

The freeware AIDA interactive educational diabetes simulator – <http://www.2aida.org> – (2) Simulating glycosylated haemoglobin (HbA_{1c}) levels in AIDA v4.3

Eldon D. Lehmann

Academic Department of Radiology, St. Bartholomew's Hospital, London, UK
and Department of Imaging (MRU), Imperial College of Science Technology & Medicine, NHLI Royal Brompton Hospital, London, UK

key words: computers, diabetes education, audit, interactive simulation, glycosylated haemoglobin, HbA_{1c}, diabetes

SUMMARY

In 1996 an interactive educational diabetes simulator called AIDA was released without charge on the Internet as a non-commercial contribution to continuing diabetes education. Over the past 4+ years over 74,000 people have visited the AIDA Web pages at <http://www.2aida.org> and over 20,000 copies of the program have been downloaded from there free-of-charge. This article builds on the experience gained from the AIDA development, and the World Wide Web distribution of the software, and highlights some of the problems which users have reported with the program. An updated release of the software (AIDA v4.3) is described and the method applied for modelling glycosylated haemoglobin (HbA_{1c}) levels within this new version of AIDA is documented. An overview is provided of the trialling and beta-testing of this latest release of the program, and the general concept of a 'virtual diabetic patient' that provides an electronic representation of a patient with diabetes – and which can be used for self-learning/teaching/demonstration purposes – is highlighted.

BACKGROUND

AIDA is a freeware computer program which permits the interactive simulation of plasma insulin and blood glucose profiles for demonstration, teaching and self-learning purposes. It has been made freely available, without charge, on the World Wide Web as a non-commercial contribution to continuing diabetes education. In the 4+ years since its Internet launch over 74,000 people have visited the AIDA Website – <http://www.2aida.org> – and over 20,000 copies of the program have been downloaded, gratis.

The AIDA software has been overviewed in a previous article in this journal issue [1]. Briefly it incorporates a compartmental model that describes glucose-insulin interaction in patients completely lacking endogenous insulin secretion (i. e. type 1 dia-

betic patients). The model contains a single extracellular glucose compartment into which glucose enters via both intestinal absorption and hepatic glucose production. The model also contains separate compartments for plasma and 'active' insulin [2,3], the latter being responsible for glycaemic control while insulin is removed from the former by hepatic degradation.

Figure 1 demonstrates a little of what AIDA can do. In the representation of an AIDA simulation shown, a baseline blood glucose simulation is displayed by the dotted line for a twice daily short and intermediate-acting (Actrapid and Lente) insulin injection regimen. Superimposed in black, shown by the solid line on the top graph, is a simulation for educational use demonstrating the hyperglycaemia that would result from delaying the mor-

Received: 2001.03.12 **Correspondence address:** Dr. Eldon D. Lehmann, Academic Department of Radiology, St. Bartholomew's Hospital,

Accepted: 2001.04.11

London EC1A 7BE, U.K., e-mail: www@2aida.org

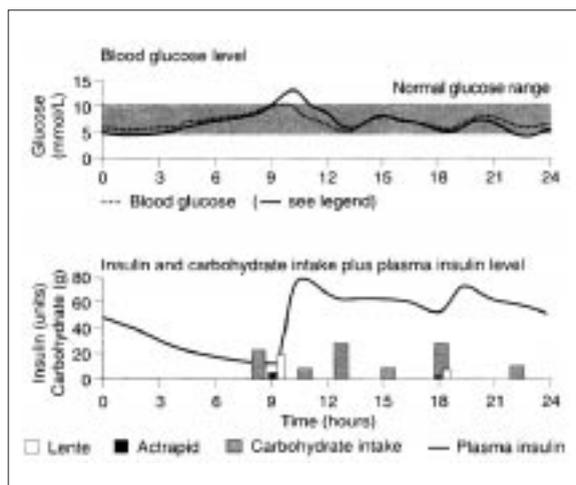


Figure 1. In the representation of an AIDA simulation shown, a baseline blood glucose simulation is displayed by the dotted line for a twice daily short and intermediate-acting (Actrapid and Lente) insulin injection regimen. Superimposed in black, shown by the solid line on the top graph, is a simulation for educational use demonstrating the hyperglycaemia that would result from delaying the morning insulin injection until after breakfast (1 mmol/l = 18 mg/dl). (Modified from Lehmann [4]). Further examples of the sort of simulations that AIDA can offer can be found elsewhere in the literature [5–7], or on the Internet at <http://www.2aida.org>

ning insulin injection until after breakfast [4]. AIDA comes with 40 such example case scenarios for simulation, and further cases can be added or created by users. Further examples of the sort of simulations that AIDA can offer can be found elsewhere in the literature [5–7], and on the Internet at <http://www.2aida.org>

This report sets out to (i) review experience with the original v4.0 release of the AIDA software and highlight some of the problems which users have reported with the application; (ii) overview an updated release of the program (AIDA v4.3); (iii) document the method applied for modelling glycosylated haemoglobin (HbA_{1c}) levels within this new version of AIDA; and (iv) overview the trialling and beta-testing of this latest release of the program (AIDA v4.3).

