

Diabetes Information Technology & WebWatch

Interactive Educational Diabetes Simulators: A Look to the Future

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IN THE LAST TWO "Diabetes Information Technology & WebWatch" columns^{1,2} various user experience with two freeware interactive educational "*virtual diabetes patient*" simulators—called AIDA and AIDA online—were documented. In this column a look is made to the future—and various more sophisticated ways in which users may interact with future generations of such simulation programs are considered.

BACKGROUND

AIDA is an interactive educational diabetes simulator that can be used for demonstration and teaching purposes to simulate the effects of changes in insulin therapy and diet on the blood glucose (BG) profile of typical insulin-dependent (type 1) patients with diabetes.³ The AIDA PC software can be downloaded without charge from the World Wide Web (from: <http://www.2aida.org>), where it is being made freely available as a noncommercial contribution to continuing diabetes education. The software incorporates a compartmental model that describes glucose–insulin interaction in patients completely lacking endogenous insulin secretion. It contains a single extracellular glucose compartment into which glucose enters via intestinal absorption and hepatic glucose production. The AIDA model also contains separate compartments for plasma and "ac-

tive" insulin, the latter being responsible for glycemic control while insulin is removed from the former by hepatic degradation.

Figure 1A shows the front end graphical display of AIDA. On this, the simulation of a newly diagnosed "*virtual patient with diabetes*" with no endogenous insulin secretion can be seen. The plasma insulin level is zero and the BG profile is markedly raised. A user-definable normoglycaemic range (3 to 10 mmol/L [54–180 mg/dL]) is shown superimposed for comparison. Figure 1B shows an interactive simulation using AIDA to demonstrate how the addition of subcutaneous insulin injections could better control the BG profile of this "*virtual patient with diabetes*." In this example, 8 units of a 50/50 premixed (biphasic) insulin preparation have been injected three times per day—before breakfast, lunch, and supper—substantially reducing the BG profile shown in Figure 1A.

The rationale underlying this interactive diabetes simulation approach is that having performed such baseline simulations users can then change any of the input variables—adding insulin injections, adjusting the dose, changing the diet, weight, renal function, or insulin sensitivity of the "*virtual patient with diabetes*"—the idea being to simulate the glycemic effects of such changes for educational purposes.

As far as it goes, freeware software—like AIDA—may be considered fun or possibly even useful. Indeed the user experience with

