

Diabetes Information Technology & WebWatch

User Reviews of AIDA online (<http://www.shodor.org/aida>): A Web-Based Interactive Educational Diabetes Simulator

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IN THE LAST “Diabetes Information Technology & WebWatch” column¹ various user experience with a freeware PC-based interactive educational virtual diabetes patient simulator, called AIDA, was documented. In this column, various independent user reviews about the linked AIDA online Website (at: <http://www.shodor.org/aida>) are provided.

AIDA online offers similar simulations to the AIDA PC software² but uses novel Web-based tools to transmit these simulations across the Internet. As a result no software downloads or local user installation are required. All simulations are displayed using standard Web browser software (e.g. Internet Explorer or Netscape Navigator), and all interactions take place using a mouse and keyboard within a familiar graphical user interface provided by the Web browser. Advantages of this approach over standard PC-based software include the fact that the simulations can be run from any computer, anywhere in the world, provided the machine has a graphical display and an Internet connection. Therefore the approach is not operating system or hardware dependent. Indeed AIDA online has even been used by patients with WebTV. With the expansion of the Internet it is likely that, increasingly, users will be able to access such facilities without even necessarily having a computer. Since records were started in August 1998, more than 38,000 simulations have been run at AIDA online, and visits have been logged from over 70 different countries.

For the website reviews that follow various different end-users were approached and asked to provide their views and comments about the website. Half of the respondents ($n = 5$) were invited by one of the system’s developers, and were known to have made some use of the website prior to the invitation. The other five respondents were invited directly by the Editor-in-Chief and were not known to have used the website before they received the invitation.

In commissioning these pieces, an active attempt was made to obtain reviews from as wide a variety of different end-users as possible—to highlight some of the many and varied ways in which people see such Web-based diabetes simulations being applied.

USER WEBSITE REVIEWS

A patient with type 1 diabetes writes:

I have insulin-dependent diabetes, that was diagnosed in 1991. Over here when you are diagnosed as having diabetes you are put under intensive insulin treatment with a not-so-

Dr. Lehmann is a co-developer of the AIDA online Website.

portable pump for 10 days (at least that was done in those bygone days). At the same time you are educated in the use and management of your nutrition and insulin-injection, notably how much insulin to inject at each specified time of the day. And of course you are fitted out with a logbook for jotting down your blood glucose (BG) readings, three times a day for me.

With my diabetologist, we were able to arrive, after groping around somewhat, at a rather stable situation after a few months. However, life is constantly changing and the insulin regimen constantly needs to be adapted to new situations. I frankly wonder what the log I was told to keep (and the attendant statistics) are good for. At the beginning, I religiously entered them into Excel and made beautiful 3D-graphs. My diabetologist gave them a glance and then turned to my HbA_{1c} measurement before making any decisions!

A better idea than just groping around in the dark, in my opinion, is to use a diabetes simulator, at least to get a first idea and start experimenting. As far as I am aware there exists only one that is widely available, called AIDA. AIDA comes in two versions, both completely free to use. A PC version, which is less comfortable for me to use because I own an Apple Macintosh computer and therefore need an emulator to run PC programs: I must open the emulation program first and then the AIDA software. The second version is a Web version, AIDA online at <http://www.shodor.org/aida> which does not even demand you have a computer at all. For example you can use AIDA online with a WebTV or those future browsers for the non-technic public which we are promised for the near future.

The substance of AIDA online is the Online Simulation page. This is where you see the 40 cases that are incorporated and where you can enter a New Case. For the latter option you have to enter all the data by hand, including times of meals and insulins injected. You are also asked about renal function and insulin sensitivity that most patients will usually know nothing about. However, AIDA online is also meant for medical students, junior doctors, and nursing staff so such facilities might be more relevant for them. Furthermore the 40 standard cases stored in the online database give plenty of scenarios for simulating before one has to start entering any further data by hand.

The Try a Quick Example Simulation is a particularly good place to start as it runs a fast-track simulation of the first case scenario in the database. This pretty much shows what AIDA online is capable of. The saying goes that a picture is worth a thousand words. Well, with AIDA online the simulation results are shown as pictures, albeit graphs, in a Web browser window. It is hard to explain in words what the simulation graphs (pictures) show but by interacting with the simulator it is possible to see the effects of changes in insulin and diet on the BG profile. Figure 1 demonstrates just one simple example of the effect of changing the amount of carbohydrate taken for a meal—the BG level before (Fig. 1a) and after (Fig. 1b) this change is shown. Visitors to the website can experiment with changes to AIDA's regimen without any risks of hypoglycaemia. As made clear at the website, and in the PC version, the simulator is only meant for educational use, not for individual patient BG prediction or therapy planning.

However, I must say that this very nice software, unique as far as I know, is a must for education (and maybe even clinical research). From the point of view of the diabetic patient it is a superb tool that should be of help in understanding one's malady, and a first step towards mastering it. It would be very nice if one could find it in the diabetic wards of the hospitals that treat diabetic patients.