‘Problems’ users have reported with the software

While the number of positive comments received about the software [5,8–11] have far outweighed any negative ‘complaints’, there have been a small proportion of potential users who have either run into technical difficulties with the program (a minority) or who feel they require some addition to the simulator to match their particular circumstances. For the first

part of this report a review was undertaken of the electronic mail notes received about AIDA over the past 4+ years in order to identify the most ‘major’ negative comments that users have had about the program. It is not possible to assign a frequency to most of these, but to put these negative comments into perspective – the most frequent problem reported related to an occasional install / setup problem with the v4.0 software. Over the past 4+ years only 49 messages were received about this – out of over 15,377 downloads of the AIDA v4.0 program – giving a reported incidence of install problems of less than 0.32%. The other ‘negative’ comments about the software are summarised in Table 1.

While these data are of interest and of use to system developers – such audit is of limited value – unless the ‘audit loop’ is closed and what is learnt is fed back so that improvements can be made to the program as a result.

In this respect, as described in the accompanying article [1], a practical benefit of the download survey that has been undertaken has been the realisation that the vast majority (> 95%) of people downloading AIDA have 32-bit Windows operating systems (Windows ‘95 / ‘98 / ‘NT or Windows ‘2000). Given this a decision was made to create and release an updated version of the software (v4.3) with a dedicated, streamlined Windows-based setup procedure; the intention being that this would facilitate installation of the program for most

Table 1. Summarises the most major negative comments received by electronic mail over the past 4+ years about the AIDA v4.0 software.

Technical/computing issues

- DOS is dead. When will a mousable/Windows based version become available?
- Why doesn't this all fit on one diskette?*
- (previous AIDA v4.0 installation program required 2 diskettes)
- Download/installation/setup problems *1
- Runtime problems/"crashes" with latest, fastest Pentium PCs *2

Diabetes issues **

- Where is Humalog / Lispro?
- Why doesn't this cater for insulin pumps?
- Where is exercise / activity?
- Why can't we simulate weights less than 30 kg / more than 90 kg?
- What about type 2 diabetes?

* Rectified in AIDA v4.3; 1 – reported n=49 times; 2 – reported n=19 times – but the problem was expected to manifest itself more frequently as faster computers became available. ** Planned to be addressed in a future, freeware dedicated Windows version of AIDA. More information will become available via: <http://www.2aida.org/windows>; DOS = Disk Operating System

users and overcome the small proportion of reported install problems. At the same time attempts were also made to address as many of the other technical 'problems' that had been documented with the software (Table 1).

Overview of the latest release of the freeware AIDA software (v4.3)

Based on this user experience a new version of AIDA (v4.3) was made available on the Internet, initially for testing, in the second half of July 2000. This version then went on widespread general release as from 1st August 2000.

The updated program contained a number of new features. As intimated above a dedicated 32-bit Windows install procedure was adopted streamlining the installation process for the vast majority of end users. Various technical upgrades were also provided in order to avoid any runtime problems which could lead to the previous release (v4.0) stopping working on the latest Pentium PCs with the fastest central processing unit (CPU) chips.

As well as these technical changes, substantive additions to the program included a facility to provide estimations of glycosylated haemoglobin (HbA_{1c}) levels for the simulations. HbA_{1c} is a marker of medium-term blood glucose control and is widely used clinically as an indicator of a patient's average or integrated glycaemic control over the preceding 2–3 months. Diabetologists and endocrinologists use assessments of HbA_{1c} levels to confirm overall blood glucose control; this test having the advantage of not being dependent on patient self-reported blood glucose values.

Furthermore since the Diabetes Control and Complications Trial (DCCT) [12] the benefits of tight blood glucose control have become much more apparent and so more proactive patients also now use HbA_{1c} levels directly themselves as an indicator of their own glycaemic control.

For all these reasons it was felt that it would be useful to include an estimate or simulation of HbA_{1c} levels within the AIDA program. This would offer patients, their relatives, students and health-care professionals an indication of what the HbA_{1c} level might be if the simulated blood glucose profile was maintained for 2–3 months. It should be stressed that such HbA_{1c} level estimations – like AIDA's main blood glucose simulations – are only intended for educational / teaching, self-learning or

demonstration purposes, and not for individual patient prediction or therapy planning.

