Telemedicine: Development of a distance care system for pre-dialysis chronic kidney disease patients

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Abstract

Introduction: The focus in the treatment of CKD is to prevent its progression through optimal medical control. The large number of patients with CKD has pressed nephrologists to assess more patients into ever-smaller periods of consultation. The use of light technologies as a promising form of health care. The internet offers the opportunity to manipulate the doctor in his professional contact with the user. **Objective:** To develop a web system to attend the patients with CKD not on dialysis and clinically stable stages at distance. **Methods:** Developed a system using the Java language, MySQL database and Prime Faces framework; available on a Glassfish application server. **Results:** The initial access is performed by the nephrologist, which registers the patients with their personal information and access data. After being registered, the patient (or family doctor) can enter the data of your query and these will be following, passed on to the nephrologist for evaluation. The form with the data of interest is pre-determined, but there is possibility to add free-form information. The system enables, in addition, there is exchange of messages between doctors and patients. In addition, users receive messages via e-mail alerting them of their duties. Confidentiality is guaranteed by individual passwords for doctors and patients. **Conclusion:** This tool will enable to increase the coverage area of nephrologists, reduce costs and bring the patient to the primary care physician, using the Family Health Program as an interface between the patient and the nephrology secondary care.

Keywords: home care services; kidney failure, chronic; telemedicine.

Introduction

Nephrology has undergone substantial changes since the early 60s, when it emerged as a medical specialty. Initially, Nephrology focused on renal replacement therapy (RRT) - dialysis and kidney transplantation - as an established mode of treatment for patients who progressed to renal functional failure (RFF).[1,2]

As of the past decade, it became clear that the progression of chronic kidney disease (CKD) in patients with high blood pressure (hypertension) and *diabetes mellitus* (DM), particularly those under nephrologist care, could be delayed or even stopped with measures such as: strict control of blood pressure, glycemic control and use of drugs that block the renin-angiotensin-aldosterone axis, to mention just a few.[1,2] Alongside these observations we published population studies and in risk groups for CKD, which have shown that the disease prevalence is far greater than previously believed.[2,3]

CKD has enjoyed increasing attention from the international scientific community, because its high prevalence has been demonstrated in recent studies. Particularly significant is the cross-sectional analysis of the National Health and Nutrition Examination Survey (NHANES), carried out between 1999 and 2004, which involved a representative

sample of the noninstitutionalized adult population of the US, with 20 years of age or older (n = 13,233). This analysis revealed that approximately 13%, or 28 million adults in the US, have CKD stages 1 to 4.[3]

In Brazil, comprehensive epidemiological studies of CKD that employ the new definition of the disease have not yet been performed. However, the study on RRT based on data collected in 2011 revealed that there were 91,314 patients on dialysis in Brazil and that the prevalence and incidence of RFF corresponded to about 475 and 149 per million in the population, respectively.[4] While the number of Brazilians in different pre-dialysis stages of CKD is not known precisely, we have to make extrapolations to measure the problem. For instance, in a study with creatinine levels carried out in a Clinical Analysis Laboratory of Juiz de Fora, employing the new CKD definition proposed by the KDOQI NKF™,[1] the authors reported that 2.3% of the individuals had glomerular filtration rates (GFR) < 45 mL/min/1.73 m^2, i.e. CKD stages 3B, 4 and 5, a percentage extrapolated to the Brazilian adult population corresponding to about 2.5 million people.[5]

Currently, the clinical follow-up of patients with CKD happens in doctors' offices, the shrine of clinical medicine. During the consultation, the doctor establishes a mutual relationship of respect and trust with the patient, obtains relevant information about health issues, and provides patients with information about the disease, its prognosis and treatment in the short and long term. On the other hand, the patient can express his/her personal preferences to the doctor, and the two can work together to build a treatment plan that meets patient needs and is grounded in clinical practice based on guidelines. However, the implementation of all these aspects of the doctor-patient relationship requires a long consultation time (a face-to-face consult, from now on: the "P-consult"), which often is not possible. This time limitation, not always the desire of physicians, reduces the likelihood of obtaining a more complete medical history and performing a thorough physical examination, and predisposes to limited medical practices.[6,7]

Telemedicine/Telehealth is the supply of healthcare-related services, where distance is a critical factor, expanding care and coverage. Such services are provided by healthcare professionals using information and communication technologies for the exchange of valid information aiming at the promotion of health, health protection, reducing the risk of disease and other health-related problems and recovery. Additionally, it provides continuing education for healthcare professionals, caregivers and patients, as well as facilitating research, assessments and healthcare management (http://www.who.org).[8]