Professor Michel Eytan, Ph.D., Strasbourg, France

A patient with type 1 diabetes writes:

I found AIDA online (at: <http://www.shodor.org/aida>) to be an intriguing tool for simulating diabetic therapy. As a person with type 1 diabetes of 12 years' duration and an un-

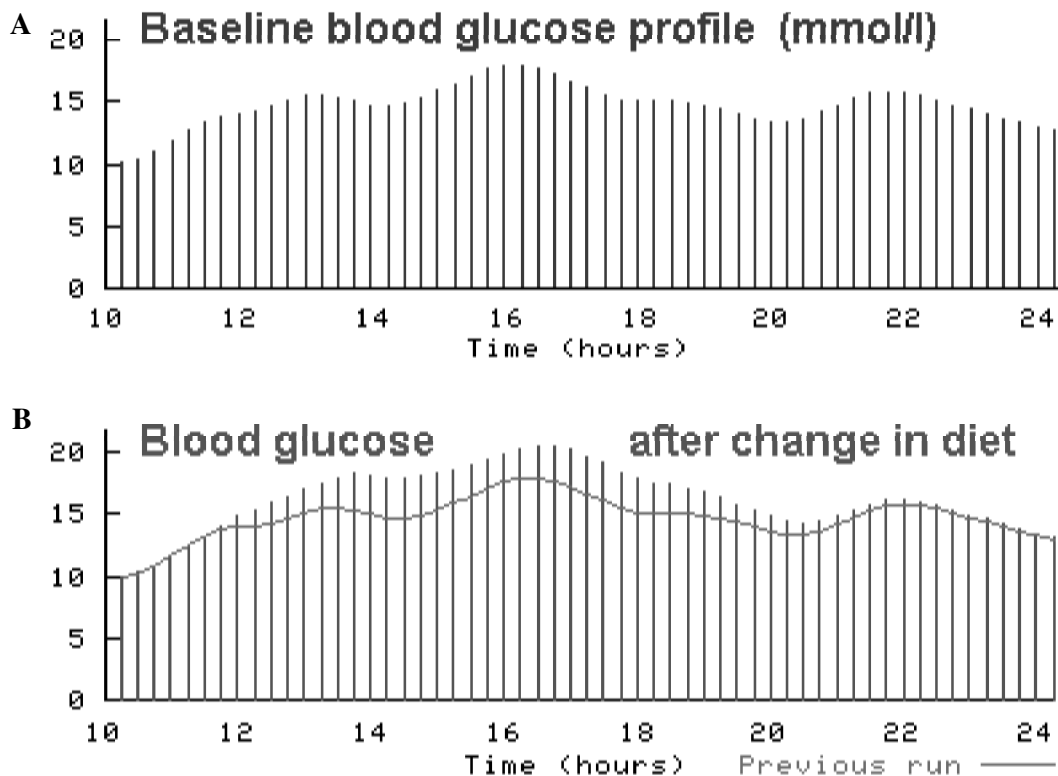


FIG. 1. An interactive simulation from AIDA online (<http://www.shodor.org/aida>). A: A baseline blood glucose profile is shown, and (B) following an increase in the carbohydrate intake.

official coach to other patients with diabetes, I have always sought effective teaching approaches that enable good blood glucose control. While the creators of AIDA online clearly remind users that the application is not meant for personal regimen design, it still is very useful for internalizing the effects of changes in carbohydrate intake and insulin administration. The application is fun to play with in its current form, and the addition of some extra features could make it even more engaging and useful to its target audience. I must admit that playing with AIDA online was a humbling experience for two reasons: First, I have had the good fortune to establish very tight control of my own diabetes and often informally advise new patients with diabetes on tips and tricks that I have learned. This has led me to believe I have a solid understanding of the disease, but the AIDA online application revealed just how hard it must be for a physician to determine an appropriate regimen for a patient even when discounting issues of patient compliance. Second, I wear an insulin pump and have learned to take for granted the flexibility this technology provides. I was on a four-injection regimen myself for many years and struggled for good control. AIDA online brought me back to the challenges of those years while clearly demonstrating that good control is possible (in a simulated environment) with conventional injection approaches. The AIDA online website has a lot going for it. The input screens allow the user to vary key variables such as insulin types and injection timing as well as meal-times, represented as carbohydrate boluses. Additionally, the user can determine if they want a broader variety of charts to analyze the patient case or keep the output limited to glucose levels and intake of carbohydrates and insulin. Perhaps most important, the online version is fast, even with a conventional modem, minimizing the patience required to run multiple scenarios.

