An Automated Voice Response System for Anticoagulant Therapy Management

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Abstract

The system described in this paper is aimed at improving the clinical workflow of post-stroke patients under oral anticoagulant therapy (OAT). The system helps both physicians and patients during the periodic control visits necessary to assess the anticoagulation status and the next therapeutic plan. Controls represent a burden for both patients, which after blood drawing must wait for the result, and for physicians, that, after assessing the therapy plan, must communicate it to patients, face-to-face or by telephone. A system is proposed, which embeds an algorithm for the patient-tailored calculation of the drug dosage and scheduling, and an automatic telephone dialogue for the communication of the therapy plan, once it has been validated or adjusted by the physician.

Introduction

For a large number of post-stroke patients, anticoagulation is a life-long therapy, necessary for secondary prevention. To avoid hemorrhage, the most severe and life-threatening side-effect, every 3–4 weeks they must measure a coagulation index, namely the International Normalised Ratio (INR). Unfortunately, this test takes some time and patients have to wait for some hours or they have to come back later-on. Then, they must contact their specialist, for communicating the INR and knowing the (perhaps updated) therapy planning and the date of next control. Information and communication technology can support several points of this care pathway: a) therapy assessment by the specialist: there are already validated algorithms for the calculation of the anticoagulant dosage, that can be computerized; b) communication of the INR value: using the web platform, it can be communicated directly by the lab to the specialist, relieving the patient of waiting for the result; c) communication of the updated therapy plan: except for new patients, that of course need face-to-face encounters for detailed explanations by their doctors, the therapy plan can be communicated by an automatic telephone dialogue; d) continuous support for patients and their relatives: the patient area of the website allows to access both a list of FAQ and a messaging facility with doctors. The last two utilities will also relieve the physicians of the burden of answering a lot of telephone calls, saving both time and work interruptions that, as known, are one of the causes of medical errors [1]. While a number of systems for management of OAT patients is described in the literature [2, 3], to our knowledge, no system exists adopting a communication modality based on an automatic telephone dialogue system that allows patients using natural language. This is particularly important for elderly people, which represent a considerable portion of these patients. The system can be considered as a homecare application, since patients may be notified of their therapy at home, through both the web and the telephone. This paper briefly illustrates the whole system, then focusing on the vocal application.

The system components

Figure 1 illustrates the system architecture. All the applications access/store data from/in the central database, and the medical users access the system through a website.

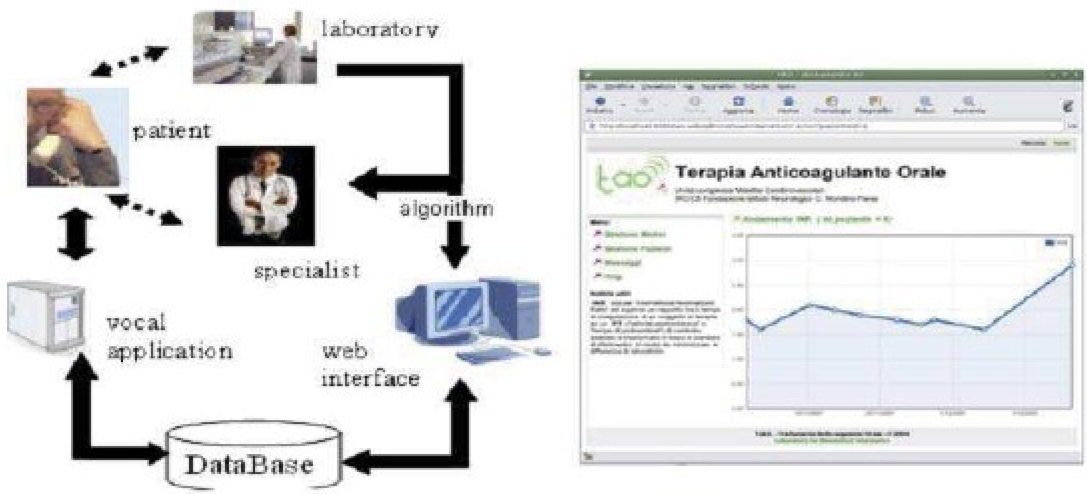

Figure 1: (left) The management of the patient under anticoagulation treatment. Full arrows representautomatic data exchange, while dotted arrows represent possible face-to-face encounters. (right) A page ofthe website with the INR trend, useful for the specialist to assess the next therapy plan.

