Computer Technology in Insulin Based Therapy of Diabetes

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Summary

Diabetes mellitus is a metabolic disorder characterised by chronic hyperglycaemia. Glucose regulation is one of the most refined ones in the body. Even slight elevation of glucose results in many hormonal and metabolic actions and it is able to produce devastating organ damages. While treating diabetes with insulin the key word is information. On the basis of information important decision considering diabetes therapy are done every day. Information technology gives possibility for rapid and easy exchange of information from patients to clinicians. In the paper the innovative use of computer technologies in health care of diabetes is presented: for education, collecting, viewing and interpreting home monitoring blood glucose data, for short and long-term glycemic control and also as a part of telemedicine techniques. At the end conclusions regarding computer technologies in insulin based therapy of diabetes mellitus improving health care utilisation in diabetes care is given.

Key words: Information and communication technology, Diabetes mellitus, insulin based therapy

Introduction

The incidence of diabetes mellitus has epidemic proportions both in the developing and developed world (http://www.who.int/diabetes/). This phenomenon has been attributed largely to westernised life style pattern and higher proportion of type 2 diabetes mellitus (Report of a WHO Consultation, 1999).
Diabetes mellitus is a metabolic disorder characterised by chronic hyperglycaemia (long term elevated blood glucose) with disturbances of carbohydrate, fat and protein metabolism. Those disturbances are resulting with defects in insulin secretion, insulin action, or both.
Sudden blood glucose elevation for a short time causes so-called “acute complications” that are life threatening and should be treated immediately. The most severe forms like ketoacidosis or a non-ketotic hyperosmolar state require immediate medical care. In conditions when blood glucose is elevated for a longer time, mostly without severe symptoms, many damages on different body sys-

tems occur. For example, eye damage from small changes to blindness, kidney damage from slight laboratory alterations to heamodialysis, vascular damage from subclinical ones to cerebral or myocardial stroke, poor peripheral circulation from undetectable one to gangrene and limbs amputation, neural damage etc. The two big famous studies Diabetes Control and Complications Trial (DCCT) and United Kingdom Prospective Diabetes Study (UKPDS) clearly illustrated that strict glicaemic control delays the onset and slow the progression of chronic complications (The DCCT research group, 1993 and UKPDS Group, 1998)

Glucose regulation is one of the most sophisticated ones in our system. Only slight elevation of glucose results in many hormonal and metabolic actions but that small elevation for a longer time produces described organ damages. Sudden drop in glucose level can result in hypoglycaemic coma and death.

Insulin, a key hormone in diabetes, is secreted from the pancreas. It regulates glucose uptake from the cell and controls many other metabolic processes. There are many types of diabetes mellitus, but most common ones are Type 1 and Type 2. In Type 1 diabetes mellitus (this type mostly occurs in childhood or in younger age before 30 yr.) humans one antibodies attack insulin secreting cells in pancreas. Destruction of such cells (called beta cells) results with immediate blood glucose elevation. Those people need insulin lifelong to survive. In type 2 (this type mostly occurs in older population) there is enough insulin- even more than normal. This insulin is not effective enough and those patients are "insulin resistant". Sometimes, not obligatory, they need insulin in therapy too.

In 1922 a 14-year-old boy Leonard Thompson, patient with diabetes type 1, was dying from ketoacidosis. He was the first patient who got insulin in therapy. Without insulin he would dye in a few days, but the fact that he lived 13 years more was considered a miracle. This historical event happened in Toronto General Hospital. Today we want that our diabetic patients all over the world live as long as non-diabetic people, we strive that they have as less complications possible and that they have good quality of life too.

So, what can we do to imitate nature? To replace complex mechanisms of glucose regulation without our own normal insulin function? It seems that some help of technology is required. Western civilisation develops every day more sophisticated, faster, reliable equipment supported by information science and technology that could be applied also in insulin treatment.

Computer technology

While treating diabetes with insulin the key word is *information,* the same word used in many other technologies. Information is necessary because on the basis of the information important decisions are done many times, every day.