AIDA online could benefit from key interface changes to simplify viewing of output and encourage increased scenario usage of the application. Some of these are tiny tweaks, such

as the addition of control bars at 80 and 120 mg/dL on output charts to highlight the degree to which a patient is within the normal range of blood glucose levels. Other enhancements would be more involved, such as combining the output graphs on one chart. One approach would involve including the 24-hour variance of blood glucose levels, carbohydrate intake, insulin injections, and insulin levels in combination on one graph. To improve readability, the user could tick checkboxes for which of the above components he or she wanted to see simultaneously and hit a separate button to dynamically update the output. This would allow users to better understand the interrelationship between key variables that drive good blood glucose control.

In the future, a more elaborate version of AIDA online could come in the form of a downloadable Java applet that would demonstrate the effects of the user's input dynamically, morphing the curves to provide a richer sense of feedback to adjustments in the patient's regimen. Such an applet could allow users to click on any time point in the patient's treatment results and then be queried onscreen as to whether they would like to insert a carbohydrate bolus or a short-, intermediate-, or long-acting insulin injection. Users will be even more likely to use the site, and learn faster, if inputting parameters is made as easy as possible, and the results are vividly represented. Since the source rules driving AIDA online are not transparent to the user (although a full technical guide is provided at <http://www.shodor.org/aida/technical.html>), I became curious about how the application was built. If not done already, it would be interesting to use averaged, real patient data to drive the model, giving it a closer link to actual patient cases. Along those lines, I would love to see the addition of other event possibilities within the application: exercise (both aerobic and anaerobic), sickness, stress, and perhaps even alcohol. The latter especially is not supposed to be part of the regimen of patients with diabetes, but since it is often used by diabetics it would help improve the instructive power of the site to include it along with other events that can significantly affect blood glucose control. Because the goal of AIDA online is to teach the user about blood glucose therapy and control in general, I will be eager to watch future iterations of the application as they more closely approximate the actual patient experience.

Matt Pozos, M.B.A., San Francisco, California

A parent of a child with type 1 diabetes writes:

What a learning experience! After spending several weeks experimenting with the AIDA online type 1 diabetes simulation model at: <http://www.shodor.org/aida> I have learned much about the impact that carbohydrate intake, timing of the insulin injections, and timing of meals/snacks can have on glycemic control. I have also been exposed to insulin regimens that I had not known about previously.

I am the mother of an 11-year-old boy with type 1 diabetes that has always been on a regimen of 70/30 insulin mix, giving two shots daily. I have become knowledgeable about how carbohydrate intake and insulin dosage affect his blood glucose levels. I also have seen other patterns with regard to the timing of his injections and his hyper and hypo levels. Since his diagnosis 3 years ago, these patterns have become familiar to me. Unfortunately, as he continues to grow, his dietary desires, his social calendar, and his daily routines tend to "upset" the regimen to which I had previously become accustomed.

Several aspects of the AIDA online simulation enabled me to see and understand some patterns without having to live through the stress of them! I was able to see the "big" picture much more clearly. As I previously mentioned, our routine has always been fairly regimented with regard to mealtime, snacktime, injection time, and carbohydrate intake. My most frequent calls to the dietician occur when we are going to have a "weird" day. We usually have injection and supper at 5:30 PM–6:00 PM and on occasion my son will have a

5:15 PM soccer game that lasts an hour. How does a 6:30 PM injection time and 7:00 PM dinner change the evening snack and blood glucose levels? What is going to happen when the family Thanksgiving dinner is scheduled for 2:00 PM? How do we divide up the afternoon snack so we can appreciate the treats being served after school in Cub Scouts? Just a few examples. Although I am able to visualize the standard graph of insulin absorption, I have difficulty adjusting it to fit different schedules. I am sure that I could manually adjust it on paper, but I appreciated the manner in which the website simulation so very quickly lets me have a clear visual image of the pattern.

With the strong wording of the caveats noting the limitations of the models, I was always fully aware that the patterns were just that, models. Nonetheless those models were easy to come by and met my immediate need for basic information. Information that I have not always had time to acquire through research. I am usually too busy packing lunches, recording blood glucose levels, doing laundry or attending to my full-time job outside of the home! Which brings me to another aspect of the simulation that was meaningful to me; the case studies. Since my son's diagnosis, I have spent the majority of time learning about his routine, blood glucose patterns, and experimenting with our regimen. I have never had time to learn about the other options that are used by diabetic patients. The case studies widened my horizons and introduced me to a variety of care plans. I could spend as little as 10 or 15 minutes playing with one of them. I was able to manipulate one field at a time and observe how that single change affected the big picture. The case studies were simple and touched upon common situations. I appreciated the hints included in problem solving many of the cases since I was uninformed and did not know where to begin. I would suggest that hints be provided for all of them! Once again, the clear and quick availability of the graphs allowed me to become more familiar with some of the different insulins.

