Digital Healthcare Empowering Europeans
R. Cornet et al. (Eds.)

doi:10.3233/978-1-61499-512-8-316

Mobile Technology Support for Clinical Decision in Diabetic Keto-Acidosis Emergency

Mirela FRANDES[a], Bogdan TIMAR[a,b], Alexandra TOLE[c], Stefan HOLBAN[c], and Diana LUNGEANU[a,1]
[a] *Department of Functional Sciences /Medical Informatics and Biostatistics, University of Medicine and Pharmacy Timisoara, Romania*
[b] *Third Medical Clinic, Emergency Hospital, Timisoara, Romania*
[c] *Faculty of Computer Science, Polytechnic University of Timisoara, Romania*

Abstract. The main challenge of effectively managing emergencies in diabetic ketoacidosis (DKA) is the fine tuning of the treatment in order to re-establish the normal metabolic homeostasis. We propose a mobile application for clinical decision support in DKA emergencies (*mDKA*), running under Android on smart phones and tablet PCs. *mDKA* provides decision support for treatment concerning the main components (i.e. choice and dose of re-hydration agent, insulin, potassium or bicarbonate) for up to 12 hours after the diagnosis. The application underwent a preliminary scanty evaluation aimed at assessing its perceived usability. The results sustained the informal hints that *mDKA*'s accuracy in deciding the treatment path was acceptable in terms of general variability of medical decision in DKA and brought evidence of positive attitude towards the application itself.

Keywords. mHealth, decision support, medical emergency, diabetic ketoacidosis

Introduction

Mobile applications have been proposed for diabetes self-management [1-3], including support for various tasks, with a review of smartphones-based glucose monitors in [4]. However, still few applications aimed at assisting medical decision have been developed, especially for junior medical doctors or general practitioners confronted with difficult medical emergencies [1, 5].

Diabetic Ketoacidosis (DKA) is an acute metabolic complication of diabetes, usually induced by a severe deficit of insulin accompanied by high levels of counter-regulatory hormones (glucagon, cortisol, catecholamine, hormone of grow), hormonal imbalances that lead to increased hepatic gluconeogenesis, glycogenolysis and lipolysis [6]. and requires simultaneous therapeutic interventions for all the imbalances. The composition of the treatment solution depends on the one hand on the measured biological parameters and on the other hand on the time point in relation to the

[1] Corresponding Author. Diana LUNGEANU, Department of Functional Sciences/Medical Informatics and Biostatistics, University of Medicine and Pharmacy, P-ta E. Murgu 2, 300041 Timisoara, Romania; E-mail: *dlungeanu@umft.ro*; Tel/Fax +40-256-490288

diagnosis moment, the main issue in effectively managing the DKA emergencies arising from the high variability of these parameters among individuals, a challenge for junior doctors facing emergency situations. Overall, the guidelines can only provide general guidance and not an exact algorithm, therefore too often, misses in controlling DKA-induced imbalances lead to serious clinical failures.

In emergency and time-pressured situations as DKA, mobile applications proved to be the viable solution for their unique characteristics concerning the timely availability on the spot [1, 7]. Herein, we propose a mobile application for clinical decision support in managing DKA (*mDKA*).

1. Description of the *mDKA* Application

The proposed algorithm is based on a holistic approach, aiming to correct any DKA specific imbalances that may occur and recommending therapeutic options at all time moments included in the protocols [6, 8]. The application was developed in Java, using the Android Software Development Kit (*https://developer.android.com/sdk*), and the public classes JSON, GraphView, and DroidText.

Figure 1 presents the general scheme of the *mDKA* application, with the principal functions for the physician-user.