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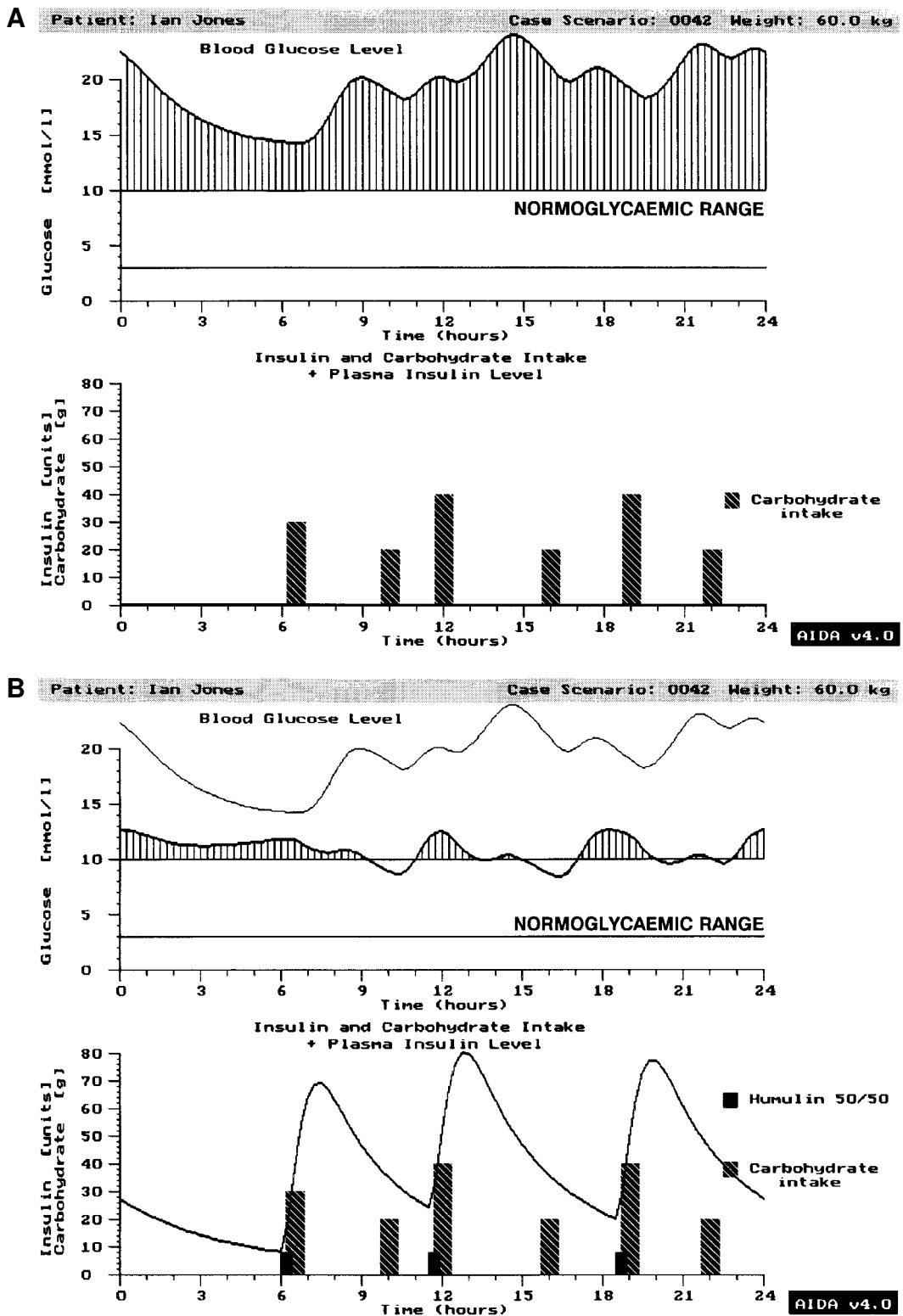


FIG. 1. A: Sample graphical display from AIDA v4.0 showing the simulation of a newly diagnosed “virtual patient with diabetes” with no endogenous insulin secretion. The plasma insulin level is zero and the blood glucose profile is markedly elevated. A user-definable normoglycemic range (3–10 mmol/L [54–180 mg/dL]) is shown superimposed for comparison. (1 mmol/L = 18 mg/dL). (Modified from Lehmann.⁴) B: Interactive simulation showing how the introduction of 8 U of a 50/50 premixed (biphasic) insulin preparation three times per day—before breakfast, lunch and supper—reduces the blood glucose profile of the newly diagnosed “virtual patient with diabetes” shown in Figure 1A. (Modified from Lehmann.⁴)

the PC software documented in a previous "Diabetes Information Technology & WebWatch" column¹ suggests that a wide range of users are finding the software of use. However, as patients, their relatives and carers, healthcare professionals, and students become more sophisticated everyday users of information technology, it is likely that they will come to expect more sophisticated functionality from such programs.

In view of this, taking a look to the future, we might consider how a user could interact with a "next-generation" interactive educational diabetes simulator. Aspects of the model and other supporting functions that might be found in future generations of such simulation programs have recently been discussed elsewhere.⁴ In the remainder of this article particular attention is paid to the user interface and ways in which users might interact with such diabetes simulators in the future.

When starting such a program a completely new user could be automatically shown a demonstration—briefly being taken by the computer through the different options and how to change insulin and dietary regimens, etc. As well as being shown the sorts of things that the program could do, this would perhaps help to allay the fears of those users who do not quite trust computers.

INTRODUCTORY TEST

The user could then be presented by the computer with a randomly selected case scenario from its database, and be asked to improve the case's glycemic control. The user would be able to make whatever changes he/she liked to the case's regimen using the intuitive Windows graphical user interface and mouse-based "point-and-click" editing tools provided.

