

## ► Web-based diabetes control

O Ferrer-Roca, K Franco Burbano, A Cárdenas, P Pulido and A Diaz-Cardama

Faculty of Medicine, University of La Laguna, Tenerife, Spain

### Summary

We developed a diabetes management system with a Web interface that allowed patients to transmit their physiological data using either a PC Web browser or a mobile phone capable of working with the WAP protocol. The system could generate automatic responses to input values in accordance with a set of ranges previously defined for each user. User analysis was carried out with personal and online questionnaires. During a nine-month study period on the island of Tenerife, 12 patients were recruited. On average, they used the system every 2.0 days (SD 2.1) and the doctors reviewed their patient data every 4.0 days (SD 3.9). The average number of visits to the Website was 477 per month. Users were satisfied with the continuity and self-efficacy of care, but lack of time was a drawback for 38% of them and 75% expressed a preference for sending their data via the mobile phone short message service (SMS).

### Introduction

---

The management of diabetes involves calculating, recording and controlling levels of ketones, blood glucose and glycosylated haemoglobin (HbA<sub>1c</sub>); careful monitoring is required of medication and food intake, especially of carbohydrates. It is a condition that benefits from the provision of health guidelines. The self-management of diabetes can be enhanced if patients have access to a PC<sup>1,2</sup>; for example, they can benefit from information and interaction offered via a Web interface<sup>3,4</sup>. In contrast, there are few examples of the Internet being used for distant patient management by doctors.

In Spain, 58% of diabetic patients own PCs and 36% use the Internet. These are commonly younger men who have received higher education, with a recent diagnosis of diabetes and few complications<sup>5</sup>. In the Canary Islands, the prevalence of diabetes is 8%<sup>6,7</sup>. There are 173,000 inhabitants aged 15–30 years on the island of Tenerife<sup>8</sup> and 19% of families have access to the Internet at home<sup>9</sup>. Thus a potential population of over 2600 diabetic patients could be managed via a Web interface.

We have developed a diabetes management system that uses a Web interface. It allows patients to transmit data such as blood glucose level and body weight using either a PC Web browser or a mobile phone that is capable of working with the WAP protocol. The data can then be reviewed by the patient or doctor via the Web interface.

### Methods

---

The system used a client/server architecture based on a Windows Web server. This was complemented with a database (Access 2000, Microsoft), an ADO data access engine (Microsoft.Jet.OLEDB.4.0) and Active Server Pages written in Visual Basic (ASP v.2).

### Web design

The Website had 241 pages. The homepage allowed access to educational content, and to the patient and the doctor interfaces. The patient interface allowed biological measurements to be entered; the system could generate automatic responses to these input values in accordance with a set of previously defined ranges (Fig 1). Both the doctor interface and the patient interface allowed the patient data to be reviewed, in either tabular or graphical format (Fig 2). The doctor interface allowed doctors to send advice to their

Accepted 6 July 2004

Correspondence: Professor O Ferrer-Roca, Faculty of Medicine, University of La Laguna 38071, Tenerife, Spain (Fax: +34 922 641 855; Email: catai@teide.net)

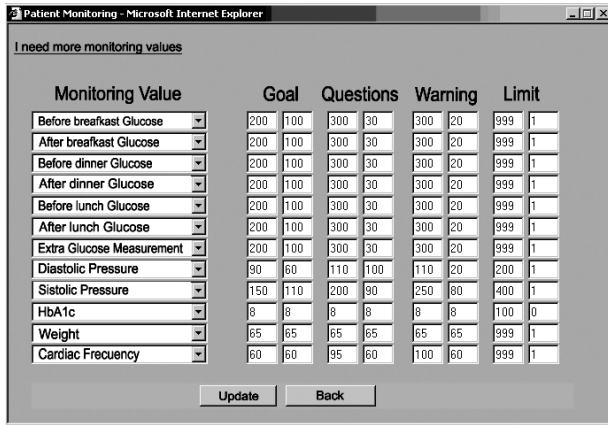


Fig 1 Page of the Web interface showing range definitions. The 'Limit' range prevented the entry of values outside a specified range. The 'Warning' range set the values for which the system would automatically advise the patient to see a specialist. The 'Questions' range set the values for which the system would automatically offer the patient a series of questions to determine whether a potential emergency existed or not.