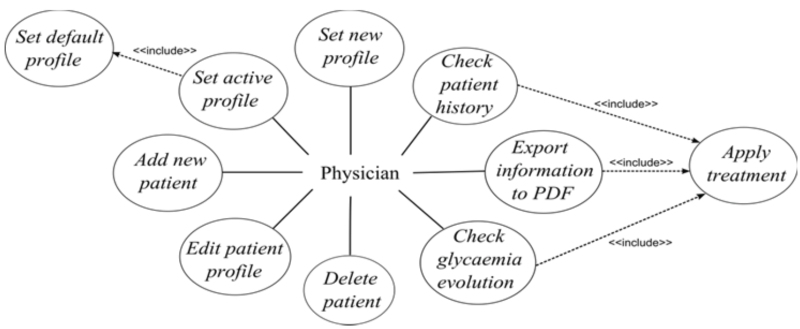

Figure 1. The *mDKA* application: general scheme and functions

The recommended treatment considers a holistic approach and is based on the medical standards for diabetes care [8-10], considering the patient's anthropometric data, laboratory data (glucose, potassium, ketones, etc.), and individual response to treatment. Depending on the time lag to the initial treatment, the user is required to re-enter or confirm the clinically-relevant information (usually laboratory analysis results), therapeutic adjustments being made accordingly. Overall, the treatment solution is reviewed and adjusted at subsequent moments: the choice of rebalancing solution (infusion of NaCl or glucose, diluted in H2O), etiologic treatment (insulin), and ancillary treatment for correcting hydro-electrolytic and acid-base imbalances (i.e. bicarbonate and potassium). The insulin prescription is initially based on patient's weight and type of rehydration agent, though readjusting at each time point (a too aggressive decrease in blood glucose can lead to cerebral oedema, i.e. a situation worse than ketoacidosis itself). Bicarbonate takes into account the initial treatment and the pH level. Potassium is influenced by the time-lag after the initiation of treatment, the presence of urine output, serum potassium value, the amount of insulin, and the solution of fluid resuscitation [9, 10].

2. Evaluation of the *mDKA* Application

2.1. Methods Employed for Evaluation

A preliminary evaluation was conducted, mainly aimed at probing target users' opinions and attitudes, and as a basis for both further developments and systematic evaluation. Two aspects were considered: on the one hand the medical accuracy and on the other hand the opinion and reaction of the medical specialists towards the *mDKA* application itself.

Table 1. Treatment recommendations made in the emergency scenarios considered for evaluating the medical accuracy. The time intervals of the start and follow-through were: T0 – beginning of treatment; T1 – after 60 minutes; T2 – after 120 minutes; T3 – after 180 minutes; T4 – after 4 hours; T8 – after 8 hours; T12 – after 12 hours

Values recommended for	Scenarios	Time
NaCl (volume[ml]*concentration)	1, 2, 3	T0, T1, T2, T3, T4, T8
Glucose (volume[ml]*concentration)	1, 2, 3	T3, T4, T8, T12
Potassium [mmol KCl]	1, 2, 3	T1, T2, T3, T4, T8, T12
Insulin	1, 2, 3	T0,T1, T2, T3, T4, T8, T12

For evaluating the compliance with the medical standards of care, three hypothetical realistic scenarios were considered to be independently handled by different evaluators: a consultant physician in diabetes (Evaluator1); two specialists in diabetes (Evaluator2 and Evaluator3); a specialist in internal medicine (Evaluator4); and the *mDKA* application (Evaluator0). All the three scenarios were designed with by a consultant physician, based on the following sequence of events: during the night, a patient is brought by the ambulance to the emergency room and is taken by the doctor on duty; the patient has diuresis and ketosis (differing on patients' background, measured biological parameters at admittance, and their subsequent evolution under treatment). Table 1 shows the recommendation issues and the time intervals of the follow-through. We analyzed the volumes and concentrations recommended by each evaluator, taking into account the scenario, the time moment, and the interaction of the two (by applying a two-way ANOVA statistical test on the log-values at each of the actual time moments for every recommended intervention).

Table 2. Opinion questionnaire for assessing the health specialists' opinion on *mDKA* and attitude towards employing it in current medical practice. Q4 was aimed at probing different facets of *mDKA*'s perceived usability on a Likert-type scale, while Q5 was designed as a separate conclusive score of usability on a four-point scale (1=not at all useful; 2=little useful; 3=useful; 4=very useful) to avoid the neutral/evasive option.

Item	Rating options/scale
Q1. Are you familiar with the mobile technology (e.g. smart phone, PC tablet)?	Yes/No
Q2. Do you use mobile electronic devices (e.g. smart phone, PC tablet) in your professional activity?	Yes/No
Q3. Is this the first time you have used the *mDKA* application?	Yes/No
Q4.1. The recommended medical treatment is appropriate...	1 → 5= totally agree
Q4.2. The time necessary for getting the recommendation is acceptable in emergency cases...	1 → 5= totally agree
Q4.3. The user interface is enjoyable and appropriate...	1 → 5= totally agree
Q4.4. Settings and profile configuration are easily done...	1 → 5= totally agree
Q4.5. Inserting new patient's data can be perfomed easily and timingly...	1 → 5= totally agree
Q5. *mDKA* is medically useful...	1 → 4= very useful
Q6. What is missing from the *mDKA*?	
Q7. Would you use *mDKA*?	Yes/No

For investigating the specialists' attitude towards employing mobile technology for decision support in DKA emergencies, we designed an opinion questionnaire and further evaluated both its internal consistency and the answers themselves (Table 2). Twelve healthcare professionals gave us feed-back, all first time users of *mDKA*.

