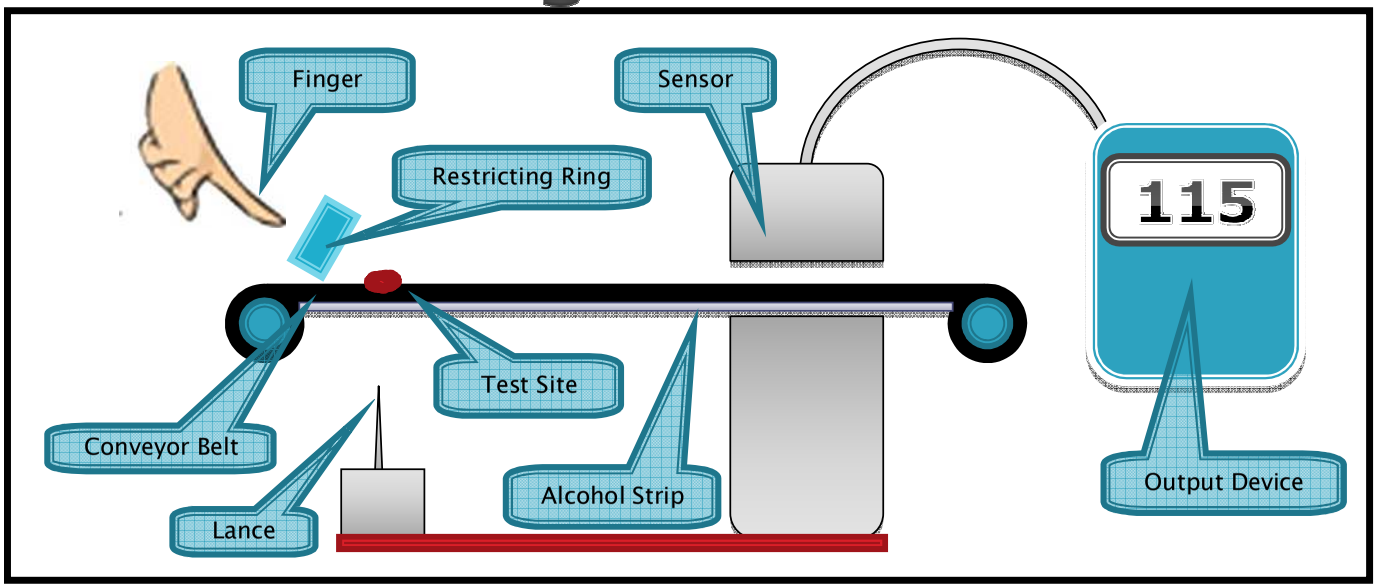


Description:
This is our DS4 – Idea 1. We had intended to incorporate a rotating disk of alternating lances and test strips to eliminate the need of individual handling. The disk is disposable, and can be readily replaced by opening a side drawer in the add-on. The disk will be manufactured with some sort of groove at the bottom, which will allow it to fit nicely over a lock-in mechanism at the base of the drawer. A conical intrusion will guide the patient's fingertip over a small opening through which the lances will shoot through. A rotating finger-massager will also be included, as to help with blood extraction. The data gathered from collected specimen of blood on the test strip will then be relayed to an existing meter to be displayed as a numerical value corresponding to the patient's blood sugar level.

Pros:
- Disposable disk of alternating lances and strips
- Conical intrusion to guide the patient's fingertip
- Massager to help with blood extraction
- See-through cover to provide additional comfort

Cons:
- Requires relay of information to existing meters, which requires glucose-detecting electrodes in the add-on itself, and they are patented/licensed
- Electrodes in the add-on itself seems extraneous, since we're coupling it anyway with existing meters which has them already