The temporal data flow is the following: the laboratory stores the INR values; based on the actual and previous INR and TAO dosages, a new therapeutic plan, i.e., dosage and next visit date, is computed using the Ryan algorithm (chosen because of its wide validation) [4]; the specialist may accept the algorithm suggestion or not (in this case he can motivate his choice), and in any case he stores the definite therapy and next visit date; eventually the patient gets this information using the vocal application. For patients with adequate skill, the same information can in principle be accessed through the website, and printed in a calendar-fashion, but we stress that elderly people highly prefer the telephone-based communication in natural language. Technologies adopted are Java (JSP and servlet exploiting Hibernate query service) and WEB2.0 2 [1]

Natural language interaction in chronic home care

A number of interactive telephone-based dialogue systems applied to the remote care domain has been deployed and tested [5, 6]. Early systems received input from the elephone's keypad, and were then restricted to menu-like, number-based navigation. Such systems (Interactive Voice Response-IVR) could be based either on pre-recorded messages or on a computer generation of human-like voice from text (text-to-speech technology-TTS). More recently, speech recognition technology enabled the use of spoken input over the phone, enabling a greater flexibility and naturalness. Despite the potential benefits in term of services cost-effectively offered and continuity of care, the number of installments is still limited arguably because voice-based solutions are still time-consuming and complex to develop [7, 8] and organizational changes are required to accommodate the additional communication channel in the existing workflow. For the design of the voice component of our system, domain experts have been involved since the beginning, because the layout of the dialogue interaction is especially critical, impacting the following factors: the amount and quality of information elicited from patients; the comfort of the telephone interaction; ability of care personnel to receive timely information and warnings, etc. Moreover, standards endorsed by the WWW Consortium, and VoiceXML most prominently, mandate that voice applications follow the web-based paradigm, and that calls are interpreted by standards-complying Voice Browsers. Higher-level formalisms are required to develop and maintain more complex interaction scripts, e.g.,

1 http://www.oreillynet.com/pub/a/oreilly/tim/news/2005/09/30/what-is-web-20.html.

supporting adaptation to patient profiles, and, since profiles change over time, access to extensive information sequentially stored in patient records. For this work we employed AdaRTE framework, previously developed in our laboratory, which allows developers to specify the phone interaction in a high-level language [9]. AdaRTE dynamically generates questions and prompts driving a standard VoiceXML interpreter. Loquendo VoxNauta platform, providing speech recognition and TTS, was adopted as Voice Browser (Figure 2).

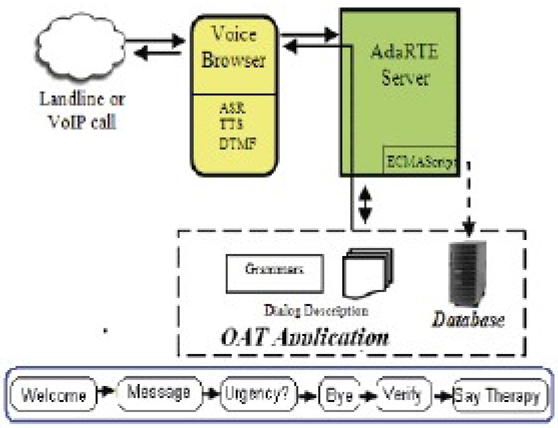

Figure 3: Block diagram of the voice architecture anddialog steps in the OAT automated dialogue

