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Original Research

A Comparison of Internet Monitoring with Continuous Glucose Monitoring in Insulin-Requiring Type 2 Diabetes Mellitus

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ABSTRACT

Objective: To compare the effects of real-time continuous glucose monitoring (RT-CGM) and an Internet blood glucose monitoring system (IBGMS) on glycated hemoglobin levels in patients with type 2 diabetes mellitus treated with insulin.
Methods: Fifty-seven patients with type 2 diabetes treated with insulin were assigned randomly to 1 of 2 groups. Group 1 had the results of their self-monitoring of blood glucose level monitored biweekly using an IBGMS. Group 2 used RT-CGM and were monitored biweekly. Both groups used a secure website to upload data and to receive feedback from their endocrinologist. A1C and laboratory test results were collected at 0, 3 and 6 months.
Results: The baseline parameters were not significantly different. After a 6-month follow-up period, both IBGMS and RT-CGM showed significant within-group improvements in A1C level. In the IBGMS group, the A1C level decreased from 8.79%±1.25% to 7.96%±1.30% ($p<0.05$). The RT-CGM group decreased from 8.80%±1.37% to 7.49%±0.70% ($p<0.001$). IBGMS and RT-CGM did not show significantly different A1C levels at baseline, 3 and 6 months ($p>0.05$).
Conclusions: The use of both IBGMS and RT-CGM significantly improved A1C levels in patients with type 2 diabetes treated with insulin in a randomized trial over a 6-month period. There were no significant differences in A1C values between groups after 6 months.

Mots clés :
surveillance du glucose par Internet
surveillance du glucose en continu en temps réel
surveillance à distance
diabète de type 2

RÉSUMÉ

Objectif : Comparer les effets de la surveillance du glucose en continu (SGC) en temps réel (SGC-TR) et un système de surveillance de la glycémie par Internet (SSGI) concernant les concentrations d'hémoglobine glyquée (HbA1C) chez les patients ayant le diabète sucré de type 2 traités par insuline.
Méthodes : Cinquante-sept (57) patients ayant le diabète de type 2 traités par insuline ont été désignés aléatoirement pour faire partie de 1 des 2 groupes. Le groupe 1 a eu les résultats de l'autosurveillance de leur glycémie deux fois par semaine en utilisant un SSGI. Le groupe 2 a utilisé la SGC-TR et a été surveillé deux fois par semaine. Les 2 groupes ont utilisé un site Web sécurisé pour télécharger les données et obtenir une rétroaction de leur endocrinologue. Les résultats de l'HbA1C et des examens de laboratoire ont été recueillis à 0, à 3 et à 6 mois.
Résultats : Les paramètres initiaux n'étaient pas significativement différents. Après un suivi de 6 mois, le SSGI et la SGC-TR ont montré des améliorations intragroupes significatives des concentrations d'HbA1C. Dans le groupe qui utilisait un SSGI, la concentration d'HbA1C a diminué, passant de 8,79 % ± 1,25 % à 7,96 % ± 1,30 % ($p < 0,05$). Le groupe qui utilisait la SGC-TR a diminué, passant de 8,80 % ± 1,37 % à 7,49 %

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± 0,70 % (p < 0,001). Le SSGI et le SCTRG n'ont pas montré de différences significatives dans les concentrations d'HbA1C au début, à 3 et à 6 mois (p > 0,05).
Conclusions : L'utilisation du SSGI et de la SGC-TR a significativement amélioré les concentrations d'HbA1C chez les patients ayant le diabète de type 2 traités par insuline au cours d'un essai aléatoire d'une période de 6 mois. Il n'y a eu aucune différence significative dans les valeurs de l'HbA1C entre les groupes après 6 mois.

Introduction

In the management of diabetes, self-monitoring of blood glucose (SMBG) and glycated hemoglobin measurements are used to assess glycemic control and modify diabetes treatment (1–5). The advent of new technologies has changed how healthcare professionals approach diabetes management. Internet platforms have been created that enable patients to upload their SMBG data. Studies have shown that an Internet blood glucose monitoring system (IBGMS) that allows patients to send their blood glucose data to their healthcare provider for review can reduce their A1C when compared with a control population using only SMBG with standard care (4).

Real-time continuous glucose monitoring (RT-CGM) is one of the most recent technological innovations in the management of diabetes. It provides the user with continuous feedback on blood glucose levels with an added benefit that, once uploaded, a report summarizing the data concisely can be sent to a healthcare professional. When compared with a control population using only SMBG, several studies involving patients with type 1 diabetes mellitus showed that using RT-CGM can help decrease A1C if used frequently and on a continuous basis (6–9). However, the data supporting the use of RT-CGM in patients with type 2 diabetes are less substantial (10).

The purpose of this study was to evaluate the therapeutic intervention of RT-CGM and IBGMS, as measured by change in A1C level, for patients with type 2 diabetes treated with insulin over a 6-month period.