Design Idea – 2

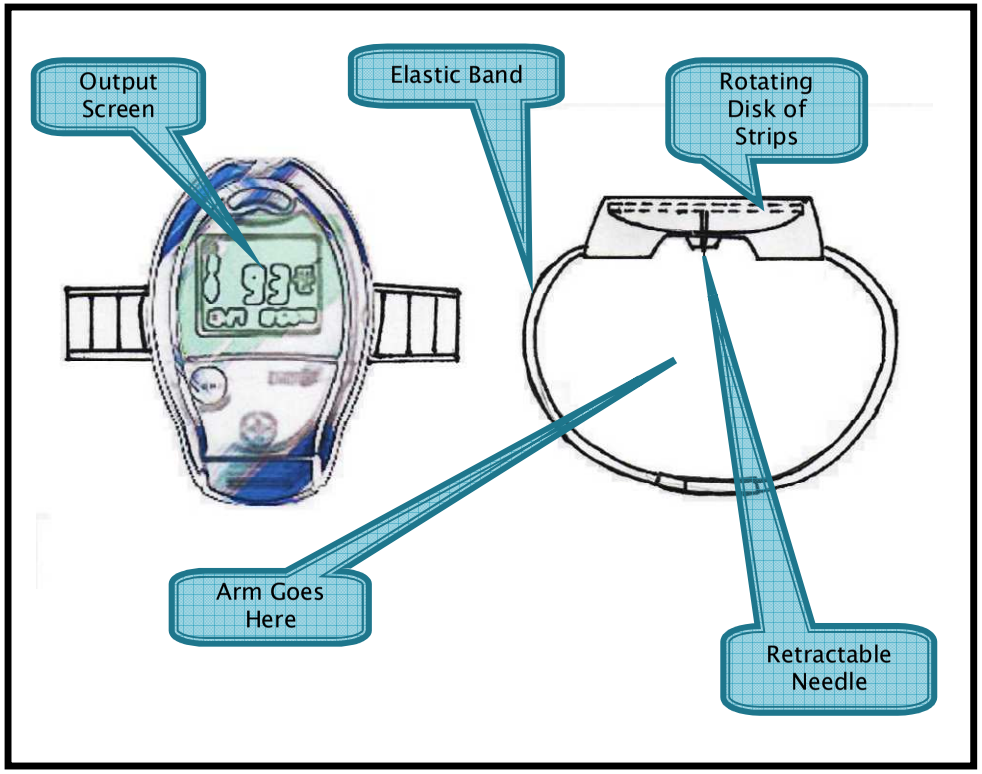


Description:
This is our DS4 – Idea 2. Similar to Idea 1, it's capability to load multiple strips and lances at once will help to eliminate the need for individual handling. The strips will come in conveyor belt-like packs, and the lances will come in rotating disks. Noticeably, the conveyor belt of strips has coupled to it an alcohol strip which the lances will puncture through, as to enhance sterilization. An inflatable ring or perhaps a cylindrical/conical channel will be implemented through which the patient will insert his/her fingertip and be guided to the testing site. Ideally, the ring/channel will also serve as a massager to help with the flow of blood at the patient's fingertip.

Pros:
- Disposable disks of multiple lances and strips to eliminate need of individual handling
- A guide for the finger, which will be helpful for patients suffering from dexterity issues

Cons:
- Having the lances puncture through the alcohol strip may introduce unwanted chemical reactions between the alcohol and the glucose oxidase located on test strips
- The original intention was to have the lances puncture through the test strips as well, which will require additional force (Additional research, however, revealed that currently there are manufactured strips with an inward groove along the side through which the lances can then come up next to without puncturing the strip itself.)
- This add-on design still requires relaying information to existing meters to be interpreted and displayed, since it's difficult to build our own meter. However, since existing meters already have sensors to read the data on the test strips, perhaps our finalized idea should incorporate existing meters more fully and take advantage of their built-in sensors.