Since 2005, CNPq and the Ministries of Health (MOH) and Science and Technology inserted telemedicine as a thematic set of edicts induction. In 2005, the pilot project was entitled Telematics and Telemedicine Project to Support Primary Healthcare in Brazil, now known as National Telehealth Program Brazil - Ministry of Health Networks, with focuses on primary care, Telemergency, remote diagnostics and remote education. In 2011, the MH instituted the National Telehealth Brazil Networks Program, from the Brazil Telehealth Program (2009-2011), aiming to encourage the creation of Telehealth Centers, based on regional municipalities consortia still in implementation and including some areas of medicine (http://www.cremesp.org.br/?siteAcao=Revista&id=725).[9]

The objectives of this study were: to develop a platform for carrying out electronic consulting (hereinafter E-consults) to work with an environment in which doctors can treat patients with CKD not on dialysis regardless of time and place where they may be, using a browser with access to the World Wide Web.

Methods and results

The study was carried out in accordance with the Declaration of Helsinki and the Good Clinical Practice guidelines from the International Conference of Harmonization, as well as local regulatory requirements from the National

Health Surveillance Agency (ANVISA). The study protocol was submitted to the Research Ethics Committee of the University Hospital of the UFJF.

Platform development "virtual office"

A system was developed using Java programming language, MySQL database and the PrimeFaces framework; this is made available from a Glassfish Server Open Source Edition (http://java.com) application server.[10]

The platform used to carry out the E-consulting is based on a server (http://econsulta.user32.com)[11] and works as an environment in which doctors can see patients, in a simple way, regardless of time and place where the later may be, using a browser with access to the World Wide Web. The system was developed using the Java programming language and MySQL database. Initially, we adopted a simple layout, with a minimum resolution of 800x600 pixels.

To ensure E-consulting safety and reliability, each study participant received information upon accessing the "virtual office." The information includes the location of the Web page, user name availability and access password to electronic medical records, which are filled with data from the study participant.

There is no restriction if the user needs someone, a relative, to help fill the data in the electronic medical record. The records to be filled in E-consult contain the same items available in the patient charts used in the E-consult, except for the sub-item on the field that contains the physical examination findings called "other data from physical examination", since this information would require examining the patient to detect changes in different organs and systems. The electronic medical record is designed so that the patient only moves forward in the form after answering each question. At the end of the E-consult, the system stores the data in the Web server and sends a message to the user stating that he/she will receive a medical evaluation of their consult within a maximum of 24 hours. Concurrently, the doctors responsible for the E-consult are notified about the consultation and a warning about the need to return to the user the medical assessment within 24 hours. Users receive a phone number to report any problems in accessing the virtual "office".

A pilot project of the virtual system was initially developed in four stages: design, elaboration, construction and transition. Improvement projects are being undertaken in order to bring functional and aesthetic improvements to the original system.

The e-consult system pilot project design followed by the steps below:

Preparation:

- Detailed survey of system requirements;
- Requirements analysis;

Construction:

- Creating business classes;
- Creation of a data access structure;
- Release 1: features related to user entries, user authentication and main pages;
- Release 2: features related to consultations;
- Release 3: features related to the exchange of messages among users;
- Release 4: features related to system alerts through e-mails;
- Alpha test;

Transition:

- System availability;
- Beta test;
- User training.

System features

The system functionality was used in the platform development and construction, as well as to measure the size of the project and thereby providing a means to improve the time taken for its development.

The features relate to participants/users who can interact with the system: user, physician and/or administrator.

- User authentication: the homepage of the "electronic medical record" enables user authentication and access to other system features. In the event of loss of password, the user can request a new password generated and sent by e-mail.