Methods

This study was approved by the Providence Health Care Research Ethics Board. We enrolled 57 patients with type 2 diabetes treated with insulin, either alone or in combination with oral antihyperglycemic agents. Inclusion criteria included a recent A1C level greater than 7.0%, Internet access and prior training in SMBG. Patients randomly were assigned to 1 of 2 groups, IBGMS or RT-CGM, using a computer random number generator. All patients were provided with a blood glucose meter (Freestyle; Abbott, Abbott Park, IL) and test strips for testing 3 times daily, and were required to perform a laboratory blood test combined with a visit to their endocrinologist at 3- and 6-month intervals. All patients had received previous comprehensive diabetes education with a team that included nurse educators, dieticians and endocrinologists. When visiting their endocrinologist, all patients were provided with standard office-based care.

Of the 57 patients recruited, 32 were randomized to the RT-CGM group and 25 were randomized to the IBGMS group. A total of 17 patients withdrew from the study. In the RT-CGM group, 7 patients dropped out immediately after being randomized because of an unwillingness to receive treatment. These patients were not included in the data. An additional 5 patients in the RT-CGM group withdrew from the study, some citing discomfort and inconvenience of treatment. Five patients also dropped out from the IBGMS group during the course of the study because they were unable to attend follow-up appointments, generally citing personal reasons unrelated to treatment. All available data, including those from patients who withdrew during the course of the study, were analyzed with intent to treat.

Patients randomized to the IBGMS group were trained by the research coordinator to upload their glucose readings every 2 weeks to a secure, commercially available website (ALR Technologies, Inc., Atlanta, GA). Glucose levels were presented in table and graph formats according to the time of day, with automatic calculations showing the mean, standard deviation and range for specific time periods. The system allowed patients to input medications, view summaries of readings and contact their endocrinologist. The endocrinologist reviewed the readings and sent feedback through the ALR messaging system.

Patients randomized to the RT-CGM group were trained by a registered nurse familiar with sensor technology to use the Guardian REAL-Time Continuous Glucose Monitoring System (Medtronic MiniMed, Inc., Northridge, CA). Patients were asked to save the sensor daily overlay report as a pdf file and e-mail it to their endocrinologist every 2 weeks. This report provides visual 7-day tracking, indicating trends and excursions, in addition to daily summaries of mean blood glucose levels with highs, lows and standard deviation. The endocrinologist's recommendations to both the IBGMS and RT-CGM groups included changes in therapy, suggestions on testing frequency, lifestyle modifications and/or encouragement to continue with no changes.

Baseline demographic data were collected from patient charts. A1C values were measured using the ADIVA Centaur Immunoassay System (Tarrytown, NY). Data were analyzed using a computerized database (Excel; Microsoft, Redmond, WA). Independent sample t tests were used to compare the within-group and between-group changes. For all analyses, statistical significance was established at a p value of less than 0.05.

We assumed that patients adhered to their insulin and medication dosages as recommended by the endocrinologist. There was no formal method of auditing insulin use or other treatment modalities.

Results

Key demographic and baseline clinical characteristics are summarized in Table 1. Baseline parameters for the 2 groups were

Table 1
Demographic and baseline characteristics of the study population

	IBGMS	RT-CGM	p value
N	25	25	
Age (y)	59.5±10.7	58.0 ± 8.8	0.351
Male/female	16/9	16/9	
Duration of diabetes (y)	17.0±7.1	17.4±7.9	0.435
BMI (kg/m^2)	34.7±5.7	34.9±6.9	0.476
A1C at baseline (%)	8.79±1.25	8.80±1.37	0.495
Blood pressure (mm Hg)	129.5±11.8/ 74.9±8.2	130.3±14.1/ 75.3±7.1	0.433
Creatinine level (μmol/L)	84.0±26.6	81.1±20.1	0.336
Daily insulin dosage (IU)	70.7±76.8	60.4±36.7	0.273
Single	6	2	
Twice daily	14	16	
MDI (>3 times daily)	5	7	

BMI, Body mass index; *IU*, international unit; *MDI*, multiple daily injections.
Data are means ± standard deviation.

similar. Of the patients in the IBGMS group, 6 patients were on single daily injections, 14 patients were on 2 daily injections and 5 patients were on 3 or more injections daily. Of the RT-CGM group, 2 patients were on single daily injections, 16 patients were on 2 daily injections and 7 patients were on 3 or more injections daily.

Measurements of A1C level are summarized in Table 2. By the 6-month follow-up evaluation, within-group changes in A1C level were significant for both the RT-CGMS and IBGMS groups. A comparison of between-group variations in A1C level showed no significant differences at 0 and 6 months. The A1C level in the RT-CGM group decreased from 8.80%±1.37% to 7.49%±0.70% ($p<0.001$). In the IBGMS group, the A1C level decreased from 8.79%±1.25% to 7.96%±1.30%, a similarly significant decrease in A1C over the study period ($p<0.05$). Insulin dosages for both within-group and between-group data were not found to be significant at 6 months from baseline. Of interest was a difference in frequency of glucose testing estimated by strip count, as summarized in Table 3.