Design Idea – 3



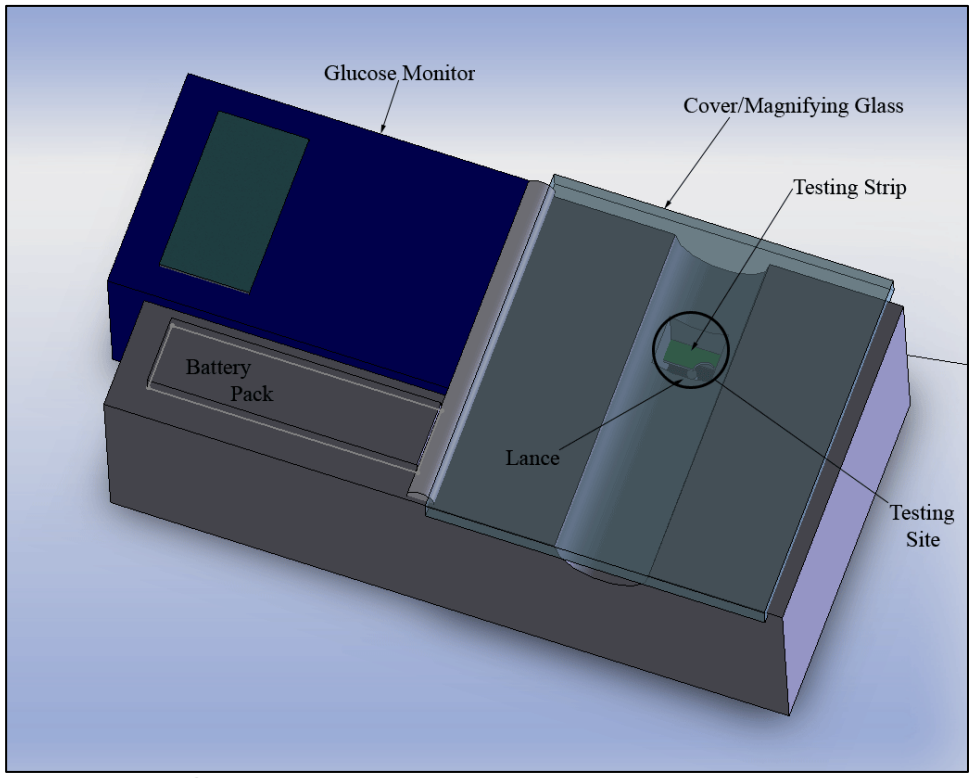
Description:
This is our stab at a more portable version of our add-on, for alternate site testing along the length of the arm rather than at the fingertips. We were hoping that this would be less painful for the patients, since there are more nerve endings gathered at the fingertips. Conceptually, the patient will strap on the add-on, and activate it at the press of a button. The add-on will be compatible with rotating disks of test strips, and a retractable lance/needle that punctures through the skin for blood extraction. We considered using a micro-needle for the retractable lance/needle, as to further reduce the pain experienced by patients during testing. Finally, information should be displayed by data relayed to existing meters (maybe wirelessly), or existing meters can be a part of the strap-on coupled to the add-on and modified to receive the gathered data.

Pros:
- Will ideally provide more portable support
- Capability to load multiple test strips, again to help eliminate the need for individual handling
- Alternate site testing along the arm, which has been said to be less painful than at the fingertips

Cons:
- Because it's meant to be portable, it should not be too bulky or heavy, which places a limit on the number of disposable strips it can load at a time
- For the same reason, it'll be difficult to make the retractable lance/needle also disposable and have multiple ones be loaded at the same time
- Maintaining sterility of a single lance/needle after multiple usages
- Micro-needles are still in developmental stages
- Requires feeding data to existing meters, as it's difficult to build a detector/meter of our own

DS5 – Chosen Idea

We modified our design in three major ways since our midterm presentation. Since we have decided to partnership with an existing company, we are now free to incorporate their existing glucose monitor into our device. Therefore, our device will serve only as an add-on to existing glucose monitors and we will not modify that monitor in any way. Consequently, we now need to address the issue of delivering the test strip to the monitor. Our conveyor belt and rotating disk idea both does not meet this design specification adequately. In place of those, we now use a linear slider to deliver the test strip from a spring loaded cartridge. However, there are existing meters with the ability to reload multiple test strips via a rotating drum and if we partner with Accuchek, for example, we can avoid having to implement our own replacement mechanism. At this point we are keeping the option open as to accommodate meters without the multi-strip loading capability, in the event that we can't reach a partnership with companies like Accuchek. Secondly, we have removed the alcohol pad from our design. After speaking with physicians at the Naomi Berrie Diabetes Center, we learned that alcohol pads tend to dry out the skin after repeated use. Finally, our add-on is now meant to be stationary rather than portable. We learned that for dexterity-impaired patients, grabbing on to a small glucose monitor may be challenging. An add-on that does not move is ideal since it provides extra stability. Portability is not entirely lost since the monitor may still be removed at any time.