Method applied for simulating HbA_{1c} levels

The approach adopted to model HbA_{1c} levels, using blood glucose data, is based on a relation first described by Nathan et al. [13]. The Nathan formula relates measured HbA_{1c} levels to mean blood glucose (calculated based on patient self-monitoring blood glucose (SMBG) data). The formula applied within AIDA v4.3 is based on this approach – and is similar also to that described by Svendsen et al. [14] – but was modified slightly by inspection to provide a relationship between mean blood glucose and HbA_{1c} which would be suitable for computer-based simulation, and which would also be clinically realistic for as wide a range of simulated case scenarios as possible.

For the AIDA simulations the mean blood glucose was taken as the average (arithmetic mean) of the 96 simulated blood glucose data points during the 24 hour period (one data point is produced by AIDA for every 15 minutes of the simulated day) [2]. The formula then applied to calculate the HbA_{1c} level for the current day's simulation was:

$$\text{HbA}_{1c} = (\text{MBG} + 86)/30 \quad (1)$$

with mean blood glucose (MBG) given in units of mg/dl (1 mmol/l of glucose = 18 mg/dl).

Table 2 shows mean blood glucose values and the associated HbA_{1c} levels using this approach (calculated every 2.5 mmol/l).

Table 2. Summarises how computed glycosylated haemoglobin (HbA_{1c}) values vary with blood glucose levels in AIDA v4.3 (based on the model of Nathan et al. [13]). 1 mmol/l of glucose = 18 mg/dl.

Blood glucose (mmol/l)	Glycosylated haemoglobin (HbA _{1c}) level (%)
0.0	2.9
2.5	4.4
5.0	5.9
7.5	7.4
10.0	8.9
12.5	10.4
15.0	11.9
17.5	13.4
20.0	14.9
22.5	16.4

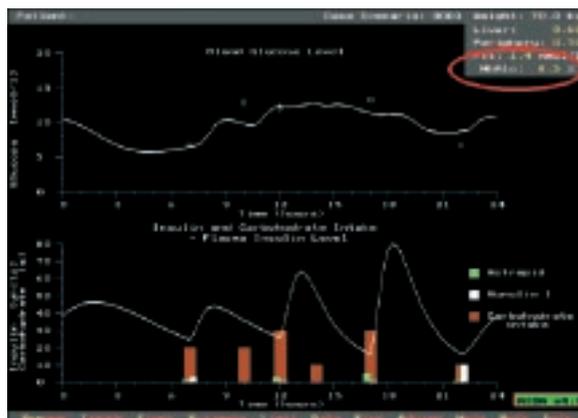


Figure 2a. Baseline 24 hour diabetes simulation from the AIDA system (from the accompanying article [1]), but now simulated using AIDA v4.3. As can be seen the system predicts that if the simulated blood glucose control was maintained in the medium term, this would give a predicted glycosylated haemoglobin (HbA_{1c}) level of 8.5% (highlighted in red, in the top right corner of the display).

Figure 2a shows the baseline simulation for ‘Steven Jones’ from Figure 2a in the accompanying article [1] – but now simulated using AIDA v4.3. As can be seen the system predicts that if the simulated blood glucose control was maintained in the medium term, this would give a predicted HbA_{1c} level of 8.5%, which is less than ideal. Figure 2b shows the same case scenario, following the insulin dosage and dietary adjustment shown in Figure 2b of the accompanying article [1], increasing the before breakfast (7:00am) intermediate-acting (Humulin I) dose from 3 units of insulin to 7 units. As can be seen, as well as reducing the previously raised blood glucose level during the course of the afternoon, longer term this leads to a substantial improvement in the predicted HbA_{1c} level (7.7%).

New features in AIDA v4.3

In addition to the HbA_{1c} simulations, other new features made available in AIDA v4.3 include the provision of an import/export facility to allow the exchange of case scenarios via electronic mail (email) and the Internet. At present AIDA is distributed with 40 standard case scenarios. However users are able to modify these to match their own particular requirements, and if need be create further, completely new case scenarios. While this offers considerable flexibility – and while modified or new cases could always be saved in the AIDA case scenario database – with AIDA v4.0 there was no easy way to transfer such cases between users.

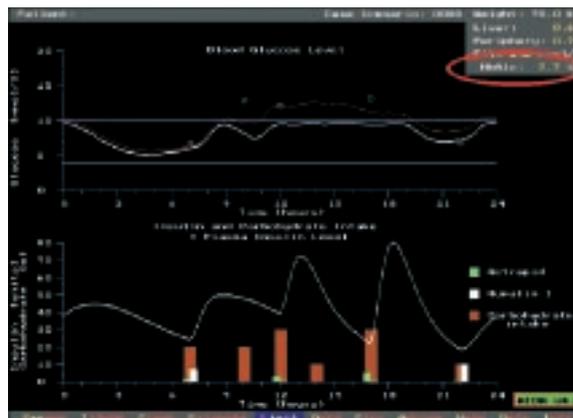


Figure 2b. Demonstrates the effect on the case scenario shown in Figure 2a of increasing the before breakfast (7:00am) intermediate acting (Humulin I) dose from 3 units of insulin to 7 units, simulated using AIDA v4.3. As can be seen such an adjustment leads to the previously raised blood glucose level during the course of the afternoon being brought more fully under control. Longer term this would also lead to a substantial improvement in the predicted glycosylated haemoglobin (HbA_{1c}) level (7.7%) – highlighted in red, in the top right corner of the display.