The proposed new regimen would be automatically simulated by the model which would be able to compare the changes made by the user with its own internal list of problems and proposed solutions provided by a built in knowledge-based system⁵ running in the background. The program would also be able to calculate the average 24-hour BG level (considered approximately equivalent to a glycosylated hemoglobin [HbA_{1c}] level), which would result

from simulation of its own proposed solutions, as well as those arising from the user's modifications to the regimen. A comparison of the computer's and user's HbA_{1c} levels would permit an objective assessment to be made of the relative merits of the various therapeutic options. A simple score could then be generated depending upon the suitability of the user's suggestions.

It is envisaged that the user would be provided sequentially with four or five randomly selected case scenarios. In each case the user would need to try and improve the case's glycemic control; an overall score based on the HbA_{1c} level and risk of complications being calculated. To broaden the range of cases for simulation, the computer would be able to randomly modify case scenarios already stored in its database. In this way, a near-infinite number of scenarios for user experimentation could be generated.

COMPUTER TEACHING/ DEMONSTRATION MODE

To facilitate teaching, following the introductory test, the program should be able to go back through the scenarios highlighting various problems (from the problem list provided by its knowledge-based system) and suggest "how about trying xxxx" as a possible solution. Similarly, the user's own original suggestions could be resimulated and the results passed through the computer's knowledge-based system. This "guidance module" would be able to highlight possible problems that could result from the user's proposed alterations. For example, if the user tried raising the morning insulin dose to reduce, say, hyperglycemia in the afternoon, the risk of sending the "virtual patient with diabetes" hypoglycemic just before lunch could be pointed out by the computer.

Clearly such interactions would require considerable flexibility in the shell surrounding the basic simulator. However, integrating knowledge-based system and modelling methodologies⁵ could provide the most "intelligent" and flexible way to apply such simulations for practical educational use in the future.

The shell could also incorporate a script of things that must be taught, demonstrated or re-

inforced during each interactive session. For example, too much insulin leads to hypoglycemia and too little insulin leads to hyperglycemia, glucose in the urine, and the risk of diabetic ketoacidosis. Diabetes educators would be able to tailor this script of minimum requirements for individual patient and local needs.

INTERACTIVE MODE

Having finished being “lectured” by the system, users would then have an opportunity to experiment freely with any of the prestored scenarios or even add new scenarios to the database. An important facility here would be the provision of a “show me” option, which the user could select at any stage. This could lead to the program taking over and highlighting problems or making suggestions that the user could consider to improve glycemic control. As a result the user would never need to sit in front of the computer wondering what to do next.

EXIT TEST

One of the current limitations of computer-aided learning is demonstrating an increase in knowledge, or a desirable outcome, from the use of the computer tool. To address this problem without requiring time-consuming and difficult-to-perform clinical studies, it is envisaged that the next generation of such simulators would present some further scenarios (not seen before) at the end of the session. The user would be required to try and improve glycemic control for these cases. This would be identical to the introductory test, except with different cases. Scores from before and after could be compared, hopefully showing an improvement.

WHEN TO MEASURE BLOOD GLUCOSE?

An important component of the insulin-dosage adjustment process is measuring BG levels at the optimum time to gain the most information (e.g., preprandially and/or 2 hours postprandially in pregnancy). Therefore, one

aspect that it would be helpful to incorporate into such computer-led teaching sessions would be for the user to select at what times to measure BG values. At those times, BG data-points could be displayed on a graph on the screen and based on these the user would have to make appropriate management decision(s) for the “*virtual patient with diabetes*”; the 24-hour profile being redisplayed for the purposes of explanation.

WHAT TO DO NEXT?

As an extension to this concept, a facility could also be provided to halt the display of a simulation at any stage, say, up to every 15 minutes during the course of a simulated 24-hour day. In this way, the simulation of a “*virtual patient with diabetes*” might start with a blank screen in the morning. After the “*virtual patient with diabetes*” woke, the computer user would have to decide what he/she wanted to do (measuring the BG level of the “*virtual patient with diabetes*” might be the “*show me*” suggestion). The resulting simulated values could be displayed on the screen; the user then needing to decide how much insulin to give the “*virtual patient with diabetes*” and how much the “*virtual patient with diabetes*” should eat.