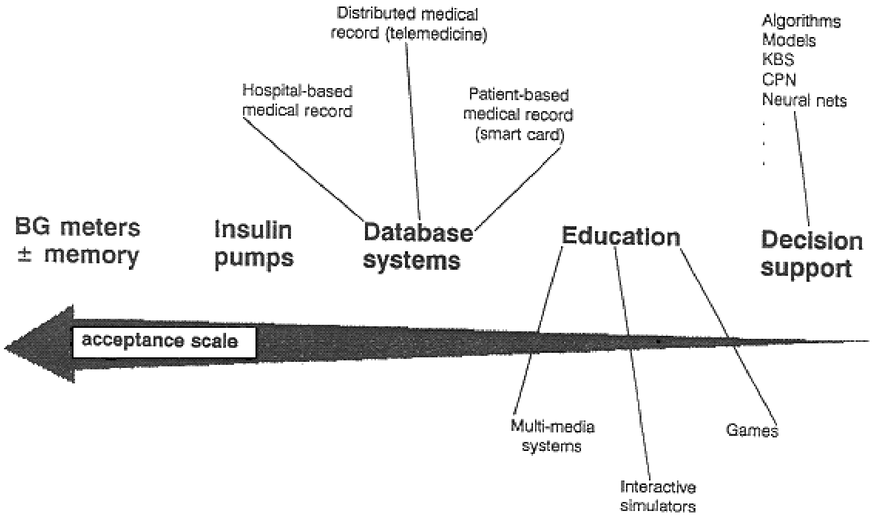
Question like following are asked … What is happening with me today? How high is the glucose level now? Am I going to eat a lot? Is my food going to contain many carbohydrates? Am I going to perform an exercise and for how long? How much insulin should I apply? Which type of insulin should be applied and when? When is the proper time to measure blood glucose again? … and many others. It is not possible to have available physician (or some other health care provider) near the patient constantly in every moment of the day.

All diabetic patients with insulin therapy (or in some circumstance members of family, or people who are taking care about patient) should be educated to answer questions like those mentioned above. Physician is contacted in time of crisis (sudden illness, sudden elevation or drop of blood sugar) and during the regular check. Information technology gives possibility for rapid and easy exchange of information from patients to physician or from one physician to another, and allows interactive communication.

Computer technologies are used for collecting, viewing and interpreting home monitoring blood glucose and diagnostic glycation tests. They are in use for insulin delivery, artificial and bioartificial pancreas, educational software, databases, for use of new biomaterials, development of new sensors etc. Finally there are telemedicine techniques connecting patient and health care provider.

There are many scientific reports about diabetes and technology published in many journals; one of them is Journal of Diabetes Science and Technology, a bi-monthly, peer-reviewed scientific e-journal published by the Diabetes Technology Society (www.journalofdst.org).

Picture 1. Applications of information technology in clinical diabetes care



Lehmann E.D. Application of information technology in clinical diabetes care Part 2. Models and education. Medical Informatics, 1997; 22, (1), 1-120

Even in recent times there were many doubts concerning computer technologies in diabetes including papers with question like “Designing computer-assisted instruction programs for diabetic patients: how can we make them really useful?” (Juge CF, 1992) However, today there is more and more evidence confirming necessity of introduction new technologies into diabetics’ daily routine. Picture 1 shows how widely some computer applications were accepted in routine clinical practice five years later. In further text computer technologies are described in same order.
The acceptance scale indicates how widely such applications were adopted in yr. 1997 into routine clinical practice. Education and decision support could be either for patients or healthcare students / professionals. (BG = blood glucose; KBS = knowledge based system CPN = causal probabilistic network).

Algorithmic-based decision support systems

Medical algorithms are decision trees that help making choice on the basis of many information collected previously. Computerised algorithms can provide support of clinical decision while being adherent to evidence based guidelines. Evidence based decisions in those solutions are up to date Some of them cover variety of scenarios and could be helpful in everyday practice.
Though, algorithms are not capable to manage all situation that diabetic patient with insulin meets. The plan of algorithmic based support system is to provide set of schemes by which patient can adjust a therapeutic insulin routine and achieve the desired glicaemic control. Albisser (Albisser A.M, 1996) described algorithmic, telemedicine-based system called HumaLink. Patient who measures blood glucose regularly accesses HumaLink system from touch-tone telephone available 24 hours a day. Unique identification number opens a variety of verbal instructions from speaking system. Patients are entering data like for example: blood glucose level, current illness, physical activity, meals etc. The HumaLink system then relays instructions in accordance with an individualised treatment plan programmed by caller’s physician.
The decision about insulin dosage is done in fully automated advisory mode or in manual recording/documenting mode. The first one, a fully automated mode, applies algorithms to modify insulin dosages within pre-defined limits set by the physician automatically. The other one, manual’ recording mode logs the patient’s readings and a physician reviews the data before leaving a verbal message for the patient on the system.

