DiasNet – an Internet Tool for Communication and Education in Diabetes

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Abstract. Although studies have shown that intensive diabetes treatment with the goal of maintaining blood glucose concentrations close to the normal range lead to a substantial reduction of the rate of the complications (e.g. blindness, kidney failure, amputations and circulatory diseases), this can be difficult to achieve using conventional means. It is recognised that a number of patients may have poor control despite specialist care, and this along with devolution of care to non-specialists suggests that alternative interventions should be developed. DiasNet, which is used by patients as a tool for education and communication, is based on a well documented decision support system used by clinicians to give advise on insulin dose. In DiasNet the patients can experiment with their own data, adjusting insulin doses or meals sizes, and thereby learning how to cope with various situations. The system can run both as an ordinary application on a standard PC, and as an Internet application using a standard web browser. The latter enables a new way of communication between patient and clinician. DiasNet is currently being tested on a small group of diabetes patients.

1. Introduction

Diabetes mellitus is one of the major chronic diseases and a growing public health problem in both developed and developing countries [1]. A WHO expert group has estimated that more than 100 million people suffer from diabetes - 10-15% with the insulin dependent form. Diabetes' direct costs in the U.S.A. in 1992 is estimated to represent 5.8 % of total personal health-care expenditures, which again represented over 14% of the GDP, and the indirect costs were even higher. In Europe diabetes is estimated to consume about 10% of the total health care budget. The substantial loss of quality of life associated with diabetes is mainly due to the so-called late complications: blindness, kidney failure, amputations and circulatory diseases. Although studies have shown that intensive diabetes treatment with the goal of maintaining blood glucose concentrations close to the normal range lead to a substantial reduction of the rate of the complications, this can be difficult to achieve using conventional means. These studies also showed that intensive treatment also leads to an increase in the frequency of severe hypoglycaemia. It is recognised that a number of patients may have poor control despite specialist care, and this along with devolution of care to non-specialists suggests that alternative interventions should be developed [2].

Decision support systems provide a possible answer to this problem, and many solutions have been proposed over the years. Some of these are based on rules or algorithms for insulin dose adjustment based on expert knowledge [3, 4], and some have used predictions of blood glucose levels based on mathematical models of the carbohydrate metabolism [5, 6]. Other systems are based on a combination of the two approaches. Despite the many lessons learned from this substantial work, none of the systems has gained widespread use or acceptance.

There may be several reasons for this apparent lack of success. One reason might be the difficulty in handling the interpatient and intrapatient variability, and other reasons might be the uncertainties in the data involved and the fact that the glucose metabolism is influenced by many factors, e.g. stress, fever, exercise and hormonal reactions to low blood glucose. Still other reasons for the evident lack of success might be the problems associated with evaluation of the safety and efficacy of the systems, which several authors have dealt with [7, 8]. The Internet based tool described in the present paper, is developed under the assumption that a decision support system in the classical sense may not be enough – that more emphasis should be put on patient empowerment, and that the keywords are *education* and *communication*.

2. Background

Dias, the Diabetes Advisory System, is a computer system for the management of insulin dependent diabetes [9, 10]. Dias incorporates a model of the human carbohydrate metabolism, which has elements describing the carbohydrate content in two compartments, the blood and the gut, as functions of processes in various organ systems. The model is implemented in a causal probabilistic network (CPN or Bayesian network), which gives it the ability to handle the uncertainty, for example, in blood glucose measurements or physiological variations in glucose metabolism.

Dias is operated in two modes: the learning mode and the prediction mode. In the learning mode standard data on blood glucose concentration, insulin injections and carbohydrate intake from one or more days are used to estimate patient specific parameters – i.e. the system is adjusted to fit to each individual patient. In the prediction mode the estimated parameters are used to make predictions of the blood glucose concentration, given the carbohydrate intake and insulin regimen. This mode can be used to predict unrecognised hypoglycaemia or to predict the effect of suggested changes in the insulin regimen or meals on the blood glucose concentration.

Dias has been evaluated in a series of studies. Two studies have verified the ability of the model to accurately predict blood glucose, and, as a part of this, to predict nocturnal hypoglycaemia. Furthermore, five small clinical studies, where Dias was used to give advice on insulin dose, have been performed. Table 1 summarises the results from the controlled clinical studies. It should be noted that the study in 1993 in London was mainly focused on the safety of using Dias, and that in the other four studies the mean reduction in HbA1c for the patients using Dias was 1.2% compared to 0.3% for the patients in the control groups (using advise from experienced clinicians), with a mean reduction in hypoglycaemia of approximately 0.3 episodes per day in the Dias group. A 1.2% reduction in HbA1c corresponds to a reduction in the risk of complications of approximately 30-40%.