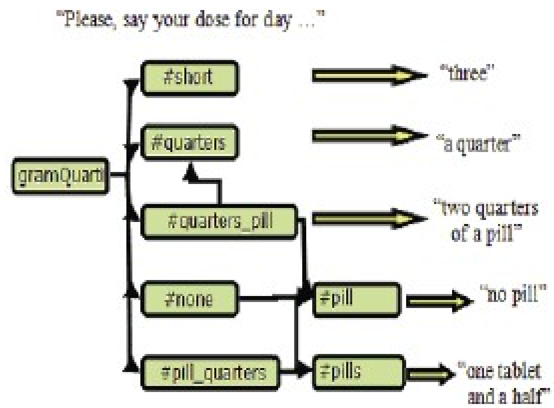

Figure 2: Speech recognition grammar fordaily dose confirmation

Dialog flow

The flow of conversation is based on the sequential activation of contexts, commanded by the logic detailed in a dialogue description. The main scope of the voice part of the OAT system is to communicate the updated therapy to the patient, once entered by the physician; afterwards, the patient is required to confirm the therapy by repeating it. The flow of the conversation is shown at the bottom of Figure 2 in a blocks-like fashion. After patient identification (via numeric PIN) and welcome, a free-text message from the physician is retrieved, if present. Then, the presence of an "Urgency" flag is checked. This flag may be set by the physician in case of situations requiring urgent attention. If set, the patient is invited to call the physician immediately. Otherwise, the dialogue goes on: the updated therapy is retrieved from the DB and communicated to the patient. Correct communication is checked by a "Verify" sub dialogue. The patient is invited to repeat how many pills (or fractions) he has been instructed to take on specific days. If the patient provides the wrong answer, the correct dose is repeated, and the call goes on with the next day. The user's input is captured by a grammar, which describes the allowed inputs in several natural-language variants (Figure 3).

Usability pre-test

For the purpose of preventing user errors as well as increasing the chance of system acceptance and usability before system deployment, the author MDV, who is a psychologist, submitted alternative dialogues and therapy notebooks for the judgment of a group of patients. The dialogue features to be evaluated were (1) the modality of therapy communication and (2) how its comprehension was verified. For what concerns the former, two variants of the system would inform the exact dates of the therapy plan, or just mention the "first day", the "second day", etc. With respect to the verification of correct communication, the first dialogue is focused on a general therapy communication, while the second one is centred on the patient's sense of responsibility and on the importance of a feedback on the correct communication procedure. Moreover, the dialogue structure may be less or more complex, including or not welcome sentences.

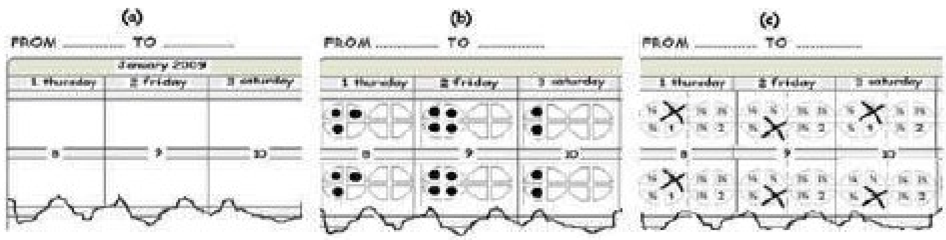

Figure 4: Different calendars for therapy annotation during the telephone call.

Patients preferred exact dates, detailed control of therapy understanding, and quick interaction. Therefore, a dialogue with these characteristics has been designed. When the patient calls, he annotates the therapy plan on a paper sheet. Once the dialogue was implemented, we compared three different therapy-table schemes (Figures 4a, b, c) with the aim of reducing the chance of transcription mistakes. All of them are monthly tables, since there are therapies lasting even three-four weeks before the next control. The first one has completely blank cells, leaving full responsibility for therapy annotation to the patient. According to our experiment, this table leads to the major number of mistakes. The second table includes a picture of two pills, each one divided into four slices; by using this table, we try to help patient to get a better mental representation of the pills picture [10]. We noticed that patients have two main problems with this table: firstly, patients get confused by the 4-slices division of the pills, and secondly it takes them too long to mark the therapy while the telephone call is continuing. Besides the pills picture, the third table contains also the numeric value of the portion of the pill (1⁄4, 1⁄2, 3⁄4, 1, 11⁄4, 11⁄2, 13⁄4, 2); in this way we try on the one hand to improve patients' mental representation efficacy [11] and on the other to speed up the annotation process. This type of table resulted the best one according to the patients' judgment.

Results

The system is now at its first evaluation phase. After ethical approval of the hospital committee, thirty-six patients have been enrolled so far, not sufficient to produce reliable statistics yet, but sufficient to show system stability and usability. A clinical trial has been planned in order to test (a) the effectiveness of the decision support algorithm in reducing the time to achieve a stable anticoagulation status, (b) the maintenance of such a condition, and (c) side effects of OAT (the full description of the trial is behind the scope of this paper). Effectiveness of the system will be also measured in terms of patients' satisfaction and time spent by both physicians and patients for the communication of therapy plans.

Conclusion

Elderly people still show difficulties to interact with computer-based systems, and telephone-based dialogues can be a solution. We integrated a vocal application within a system for OAT management, stressing the importance of psycho-cognitive methods (as illustrated in section 5) for capturing patients' preferences and increasing acceptability, while decreasing users' errors. A weakness of our study is lack of discussion on medico-legal aspects: in fact the system is now configured as a “research experiment”, but for a routinary implementation those aspects would be faced.

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