Having entered these data into the simulator, the day would progress and when the user saw fit they could choose for the “*virtual patient with diabetes*” to recheck the BG level, inject insulin, have meals/snacks, or exercise. In this way the user would be able to interact with the simulation. “Peek” facilities could be provided—if required—allowing the user to see the entire BG profile, not just when they had measured BG values for the “*virtual patient with diabetes*.”

At any stage the user would be able to adjust the meal plan, insulin regimen, or life-style variables of the “*virtual patient with diabetes*” and the program could automatically resimulate the case from that point in time. However, users would not be able to go back, and would “pay” for their mistakes or errors of judgement in semi-real time. If the “*virtual patient with diabetes*” ate too much and did not take enough insulin, the user would see the BG level rising—but would not know how fast or how high

it would go. Therefore, the user would need to make decisions for the “*virtual patient with diabetes*” about what to do next. The user could always ask the knowledge-based system (KBS) for advice (the KBS would have the advantage of knowing internally the results of the full 24-hour simulation). However, the intention would be for users to interact in speeded up real-time mode not knowing in advance the consequences for the BG profile of the life-style or therapy changes they had made. Given this, users could “live through” a simulation—albeit more rapidly—rather than only adding to it after a full 24 hours.

Taking this “real time” mode to its logical conclusion—patients could interact with the system with no BG graph. In this mode they could select appropriate times to test the BG values of the “*virtual patient with diabetes*”—making “real-time” decisions on the basis of these data. As patients, for the most part, do not automatically get graphs plotted for them of their results, it might be useful to have the option for better patients or students to see the BG values of the “*virtual patient with diabetes*” shown as digits on a simulated BG meter liquid crystal display. This would make patients have to act on the data in an identical manner to they would when receiving the values in real life.

Continuing the diabetes simulation theme—in a future “Diabetes Information Technology & WebWatch” column—issues related to the wider application of Internet-based, on line interactive educational diabetes simulators will be considered, together with the use of diabetes simulations incorporated within educational games.

SYSTEM AVAILABILITY

The latest AIDA PC software can be freely downloaded, without charge, from the Internet from <http://www.2aida.org> on the World Wide Web. The program runs on IBM PC or compatible 386/486/Pentium-based machines and requires approximately 3 Mb of hard disk storage space. AIDA can also be used on Apple Macintosh computers, running SoftWindows v2.0 or later, or Virtual PC. AIDA online can be accessed on the Internet at <http://www.shodor.org/aida>,

where it is also being made available without charge as a noncommercial contribution to continuing diabetes education. People who wish to be informed automatically about updates and enhancements to either the AIDA PC software or AIDA online can subscribe (for free) to the AIDA/AIDA online registration/announcement list by sending a blank email note to: subscribe@2aida.org

FURTHER TOPICS

If you would like to suggest further topics or Websites for future “Diabetes Information Technology & WebWatch” columns, please E-mail information—with a brief description of the site/suggestion—to: Dr. E.D. Lehmann: info-www@2aida.org (please write *Diabetes WebWatch* in the subject line). You can also fax information to: (503) 218-0828, quoting “Diabetes Information Technology & WebWatch.”

REFERENCES

1. Lehmann ED: User experience with the AIDA interactive educational virtual diabetes patient simulator. *Diabetes Technol Ther* 2000;2:165–171.
2. Lehmann ED: User reviews of AIDA online (<http://www.shodor.org/aida>): A web-based interactive educational diabetes simulator. *Diabetes Technol Ther* 2000;2:329–342.
3. Lehmann ED: Experience with the Internet release of AIDA v4.0—<http://www.diabetic.org.uk/aida.htm>—an interactive educational diabetes simulator. *Diabetes Technol Ther* 1999;1:41–54.
4. Lehmann ED: Interactive educational diabetes simulators: Future possibilities. *Diabetes Nutr Metab* 1999;12:380–387.
5. Lehmann ED, Deutsch T: AIDA²: A Mk. II Automated Insulin Dosage Advisor. *J Biomed Eng* 1993;15:201–211.

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