Glucose Monitor – An existing glucose monitor will attach to our add-on and measure the patient blood glucose levels.

Testing Site – The patient places his finger in at the testing site where a lance will come up via a spring loaded mechanism. Blood from the patient's fingertip will fall down onto the testing strip.

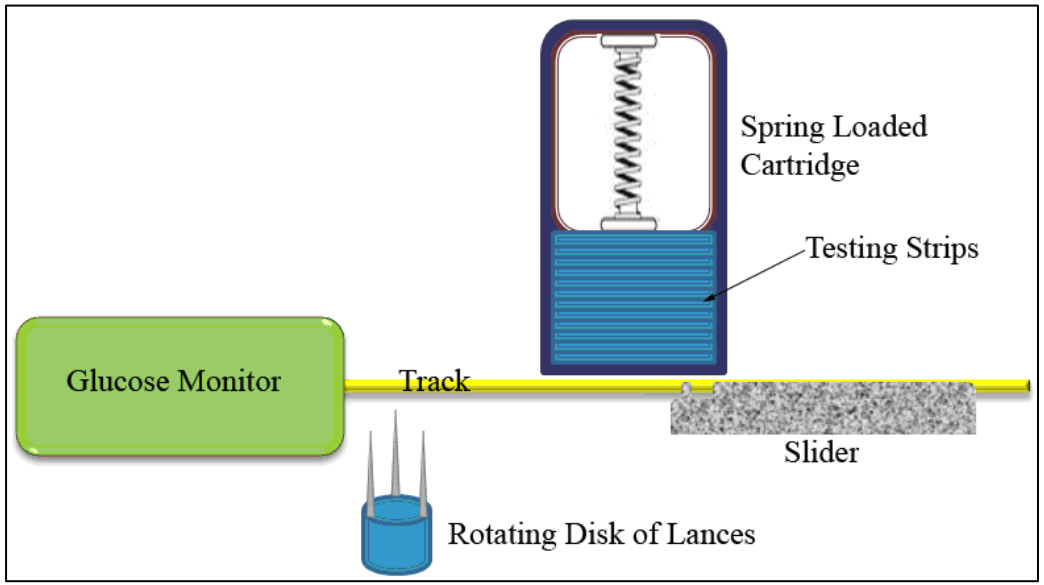
Testing strip – Contoured to facilitate absorption of blood from the patient's fingertip. In the diagram, it is already loaded into the machine. Replacement of the testing strip will be done by a linear slider.

