Supporting Shared Decision Making within the MobiGuide Project

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Abstract

This paper describes our approach for fostering and facilitating communication among patients and caregivers in the context of shared decision making, i.e., when decisions must be taken not only on the basis of scientific evidence but also of the patient's preferences and context. This happens because clinical practice guidelines cannot provide recommendations for every possible situation, and cannot foresee every change in a patient's context, which might imply the deviation from a previously acknowledged recommendation. Within the EU-funded project MobiGuide (www.mobiguide-project.eu), supporting remote patient management, we propose decision theory as a methodological framework for a tool that, during face to face encounters, is used to tailor pre-defined, generic decision models to the individual patient, by involving the patient himself in the customization of the model parameters. Although this approach is not appropriate for all patients, it leads, in well-chosen cases, to a more informed choice, with potentially better treatment compliance.

Introduction

Different patients have different behaviors when facing an unequivocal clinical decision that must be taken about their health[1]: some of them opt for a passive approach, and let caregivers fully decide for them. On the very opposite side, there are patients who tend to gather all of the possible information (often using the Web) about their disease, and seek for medical advice only after forming a personal opinion about their treatment options. An "intermediate" attitude is that of the patient who methodically inquires the doctor on the details and the rationale behind the available options, in an attempt of obtaining in-depth understanding and possibly participating in the decision. Doyal[2], while discussing the pros and cons of shared decision making, had forcefully argued that although certain errors of risk evaluation do plague patients, not all patients make them, and many of them can benefit from information customized to their needs; and that although many patients would rather leave the decisions in the hands of their physicians, there are several indications that a significant portion of the patients desire information about their choices and can make them coherently and to good effect.

In a classical paper, McNeil et al.[3] demonstrated the importance of involving patients in the decision-making process, by actually asking operable lung-cancer patients, who needed to decide between surgery (risky, but offering better chances for long-term survival) and irradiation (less risky, but offering a lower chance for long-term survival), whether 5-year survival is indeed their main objective. At least for a subset of the patients, this was not the case: although surgery offered better chances for long-term survival, they were quite averse to taking a risk that involved the possibility of immediate death. Thus, radiotherapy would have been the preferred therapy option for that subset. In another classical study by McNeil et al.[4], the trade-off between longevity and quality of life, in the case of surgery (which involves the removal of the larynx and had a 60% 3-year survival rate) versus irradiation (which had a 30% to 40% 3-year survival rate) for laryngeal cancer, was powerfully highlighted: 20% of the subjects interviewed would have preferred irradiation, with a decreased 3-year survival rate, but with the benefit of retaining their speech. In both cases, one might well argue that, had a clinician insisted on using long-term survival as the only yardstick for therapy selection, the patient's preferences would have been replaced by those of the physician's (or society).

Assuming that a shared decision model is the right one to use, Woolf et al.[5] listed three options of offering decision counseling to patients: by clinicians who lack any formal training, by clinicians with informed-choice training, and by impartial decision councilors. None appears ideal, and controlled studies are needed to determine which is best.

Our view is that such a shared decision-making service must be smoothly integrated within a wider decision support system (DSS). As a matter of fact, a DSS must be flexible, providing evidence-based recommendations when possible, and offering patients several options whenever more than one is reasonable, eliciting their preferences, and proceeding to provide detailed support to the option indicated by the patient's preferences.

In this paper we describe how the MobiGuide DSS, which we are developing for remote monitoring and care of chronic patients, supports this challenging task. The medical applications on which we are currently focusing within the MobiGuide project are atrial fibrillation (AF), that is a particular heart arrhythmia, and gestational diabetes with or without hypertension. However, the proposed approach may be generalized to any kind of disease for which clinical practice guidelines are available and for which decision models may be developed.

Introducing shared decisions into clinical-guideline-based decision support systems

Guideline-based DSS, on the basis of a computerized representation of evidence-based established clinical practice guidelines (GLs), and of the patient's medical record, automatically generates diagnostic and therapeutic recommendations. GLs are written on the basis of scientific evidence and by definition cannot include personal context and preferences for which evidence does not exist. Nevertheless, when scientific evidence is not strong enough to recommend one option versus another one, the patient's involvement might be preferable to an arbitrary decision by the care provider. In order to support caregivers and patients in shared decision-making as part of a DSS, the knowledge base should contain not only the customary representations of the evidence-based GLs as task-network models[6] but also include a synchronized decision-theoretic model that supports reasoning with patient preferences. Such customized decision models would be created based on medical literature relating to disease states resulting from alternative treatments. To create personal instances of the models for a specific patient, her preferences would need to be elicited during GL enactment time, using a shared decision-making process. Therefore, a methodology is needed to first detect, and then incorporate shared decisions and personal considerations into the process of an implementation of clinical guidelines.