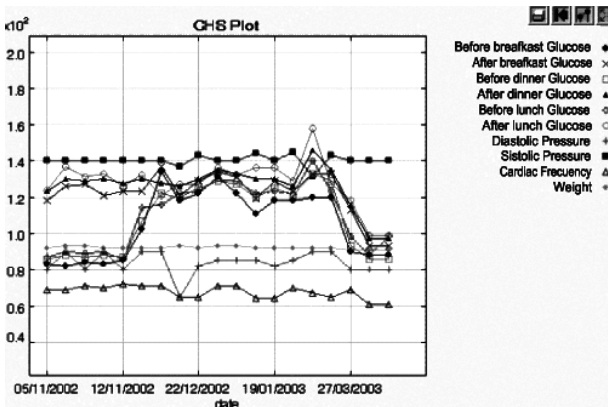


Fig 2 Graphical presentation of patient data.

patients that could be read during the patient's next online session.

### Patient recruitment

Patients were recruited on the island of Tenerife from September 2002 until June 2003. The criteria for trial entry were: a diagnosis of diabetes; aged 18–75 years; Internet access at home or work, or alternatively via mobile phone capable of using WAP services; and basic knowledge of the information technology. All patients gave informed consent. Ethics committee approval was not required.

Usability and user acceptance were evaluated in four ways:

- (1) *An online questionnaire* (see Table 1). This was completed by 160 users: 135 non-diabetic telemedicine students who tested the system, and

25 diabetic patients, 12 of whom participated in a trial of the system. Questions were scored on a five-point scale (1=not true, to 5=very true). Questions were counterbalanced in terms of positive and negative phrasing. Scores of 1 or 2 on negatively phrased questions and of 4 or 5 on positively phrased questions were categorized as 'positive' evaluations of the system; scores of 3 were categorized as an evaluation of 'indifferent'; and scores of 4 or 5 on negatively phrased questions and of 1 or 2 on positively phrased questions were categorized as 'negative' evaluations of the system.

- (2) *Online comments*. Patients could send email messages to their doctor or to the Web master, and doctors could send messages to their patients. All messages were recorded on the database, together with details of the sender, recipient and time of transmission.
- (3) *Telephone interview*. The telephone interview comprised 20 questions (see Table 2) in closed format (i.e. they required responses of 'yes', 'no' or 'don't know'). Some questions evaluated: patients' willingness to use the Internet or their preference for using the short messaging service (SMS) for mobile phones; the anxiety and stress resulting from the patient having different sources of information<sup>10</sup>; the patient's lack of time to use the system<sup>11</sup>; the readability of the information presented<sup>12</sup>; and technical difficulties. Further questions were related to patient benefits<sup>13–15</sup>.
- (4) *System usage*. System usage was measured by counting the number of times Web pages were visited and examining the log-file of the system. Web log analysis was carried out with free software (Web Log Expert 1.61)<sup>16</sup>.

### Results

During the nine-month study period, 12 patients were recruited, which represents less than 5 per 1000 of the population meeting the trial requirements. During the last three months no new patients were recruited (Fig 3). The patients were aged 27–68 years (mean 39, SD 15). They reported technical difficulties with their PCs or modems, as well as slow or otherwise problematic access to the Website. Doctors reported difficulties with finding appropriate patients who had local Internet access and sufficient technical knowledge to use the Internet, as well as difficulties in accessing the Website.