With the launch of AIDA v4.3 a decision was taken to include a facility to export a case from the main database or import a case into the main database to/from a standard (fixed) format file.

The file format that was adopted for this purpose was a CSV (Comma Separated Values) format standard ASCII text file. This standalone file, which is produced using the AIDA export facility, can be copied to diskette, sent by electronic mail as a standard file attachment (with a file size of < 1 Kb), or transferred via the Internet through Newsgroups or discussion lists. In this way, as well as allowing AIDA users to easily transfer cases between computers, it is also hoped that over time a larger central repository of AIDA cases (> 40) will become freely available for downloading from the AIDA Website (<http://www.2aida.org>).

Connected with this it is planned shortly to set up a dedicated AIDA forum/discussion list/bulletin board (accessible via: <http://www.2aida.org/forum>) which will allow AIDA users to communicate with each other, directly. Such lists operate by automatically ensuring that any messages sent to the list, or posted on the bulletin board, are immediately copied to all subscribers/members. As this can generate some considerable electronic traffic – as well as being able to specify to receive each message individually by email, alternative subscription options

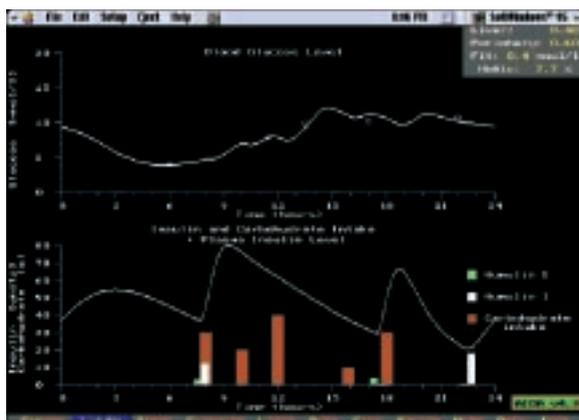


Figure 3. Screen display showing AIDA v4.3 operating on an Apple Macintosh computer running SoftWindows'95 PC emulation software.

are provided to receive messages in a 'digest' format with one larger email containing all posted messages per day. In addition a facility is planned whereby no emails will be sent but subscribers will be able to view messages on-line, via the Web. Further information about the AIDA discussion forum/list/bulletin board will be made available in due course at: <http://www.2aida.org/forum>

Just as it will be possible to circulate messages about AIDA using this facility, so it will also be possible in this way to distribute AIDA case scenario files more widely. In this respect, the chosen format also permits case scenario data to be read by external programs (such as Microsoft Excel™ and Microsoft Word™) which also facilitates further dissemination of information/data.

AIDA usage on Apple Macintosh computers

AIDA v4.3, being more robust than v4.0, has been tested quite extensively on Apple Macintosh computers. The latter can mimic IBM compatible PCs (and run Windows software) provided they have a PC emulation program running. Two of the most widely available PC emulators for Apple Macs are 'SoftWindows' and 'Virtual PC'. Figures 3 and 4 show AIDA v4.3 running under both these environments.

Overview of testing of the updated version of AIDA (v4.3)

One method of learning about how people are applying a piece of software is through a process termed 'beta-testing'. This is widely used by software developers and involves making a program availa-

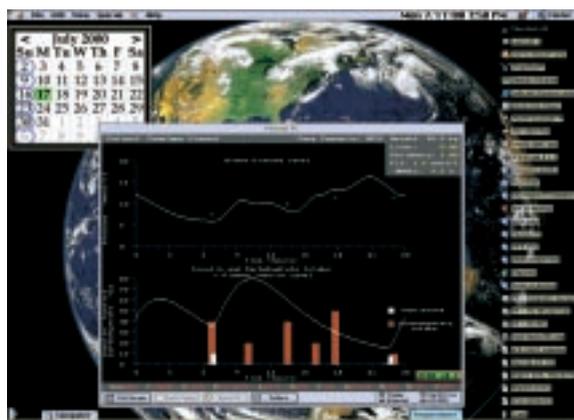


Figure 4. Screen display showing AIDA v4.3 operating in a 'virtual Window' on an Apple Macintosh computer running the Virtual PC emulation software.

ble to a group of end-users, before more widespread general release. The testers can then try out the application and report their experience (and any problems) prior to the software being disseminated more widely; the intention being that it should be easier to correct any problems identified in this way, before the application is distributed further afield.