Educational tutorials

As already mentioned, extremely important part of the insulin therapy is education: how to use insulin and control its effect. There are many types of education: a group education, a single education etc. (Zgibor JC, 2007). Mostly, patient gets first information in direct contact with health care provider-a medical educator. For further information or repetition Internet could be an option.

There are web sites designed for educational and teaching purposes. Some web pages describe basic instruction like "how to apply insulin", other more sophisticate ones provide examples of diabetes case scenarios with problems to be slowed (Reed K, 2006).

On the basis of educational level or current situation it is possible to choose a scenario (pregnancy, low glucose, flu etc.) and tray to solve it. Some tutorials combine written information with an interactive diabetes simulator. AIDA, available on the World Wide Web since 1997/1998 without charge is one of such sites (http://www.2aida.net/welcome). It′s purpose is strictly highlighted: *AIDA is only for general use, without intention to provide personal medical advice or substitute advice of doctor.* AIDA is constantly growing. Enhancements of the software are accompanying insulin development and innovations (Lehmann ED, 2007). Educational systems are also used for teaching purposes of health care professionals, especially students.

Databases

Databases in a global view are the basis of modern health care service. Many different computer database programs that consider diabetes are being developed with more or less success-DIAMOND, DIABCARD, DIABTel etc. (Lehmann ED, 1995). The basic idea of such databases is that information about patient with diabetes is accessible locally, regionally and nationally for statistics, research and clinical practice. Some of the mentioned databases are accessible for primary, some for secondary care, or for both. The "must be" is data security and patient confidentiality while transferring the data.

In 1997, the same year when AIDA was introduced on www, a database system in Croatia called CroDiabNET was initiated for the first time (Metelko Ž, 2001). It is a first register in Croatia based on daily data entries from everyday clinical practice. The basic information sheet is the main part of the system. It contains all the data collected on regular check-ups (identification data of patient with diabetes, type of diabetes, year of diagnosis, treatment started date, oral drugs/insulin introduction, purpose of visit, risk factors, blood glucose self-control, education, body weight, height, blood pressure, laboratory data, complications of diabetes, other diseases etc.). Croatian National Diabetes Registry is firs public health registry where users can input data through www (http://crodiab.continuum.hr).

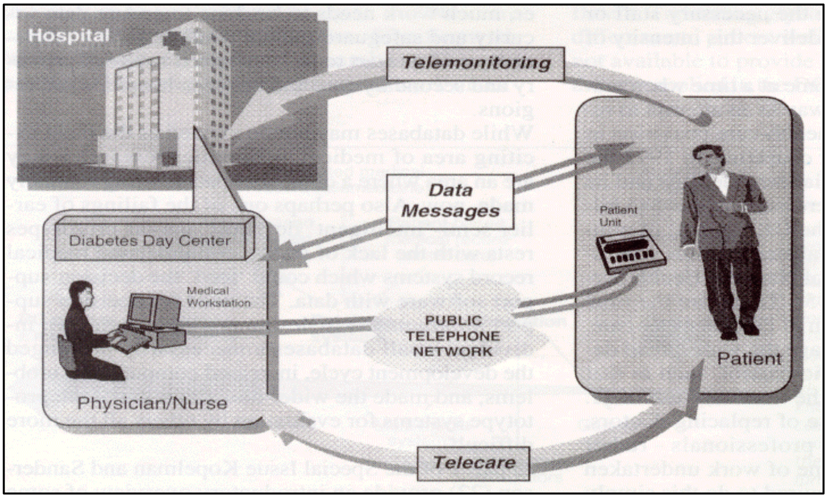
Practical application started in 1999; at the end of 2003 data from 33,000 patients in 19 centres in Croatia have been collected. The program is currently being used in the referral centre, regional centres for diabetes, county centres and other diabetes centres. CroDiabWEB has been designed for the annual registration of diabetic patients at the general practitioners' offices.

Telemedicine

Telemedicine is medicine at distance or use of computers and computer networks with the idea to facilitate communication among two or more medical professionals or among medical professional and patient. Telemedicine exchanges health care services without necessity to be present at the same time in the same place (McLaren P, 1995). The first experiences from 1960th in North America and Northern Europe intended to improve communications between patients and physicians, but now there is a trend to assist in everyday situation.

A good example is a small Italian study from 2003 that proved telemedicine provided benefit in treatment of insulin dependant diabetes. (D’Annunzio G, 2003) A system of two main components was used: a medical unit (web-based workstation) in the hospital close to the health care provider and a patient unit (patient logbook, therapy consultation, electronic messages, communication system; implemented as a PC based software). Both were connected trough a telecommunication system. Through telemedicine system patients were able to send easily their self-monitoring data of the glucose level, insulin dosages and urinalysis. The data were sent weekly. During mean follow-up period of 415 days, 901 blood glucose levels per patient were collected and analysed. An increase of links between patients and physicians were noticed.