- Main User Page: The main page consists of information in the form of messages for the user to tend to pending issues. An example is a warning message about consultations to be held shortly or that are overdue.
- Physicians Main Page: The main page consists of information in the form of messages so that the doctor can tend to pending issues. An example is a warning message about consultations to be held shortly or that are overdue.
- Administrator's Main Page: This page has information in the form of messages so that the administrator can check the pending issues of other users.
- User Registration: this is the part of the system, which is responsible for adding, changing, deleting, and listing users. Doctors and administrators can enter, modify, delete, or list users. This registration is made up of general personal information, system access and medical information. The user is only allowed to change general personal information and system access information.
- Doctors Register: this is the part of the system responsible for adding, changing, deleting and listing doctors. Administrators can add, update, delete, or list doctors. This registration will consist of general and specific personal information and access to the system. The doctor will be allowed to change only the general personal information and system access.
- Managers Register: this part of the system is responsible for adding, changing, deleting and listing system administrators. This function is only allowed to administrators. This registration is composed of general personal information and system access information.
- Consult: the consult is made up of a number of fields for the user to enter the requested data. This is the same data as that in the medical records used in face-to-face consultations, a field for free text input (if the user needs to add information about his/her illness) and inputs (upload) of files (such as photos or tests). After finishing entering the clinical data, the user can no longer change the record, reading it to be saved and finalized at another time of the consult, if needed.
- List consults: Administrators can list the consults in the system. Doctors can list those consults in the system that are of their responsibility. Users can list only their own consults.
- Changes to the consult: administrators and doctors can change the consults that are listed in the system. Users only have permission to view their own consults.
- Consultation service: after the consultation is completed by the user, it is sent to a doctor (a member of the project) who should tend to it within a maximum of 24 hours. The attending physician can then tend to the consult through a text field.
- Message exchange: the system has a mechanism by which users can exchange messages. Administrators can send messages to any other user. Doctors can exchange messages with other doctors and users. Users can exchange messages with the doctors that are seeing them. Messages cannot be deleted or changed.
- E-mail alerts: the system will send e-mails to users when an activity is planned or is delayed or when the results of the consultation are sent to them.

Information contained in the e-consultation (figures 1, 2, 3, 4 and 5)

User identification and demographic data;

1. Medical history

1.1. Space for description (free text) of recent clinical complaints;

1.2. Field with structured questions (yes/no) on CKD;

Figure 1. Platform for the virtual office.