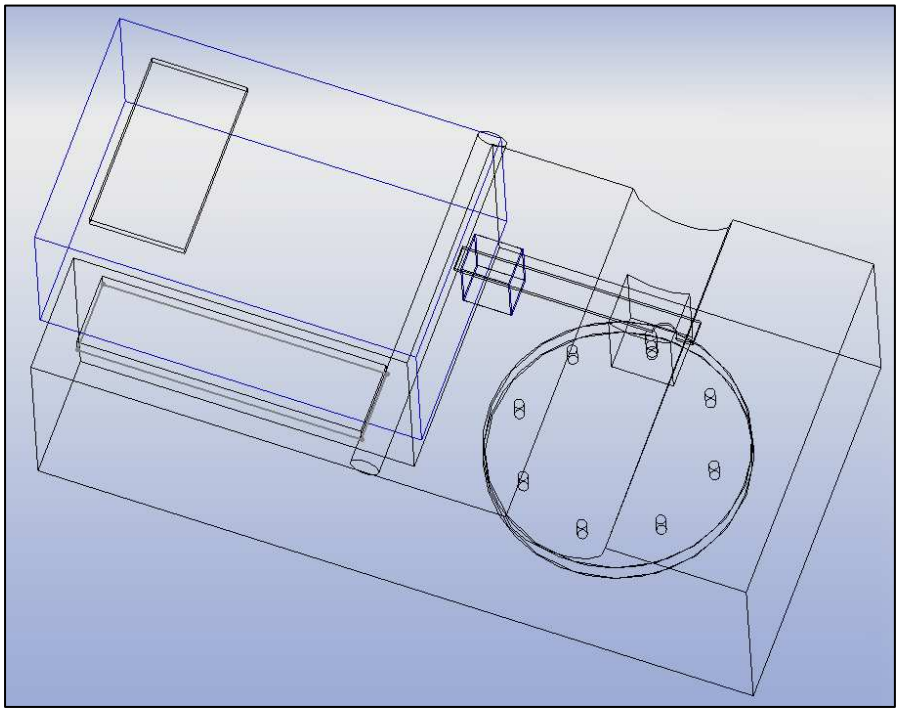
Lance – Loaded on a rotating disk of needles. Each individual needle is pushed up and the disk rotates to replace the needle.

Cover/Magnifying Glass – This piece of glass is hinged at the center of our add-on. When it is flipped to the side of the testing site, it functions as a cover, preventing dust from entering our testing site. When it is flipped to the side of the glucose monitor, it serves as a magnifying glass to make the numbers on the glucose monitor easier to see for visually-impaired patients.

Battery Pack – Since our device is meant to be stationary, the battery pack is mostly optional. However, it is available if the patient needs it.

Crevice – To help guide the finger to the testing site and stabilize it. In addition, a *restricting ring* (not depicted here) will also help guide and stabilize the finger as well as assist in squeezing blood from the finger.
The inner workings of our add-on are detailed in this schematic.



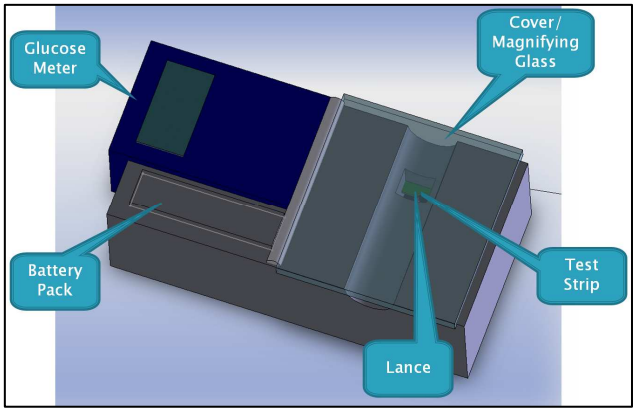


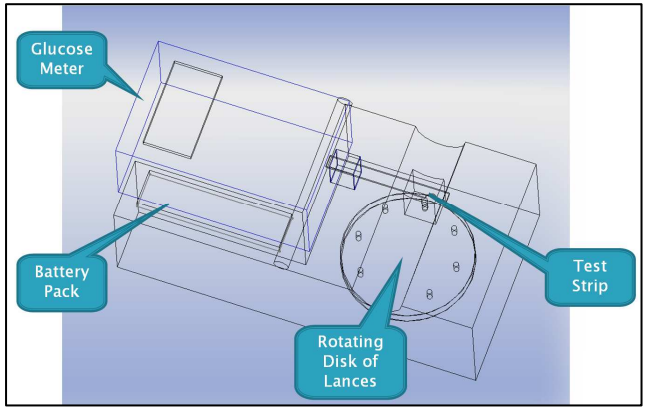
Slider – The slider will be made of an inert yet mechanically stable material like Teflon so that it does not interact with the chemicals on the testing strip. The slider will lock onto a testing strip and deliver it from the spring loaded cartridge to the glucose monitor and back. The slider will move along a track.

