Preventing Risk Situations at Type-II Diabetes Mellitus Patients Through Continuous Glucose Monitoring and Prediction-based Teleconsults

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***Abstract*—We present a scheme of eHealth based on teleconsults aimed to reduce unexpected events and complications in type-2 diabetes mellitus (DM-II). To this end, this study has considered the history of glucose tests taken as input inside a predictive mathematical scheme based on probabilities. The resulting output goes to a real-time monitoring system in order to detect and update those cases where patients would require of rapid assistance. The simulations have shown that the opportune intervention of teleconsults might be effective in the sense of monitoring diet and drug-based treatment by employing simple mobile phones and minimal software applications. For example, the case of a critic patient with a rapid increasing of glucose above 200 mg/dL, the opportune intervention of teleconsults might reduce these values by a 50% during a time of 20±2 days. It can also be traduced as the improvement on the stability of patient against the risk of cardiovascular events, or others DM-II inherent complications.**

***Keywords*—Telemedicine; Type-2 Diabetes Mellitus;**

I. Patients Selection and Pattern Identification

We have selected 10 DM-II patients belonging to a peri-urban area located at the zone Los Olivos, Lima city, with the following characteristics: (i) very low incomes per month, (ii) poor praxis of selfcare, (iii) ages between 30 and 60 y.o., (iv) weight between 70 and 110 Kg., (v) diagnosis on early 2014, (vi) running a vidagliptin and metformin therapy, (vii) running a nutritional diet, (viii) weekly monitoring values of glucose through fast test, and (ix) poorly advise on nutritional facts. Most of the selected patients have manifested complications and difficulties for attending health center. As starting point of this study let us to assume that each DM-II patient uses a mobile phone and glucometer with accessories. This study has corroborated that the prescription of vidagliptin and metformin 50mg/500mg turns out to be insufficient to decrease the glucose values around 250 mg/dL [1][2][3]. After of three months with this terapy, the patient follows a second therapy with 50mg/850mg together to a diet-1 resulting to be effective. In fact, this synergy is seen in the glucose values down 200 mg/dL reaching 100 mg/dL. However, this promising value drops on the 6th and 7th month by showing substantial fluctuations at the end of the year because the patient started a second disordered diet (diet-2). Despite of the fact that the effectiveness of a second therapy is quite promising for stabilizing the glucose value inside the desired range (70-110 mg/dL), it is not difficult to observe that the glucose value is clearly affected by the discontinuity of a consistent diet. This fact would increase the probabilities for cardiovascular risk [4]. In other words, the efficacy of the combination of vidagliptin and metformin apparently should be accompanied of a rigid policy of nutrition. It is important to remark the role to be played by the nutritionist during the time where the patient runs a 2th (or improved) prescription. Thus with the glucose history of the patient along the 2014 year, a mathematical expression that fits well to the glucose distribution versus time can be written in the following manner

$$\mathrm{G}(t) = \left[\frac{\beta_1}{1+\beta_4 \exp(t-\beta_5)}\right]\left[1+\beta_2\frac{\sin(t^3-\beta_3)}{t}\right] \quad (1)$$

where t is expressed in days, and β_j $j \subset$ [1,5] are the fitting parameters. In essence $\mathrm{G}(t)$ has the form of a step-like function "1/(1+exp)" but is substantially contaminated by the nonlinear part namely "$\sin(t^3)/t$". Actually, the fully nonlinear part is driven by the value of β_2 which adjusts well to the second diet period. It should be noted that the shape of $\mathrm{G}(t)$ is quite sensitive to small fluctuations of β_2. On the other hand, the β_1 would denote the expected glucose value which is ranging between 90 and 110 gr/dL. As consequence, Eq. 1 would serve as a class of pattern that identifies the type of patient selected for this study. With this information it is possible to simulate up to 100 samples through the Monte Carlo technology, by assuming small deviations in all 5-parameters and other random fluctuations.

II. Scheme of Teleconsults and Results

The central idea of the teleconsult dynamics is sketched in Fig. 1. where $j+N$ patients decide to send a text message with current glucose value to a receiver which has access to operate server software [5]. It enters as input into the predictive algorithm in order to generate the priorities. The output is written in a txt file to be sent to the available health experts. The sketch shows the case where one finds two possibilities: there is availability for accessing a health expert or busy system. The server turns its attention to the cases where a high value of glucose is reported [6]. The health expert would receive the following information: (i) patient ID, (ii) glucose value, and (iii) updated glucose history. If the glucose value is above the allowed and expected ones, the

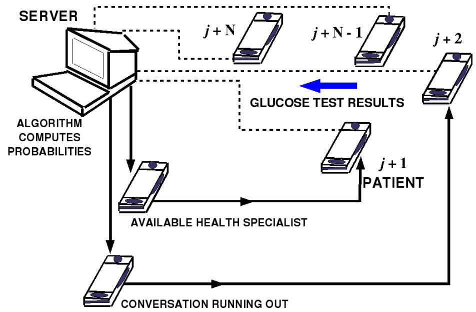

Fig. 1. Sketch of the proposed teleconsults system. The text messages go to a server that make decisions to initialize a telesession between the patient and a health specialist in real time.