Picture 2. Telemedicine for diabetes care using telephone communication



Gomez E., del Pozo F., Hernando E.: Telemedicine for diabetes care: the DIABTel approach towards diabetes telecare. Med. Inf. 1996; 21: 283-295

In particular, the medical unit sent to the patient unit an average of 56 messages; and an average of 35 messages were sent by the patient unit to the medical unit. The system seemed to be feasible and provided clinical benefits. The most in-

teresting thing was that the patents were children aged 9.9-15.8 years who were open towards new technologies.
Today, benefit of telemedicine is discovered in many countries, also in Croatia. 2007 began a pilot project called “Telemedicine on Croatian islands”. The aim of the project is to connect and improve health care on the Croatian islands (http://www.mmpi.hr/userdocsimages). Picture 2 shows a simplified example of interaction between hospital and patient through telemedicine.

Glucose monitoring and insulin pumps

Today’s majority of diabetes computer technology is used in glucose monitoring and recently in insulin pumps. Usual method of checking glucose levels is pricking a fingertip and then using a glucose meter that measures the blood sample’s glucose level.
Continuous glucose monitoring systems use a tiny sensor inserted under the skin that checks glucose levels in tissue fluid. The sensor in inserted in average for three days, during this time a transmitter sends information about glucose levels through radio waves from the sensor to a pager like wireless monitor. Special software is available to download data from some glucose meters, or continuous glucose monitoring systems. In that manner it is possible to display trend graphs on the monitor screen.
Data management systems can store hundreds of test results and other information (the time and date of analysis, types and doses of insulin, meals, and a log of exercise). Almost 10 years ago motivated patient could print the graphs and take them to the clinic (Lehmann ED, 1999), but today graphs can be easily send by mail.
Insulin pump is a device that delivers insulin continuously into the body. In that way it imitates better physiological insulin secretion then standard insulin application. Insulin pump consists of the pump itself (including controls, processing module and batteries), a reservoir for insulin inside the pump (patient is refilling the reservoir), a disposable infusion set (patient is changing the set every 2-3 days). A disposable infusion set has a short tube with a needle (cannula) placed under the skin and a tubing system that connects insulin reservoir to the cannula. Insulin pump delivers insulin for 24 hours*: a basal rate* continuously and short smaller doses before meals*: a bolus*. The physician predefines a basal rate, mostly after analysis of continuous blood glucose monitoring data sheet. A bolus doses are set before the mealy by the patient. An insulin pump eliminates individual insulin injections and improves glicaemic control. It requires maximal co-operation of the patient and some technology skills.
The latest, still experimental project is an artificial pancreas. Artificial pancreas integrates continuous glucose monitoring and insulin pump with a closed loop system that provides the right amount of insulin at the right time. The data from continuous glucose monitoring are providing blood glucose reading every few minutes; a sensor is connected via wire to the insulin pump. Blood glucose

variation is signalling automatically to the pump sending information how much insulin to deliver (Friedrich M J, 2009).

Conclusion

There are many evidences that computer technologies are applicable in the insulin-based therapy of diabetes mellitus. A large meta-analysis of twenty-six studies (with over 4,811 participants) reported that interactive information technology in diabetes care improved health care utilisation, behaviours, attitudes and knowledge (Jackson CL, 2006).
Though, there is still much to learn and to improve. Technology sets new demands to the both patient and physician. Patient with diabetes needs to be more proactive and needs to learn both medical and computer skills.
At the end, I would like to quote Aaron Kowalski, research director of the Juvenile Diabetes Research Foundation’s Artificial Pancreas Project: “We have data on hand today that suggests that you could get much better diabetes outcomes with the computer taking the lead instead of the person with diabetes doing it all themselves.” In 1977, at the age of three, Dr. Aaron Kowalski’s brother Stephen was diagnosed with type 1 diabetes. In 1984, at the age of thirteen, Aaron himself was diagnosed with type 1(http://www.jdrf.org).

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Links

http://crodiab.continuum.hr (15.9.2009)
http://www.2aida.net/welcome/ (15.9.2009)
http://www.jdrf.org/ (15.9.2009)
http://www.journalofdst.org/ (15.9.2009)
http://www.mmpi.hr/userdocsimages/2007/vrh-252-09-otoci-zdravst.pdf. (15.9.2009)
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