Continuous Glucose Monitoring
2012

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Disclosure of Relevant Financial Relationships

• Was on Board of Directors of Minimed, Inc. (prior to acquisition by Medtronic) at time of development of the first continuous glucose monitoring systems.
• Currently on Board of Directors of Dexcom, Inc.

History of CGM

Nature 1967; 214:986–988

Glucose + O2 → Gluconic Acid + H2O2

Updike
Enzyme Electrode Glucose Sensor

The Enzyme Electrode

Glucose Oxidase

Glucose + O2 → Gluconic Acid + H2O2

Updike
Glucose Enzyme Electrode

• Nature; volume 214; 986-988, June 3, 1967
• SJ Updike and GP Hicks

Soeldner
Platinum Electrode Glucose Sensor

Nature 1967; 214:986-988

Glucose Oxidase
Wilson
Implantable Glucose Sensor

Gough
Implantable Glucose Sensor

MiniMed-MRG
Implantable Glucose Sensor

Dexcom Implanted Continuous Glucose Sensor System
Shichiri Wrist-Watch Type Glucose Monitoring System

CGM Products

Cygnus GlucoWatch Biographer Minimally Invasive Iontophoresis System

Menarini GlucoMen®Day Microdialysis System

MiniMed Continuous Glucose Monitoring System (CGMS)

MiniMed Guardian Telemetered Glucose Monitoring System
Dexcom G4
Continuous Glucose Monitor

Dexcom sensor technology will communicate with several insulin pumps

Navigator, Dexcom G4, and Medtronic Enlite Comparison

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CGM for ICU

Echo Symphony tCGM System

Prelude-SkinPrep System
- Painlessly removes stratum corneum for accurate measurement of glucose
- Patented feedback control mechanisms for optimal skin permeation

Transdermal Glucose Sensor
- Electrochemical glucose sensor plus short-range RF transmitter
- Affixed to area prepared with Prelude

Wireless Remote Monitor
- Accurate readings
- Compatible with ICU software
- Potential use for other devices
- Customizable early-warning alarms for hypo- or hyperglycemia
**Echo Symphony tCGM System**

**Optiscanner**

**Optiscanner Outline**

**GlucoClear, Hospital-Based System**
Collaboration between DexCom and Edwards Lifesciences

**Technologies for Non-Invasive Glucose Monitoring**
- Near infrared spectroscopy (NIR)
- Mid-infrared spectroscopy (Mid-IR)
- Optical coherence tomography
- Temperature-modulated localized reflectance
- Raman spectroscopy
- Polarization changes
- Ultrasound technology
- Fluorescence technology
- Thermal spectroscopy
- Ocular spectroscopy
- Impedance spectroscopy
- Electromagnetic sensing
- Fluid harvesting
- Iontophoresis
- Crystalline colloidal array (CCA) technology
CGM Proposals

**Futrex Dream Beam**
Near Infrared Spectroscopy System

**Biocontrol Diasensor**
Near Infrared Spectroscopy System

**Sensys Medical Systems**
Near Infrared Spectroscopy System

**Instrumentation Metrics**
Near Infrared Spectroscopy System
Cybiocare Photonic Glucose Sensor
Near Infrared Continuous Alarm System

InLight Solutions
Near Infrared Spectroscopy System

Visual Pathways Inc. GlucoScope Monitor
Infrared light to measure glucose in the eye

Infratec Thermal Emission Spectroscopy for Noninvasive Measurement of Tympanic Membrane Glucose

PreciSense Fluorescence Resonance Energy Transfer Glucose Sensing System

Pendragon Electromagnetic Wave Glucose Sensing System
**Sensors for Medicine & Science**

**Light Emitting Diode**

- Fluorescent glucose dehydrogenase biosensor
- Rigid, non-invasive encasing

**OrSense Occlusion Spectroscopy Technology**

- Monitor reveals glucose level through skin

**SpectRx MicroPore Glucose Sensing System**

- The transdermal glucose monitoring technology involves a patch that may be placed almost anywhere on the body.
- The sensor is connected to a reader and transducer.
- Minimally-invasive (ISF)
- Micropore sampling

**Cell Robotics MicroPore Glucose Sensing System**

- Lanced Micropore

**Glucom Medical Reverse Iontophoresis Glucose Wristband**

- Inserted into the subcutaneous adipose tissue
- Double lumen catheter
- Acquires glucose readings every 30 minutes
- Goal – subcutaneous glucose sensing/insulin delivery system

**ADICOL Project**

- Percutaneous micro-pump
- Dual lumen probe

Integrity GlucoTrack
ultrasonic, electromagnetic and thermal noninvasive glucose monitor

C8 Medisensors
Wearable Raman Spectrometer for Noninvasive Glucose Monitoring

BD Glucose Binding Protein

Nano-engineered Fluorescence Fibre-Optic Glucose Sensor Microcapsules Based on Glucose/Galactose-Binding Protein

Reversible Near-Infrared Fluorescence Quenching of Surfactant Suspended Single-Walled Carbon Nanotubes in Response to Glucose

Impedance Spectroscopy for Glucose Monitoring
**Solianis Impedance Spectroscopy**

**Fluorescent Hydrogel Fiber for Long-term In Vivo Glucose Monitoring**

Heo Y J et al. PNAS 2011;108:13399-13403

In vivo continuous glucose monitoring in mice using the implanted fibers


**GlySens Sensor Array with Integrated Telemetry System**

iSenseiSense (now Bayer)

• 4 metrics
• Snap Shot
• Movie
• Box Graph
• Continuous Glucose Moving Average
**Electrochemical Non-enzymatic Glucose Sensors: A Perspective and an Evaluation**

The fabrication of a variety of nanostructures and modification of relatively new electrode materials, though aesthetically pleasing in the publication, are posing no significant improvement relative to enzymatic electrode design.

The sophisticated and innovative 'wired' enzyme design developed by Heller et al over the past 20 years epitomises the idea of a new and exciting electrochemical approach, and it is a comparable advancement that is missing from non-enzymatic research.


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**Review of Fluorescence-Based Glucose Sensors**

There are few fluorescence-based glucose detection methods that have reached the stage of testing in vivo, and none have entered clinical practice in diabetes management. This will clearly be an area of active investigation in the coming years—we will need, for example, to explore potential interferents and the stability and accuracy under real-life conditions.

Non-invasive glucose sensing is the ultimate goal of glucose monitoring, but the most investigated approach, nearinfrared (NIR) spectroscopy, is presently too imprecise for clinical application.

Pickup et al. Biosensors and Bioelectronics 2005; 20:2555–2565

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**Current Problems and Potential Techniques in In Vivo Glucose Monitoring**

For implanted devices, poor biocompatibility of the materials used for fabrication remains a major challenge, whilst progress in the commercial development of non-invasive devices is hampered by the problem of multiple interference between the detected signals and the biological components.