Even though the results may seem to indicate a benefit from using Dias, the studies also revealed some weaknesses:

First of all, the restrictions imposed by the study protocols, especially in the earlier studies, made the trials quite different from using the system in real life situations: For example, the first two studies were double-blind, and in the first study Dias was used to adjust the insulin dosage based on only one set of collected data per patient, whereas in the later studies, a more flexible protocol was used allowing for up to 6 adjustments in the most poorly regulated patients.

On the other hand, the later studies, where the patients were sitting in front of the computer, while the system was used to analyse their data, showed a clear benefit from using Dias to explain, for example, the rationale behind changing insulin regimen to the patients – in fact, many patients showed a striking enthusiasm seeing their data being used to generate their own personal advice.

Table 1. Summary of the results from the controlled clinical studies. Significant differences are denoted by a *.

Year	1993	1993-94	1994-95	1997-98	1998
Clinical site	London UK	Sønderborg Denmark	Aalborg Denmark	Portsmouth UK	Foligno Italy
Number of patients	20	12	13	20	17
Double-blind	Yes	Yes	No	No	No
Reduction in hypoglycaemia (episodes per day) Dias vs. control group	0.0 vs. 0.0	N/A	0.3 vs. 0.1	0.2 vs. ÷0.1*	0.3 vs. N/A
Reduction in HbA1c (%) Dias vs. control group	N/A	1.9 vs. 0.9	0.6 vs. 0.3	1.5 vs. 0.8*	0.8 vs. ÷0.5*
Significant difference between Dias and control group ($p<0.05$, denoted by a *)	No	No	No	Yes	Yes

3. DiasNet

Based on the experience from the clinical studies, a new web based prototype, DiasNet, is now being implemented:

First of all, the scope of this version of the system has been shifted; from being used by clinicians to give advise on insulin dose, to being used by patients as a tool for education and communication. This means that the patients can experiment with their own data, adjusting insulin doses or meals sizes, and thereby learning how to cope with various situations. The system can run both as an ordinary application on a standard PC, and as an Internet application using a standard web browser. The latter enables a new way of communication between patient and clinician: The patient can sit at home entering his data into the system running on his home PC, and in case of questions or problems he can phone (or email) the clinician, who can use a web browser on his office PC to view the data that the patient just entered.

Second, the interface has been made simpler and much more user friendly. The top half of Figure 1 shows 3 days of patient data on carbohydrate content in meals (upper green bars), regular and NPH insulin injections (lower yellow and blue bars) and blood glucose