GL recommendations and patients' preference

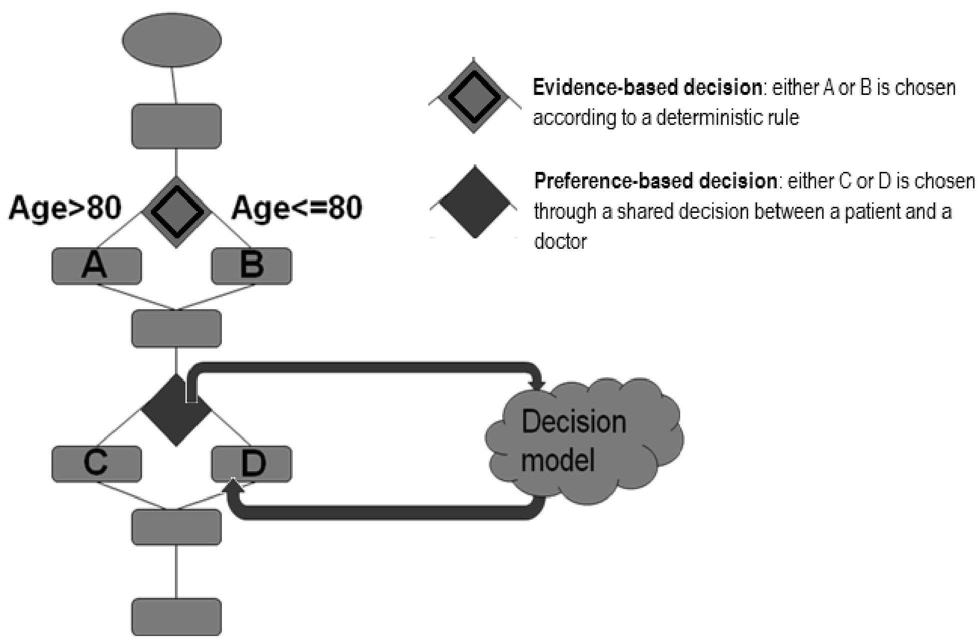

Figure 1 – A flowchart representing a portion of a hypothetical clinical practice guideline. In the case of decisions for which no established rules exist, decision models can be applied to select the optimal option.

In case of lack of scientific evidence, sometime the guideline itself may recommend considering the patient's preferences. As an example, consider the following recommendation from the AF guideline[7]:

For primary prevention of thromboembolism in patients with nonvalvular AF who have just one of the following validated risk factors (...see GL text), antithrombotic therapy with either aspirin (ASA) or a vitamin K antagonist is reasonable, based upon an assessment of the risk of bleeding complications, ability to safely sustain adjusted chronic anticoagulation, and ***patient preferences*** *(Level of Evidence: A).*

An illustration of how MobiGuide manages this recommendation is given in the next sections and visualized in Figure 1.

The flowchart models a generic task network, with diamonds representing situations in which a decision must be taken about possible treatment options. Note that in the case of the first decision, there is no ambiguity, since scientific evidence recommends either A or B, according to the patient's age. For the second decision, on the contrary, scientific evidence is not enough to provide a rule for choosing between C and D (as in the recommendation reported above). Thus, a decision model may be applied at this point. The model depicts possible consequences of C and D, and the shared decision tool illustrates them through a suitable interface. According to the available knowledge, the model can be either solely qualitative, or also quantitative, providing estimates of some quantities of interest for the patient. Once the option has been agreed, e.g., node D was selected, the "standard", evidence-based guideline flowchart is resumed. The next section provides a deeper view of the "decision model" of Figure 1.

Decision trees as a communication tool between patients and their care providers

To be able to participate in medical decisions, patients should be cognitively able and interested in participating in such decisions, or must be assisted by family members (or decision consultants) who can help them in such a task. They should be made aware of the possible options, of the main scientific results already obtained about them, the risk levels of the major complications, and additional non-medical consequences of possible interest (e.g., costs). At the same time, they should not be burdened with too much information that could confuse them. Thus, we need a communication tool able to clearly and simply highlight for the patient the key outcomes of a decision problem.