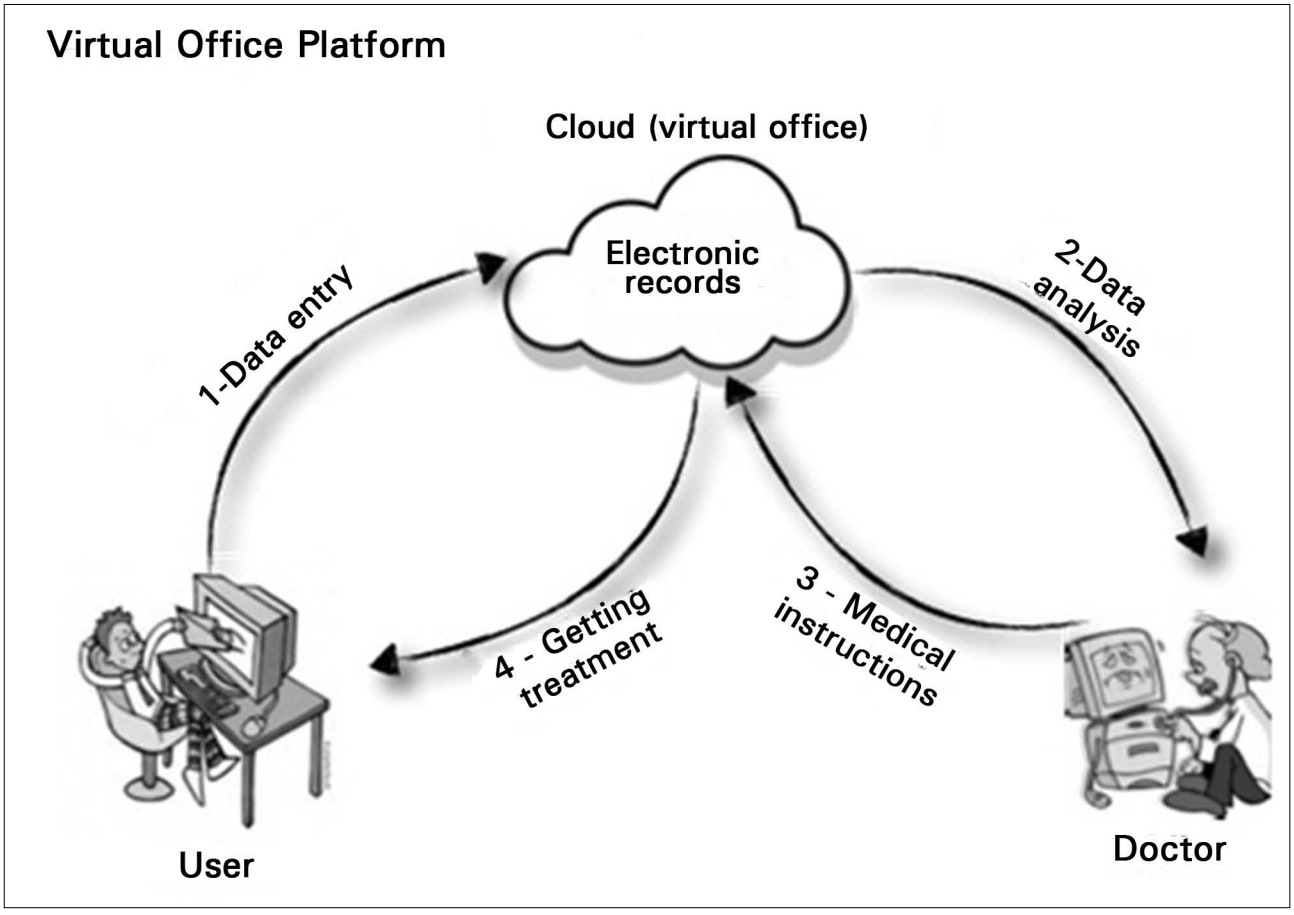


Figure 2. Print screen from the E-Consult Platform.

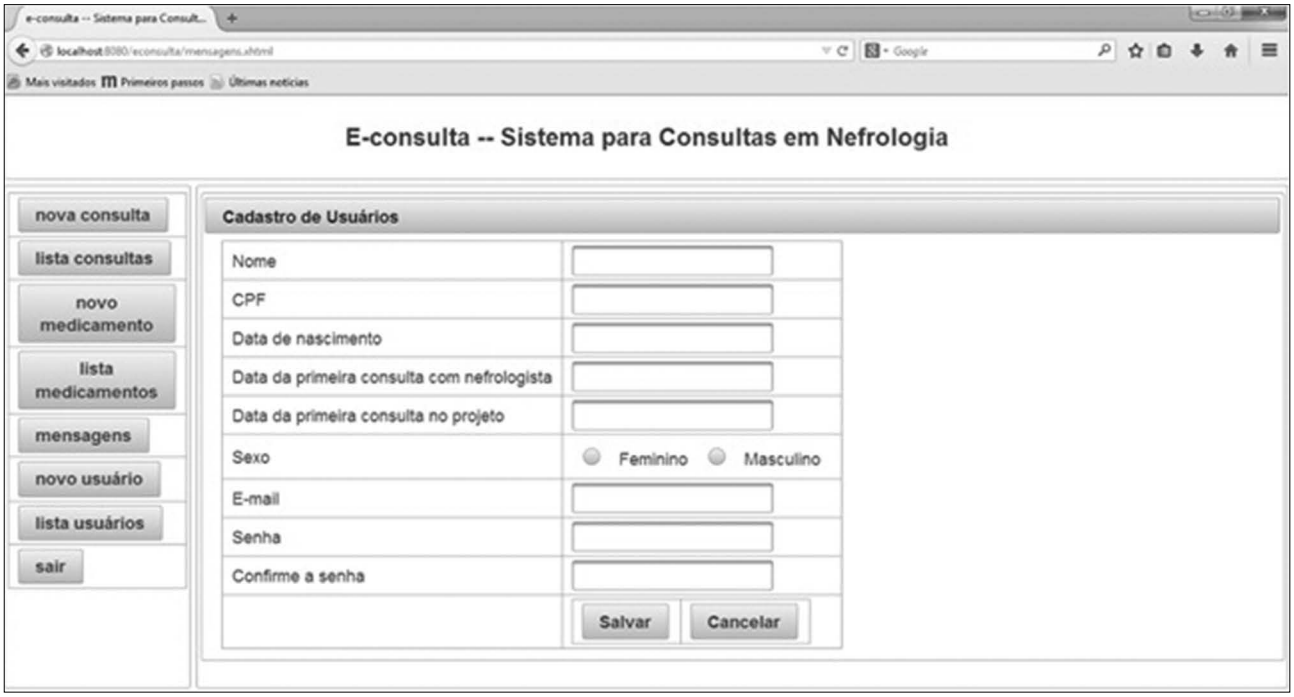


Figure 3. Print screen from the E-Consult Platform.