This approach was used to good effect back in 1996, before the widespread release of AIDA v4.0. In this respect in March / April 1996 a beta version of AIDA was made available to 60 beta-testers via email and the Internet and their feedback was solicited prior to the more widespread distribution of the program in June of the same year [5].

A similar approach was adopted in the second half of July 2000 – prior to the formal launch of AIDA v4.3. In order to understand more about who was actually downloading and testing the program a series of beta-testers were invited to try out the program via the AIDA Website between mid-July 2000 and early August 2000. One of the more interesting aspects of this whole beta-testing process has come from the personal / individual comments sent in via email by some of the beta-testers. A selection of these are documented below, illustrating the wide geographical distribution of testers, and the many and varied ways in which they have applied the program.

Beta-tester feedback comments

A patient with insulin-treated type 2 diabetes from San Francisco, California, USA writes: 'The new version of AIDA works very well. It is easy to do-

wnload and run. I ran several simulations but didn't develop a new one, yet. Later for that. Testing was easy and the controls work well.'

A patient with type 1 diabetes from London, UK writes: 'I love the ability to compare 'real' blood glucose data with estimated (I think this shows graphically that the 'applicability' of suggestions isn't guaranteed. I would still like Humalog (although insulin lasts so long in me, I think using Actrapid, for me, gives a better picture).'

A patient with type 1 diabetes writes: 'I thought AIDA v4.3 looked good and could be useful to individuals with type 1 diabetes. Your programs get better all the time! I can tell a lot of thought goes into them.'

A newly diagnosed type 2 diabetic from the UK writes: 'As a newly (4 months) diagnosed type 2 diabetic I feel that the program has helped me to visualize the process of matching insulin with carbohydrates in simplified terms through the course of the day. It could be very useful for the care team to demonstrate these effects and for the patient to think clearly about the effects of changes on control. Although the profile of the Glicizide [hypoglycaemic] tablets I take (240 mg/day) are not on the database I used the slow acting injections to simulate the effect and it came quite close. As there are a large number of type 2 diabetics who could benefit from having their profiles simulated, you should consider extending the model to non-insulin dependent diabetes as well.'

A patient with type 1 diabetes from Ontario, Canada writes: 'I think every diabetic patient should play with AIDA to learn how insulin and carbohydrates interact to control blood glucose. Although you warn not to use it to adjust your own dose, I actually used AIDA to model 'what would happen if...' and then cautiously tried it. Your 'expert system' [knowledge based system] is quite useful in that regard. It gets it fairly right the first time. Very useful feature.'

The husband of a diabetic patient from Lake Luzerne, New York, USA writes: 'I have installed AIDA version 4.3. It runs well. I like the new transfer option this allows me to print out the results for my wife's care givers to review.'

A doctor using an Apple Macintosh computer from Bridgeport, Connecticut, USA writes: 'I am a physician in the US and I saw your post. I successfully

ran your AIDA program on my Apple Mac running SoftWindows 95, version 4. It ran smoothly and without any difficulty.'

A patient with type 1 diabetes from Ontario, Canada writes: 'I find this is an excellent program! It's given me a much better understanding of the metabolism mechanisms that affect a diabetic. I've used AIDA (in conjunction with my endocrinologist, of course) to examine potential therapy changes. Thanks for making this outstanding program available to the diabetic community.'

A Professor of Chemistry with diabetes from Italy writes: 'I tried AIDA v4.0, and AIDA v4.3. AIDA v4.0 did not work on a Pentium III, 550 MHz machine with Windows'98. As you suggested, I tried it on a slower PC (Intel 486 CPU, straight DOS) and it worked all right.... I have also experimented extensively with AIDA v4.3. I am an author of educational software similar to AIDA to some extent, therefore I am convinced that AIDA is a very good program, and deserves diffusion in many fields: among students, especially medical students, for learning both about models and about diabetes; among medical doctors; it is a good example of science divulgation; it may be a useful addition to materials about diabetes in commercial exhibitions. I found no major bugs in AIDA v4.3. I found no errors of a medical or modeling nature. AIDA v4.3 is substantially improved relative to v4.0. The problem with too fast CPUs [central processing units] is fixed. The distribution file is smaller, and its fitting on a single floppy disk makes a big difference. The installation is easier, as one does not have to uncompress the files and then run setup, but all is done simply by running the installation file. I very much like the new feature for exporting and importing cases. Following your request, I built a case with some of my personal data. I could save and retrieve the data with no problems. Thank you for your effort in developing and maintaining AIDA. I hope to hear again about future developments.'

A patient with type 1 diabetes from San Diego, California, USA writes: 'I thought that if we tested the beta version and it worked okay we didn't need to write. My mistake! I downloaded and tested the AIDA software and everything worked fine. It is pretty thoughtful in giving comments and options.'