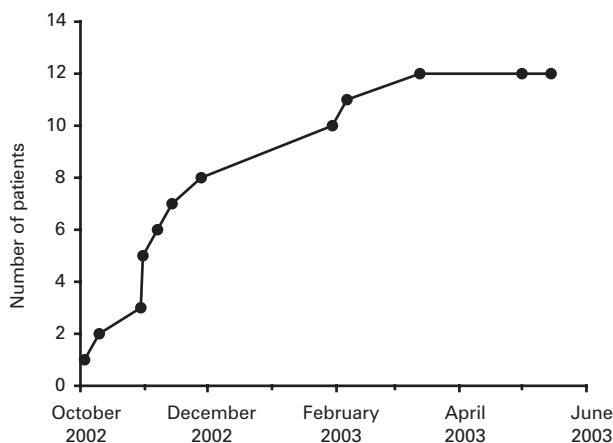
### Online questionnaire

The 20 items of the online questionnaire were scored by 160 users. Of all these item-level responses, 42%

**Table 1** Numbers (%) of responses in each category (1–5<sup>a</sup>) of the online questionnaire (n=160)

Question	1	2	3	4	5
1. I would like to go on using the system in the future	5 (3)	10 (6)	80 (50)	42 (26)	23 (14)
2. I would recommend the use of this system to my family members, to my friends or to other patients	6 (4)	12 (8)	49 (31)	61 (38)	32 (20)
3. It took me a lot of time to learn how to use this system (negative)	36 (23)	39 (24)	51 (32)	25 (16)	9 (6)
4. I am satisfied with the tuition I received before I started using this system	1 (1)	17 (11)	57 (36)	50 (31)	35 (22)
5. It was easy to use this system, once I learnt how	2 (1)	11 (7)	46 (29)	59 (37)	42 (26)
6. I find this system to be a useful and efficient adjunct to my care	4 (3)	12 (8)	56 (35)	58 (36)	30 (19)
7. I felt uncomfortable disclosing intimate information to this system (negative)	35 (22)	28 (18)	53 (33)	28 (18)	16 (10)
8. The use of this system was expensive for me (negative)	49 (31)	37 (23)	57 (36)	13 (8)	4 (3)
9. Using this system was bothersome or boring (negative)	30 (19)	39 (24)	67 (42)	17 (11)	7 (4)
10. Every time I used this system, I found it to be warm and human	16 (10)	33 (21)	72 (45)	32 (20)	7 (4)
11. I have concerns regarding confidentiality with this system (negative)	14 (9)	31 (19)	59 (37)	36 (23)	20 (13)
12. It was easy to access the system whenever I tried	6 (4)	12 (8)	70 (44)	46 (29)	26 (16)
13. Technical problems interrupted my use of this system (negative)	10 (6)	15 (9)	68 (43)	32 (20)	35 (22)
14. I took me a lot of time to complete my interaction with this system (negative)	20 (13)	33 (21)	76 (48)	25 (16)	6 (4)
15. The information provided by this system was clear and easy to understand	2 (1)	6 (4)	56 (35)	63 (39)	33 (21)
16. The error messages that this system gave me, when I made mistakes, helped me fix them easily and quickly	6 (4)	15 (9)	76 (48)	44 (28)	19 (12)
17. I like using this system	2 (1)	9 (6)	62 (39)	61 (38)	26 (16)
18. There are many things about this system that could be improved (negative)	1 (1)	15 (9)	66 (41)	48 (30)	30 (19)
19. Overall, I am satisfied with this system	4 (3)	5 (3)	68 (43)	67 (42)	16 (10)
20. The use of the system has affected my relationship with my doctor (negative)	17 (11)	19 (12)	85 (53)	27 (17)	12 (8)
Total number of responses for the 11 positive questions	54 (3)	142 (8)	692 (39)	583 (33)	289 (16)
Total number of responses for the 9 negative questions	212 (15)	256 (18)	582 (40)	251 (17)	139 (10)

<sup>a</sup>1 = not true; 5 = very true.

**Fig 3** Patient recruitment during the trial.

were 'positive', 40% 'indifferent' and 18% 'negative' (Table 1). Patients and non-diabetic subjects differed significantly in their responses to certain questions, as shown by a  $\chi^2$  test (question 2,  $P < 0.01$ ; question 5,  $P < 0.05$ ; question 6,  $P < 0.05$ ; question 12,  $P < 0.01$ ): on question 2, 86% of the patients said that they would recommend the site, compared with 40% of non-diabetic subjects; on question 5, 71% of patients and 92% of non-diabetic subjects agreed that the system was easy to use; on question 6, 33% of the patients did not find the system useful and efficient, compared with