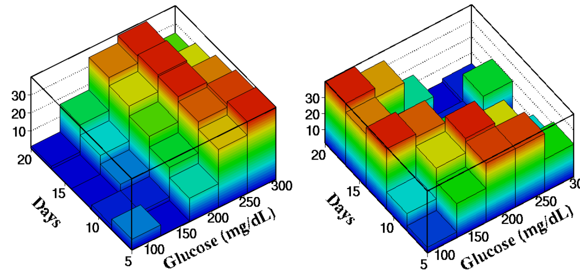

Fig. 2. Results of computational simulations given as 3-D histograms: number of patients (z-axes) versus days (y-axes) and glucose values (x-axes) for Γ = 0.2 (left) and 0.8 (right), respectively. We used 100 simulated samples.

patient will receive a phone call from the available health specialist, immediately. The health specialist already knows the current glucose value and possible values for subsequent two weeks. With this information the specialist might make new recommendations. On the other hand, the efficiency of the teleconsult can be measured by $\Gamma = \mu \frac{\mathcal{P}_{\rm HS}}{l_{\rm Patients}}$ where $\mathcal{P}_{\rm HS}$ number of available health specialists per time unit, $l_{\rm Patients}$ number of patients accessing teleconsult per time unit, and μ parameter that measures the quality of teleconsult. Actually μ is defined in terms of data server connectivity, software and hardware infrastructure (phone machine and installed applications) of both patient and health specialist, and the availability of health specialists per time unit. In addition Γ also depends on the quality of service (QoS) that measures the probability of success of call completion. For example, consider the case where 5 patients are presenting glucose values above 250 mg/dL. The data server have counted up to 4 available health specialists for only 1 hour. For a QoS of order of 80%, one obtains for μ to be of order of 0.8 since the server works under a connection of 1Mbps, resulting for Γ=0.64. In Fig. 2 histograms of the number of patients (z-axes) versus days (y-axes) and glucose values (x-axes) for two different scenarios, are displayed [7]. Here, we used the 100 samples generated by the Monte Carlo method. To note also that the histograms only plots from the 5th day where effects by any change or reconfiguration at the running prescription and diet are perceived. In left panel the case where Γ=0.2 is plotted. One can note the prevalence of number of patients with higher values of glucose up to for first three weeks, which is translated as a weak impact of teleconsults in patients. One reason of that is the absence of health professionals to attend patients during the hours already arranged by the data server. However, even in the case where the teleconsult is already to be performed, it can be aborted by poor quality of service due to mobile phone quality (with μ parameter below 0.2). Most interesting is the case of right panel, where Γ=0.8 which means that teleconsults of high quality were performed. In this scenario most of the patients had to be advised to change urgently metformin prescription and lifestyle. In fact, patients with glucose values above 200 mg/dL during the 5th day becomes successful with 850 mg metformin treatment together to a 2th diabetes diet. On the other side, patients already running a 2th doses of 850 mg metformin are asked to reduce carbohydrate-based foods urgently. Around a 50% of patients have shown improvement in their 20±2 days teleconsults therapy as seen in the bottom histogram where 30 patients achieved to reduce glucose values around 100 mg/dL and 20 below 120 gr/dL. The stability of these results clearly needs of a concrete plan of continuity for the next weeks. These results support the idea that the teleconsults might to useful in the sense for reducing the probability of being assaulted by a cardiovascular event (or others complications) in those cases where the patient does not follows a rigorous control of glucose [4].

III. Conclusion

In this paper, a scheme for preventing possible risk situations at DM-II patients through continuous glucose monitoring and subsequent prediction-based teleconsults modeling was presented. The main methodology has consisted in computational simulations from one DM-II patients glucose history in order to define priorities for accessing teleconsults. For this end the data manager arranges a teleconsult between patient and health professional through a simple phone call. The results of simulations have indicated that drug therapy, adequate diet and opportune teleconsults might be crucial to enclose glucose values in ranges between 90 and 120 mg/dL for DM-II patients with ages of 30 up to 60 years old. In addition, for values of Γ >0.75 the exposed scheme can be translated as a potential methodology to counteract sudden increasing glucose values and therefore, avoid unexpected cardiovascular events, among other expected (unexpected) type-2 diabetes mellitus complications.

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