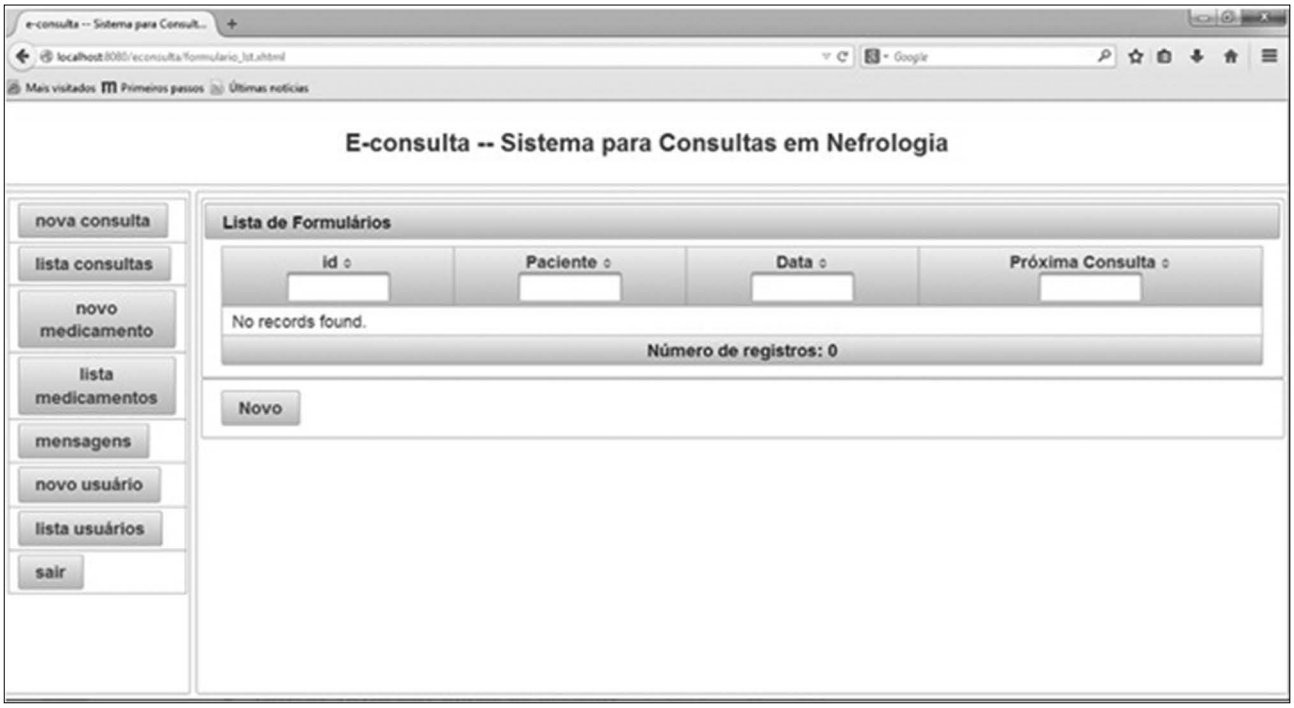
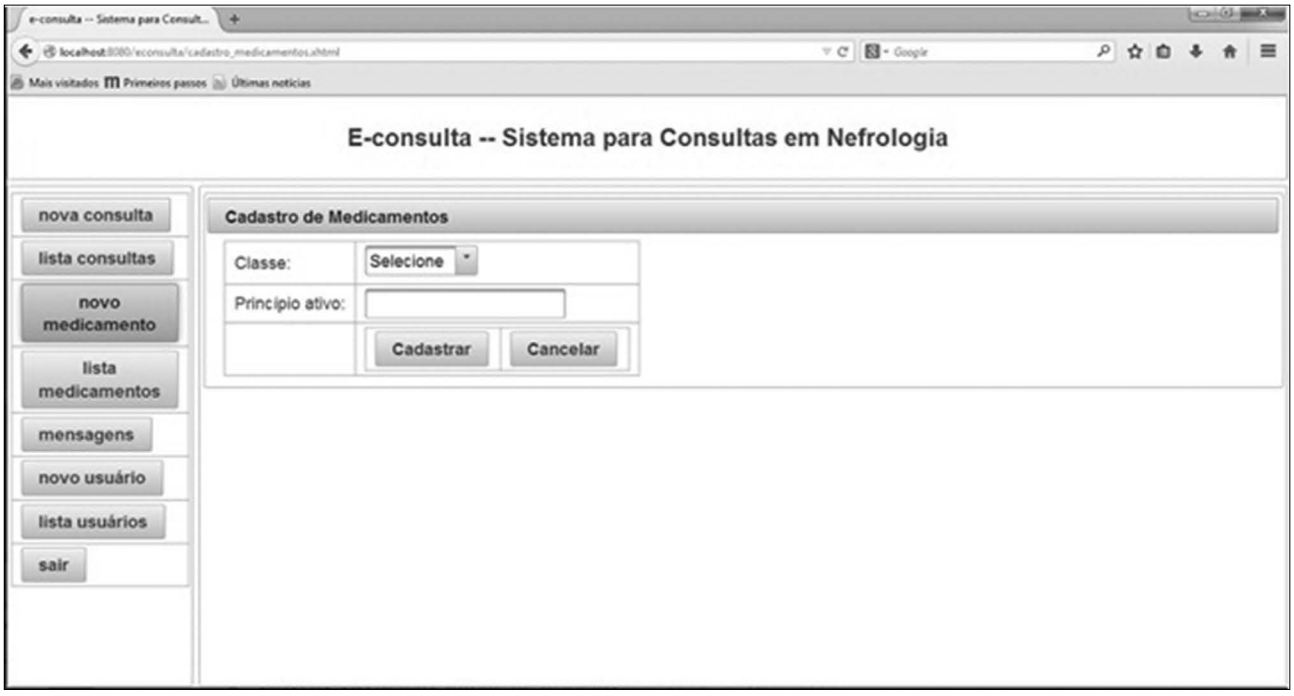