**Table 2** Responses of eight patients participating in the trial to the telephone interviews<sup>a</sup>

Items	Yes	No	Do not know/ no reply
Willingness to use the Internet	4	4	0
Preference for SMS	6	2	0
The anxiety and stress caused by having different sources of information	2	6	0
Lack of time in which to use the system	3	5	0
Difficulties of readability	1	7	0
Technical difficulties	4	4	0
Greater patient self-efficacy	4	4	0
Greater satisfaction with care	2	5	1
Greater satisfaction with continuity of care	5	2	1
Greater satisfaction with provider	3	3	2
Greater satisfaction with quality of health outcome	1	5	2
Decreased HbA <sub>1c</sub> levels	0	5	3
Decrease blood glucose levels	1	3	4
Improved diet	0	5	3
Improved body weight control	1	4	3
Lowered cholesterol levels	1	5	2
Lowered perception of diabetes intrusiveness	2	5	1
Improved quality of life	1	5	2
Less depression	1	4	3
Decreased incidence of diabetic complications	0	6	2

<sup>a</sup>Four of the 12 patients could not be contacted for this interview.

the 12% of the non-diabetic subjects. On question 12, 50% of patients said they had difficulties in accessing the system, compared with 88% of the non-diabetic subjects.

### Online comments

During the trial, email messages reporting Website communication problems came from two of the 12 patients. Messages sent to patients were automatic warnings, based on the measurements posted by the patients and the ranges set by doctors. Although the doctors could send messages to the patient from their Web interface, they did not use this facility. However, it was sporadically used by the Web master.

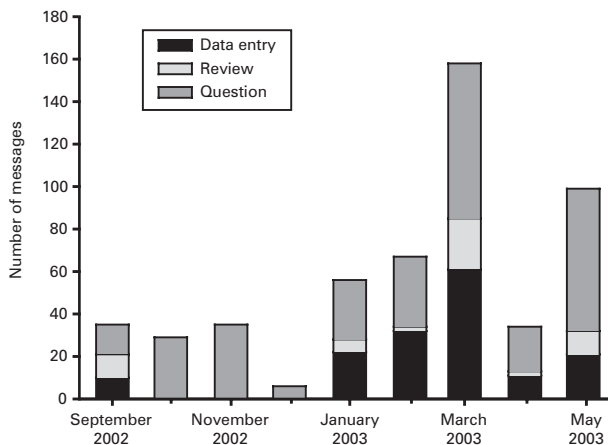
### Telephone interviews

Four patients could not be contacted for telephone interview. Half those contacted said that they were willing to use the Internet to manage their diabetes; three-quarters said that they would prefer to use SMS. The responses are summarized in Table 2.

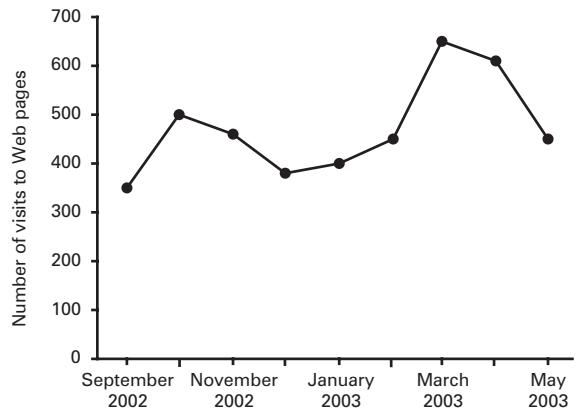
### System usage

The numbers of messages sent by the patients, including data entry, data review and questions, are shown in Fig 4. None of the patients used the WAP interface. Of the Web logins, 94% were followed by some kind of action (e.g. data or data review). The average number of Website visits was 477 per month (Fig 5). During the first three months, the Website was visited by patients and doctors in similar proportion but thereafter more visits were by patients. There were fewer visits to the Website in the month of December, perhaps because of Christmas (Fig 6).