A beta-tester from Canada writes: 'Well, I've tried AIDA, and I must say, for a DOS program, it works incredibly well for my setup (Windows'98). The in-

stall went off without a hitch, and I'm sure it simplifies the process a lot for most users. The program behaves very well in all situations. Even without using the shortcut file, AIDA worked perfectly.'

A patient with type 2 diabetes writes: 'Thank you for allowing me to participate in your program. When I signed up to test I really didn't know what to expect. I'm not sure how I will use this program, but I think it is 'neat'. I was diagnosed with type 2 diabetes in March 1996. Until August 1999 my control was with oral medication and diet. I am now taking insulin three times daily. For your information: The download was no problem and fast (I didn't time it but it was less than 4 minutes). The case scenario transfer file was no problem to download and import into the database (following the instructions, which were clear and concise). I plan to share this software with my endocrinologist and her staff, to use as a teaching tool.'

A lecturer in Biomedical Engineering with diabetes, from Ontario, Canada, who got some of his students to try out AIDA: 'I 'voluntold' a few students to check out AIDA on various CPU [central processing unit] chips to see if the 'compiler / CPU' theory is an issue. . . . One graduate student, who is diabetic, was delighted with AIDA, and used it to shift his duties around so that he could have lunch a bit earlier and thus avoid some 'hypos' he was having. He is currently testing this scheme to see if it really eliminates the 'hypo' feeling.

Personally, I am a type 2 diabetic turned type 1 diabetic (now completely insulin dependent and quite resistant). When the pills started to fail, I supplemented them with 3 units of Humulin U, then 5 units, then 7, then 10, 15, 20, 25, 30 units. Sometime during this process I started to add Humulin R, stepping up the dose(s), and number of injections. Then later still I added Humalog first thing in the morning to 'slay' an enormous morning rise in blood glucose. (Dawn blood glucose around 4 to 5 mmol/l – fasting blood glucose at 7:30am around 8 to 10 mmol/l, rising to 12 to 15 mmol/l at noon despite 17 units of Regular insulin plus 10 units of Humalog and 25 units of Humulin U, all at 7:30 am, and a fairly small breakfast). This regimen was getting somewhat crazy, and still leaving me with higher than desired HbA_{1c} levels. So last August I decided on a more scientific approach.

Amongst various things, I ran across AIDA on the Internet, saw its vast potential, but, it crashed all

the time. Upon hearing that it might be a CPU / compiler issue I tried it on my old 486 computer. It worked just fine, so I used AIDA, despite your multiple warnings, to sort out my own new insulin regimen. Please rest assured that I discussed any and all changes that I was about to make with my doctor before I made them. By the end of October I had things well under control. Then the hard disk on the 486 died and with it so did AIDA. I downloaded a fresh version of 4.0 from the AIDA Website, but it still crashed on my Pentium II PC, so when you announced the new version 4.3 and wanted beta testers, well, here I am.

If I can be of any further help please do not hesitate to ask. Please do let me / us know if and when newer versions become available. Many thanks for providing AIDA, I think you have done a fantastic job. '

While these comments are clearly from interested and self-motivated patients (and their relatives) it is informative to see how positive they are about the AIDA v4.3 diabetes simulation software.

In this respect, judging by the number of downloads of the program which are being logged at the Website, interest in AIDA continues to grow. For instance last month (January 2001) there were over 900 downloads of the program, and if anything the numbers are increasing. The monthly average number of downloads for the year 2000 was 591, as compared with an average of 423/month in 1999, 247/month in 1998, 188/month in 1997, and 184/month in 1996.

DISCUSSION

Diabetes simulation programs such as AIDA may appear to be of benefit, and judging by some of the feedback comments received from beta-testers, a range of AIDA users are clearly finding the software of interest / use. Nevertheless there is a great need for such applications to be formally evaluated. In this respect it is incumbent on educational system developers to actually demonstrate a clinical role or use for their application(s).

Therefore, while intuitively AIDA might be regarded as doing some good – or even being useful – it is clear that this remains to be objectively demonstrated. Furthermore while user testimonials about the software [5,8,9] – together with more spontaneous short comments received by the AIDA system developers by electronic mail [10,11] – have

been very encouraging, prospective, clinical randomised controlled trials (RCTs) are clearly required to actually establish, objectively, the educational utility of the approach. In this respect an open randomised controlled trial protocol to formally test out such simulation software in a small-group patient teaching sessions has recently been developed [15] and an initial pilot study using AIDA v4.3 has been completed [16], with a larger, multi-centre assessment of the approach planned to commence during 2001.