Figure 4. Print screen from the E-Consult Platform.



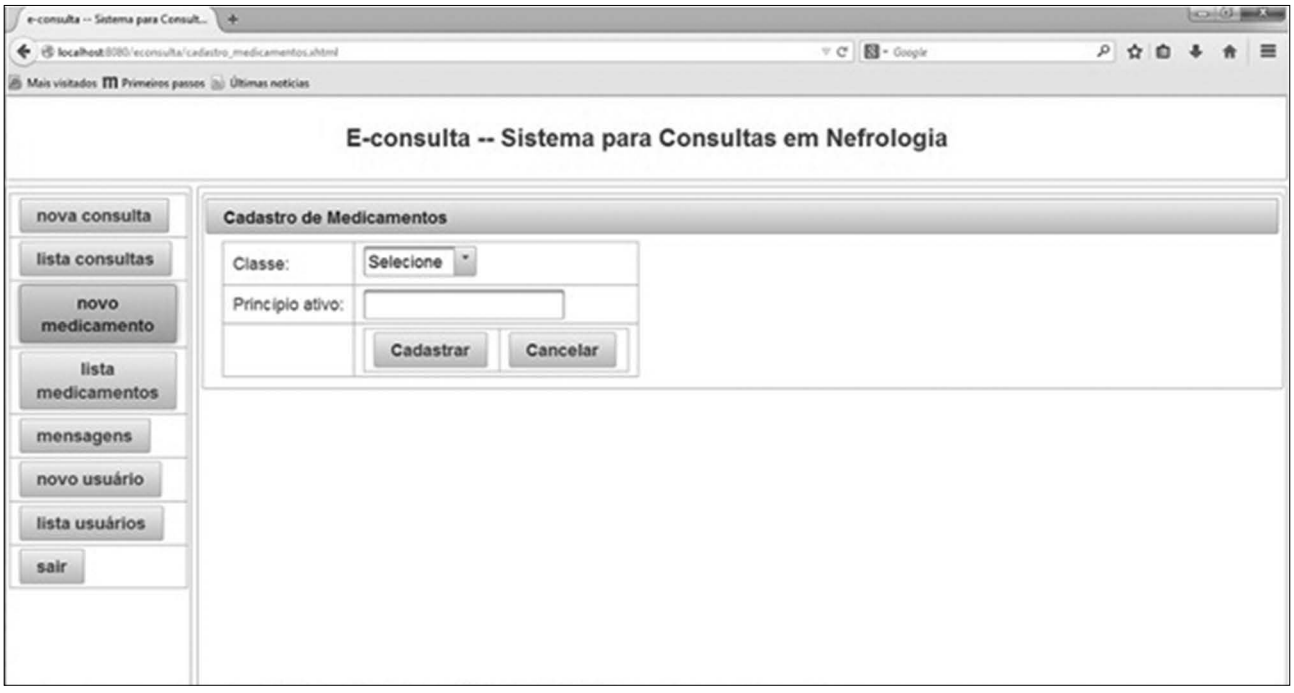
2. Physical examination: blood pressure (systolic and diastolic) measured with outpatient blood pressure measuring device; heart rate, respiratory rate; axillary temperature; recording the presence or absence of leg edema; height and weight;

3. Field to record test results;

4. Link to upload photos on clinical signs, test results or more descriptive text on recent medical events (hospitalizations, opinion of other specialists);

5. Field for ordering tests;

Figure 5. Print screen from the E-Consult Platform.