Furthermore I appreciated the simplicity of the simulation. It took little time to get it running. At one point, my 11-year-old son was observing me and he was able to participate in running one of the case study simulations. I think it would be meaningful to him as he learns more about diabetes care plans and has questions about his options.

One suggestion that I have is related to my unfamiliarity with terms, conditions, and types of insulin. I would have appreciated a glossary or just a short explanation of terms such as "impaired renal function" and how they affect blood glucose levels. It would also be of benefit to see exercise included as a variable. And as I previously mentioned, I would have linked hints on each of the case studies since I was not familiar with other insulin regimens. More case studies of young, active children would naturally have been valuable to me. The time that I have spent exploring AIDA online was enjoyable and informative. I will look forward to new case studies, or even being able to "order" some specific types of cases that are of interest to me.

Mary Ann H'Doubler, B.S. Ed., University of Missouri, Springfield, Missouri

A diabetologist writes:

As a practicing diabetologist interested in patient education I was immediately intrigued by the AIDA online website at <http://www.shodor.org/aida>

AIDA is a powerful teaching tool that has in itself the property of concentrating the attention of the user on the programming function of the human brain. My experience with 25 years of diabetes education is that it is extremely difficult to persuade patients into forward thinking about what-if type questions. They tend to stick to the actual results of the self-monitoring blood glucose (BG) data and tailor the next dose solely on the basis of that number irrespective of the food, exercise, and anything else that is going to interfere with their BG levels. The consequences can be disastrous and can give rise to unexplained fluctu-

tuations in the BG levels. Things are even worse when one is dealing with the bedtime insulin dose. The inability to tailor the individual dose can give rise to continuous pointless BG monitoring, chasing the readings, with skyrocketing costs but with little impact on overall BG control.³

AIDA online offers an important route towards a solution, that couples the power of computer simulation with the power of the Internet. I use it somewhat extensively in my teaching sessions. The human brain can tend to think linearly, thus failing to see the end results of an action. When it must cope with a difficult task such as the use of insulin, in a context made worse by the anxiety of personal involvement, hackles can be raised. Problems include: the difficulty to integrate multiple information (previous experience, carbohydrate ingested, physical activity, and more) into a single black box (package); the difficulty to think forward (what might follow) rather than backwards (on the basis of what has already been); and the difficulty with abstract thinking, that thwarts all attempts at theoretical explanations.

AIDA online helps to overcome many of these problems by stimulating people to use their abilities for actual problem solving. This is the main power of computer simulation. We have found that it is most useful to use AIDA with a small group of four to five patients. After a brief explanation we start by asking them to guess the solution to one of the case histories, then progressively we give them the key to the solution. Next we try another simulation. At that time we leave the patients alone, and there is initially a competition, followed by a strong and loyal cooperation to solve the problem. This also encourages bonding. We have also observed that AIDA is of great help for those who are visually oriented, since the graphs, and the images on the screen are of great importance to them.

Although the authors correctly warn against the use of AIDA as a guide to therapy, the projection tends to be highly correlated with the actual results, and the best fit of the simulator, particularly the PC version, is very close to the best guess of an experienced diabetologist (data on file).

The ease of access through the Net is another ace for the program. AIDA comes as a package to be installed on the PC and as an online version. It is currently released only in English, and this is a limitation for the users of other languages. Furthermore the advent of the new insulin analogues will change somewhat the scenarios, and the inclusion of these in an updated AIDA has been advocated by many of my patients. In view of its important role as an educational tool and the wide distribution that AIDA online can have, we hope that a new version which incorporates these features will be released soon.

Patrizio Tatti, M.D., Chief of Diabetes, Ospedale di Marino, Rome, Italy

A certified diabetes educator (CDE) writes:

First, congratulations to the developers of the AIDA online type 1 diabetes clinical simulation model (at: <http://www.shodor.org/aida>). It is both a highly sophisticated model of the human glucoregulatory system in all its complexity and at the same time a really fun "toy" (as noted in the caveats) for, in this case, a healthcare professional to generate simulations in a new and thought provoking way.

I am an advanced practice nurse and Certified Diabetes Educator. My current practice setting is one offering Web-based disease state management with nurses providing teaching, coaching, and supporting selfcare while at the same time alerting patients and physicians to vital sign, blood glucose, and symptom trends and patterns that signal problems. The patients report data via specially designed Web pages or IVR (interactive voice response) telephone links. My experience has shown very few barriers for people living with diabetes

using computers interactively to communicate about their health and to learn even more to support their selfcare. As I jumped into using AIDA online and ran simulations I imagined how some of those same patients might experience AIDA online as part of their education. Primarily though, I was evaluating the experience as a component of the diabetes pattern management classes that I teach to other health care professionals.