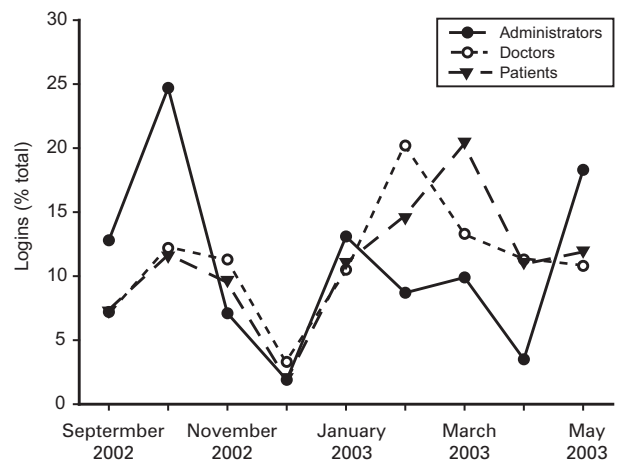
On average, the patients used the system every 2.0 days (SD 2.1) and the doctors reviewed their patient data every 4.0 days (SD 3.9). Login analysis showed that patients provided data in half their logins and that doctors reviewed at least one set of patient data during each login. Only four of the 12 study patients regularly provided data through the Web interface after nine months.



**Fig 4** Numbers of patient messages (concerning data entry, data review, or questions) sent during the trial.



**Fig 5** Numbers of times per month that the Web pages were accessed during the nine-month trial.



**Fig 6** Logins by administrators, doctors and patients: proportion (%) of all logins over trial duration, by month, separately for administrators, doctors and patients. The lowest activity occurred during vacation periods (Christmas and Easter).

### Discussion

Only 5 per 1000 inhabitants who met the trial inclusion criteria were recruited. Nonetheless, the trial demonstrated the usability of the system, although certain difficulties were identified. The main problems were access to and knowledge of the Internet, on the part of both patients and doctors, which suggests that a simpler solution is needed, such as sending data by mobile phone and SMS<sup>17</sup>. Monitoring values defined separately for each patient gave flexibility, since the initial management plan could easily be modified.

The effectiveness of the system relied on regular contact. The contact frequency provided an indication of the level of acceptance and the extent to which use of the system had become a habit. Web administration decreased over time, while patients and doctors

increased or maintained their usage of the system (see Fig 6).

The main problems were the unreliability of the Web server, which was located on a university network, and the limited knowledge of information technology (IT) on the part of patients and doctors. The proportions of all questionnaire responses that were positive or 'indifferent' evaluations were similar (42% and 40%, respectively), while negative evaluation was low (18%). The most frequent positive responses were for ease of use and understanding, together with efficient care and low cost (an average of 54%). The need for improvements and the technical problems were evident in the frequent negative responses to these questionnaire items (an average of 46%).

A major factor detracting from the success of the system was the lack of messages to patients from doctors<sup>15</sup> — doctors did not once use this facility, which was disappointing because the patients felt there was no case management by the doctors. In the telephone interviews, five of the eight patients reported being satisfied with the continuity of care but only three with the care provider and one with the quality of health outcome. Similarly, in the telephone interviews users generally reported that the system did not lessen their perceptions of the intrusiveness of diabetes, improve their quality of life, lessen feelings of depression or decrease the incidence of diabetic complications.

The telephone questionnaire suggested that most users did not experience any anxiety and stress from having different sources of information, nor did they have any difficulty with the readability of the information presented. Nevertheless, lack of time to use the system was reported by three of these eight users and six of them said they would prefer to use mobile phone SMS rather than a Web interface to access the system (none had used the WAP interface). In summary, the Web management system for diabetes was considered satisfactory by its users, despite rather low recruitment into the trial, certain technical difficulties and limited Internet access.

**Acknowledgements:** This work was done as part of the EU research programme IST-1999-13352 Citizen Home Service-CHS project; we thank all the project partners for their support. We acknowledge the help of Maulin Soneji and Lesley Nichols, exchange telemedicine students in the Asklepios project from the St Louis University School of Medicine, who collaborated in reviewing the English version of the typescript.