6. Field to generate the medical prescription;
7. Clinical Alerts (red flags) on:
7.1. Unreached clinical goals;
7.2. Potential drug interactions;
7.3. others: for example: vaccination.
8. Posts:
8.1. To the user: Upon completion of the E-consult a message is sent informing that the user will receive the medical report within 24 hours;
8.2. To the doctor: Informing that there is an E-consult and the need to send medical advice within 24 hours.

Assessment of doctor and user satisfaction with the e-consultation

User and physician satisfaction on the use of E-consult on CKD clinical management is qualitatively performed using a Likert scale, recorded with the following questions:

1. In comparison with the P-Consult, is the quality of the E-Consult higher, lower or the same?
a. Extremely higher
b. Moderately higher
c. Slightly higher
d. Same
e. Slightly lower
f. Moderately lower
g. Extremely lower

2. In general, how satisfied or dissatisfied are you with the clinical management of CKD through the E-consult?
a. Extremely satisfied
b. Moderately satisfied
c. Somewhat satisfied
d. Neither satisfied nor dissatisfied
e. Somewhat dissatisfied
f. Moderately dissatisfied
g. Moderately dissatisfied
h. Extremely dissatisfied

3. How convenient is the clinical management of CKD with E-consulting?
a. Extremely convenient
b. Very convenient
c. Moderately convenient
d. Little convenient
e. Nothing convenient

4. To what extent would you recommend the use of E-consulting in the clinical management of CKD?
a. Extremely likely
c. Very likely
c. Moderately likely
d. Unlikely
e. Nothing likely

Table 1 lists the variables and their respective goals to be evaluated in the monitoring started with patients.[2]

Additionally, the system will record deaths and their respective causes according to the International Classification of Diseases (ICD-10) and, when applicable, data on hospital stay, its duration and cause.

For later use in estimates, the systems takes note of data regarding travelling and waiting time for consultations and the associated costs. The time to complete the electronic medical record is obtained automatically from the beginning and the end of the on-line access. The systems also records any additional consults to those previously established in the study protocol and difficulties with the E-consult, its convenience and suggestions from users are considered to improve the system.

Table 1 Variables and goals assessed in the patient

Variables	Goals established
Blood pressure	≤ 140/90 mmHg 130/80 mmHg (for diabetic or with albuminuria > 1.0 g/day)
GFR reduction	< 5 mL/min/year
Hemoglobin*	> 11.0 g/dL
Potassium	3.5-5.5 mEq/L
Venous bicarbonate	≥ 22 mEq/L
Phosphate	2.7-4.6 mg/dL
Fasting glucose	< 100 mg/dL
Glicated hemoglobin **	around 7.0%
LDL cholesterol	< 100 mg/dL
Triglycerides	< 150 mg/dL
Proteinuria***	≤ 1.0 g/day
Urinary sodium	< 100 mEq/day

*We shall follow the Ministry of Health protocol (replacement of the erythropoiesis stimulating agent when hemoglobin is below values of 11.0 g/dL; **HbA1c > 7.0% will be acceptable in users with comorbidities or limited life expectancy.; ***or 50% reduction in the basal value in cases of massive proteinuria; #Consulting frequency: P-consult: 4/year and E-consult: 1(first face-to-face) + 3 "virtuals".

Discussion

In general, we use the discussion section to discuss the results in detail. In this case, the results are the platform development. Then, we discuss the literature results from similar systems already evaluated and propose new uses with our platform.

The large number of CKD patients has pushed nephrologists to see more and more patients within shorter consultation periods. This was evident from the proposed new definition of CKD, early last decade, by the KDOQI NKF™,[1] which enabled the diagnosis of patients in asymptomatic stages of the disease, and alert the nephrology community about the huge number of patients at different levels of kidney functional involvement.[1-3] Moreover, constant advances in medicine have surpassed the ability of the physician to apply them, due to lack of time and the complexity of the health care system in the world. There is an urgent need to establish new technologies that improve medical communication, and thus improve the doctor-patient relationship. New strategies for the doctor-patient relationship can also assist in other major problem - the rising costs of healthcare - reducing the need for in-person visits (face to face) to doctors' offices and increase the "capillarity" of nephrology as a specialty in the regions where it is lacking.