Connected with this, while randomised controlled trials offer a 'gold standard' method of evaluation, much can also be gained from 'lesser' methods of assessment. Given this, with AIDA we have been striving to learn as much as possible about what people think of the software, and how they are using it. In this respect, we have recently been endeavouring to look at certain technical, clinical and usability (user satisfaction) indicators regarding the program, and we have also been trying to obtain feedback to help us in the further refinement and development of the system [1]. An early step in doing this has been to audit downloads of the program.

The data overviewed in the accompanying article [1], has highlighted in a large survey carried out over an 8 month period, that over two thirds of people downloading the software were individuals with diabetes or their relatives. It is important not to over-interpret these findings, but it is illuminating that such a large proportion of patients and relatives are turning to the Internet for diabetes-related information.

This observation is mirrored by other reports from elsewhere in the literature. In this respect, the last few years have seen a massive expansion in the size and use of the Internet. For instance, studies have shown that in 1997 the penetration rates for PCs and the Internet in US households were 41% and 20% respectively [17,18]. The current figure for Internet penetration in the USA is estimated to be about 30% of homes, a feat that took the telephone 40 years to accomplish [19,20]. The Internet, particularly the World Wide Web, as a source of data and information is now nearly as ubiquitous as the printed newspaper and wireless media, such as radio and television. Its pervasive influence on health and healthcare is demonstrated by recent studies which have shown that 65% of consumers in the USA get medical / health information from the Web and up to 45% of all Web searches are health-care related [20].

Connected with this a substantial proportion of patients with chronic diseases seem to look for information about their disease on the Internet; the implication being that they may not be getting all they need from their health-care professional(s) locally. In diabetes care, perhaps this is not surprising – due to the lack of time and resources available to health-care professionals and the increasing numbers of patients with diabetes who actually require treatment and long-term care.

In this respect there is clearly a gap between the intellectual knowledge of clinicians and the needs of patients. However a question which remains to be formally assessed is whether information technology (IT) can help to bridge some of this gap.

Repeating Education

There is a clear need for education in diabetes care – but perhaps more importantly there is also a need for education, once delivered, to be repeated. As such it may well be that IT is of particular use, certainly initially, in providing educational reinforcement for topics taught in more standard or conventional lessons. Using such an approach repeat IT-based diabetes lessons might be offered in small clinic groups, or possibly even via the Internet straight into patients' homes, at low / minimum cost. Connected with this an on-line, Web-based version of AIDA is already available (accessible at <http://www.2aida.org/online>) which allows diabetes simulations to be run via the Internet without even having a computer (e.g. via WebTV) [21].

Clearly with such an educational approach available, diabetes simulation necessarily should only be one component of the teaching provided. Related to this, educational compact discs (CD-ROMs) which incorporate basic diabetes simulation facilities along with more extensive databases of educational material have also been described [22], and further developments in this regard can be expected, particularly via the Web [23,24].

However it is important to make clear that computer-based simulation / education is not neutral with respect to health-care infra-structure. Neither is it neutral with respect to the role of health-care professionals as teachers. Therefore it may well be necessary to change the way certain things are done in the health-care setting – (e. g. the way education is delivered, and the availability of computers in clinics for patient use) – in order to take full advantage of computer-assisted learning, and actually get

the most out of information technology, in the clinical diabetes care setting.

Closing remarks

There is a widely recognised phenomenon in medical-computing today of locally successful systems failing when deployed in new settings. We seem to have overcome this problem with the widespread distribution and usage of AIDA via the Internet.

However clearly people are unlikely to be using AIDA all the time. As one AIDA user with type 2 diabetes wrote in an email note (from West Halifax, Vermont, USA): 'AIDA is something I may be intensely interested in during a short period of time and would want all the information I could get. But the rest of the time it wouldn't be used so much.'

In this respect, it is to be expected that many people might make use of the program intensively for a bit – and then stop – once they have learnt what they are seeking to know. However this is one of the ways that computer aided educational tools should be applied – people being able to use them as they need them, at their own pace. Education 'on demand', so to speak.

We believe that such use of AIDA should be encouraged if it can aid or enhance user understanding about the processes involved in balancing insulin and diet in diabetes.

CONCLUSIONS

1. The AIDA diabetes software simulator is being widely used and seems to be well received, particularly by patients with diabetes and their relatives.
2. The new v4.3 release of the program demonstrates how it is possible to provide glycosylated haemoglobin (HbA_{1c}) estimates for blood glucose simulations.
3. Usage of a 'virtual patient' that provides an electronic representation of a patient with a particular condition for educational / teaching, self-learning or demonstration purposes is a concept that warrants wider application and further assessment in other medical fields, in addition to diabetes.