## References

- 1 Project Glucosa-Control. See <http://glucosacontrols.filnet.es/>. Last checked 2 July 2004
- 2 Diabetes Management System 1.0. See <http://www.dragiton.com/software/Detailed/8206.php4>. Last checked 2 July 2004
- 3 Zhao N, Roudsari A, Carson E. A web-based diabetes management system: DiabNet. *Journal of Medical Internet Research* 1999; Supplement: Proceedings of the 4th World Congress on Internet in Medicine. See <http://www.jmir.org/1999/1/suppl1/e68/>. Last checked 2 July 2004
- 4 Starren J, Hripscak G, Sengupta S, et al. Columbia University's Informatics for Diabetes Education and Telemedicine (IDEATel) project: technical implementation. *Journal of the American Medical Informatics Association* 2002;**9**:25-36
- 5 Giménez-Pérez G, Gallach M, Acera E, et al. Evaluation of accessibility and use of new communication technologies in patients with type 1 diabetes mellitus. *Journal of Medical Internet Research* 2002;**4**:e16. See <http://www.jmir.org/2002/3/e16/index.htm>. Last checked 2 July 2004
- 6 *Servicio del Plan de Salud e Investigación del Servicio Canario de Salud. Encuesta Nutricional de Canarias 1997-1998. Volumen 2: Factores de riesgo cardiovascular.* [Health Plan of the Health Canarian Service. Nutritional survey of Canary Islands 1997-1998. Vol. 2. Cardiovascular Risk Factors.] Santa Cruz de Tenerife: Consejería de Sanidad y Consumo del Gobierno de Canarias, 1999
- 7 De Pablos Velasco PL, Rodríguez Pérez F, Pérez Moreno JE, et al. *Prevalencia de la Diabetes Mellitus no dependiente de la insulina en Santa María de Guía. Estudios sobre Diabetes Mellitus en Canarias.* [Prevalence of non-insulin-dependent diabetes mellitus in St Maria de Guia. Study on diabetes mellitus in Canary Islands.] Santa Cruz de Tenerife: Servicio Canario de Salud, Consejería de Sanidad y Consumo del Gobierno de Canarias, 1999
- 8 *Censos de Población y viviendas, Canarias 1991. La Población, características principales.* [Population and housing census, Canary Islands 1991. Population, principal characteristics.] Santa Cruz de Tenerife: Instituto Canario Estadística, Gobierno de Canarias, Consejería de Economía y Hacienda, March 1993
- 9 Ballesteros F, Gonzalez Seara L, Lopez-Tafall JJ, et al. *España 2002. Informe anual sobre el desarrollo de la Sociedad de la Información en España.* [Spain 2002. Annual report on the development of the information society.] Madrid: Fundación AUNA, 2002
- 10 Murero M, D'Ancona G, Karamanoukian H. Use of the Internet by patients before and after cardiac surgery: telephone survey. *Journal of Medical Internet Research* 2001;**3**:e27. See <http://www.jmir.org/2001/3/e27/index.htm>. Last checked 2 July 2004
- 11 Health on the Net Foundation. Evolution of Internet use for health purposes — February/March 2001. See <http://www.hon.ch/Survey/FebMar2001/survey.html>. Last checked 2 July 2004
- 12 Zrebiec JF, Jacobson AM. What attracts patients with diabetes to an internet support group? A 21-month longitudinal website study. *Diabetic Medicine* 2001;**18**:154-8
- 13 Tattersall RB, Gale EA, eds. *Diabetes: Clinical Management.* Edinburgh: Churchill Livingstone, 1990
- 14 Feil EG, Glasgow RE, Boles S, McKay HG. Who participates in Internet-based self-management programs? A study among novice computer users in a primary care setting. *Diabetes Educator* 2000;**26**:806-11
- 15 McKenna MK. E-Health and the practicing physician. See <http://rxrama.com/news20010722.html>. Last checked 2 July 2004
- 16 Web Log Expert 1.61. See <http://www.weblogexpert.com>. Last checked 2 July 2004
- 17 Ferrer-Roca O, Cárdenas A, Diaz-Cardama A, Pulido P. Mobile phone text messaging in the management of diabetes. *Journal of Telemedicine and Telecare* 2004;**10**:282-5