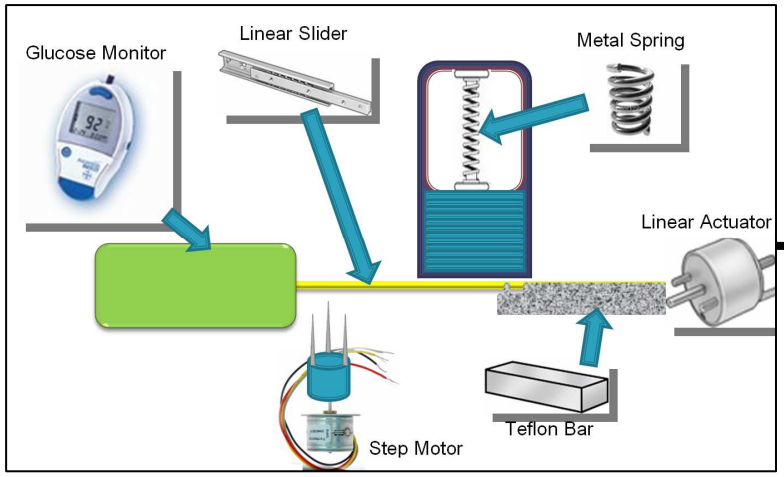
Spring Loaded Cartridge – A spring will press down on a vertical stack of testing strips. When the bottom-most strip is used up, a new strip is pushed down to replace it.