System availability

The AIDA diabetes simulation software continues to be refined and developed. The latest release of

AIDA (v4.3) can be downloaded, without charge, from <http://www.2aida.org> on the Internet. The program runs on IBM PC or compatible 80386/80486/Pentium based machines and requires approximately 3 Mb of hard disk storage space. AIDA can also be used on Apple Macintosh computers running PC emulators such as Virtual PC or SoftWindows. People who wish to be automatically informed about updates and enhancements to the AIDA software range can subscribe (for free) to the AIDA simulator announcement list by sending a blank email note to: subscribe@2aida.org

Any readers who might be interested in collaborating by applying a standardised randomised controlled trial (RCT) protocol [15] themselves in an evaluation of AIDA in their own unit(s) for clinician / specialist nurse / educator-led patient teaching sessions are invited to contact the author. Further information about the evaluation of AIDA for patient use can be found at: <http://www.2aida.org/evaluate> on the Web.

Acknowledgements

The author would like to acknowledge the kind assistance of: Dr. Tibor Deutsch (Budapest, Hungary) and David Broad (London, UK) in the original development of the AIDA v4 software.

REFERENCES:

1. Lehmann ED: *The freeware AIDA interactive educational diabetes simulator* – <http://www.2aida.org> – (1) A download survey. *Med Sci Monit*, 2001; 7(3): 504-515
2. Lehmann ED, Deutsch T: *A physiological model of glucose-insulin interaction in type I diabetes mellitus*. *J Biomed Eng*, 1992; 14: 235-242
3. Berger M, Rodbard D: *Computer simulation of plasma insulin and glucose dynamics after subcutaneous insulin injection*. *Diabetes Care*, 1989; 12: 725-736
4. Lehmann ED: *Diabetes moves onto the Internet*. *Lancet*, 1996; 347: 1542
5. Lehmann ED: *Preliminary experience with the Internet release of AIDA – an interactive educational diabetes simulator*. *Comp Meth Prog Biomed*, 1998; 56: 109-132
6. Lehmann ED: *Interactive educational simulators in diabetes care*. *Med Inform*, 1997; 22: 47-76
7. 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
8. Wilson DM: *Diabetes simulators: ready for prime time?* *Diabetes Technol Ther*, 1999; 1: 55-56
9. Lehmann ED: *User experience with the AIDA interactive educational virtual diabetes patient simulator*. *Diabetes Technol Ther*, 2000; 2: 165-171

10. Lehmann ED: Spontaneous comments from users of the AIDA interactive educational diabetes simulator. *Diabetes Educ*, 2000; 26: 633-643
11. Lehmann ED: Short user comments ('sound bites') regarding usage of AIDA v4 – <http://www.2aida.org> – an interactive educational diabetes simulator. *Diabetes Technol Ther*, 2000; 2: 663-666
12. The Diabetes Control and Complications Trial Research Group: The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. *N Engl J Med*, 1993; 329: 977-986
13. Nathan DM, Singer DE, Humthal K, Goodson JD: The clinical information value of the glycosylated hemoglobin assay. *N Engl J Med*, 1984; 310: 341-346
14. Svendsen PA, Lauritzen T, Soegaard U, Nerup J: Glycosylated haemoglobin and steady-state mean blood glucose concentration in Type 1 (insulin-dependent) diabetes. *Diabetologia*, 1982; 23: 403-405
15. Tatti P, Lehmann ED: A randomised-controlled clinical trial methodology for evaluating the teaching utility of interactive educational diabetes simulators. *Diabetes Nutr Metab*, 2001; 14(1): 1-17
16. Lehmann ED, Tatti P: Prospective randomised-controlled clinical trial methodology for evaluating the teaching utility of interactive educational diabetes simulators. *Diabetes Technol Ther*, 2001; 3(1): [abstract] A55-A57
17. Williams MD: PC penetration tops 40% in US homes, survey says. *Bloomberg News*, June 9, 1997
18. Pospischil R: Fast Internet – An analysis about capacities, price structures and government intervention. *Telecommunications Policy*, 1998; 22: 745-755
19. Gruen J: The physician and the Internet: Observer or participant? *MD Computing*, 1999; 16(6):
20. Lun KC: Strategies for educating people with diabetes on the World Wide Web. In: *International Symposium on Computer and Diabetes Care, Rochester, Minnesota, USA, September 2000*, p. 27 [abstract]
21. Lehmann ED, DeWolf DK, Novotny C et al: Dynamic interactive educational diabetes simulations using the World Wide Web. *Diabetes Technol Ther*, 2001; 3(1): A17-A20 [abstract]
22. Day JL, Rayman G, Hall L, Davies P: 'Learning Diabetes' – a multi-media learning package for patients, carers and professionals to improve chronic disease management. *Med Inform*, 1997; 22: 91-104
23. Lehmann ED: Interactive educational diabetes simulators: future possibilities. *Diabetes Nutr Metab*, 1999; 12: 380-387
24. Lehmann ED: Interactive educational diabetes simulators: a look to the future. *Diabetes Technol Ther*, 2000; 2: 507-512