The resulting data from both arms of evaluation were processed using SPSS v15.

2.2. Evaluation Results

Table 3 shows the results on the evaluation of the medical accuracy by the five evaluators (one being the *mDKA*) for the three hypothetical medical scenarios. We can see there was a quasi-uniform variance over time and scenarios, to be further investigated in future systematic evaluation

Table 3. Results of the *Two-way ANOVA* test applied on the log-values at each of the actual time moments (log-values were used in data processing, so variance did not increase with the actual values). *df* stands for *degrees of freedom*: the values are different for the four components of treatment recommendations, as not all were issued at each time moment. All p-values were well over the 0.05 level of statistical significance.

Two-way ANOVA (log-values)	**F**(df); **p**	**NaCl**	**Glucose**	**Potassium**	**Insulin**
Main effects	Combined	1.281(7); 0.282	0.011 (5); 1.00	0.931(7); 0.494	1.009(8); 0.437
	Time	1.609(5); 0.178	0.012 (3); 0.998	0.309(5); 0.905	1.321(6); 0.259
	Scenario	0.302(2); 0.741	0.013 (2); 0.987	2.564(2); 0.090	0.079(2); 0.925
2-way interaction	Time*Scenario	0.033(10); 0.827		1.325(9); 0.257	0.508(12); 0.903
Model		0.655(17); 0.827	0.011 (5); 1.00	1.238(16); 0.286	0.715(20); 0.798

For evaluating the healthcare professionals' opinion and attitude towards using *mDKA* in current medical practice, the feed-back collected from the 12 answered questionnaires underwent a descriptive analysis: all came from professionals familiar with the mobile technology but first-time users of the *mDKA* (two consultants, two specialists, seven residents, one nurse); most of them (10 out of 12) already using mobile technology in their professional activity.

The questionnaire's reliability testing was performed for questions Q4, Q5 and Q7 (a total of seven items, see Table 2): Cronbach's Alpha was 0.73, Keiser-Meyer-Olkin measure of sampling adequacy was 0.728, and the Bartlett's test resulted in a p-value <0.001. Although both the number of items and that of the collected filled-in questionnaires were reduced, we concluded the collected feed-back was trustworthy, so we further proceeded with the interpretation.

Table 4. Feed-back on the healthcare professionals' opinion and attitude towards using *mDKA* in current medical practice (questionnaire's items described in Table 2).

Total answers: 12	**Q4.1**	**Q4.2**	**Q4.3**	**Q4.4**	**Q4.5**
Median score (Q1 – Q3)	4 (3.25 – 5)	5 (4 – 5)	4.5 (3.25 – 5)	3 (2 – 4)	4 (3.25 – 4.75)
Number scores of 4-5 (%)	9 (75%)	10 (83%)	9 (75%)	5 (42%)	9 (75%)
Total sum of scores in Q4 (i.e. *mDKA* rating) Range: 13(min) – 25(max); Mean: 19.67; StdDev: 3.87					

Answers at the five Q4-items are shown in Table 4. When measuring the opinion and attitude, the rating scales hardly can be viewed as equidistant, so we chose to treat each Q4 item as an ordinal variable and sum them up for a compact overall score. Eight out of 12 (67%) answers at Q5 were at the maximum (i.e. 4=*mDKA* is very useful), but four out of the 12 professionals (one third) said they would not use *mDKA* We found out a statistically significant relation to the application's perceived usability (p=0.004, Mann-Whitney U-test for the total sum of scores in Q4 for the two Q7-groups). Q6, aimed at gathering free-text additional feed-back for further improvements, did not provide statistically processable data.

3. Discussion and Conclusions

Regarding the accuracy in decision, the results sustained the supposition that *mDKA* was acceptable in terms of general variability of medical decision in DKA treatment path. Regarding the usability, the answers at Q7 were disappointing at first sight, one third of the health professionals saying they would not use *mDKA*. This attitude might be related to the professional experience (i.e. consultants or specialists being less inclined to declare they would use it) and is coherent with the answers at Q5.

In conclusion, mobile technology offers increased access to the point-of-care tools for decision support in general [1, 2, 5, 7], while we found out hints that employing it for support in DKA emergencies would be a viable and valuable solution. At the same time, acceptance is related not only to the medical accuracy and timely response, but also to the perceived usability of applications themselves.

Acknowledgements

We gratefully acknowledge the contribution of our colleagues from the University Emergency Hospital of Timisoara who helped us evaluate the *mDKA* application. We also kindly thank Cosmin Cernazanu-Glavan from the Polytechnic University of Timisoara for his support and useful comments on the early results of our work.

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