Among the AIDA online properties that I appreciate are the complex parameters considered in the model, that assumes no endogenous insulin secretion, but which includes insulin absorption, insulin elimination, and kidney, liver, brain, gut and muscle functions. The player can not only modify insulin doses/types/timing, but also carbohydrates/grams/timing and even modify factors such as renal function. The ability to vary insulin sensitivity is also a real bonus with this model. With all this available, though, the model is still not complete. Exercise factors are not able to be a variable and this is a needed component.

Pluses are the ability to change mmol/l to mg/dL. The 40 case studies are a wonderful mix. It would be a bonus to have body mass index (BMI) calculated for each case (as only weight is given). The BMI then could be an active field, recalculated for any current weight updated. I would also have appreciated having a recent HbA_{1c} for each case to help put the blood glucose control into perspective. Having a way to pull up all the insulin options was very necessary for this U.S. nurse. Under short-acting insulins there are 9 choices, and under intermediate-/long-acting insulins there are 22 choices. There is overlap with different European manufacturers/products, but this is still an amazing variety of choices, not counting the biphasic, premixed preparations! Enough to create insulin envy. Unfortunately, the omission at present of the analog lispro limits the utility of the simulations. Insulin lispro has a strong usage with intensive diabetes therapy. It will be a real improvement when added to the scenarios. Soon other analogs will become available and hopefully also included as options. Finally, the ability to enter insulin pump (CSII) regimens will also improve the options. Many of the patients with diabetes that may benefit from practicing simulations use analog insulin and/or insulin pumps. Notwithstanding this, the technology is robust, offering the results of simulations very quickly at the AIDA online website.

Also, I appreciate the careful wording of the caveats as to the limitations of the model clinically for a single real subject. With that caution in mind, I would highly recommend the AIDA online site to healthcare professionals and appropriate patients with type 1 diabetes for practicing a model of glucose regulation.

Finally, because the developers tackled type 1 diabetes with such sophistication, is there any plan in progress to offer type 2 diabetes with endogenous insulin secretion and relative insulin resistance, as well? Increasingly there are more patients with type 2 diabetes on multiple insulin injections, practicing carbohydrate counting, and needing to learn most of the same concepts in glucose regulation as patients with type 1 diabetes. I think computer models such as this can be a strong motivator for patients to learn the dynamics of pattern management. The payoff is obviously in achieving goals in HbA_{1c} and preventing complications.

*Cindy Onufer, R.N., M.A., C.D.E., Quality Improvement and Clinical Education Coordinator,
LifeMasters Supported SelfCare, South San Francisco, California*

An optometrist with type 1 diabetes writes:

I was pleased to find out about the AIDA online Website at <http://www.shodor.org/aida> hosted by a nonprofit group dedicated to the reform and improvement of math and science technologies in education. I have recommended it to many of my colleagues in diabetes education. This site would be good for all patients with type 1 diabetes, and their families,

who have not yet grasped the interaction between timing and amount of carbohydrate with timing, amount and type of insulin injections.

I. The need for a mathematical simulation of blood glucose levels in diabetes:

As an eye doctor: I am committed to detection, intervention, and minimization of diabetic eye disease. Ninety-five percent of the risk reduction leading to blindness associated with diabetes is done by the patient. We need to educate patients in their control of blood glucose (BG) levels. AIDA online is an excellent educational model, computer game, or "toy" for the diabetic patient to play around with. As I live in a fee-for-service or managed care environment of medical care, the more that can be learned with an interactive "game," the better as this is much less costly than using a lot of self-monitoring (BG) strips, or actual trips to the hospital for hypoglycemic or hyperglycemic crises.

As a patient: Let me play with someone else's body without suffering the personal crises called out by the simulator as high or low BG levels. Timing and amount of each insulin and dietary component, and balancing these, are clearly demonstrated as the true keys to control that they are.

As a diabetes educator: (i) Prevent crisis trips to the hospital. AIDA online gives excellent immediate pattern adjustment suggestions to stay away from extreme hyper- or hypoglycemic events. (ii) By watching the overall daily glucose variations in the simulation, you can get to the point of predicting your overall control, and with pattern adjustments coordinated with each patient's doctor overall risk of complications can be minimized.

II. How well does AIDA online do this?

Much better than anything else I have seen. The simulations are effective for the patient, the doctor and the educator. With minimal instructions online, a novice can start playing around with carbohydrate counting meals, and short-, intermediate- and long-acting insulin injections as they effect BG levels.

III. Can this website be improved?

Yes, BUT, it is already very useful. Perhaps by creating a version with an online "game." Introducing levels of play to be put into the program, from simple, BG levels with crash points of low BG, with chronic hyperglycemic trips to the hospital—and then to an estimation of complications based on HbA_{1c} levels—going on to the micro-vascular events, and more sudden macrovascular death as bomb points, or requiring restarts because you lost it!