Discussion

Patients with diabetes treated with insulin are often concerned about the risk of hypoglycemia and/or hyperglycemia. The advent of new communication technologies provides an opportunity for such patients to report to their physician and receive feedback regarding changes in insulin dosage to achieve stated glucose targets. This study tested the utility of both IBGMS and RT-CGM for people with type 2 diabetes treated with insulin. In each group, the data showed a significant improvement of mean A1C level over the 6-month study period. These results support previous literature that investigated these modalities separately (4,6–11) and show a treatment supplement that addresses the limitations of SMBG (1–5). These findings are of clinical significance because of the standard of care required for blood glucose control to reduce the chronic complications associated with type 2 diabetes (12,13).

It is worthy to note that at 6 months there was no difference in the 2 groups despite the fact that RT-CGM provides immediate feedback to the user in 5-minute intervals, 24 hours a day. In addition, the frequency of self-monitoring for patients on RT-CGM was higher than for patients on IBGMS, as indicated by the strip count over the 6-month period. A closer look showed that RT-CGM patients used more strips from 0 to 3 months as a result of patients calibrating their sensors. From 3 to 6 months, the difference in strip count between the 2 groups was negligible. Overall, during the course of the study, the RT-CGM group used approximately 95 more strips per patient than the IBGMS group, adding to the overall cost of treatment.

Severe hypoglycemia in both groups was negligible with no serious events. The number of patients with self-reported hypoglycemia (<4.0 mmol/L) did not significantly differ between the 2 groups.

Of 25 patients in the RT-CGM group, there were 2 reported adverse events. One patient suffered a subcutaneous infection requiring antibiotic therapy and discontinued the study. One patient developed a cyst, resulting in temporarily suspending sensor use and did not require antibiotic therapy; this patient continued with the study.

Table 2
Measurements in A1C level over the study period

	Baseline	6 months	p*
RT-CGM	8.80%±1.37%	7.49%±0.70%	0.0001
IBGMS	8.79%±1.25%	7.96%±1.30%	0.0170
p†	0.496	0.081	

* Refers to baseline p value versus 6-month follow-up evaluation.
† Refers to RT-CGM versus IBGMS.

Table 3
Average total strips used per patient

Time period	IBGMS	RT-CGM	p
Total (0–6 months)	428.8±185.7	523.7±124.5	0.044
0–3 months	204.3±88.3	298.1±83.4	0.01
3–6 months	224.5±109.4	225.6±56.8	0.23

A routine-care cohort was not part of the experimental design. In addition, patient dropouts resulted in less reliable data. We are also aware that the RT-CGM group was subject to self-selection bias from patients. Overall, 12 patients withdrew from the RT-CGM group in comparison with 5 patients from the IBGMS group. Thus, it is possible that the resulting constituents of the RT-CGM group were more motivated and conscientious. Despite this, the 2 groups showed a similar decrement in A1C level.

This study must be put in a clinical context. There are inherent advantages of IBGMS. It is less invasive, it can be used with several brands of meters, and it is less expensive. One limitation noted in the literature was a lack of remuneration for healthcare professionals using an IBGMS (4); however, in British Columbia this is no longer the case because the Medical Services Plan now reimburses Internet blood glucose management (14).

RT-CGM is more invasive and is more costly for training and materials. Although the majority of studies have been conducted on patients with type 1 diabetes (8,15), RT-CGM has been shown to improve glycemic awareness even without clinical intervention (11) and also may convey additional benefits by reducing hypoglycemic exposure (8) and post-prandial hyperglycemic excursions (15).

Conclusions

We found that both IBGMS and RT-CGM improved A1C values for patients with type 2 diabetes treated with insulin. When comparing the treatments after 6 months, no statistically significant difference was found between the groups ($p>0.05$). RT-CGM, although effective, proved to be invasive, costly and subjected patients to subcutaneous infection. With comparable efficacy as interventions, IBGMS can be seen as more favourable because of its convenience, affordability, safety and noninvasiveness.

Author Disclosures

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No other potential conflicts of interest relevant to this article were reported.

Author Contributions

HDT designed the study, developed the protocol, collected and interpreted data, wrote the manuscript, and reviewed and edited the manuscript; AMW, JHMC and ABM analyzed data, wrote the manuscript, contributed to protocol development and collected the data; SAR contributed to the study design, protocol development and reviewed and edited the manuscript; HGT and AML analyzed data, wrote the manuscript, and reviewed and edited the manuscript; TT contributed to the protocol development and reviewed and edited the manuscript; ASW contributed to the study design and protocol development, interpreted data and reviewed and edited the manuscript. All authors read and approved the final manuscript.

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