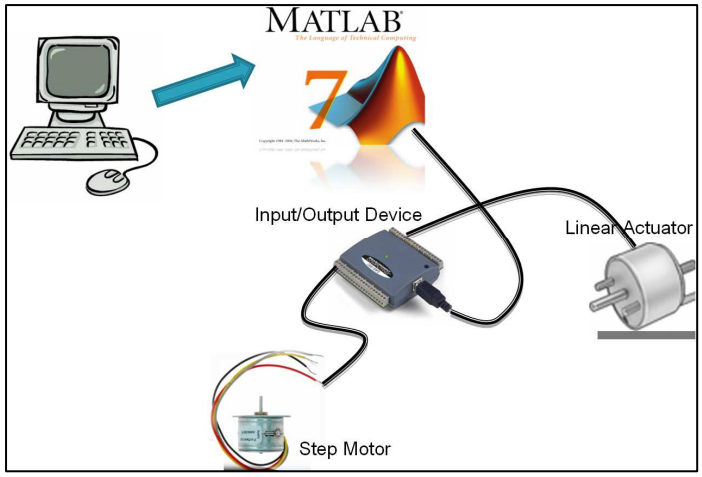
DS6 – Prototype Development Plan

Components and Setup







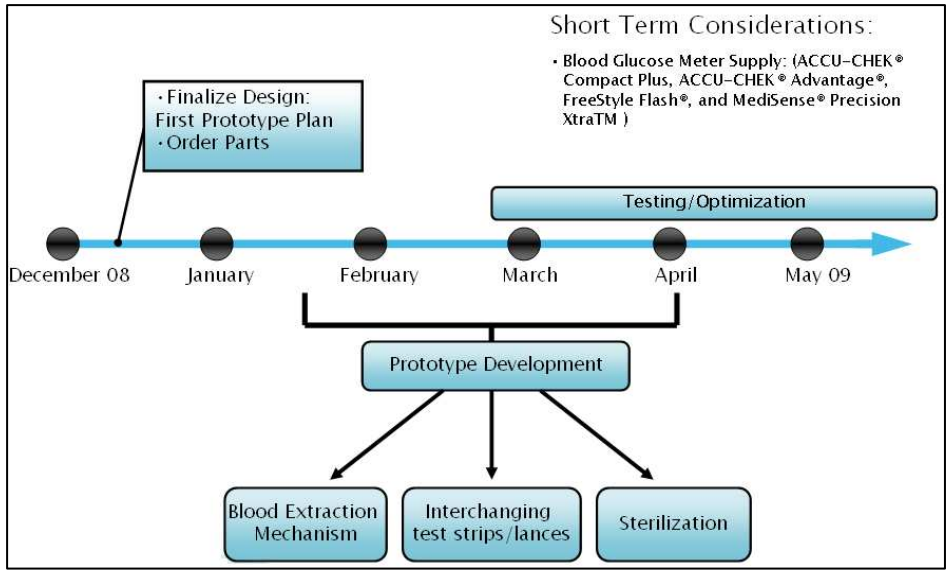


Our prototype will consist of a commercially available blood glucose monitor, linear slider, linear actuator, and step motor. In addition, a custom built spring driven cartridge will be built to house the test strips. To coordinate and test the movements of the step motor and linear actuator, a MATLAB program will be written to control these components. We hope to eventually automate the process on a portable platform such that the mechanical parts are controlled by the user. Also, we will intend to make the changing of test strip cartridges and disk of lances easier for the user by making them more accessible.

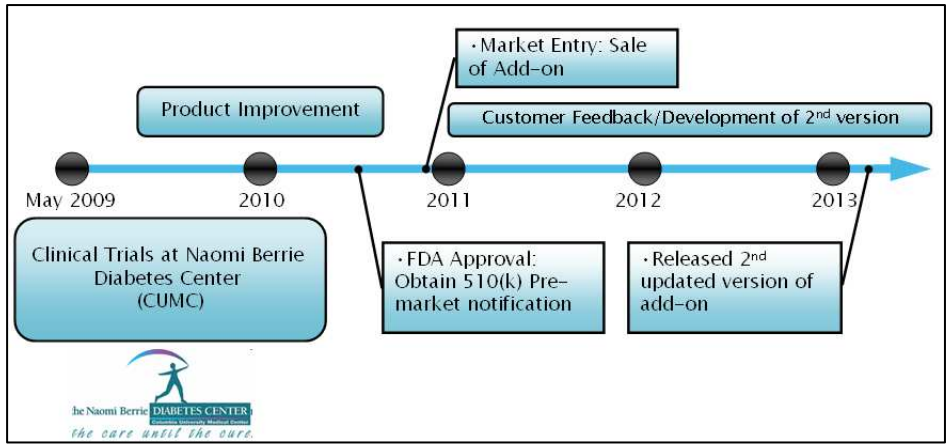
Projected Development Timeline

For our development plan, we are looking to first, finalize our design and order the necessary parts for first prototype development next spring. In the first few months of 2009, we will begin the initial phases of prototype development which involves engineering the mechanics behind our blood extraction mechanism, the interchanging of test strips and lances, as well as sterilization. During this process we will continually perform testing and optimization of our working prototype. In our long term plans, we wish to begin clinical testing offered by the Naomi Berrie Diabetes Center up at Columbia University Medical Center by May 2009. We will then hopefully obtain 510(k) pre-market notification for market entry by 2011. Once we enter the market, we will continually obtain customer feedback and proceed with the development of the 2nd iteration of our device. Hopefully by 2013, we will release this 2nd updated version of our add-on.

Short Term



Long Term



Costs

In addition to the $500 budget allotted to our team by the Biomedical Engineering Department, we have been given a generous supply of blood glucose meters (ACCU-CHEK® Compact Plus, ACCU-CHEK® Advantage®, FreeStyle Flash®, and MediSense® Precision Xtra™), test strips, and lances to work with during prototype development. The following table lists required components, manufacturers, prices, quantities, and total projected cost. Depending upon the chosen blood glucose monitor to be incorporated into our design, we plan to rapid prototype the test strip cartridge as well as the housing which encases the mechanical parts of the device.

Component	Supplier	Price	Quantity	Cost
Stepper Motor	Digi-Key	$17.74	2	$35.48
Linear Slider	McMaster-Carr	$89.95	2	$179.90
Spring-loaded Cartridge	Spring: McMaster-Carr Cartridge: Rapid Prototype	$7.87	2 Pack (6)	$15.74
Linear Actuator	Anaheim-automation	$74.10	2	$148.20
Page Magnifier	McMaster-Carr	$1.65	2	$3.30
Blood Glucose Monitors	Donated by Naomi Berrie Diabetes Center	N/A	N/A	N/A
Teflon Bar	McMaster-Carr	$19.95	2	$39.90
			Total Cost	$422.52