This model can also be useful for the patient with type 2 diabetes who is taking insulin, since it has an ability to adjust liver and peripheral insulin sensitivities where metformin, and the new thiazolidinediones, act. It is also much easier to adjust a patient's weight with this simulator than it is in reality. Therefore AIDA online can demonstrate to the patient in a tangible way the benefits of lowered weight. As someone with diabetes myself, I also found AIDA online very useful for me personally, as I could experiment freely without suffering any risks of the hypos and hypes identified by the simulator.

Roger Phelps, O.D., Optometrist, Ojai, California

Two designers of diabetes management software write:

The AIDA diabetes simulation software has long been regarded as a novel technology for diabetes education. The program, which utilizes a simplified model of the human glucose regulatory system, allows users to simulate the effects of food and insulin on the blood glucose profiles of example diabetes patients. Since its inception, more than 10,000 downloads of the PC software have taken place, attesting to its popularity.

The adoption of the AIDA program to the Internet at AIDA online (<http://www.shodor.org/aida>) now allows patients with diabetes, educators, and researchers better access to this valuable tool. The simulations can be run from any computer (PC, Apple Mac, Linux, Unix server, etc) from anywhere in the world provided the computer has access to the Internet. There is also a registration/announcement list that AIDA users can subscribe to at the Website (or by emailing aida_simulator-subscribe@listbot.com), so that information on any enhancements or modifications to the system immediately can be notified by email as they become available worldwide.

Modeling biological systems such as these is incredibly complicated due to the myriad of variables implicit in human glucose metabolism. Yet the algorithms for insulin absorption and glucose metabolism in the AIDA model are robust enough to produce a viable simulation.

This simulation model and the surrounding Web domain is presented clearly enough for use by patients, their families and diabetes researchers. Catering the Website to these users who have a variety of different physiological, educational and cultural backgrounds has been successfully accomplished by providing 40 case studies of different patient scenarios in addition to a comprehensive description of the scientific background behind the simulation model. Caveats to the simulation are well addressed and endowed with the necessary emphasis and repetition, the most important of these being that the simulation should not be used as a predictive model of a patient's blood glucose values. Users should also be aware that any simulation with hypoglycemic values is an unacceptable scenario, and that simulated blood glucose values for the overnight period may be slightly underestimated due to the fact that the patient's metabolic rate decreases during sleep.

The interface is functional and user friendly. Most notably, the architecture of the website accommodates easy navigation through the simulation features and supporting informational material. Graphical representations of the example patient's blood glucose profiles, insulin absorption, and glucose balances allow the user to better conceptualize the effects of changes in patient regimen. As a possible future adaptation, the simulator display page could be complemented by adding a link from the simulator to a graphical representation of each available insulin type for comparison.

In summary, the website simulation is a stimulating, well developed tool for anyone with at least a grass-roots knowledge of diabetes. AIDA continues to be an invaluable research and educational tool, and we would encourage anyone with an interest in diabetes to visit the AIDA online website and try the simulations. Potential future adaptations to the model include adding algorithms for exercise, the incorporation of lispro/Humalog™ insulin, and the variation of carbohydrate inputs by their duration of action. We look forward to seeing any expansion of the model along these lines.

Erik Otto, B.Sc. (Eng), Ottawa, Ontario, Canada

Jan Andrysek, B.Sc. (Eng), Toronto, Ontario, Canada

An engineer writes:

Dynamic models figure prominently in a wide range of engineering applications including model-based control, design optimization, and even training simulation (e.g., aircraft flight simulators). The AIDA online simulator model falls into the latter category, providing a relatively high fidelity dynamic model of the glucose/insulin metabolic system. As with any modeling application, one has to address tradeoffs between oversimplification and excessive detail, and this is effectively accomplished with the AIDA online model. As described

at the Internet site (<http://www.shodor.org/aida>), the model is intended for educational/teaching/demonstration/self-learning purposes and not therapy planning, and the developers provide a model with an appropriate level of detail.

In technical terms the model is a lumped compartmental approximation of the complex distributed behavior of both glucose and insulin in the human body. Full mathematical details can be found in the online technical guide (at: <http://www.shodor.org/aida/technical.html>). Such models have been described elsewhere in the literature, and range from the well-known Bergman model⁴ that has three states (or underlying differential equations) corresponding to the lumping of the body's behavior into three compartments, all the way to detailed pharmacokinetic models such as those published by Sorensen and Colton⁵ and Parker and Doyle⁶ which are based on six compartments, several of which are subdivided into tissue and capillary spaces. These detailed compartment models can have well over 25 differential equations. A significant difference between these two classes of models is the parametrization of metabolic effects; the simple Bergman model has five coefficients available for fine-tuning including insulin sensitivity, while the detailed compartment models have over 24 different coefficients that can be adjusted. The AIDA online model strikes a compromise here, and only releases five parameters to the user: patient weight, renal threshold of glucose, renal function, liver insulin sensitivity, and peripheral insulin sensitivity.