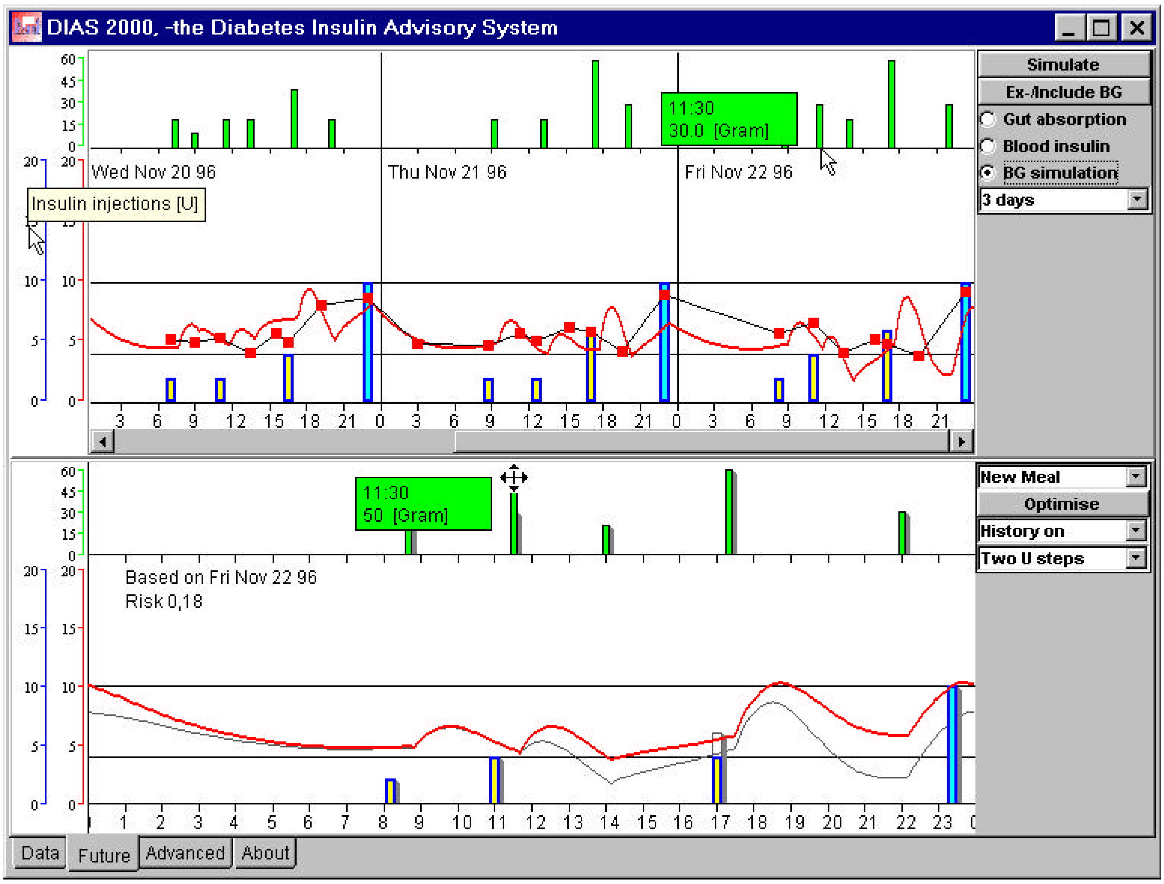

Figure 1. User interface of DiasNet. The top half of the figure shows 3 days of patient data on carbohydrate content in meals (upper green bars), regular and NPH insulin injections (lower yellow and blue bars) and blood glucose measurements (red squares connected by straight lines). Blood glucose 4 and 10 mmol/l is indicated by horizontal lines. The smooth red curve shows the blood glucose prediction generated by the system. The bottom half of the figure shows a window, which allows the patient to change meals or insulin doses by simply using the mouse to drag the bars, and immediately seeing the resulting blood glucose prediction. The lower grey and red curves show the blood glucose prediction before and after these adjustments.

measurements (red squares connected by straight lines). Blood glucose 4 and 10 mmol/l is indicated by horizontal lines. The smooth red curve shows the blood glucose prediction generated by the system: For example, on November 22, the system predicts a severe hypoglycaemia around 14.00, which, due to the pre lunch regular insulin being increased (relative to the previous day), seems plausible. In fact, the actual patient had reported cases of symptomatic hypoglycaemia at that time of the day. Placing the mouse cursor on a data point, as shown for the lunch on November 22, will display the exact time and amount. Likewise, pointing at the axes, as shown to the left in the figure, will display their labels.

The bottom half of the figure shows a window, which allows the patient to change meals or insulin doses by simply using the mouse to drag the bars, and immediately seeing the resulting blood glucose prediction. As an example, the problems on November 22 has been addressed by increasing the meal at lunch time (from 30 to 50 grams, as shown in the figure) and decreasing regular insulin at 17.00. The grey and red curves show the blood glucose prediction before and after these adjustments. Likewise, meals and insulin injections can be easily removed or added, and the effect of using various other types of insulin, e.g. lispro or mixed insulin, can be predicted.

4. Discussion

Dias is a decision support system, which has been evaluated in several controlled clinical studies suggesting a significant effect of using the system.

Based on the experience from the clinical studies, a new web based prototype, DiasNet, is now being implemented. DiasNet can be used by patients as a tool for education and communication. In DiasNet the patients can experiment with their own data. The patients can, retrospectively, adjust insulin doses or meals sizes, and thereby learn how to cope with various situations. The system is implemented in Java and designed to run both as an ordinary application on a standard PC, and as an Internet application using a standard web browser. Likewise, both the database and the engine generating the blood glucose predictions can run both on the client, i.e. on the patients PC or handheld computer, and on a central server located at, for example, the hospital. Thereby, a new way of communication between patient and clinician is possible: In case of any problems, the patient simply phones the clinician, who immediately, using his or her office PC, can take a look at the data the patient has entered. Likewise, home blood glucose measurements from, for example, newly diagnosed diabetes patients can be regularly monitored by the clinician.

DiasNet is currently being tested on a small group of diabetes patients. To begin with, the patients had a training session where a nurse and a doctor first explained DiasNet to the patients, and the patients then had time to play with the system on their own. The patients then got usernames and passwords enabling them to access DiasNet over the Internet. Preliminary results are promising.

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