Although controversial when first reported in the 60's, the user-computer dialogue has been the subject of study of great interest, particularly because of the widespread use of computers. Over the last five decades, several studies have shown the potential of user-computer dialogue in obtaining comprehensive and accurate medical histories on different medical conditions, with good acceptance by both the physician and the patient/user.[11-20]

However, despite these favorable reports, medical consultation through the computer has been relatively neglected in clinical practice, particularly in public healthcare services. It is not hard to imagine that a doctor who has to see 16 patients in a four-hour shift - which is still common in outpatient clinics of the National Healthcare System - prefer to record the consultations in the conventional way, that is, on paper, than in an electronic medical record, because many of them do not have the dexterity to handle the machine. The World Wide Web offers a new opportunity

to instrumentalize doctors (through computers, tablets, smartphones) in their professional contact with the user, providing the virtual environment for a virtual consultation (e-consultation), combining the advantages of having a consult in the patient's home (with privacy and comfort) and the convenience of time and place set by the clinician.

In addition to convenience, E-consulting has the potential to offer the user the efficiency and possibly lower cost, when compared to the P-consulting.[20] The main concerns with E-consulting are related to the quality of care provided, including accurate diagnoses, appropriate use of laboratory tests, need for follow-up visits and unnecessary drug prescription. In this direction, two recently published studies have shown the potential of adding E-consulting to current medical practices. In the study by Adamson & Bachman,[19] the authors followed 1,159 users for two years, who agreed to be followed up by E-consulting (which generated 2,531 virtual meetings) by their physicians in the Department of Family Medicine of the Mayo Clinic, in the United States. The E-consultations were held mainly by women during working hours and stemmed from 294 different medical problems. Of the 2531 E-consultations, 62 (2%) included uploading or sending photos. The E-consulting made P-Consulting unnecessary in 1,012 (40%) cases; in 324 cases (13%), there was a need to refer the patient to a P-consulting. The results were considered very good for both the quality of care offered as for the cost-effectiveness of the approach.

In another study, published in early 2013, the authors were interested in characterizing the differences between the E-consultations and the P-consultations, comparing the care provided by both forms of consultation for two diseases: sinusitis and urinary tract infection (UTI).[20] We evaluated all E-consultations and P-consultations for sinusitis and UTI held by 63 doctors in four primary care clinics of the University of Pittsburgh in Pennsylvania, United States. Clinical and laboratory data were extracted directly from the electronic medical records of the users. Of the 5,165 consultations, 9% and 3% were E-consultations for sinusitis and UTI, respectively. They reported that the E-consultation doctors requested less relevant tests for the diagnosis of UTI and had a lower propensity for educating patients on preventive measures in both diseases. Both for sinusitis as for UTI, doctors prescribed more antibiotics in the E-consultations. There was no statistical difference in follow-up visits when the E-consultations were compared to P-consultations, either considering the diseases in the study or any other medical condition. Among users first seen by E-consulting, there were 147 subsequent episodes of sinusitis or UTI and among these, 73 (50%) were followed up by E-consulting. Finally, the authors concluded that their findings contributed to the notion that E-consulting can reduce healthcare costs.

Final remarks

This study showed the development of a web system for carrying out electronic consulting for the treatment of patients with stable CKD in pre-dialysis stages. When available and used as an alternative to face-to-face consultation, this tool will help expand nephrology care coverage for stable patients. Should we show that we can track our patients with E-consulting as well as we do it with P-consulting, we may use this strategy to other patients who do not have Internet access or who do not "master" the computer using APS physicians, lowering costs and bringing the patient closer to the primary care physician, using family health as an interface between the patient and nephrology care.

As future papers to be carried out, we can say that: a study to investigate the effectiveness of electronic consultation when compared to face-to-face in case of stable pre-dialysis CKD (already in progress); assessment of user satisfaction and medical usability study regarding medical information systems, in addition to checking the need for adding new features.

This tool will help expand the coverage area of nephrologists, reduce costs and bring patients closer to the primary care physician, using family healthcare as an interface between the patient and nephrology care.

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