One of the most effective elements of the AIDA online simulator is the graphical user interface (GUI), set up with a convenient World Wide Web-based form. Users can enter a profile for meals (including snacks) and insulin administration. The latter includes details for different short-acting and intermediate-to-long acting insulin formulations. A particularly convenient element of this simulator is the pre-programmed suite of 40 case studies that represent a wide range of hypothetical patient scenarios that can be accessed quickly for user evaluation. The user can also create his/her own cases.

Considered from a perspective in engineering, dynamic modeling and model-based control the AIDA online package is very effective in achieving its intended goal as an educational simulator. One extension that might be considered for a future development is the inclusion of stochastic variability in the simulations, either on a run-by-run basis, or else the inclusion of distributions of responses. This option could be selected by the patient before the simulator is started (e.g., a deterministic versus stochastic run). For example, one could program different parameters to vary stochastically each time the simulator is accessed so that no two runs are identical (even with the same user-defined parameters), or else one could show confidence intervals for a given run. This could further reinforce the inherent variability of the diabetes problem.

However, even without this functionality, the package is a rather effective tool for demonstrating the complex transient behavior associated with diabetes, and AIDA online represents one of the more successful uses of the World Wide Web in providing an interactive learning medium.

*Francis J. Doyle III, Ph.D., Department of Chemical Engineering,
University of Delaware, Newark, Delaware*

A pharmacy educator writes:

The Pharmacy Undergraduate Curriculum is a 3-year professional program. Our students receive a total of 6 hours of didactic diabetes education during the endocrinology course, taught in the second professional year of the program, at a point when students have not acquired any clinical experience or exposure to patient care activities. The AIDA online diabetes case simulator was used as a required web assignment for the endocrinology course. Students were divided in groups of two and assigned one of the 40 case scenarios. Students

were specifically asked to review and assess the baseline data provided, identify problems, and define glycemic goals. Based on this assessment they were to devise new treatment regimens involving insulin dosing and carbohydrate intake in order to achieve the specified glycemic goals. Students ran several simulations by experimenting with a number of changes in insulin therapy or carbohydrate intake, or both, and identified the best course of action. They summarized their findings and provided graphical simulations of baseline data, and the final course of action. In all cases, the recommended regimens resulted in an improvement in glycemia compared to baseline. In the majority of cases student-devised regimens led to 24 hour glycemic control with minimal hypoglycemia.

The AIDA online diabetes simulation has proved to be a valuable educational tool that complements the didactic portion of the course. The program provides various virtual models of diabetes that differ significantly in presentation and in approaches to treatment. This reinforces the heterogenous nature of diabetes and emphasizes the need for individualizing treatment. The program allows the interactive simulation of the effects of minute changes in insulin dose and/or carbohydrate intake on the 24-hour blood glucose profile of a patient with diabetes. The website allows students the opportunity for experimentation and manipulation of insulin therapy including doses, frequency, and types—and the patient's dietary intake including amounts and frequency—and patient-specific characteristics such as weight, renal or hepatic function status. The simulations help students to understand the dynamic nature of the relationship that exists between blood glucose concentrations, insulin dosing, and dietary regimens. Therefore students can gain an appreciation of the challenges, and difficulties, of achieving an appropriate balance between these variables.

Students were required to provide an evaluation of the assignment. Their comments were extremely positive. From the student's perspectives the assignment has strengthened, reinforced, and enhanced the didactic information provided during the course. It has also led to a better understanding of the importance of the rather difficult task of achieving normal glycemic control. Students described the assignment as educational, informative, challenging, and enjoyable. Many have indicated that the on-line simulations have allowed the application of knowledge learned in class, by experimentation with several different therapeutic plans, without putting patients at risk. These simulations are particularly useful in understanding the difficulties associated with insulin regimens by exploring the drastic effects of a small change in insulin dose or timing on plasma glucose concentrations, and in advancing students' knowledge and skills in the cautious and accurate dosing of insulin.

The changing trends in the health care system mandate an expansion of pharmacy practice beyond traditional distributive duties, and pharmacists are increasingly challenged to take more active roles in patient care. Successful diabetes management requires an entire team of health care providers, including a pharmacist. In addition, diabetes management is a unique challenge that requires substantial knowledge acquisition, training, and practice. The emphasis on achieving normoglycemia in patients with diabetes has resulted in increasingly complex regimens of insulin, oral hypoglycemic agents, and nutrition requiring more intense monitoring and interpretation of blood glucose data. The AIDA online diabetes simulation is a worthwhile educational tool that allows the learner to apply new knowledge, and to experiment with various therapeutic regimens, without any risks to patients.

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A past president of the American Association of Diabetes Educators writes:

Educating primary care practitioners regarding the complexities of type 1 diabetes management is a challenge due to the difficulties of finding practice experience for students. In-

dividual primary care settings may have only a few patients with type 1 diabetes and opportunities to learn diabetes management principles may be limited. Equally daunting is the concern of students making decisions that can be life threatening to real persons. The AIDA online <http://www.shodor.org/aida> interactive diabetes management simulation has been an exciting tool that alleviates many of these problems. Students are given the opportunity to practice adjusting insulins including the type, dosage and timing of injections as well as adjusting carbohydrate intake for simulated patients. The immediate feedback enables them to evaluate their decisions instantly, unlike the real world where it may take weeks before the effect of decisions will be known.

At San Francisco State University's Family Nurse Practitioner (FNP) Program our students have the opportunity to practice at the AIDA online Website and learn the principles of type 1 diabetes management. New trainee FNPs would rarely treat type 1 diabetic patients independently, however, understanding the principles of glycemic management is an essential component of their education.

Our FNP program utilizes the Internet as an adjunct to in-class instruction and we encourage the use of certain Websites as sources of professional and scientific information. Many professional websites contain standards of care and full text research articles. Using the Internet for these purposes is useful and their value is in finding current medical information, not unlike reading a journal or textbook. The AIDA online website is the first site that we have used which teaches about a complex medical problem and is interactive, engaging the students in the decision-making process with immediate feedback.

In making the assignments to the program, the instructor first makes a decision regarding which of the 40 standard case scenarios at the website would be appropriate for first time students. The initial cases are selected for their simplicity so that the students can gain an understanding of the many factors that affect the simulated patient's blood glucose level. Students are instructed in the pathophysiology of diabetes mellitus including the many factors that can influence glycemic control. Treatment principles of nutrition, exercise, and medication are presented. Lecture topics include identification and prevention of complications of diabetes, including hypoglycemia and diabetic ketoacidosis. Current research regarding the glycemic levels necessary to prevent the macrovascular and microvascular complications of diabetes are presented with discussions regarding the process of achieving those normoglycemic levels.

Students are guided through their first simulation with instructions to first read the detailed description of the case. They must change the blood glucose to milligrams per deciliter (mg/dL) and change the insulin types to those most commonly used in the United States. They are given the height of the simulated patient since this is not included in the simulation. They are then required to calculate the simulated patient's body mass index (BMI) or they may use a standardized chart to determine this. Based on that information, they calculate the simulated patient's expected nutritional needs, and the total daily number of grams of carbohydrate required. They examine the simulated patient's carbohydrate intake and determine if it is adequate, and if the distribution of the meals is appropriate in light of the current glycemic profile. Students are encouraged to change the carbohydrate amounts and meal-plan, if that is indicated, based on their calculations.

When choosing the insulin dosages, students are asked to try various regimens including multiple injections of short-acting with intermediate-acting insulin, and then short-acting with long-acting insulin. Premixed (biphasic) insulin preparations are compared with nonpremixed regimens. The dosages of insulin and the timing of the injections are changed to determine their effects. Once the predetermined glycemic goals are achieved, students are then asked to change the renal threshold and renal function levels to evaluate those effects on glycemic levels. The same is then done with the insulin sen-

sitivities in the liver and peripheral muscles. When students see the dramatic differences these changes can make to the simulated glycemic levels, it opens discussions as to what exactly is happening. They learn that each patient is an individual and will respond differently to often very subtle changes in their treatment regimen. After completing their assigned cases, they are asked to print out their solutions and the cases are brought to class for discussion and grading.

At San Francisco State University we have found the AIDA online interactive website to be an invaluable tool in teaching our FNP students about the complexities of diabetes management. Students find the Internet access to be an asset since they can practice on the simulations on their home computers at a time convenient to them. This program offers a learning experience that is unparalleled in diabetes management education.

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DISCUSSION

These users have all clearly found AIDA online of some interest and use. Their comments mirror those which can be found elsewhere in the literature about the online website,⁷ as well as elsewhere on the Internet (e.g., at the American Diabetes Association Website).⁸ However while intuitively the benefits of making such interactive educational diabetes simulations available via the Web may seem self-evident, it is important to emphasise that the clinical and/or educational utility of such simulations still remains to be proven in formal randomised-controlled clinical evaluation studies.

The user comments about the PC version of AIDA, documented in the previous column,¹ and about AIDA online, documented above, will all be considered together with other user suggestions when the next versions of PC AIDA and AIDA online are released.

In the next "Diabetes Information Technology & WebWatch" column a look will be made to the future and various ways in which users may interact with future generations of such interactive educational diabetes simulators will be considered.

SYSTEM AVAILABILITY

AIDA online can be accessed on the Internet at <http://www.shodor.org/aida> where it is being made available, without charge, as a noncommercial contribution to continuing diabetes education. People who wish to be automatically informed about updates and enhancements to the AIDA online website can subscribe (for free) to the AIDA/AIDA online registration/announcement list by sending a blank email note to: aida_simulator-subscribe@listbot.com

FURTHER TOPICS

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

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