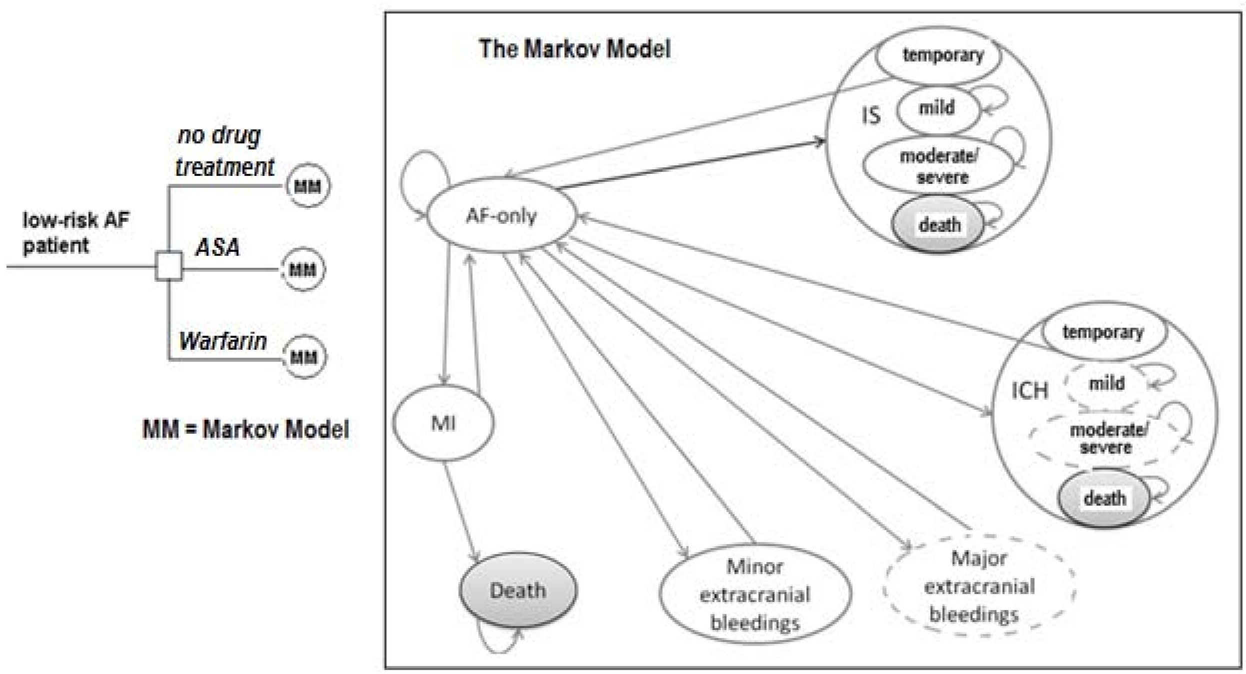

Figure 2. A simplified view of the decision tree representing options and their consequences for the prevention of thromboembolism in non-valvular AF. Ovals indicate disease states and arcs indicate possible state transitions. ASA = Acetylsalicylic acid; ICH =Intracranial hemorrhages. For patients on anticoagulant treatment, dashed lines indicate that, entering those states, implies a switch from Warfarin to ASA.

The core of the MobiGuide approach to shared decisions is to use decision trees (DTs)[8] with embedded Markov models[9] as a suitable probabilistic, graphical decision-theoretic formalism for representing and communicating the critical parameters for decisions.

A DT starts with a decision node, from which the possible options depart. Figure 2, on the left, depicts the DT for the afore-mentioned recommendation, in which the options are (i) no drug treatment, (ii) acetylsalicylic acid (ASA), and (iii) Warfarin (a vitamin K antagonist oral anticoagulant). The possible health states departing from the three initial options are represented in the figure using a Markov model, i.e., a mathematical approach in which changes in (health) state are quantified by the so-called transition probabilities. Probabilities may change according to the initial therapeutic option and are also modulated by time.

Thus, a DT embeds both the current condition (in this case AF-only, i.e. without complications) of the patient, and all co-morbidities and complications that he could experience in the future.

Figure 2 shows the graphical display for the caregiver to start the conversation with the patient. Text, images and movies are then used to communicate the semantics of each health state and of other concepts (see Figure 3). Moreover, the care giver may choose different versions of such media encompassing variable level of complexity and detail according to the patient's level of education, communication, and cultural background. These personal context considerations are represented in MobiGuide in an ontology of contexts; their effects on decision-making are represented explicitly within the guideline's formal representation. For example, if the context of the patient is that he is cognitively impaired, so that his compliance to drug therapy is compromised, and he has no support person who can help him in such task, then the effect is to limit the decision options to ASA or no treatment. As a matter of fact, anticoagulant drugs require perfect compliance with respect to doses and timing to avoid risks. The care giver could then use the DT with only the two other options.

The simple display of a DT with its health states in their qualitative format, i.e., as an illustration of "what can happen", could per se be a useful communication tool. Figure 3 illustrates some of the Web pages used for this purpose.

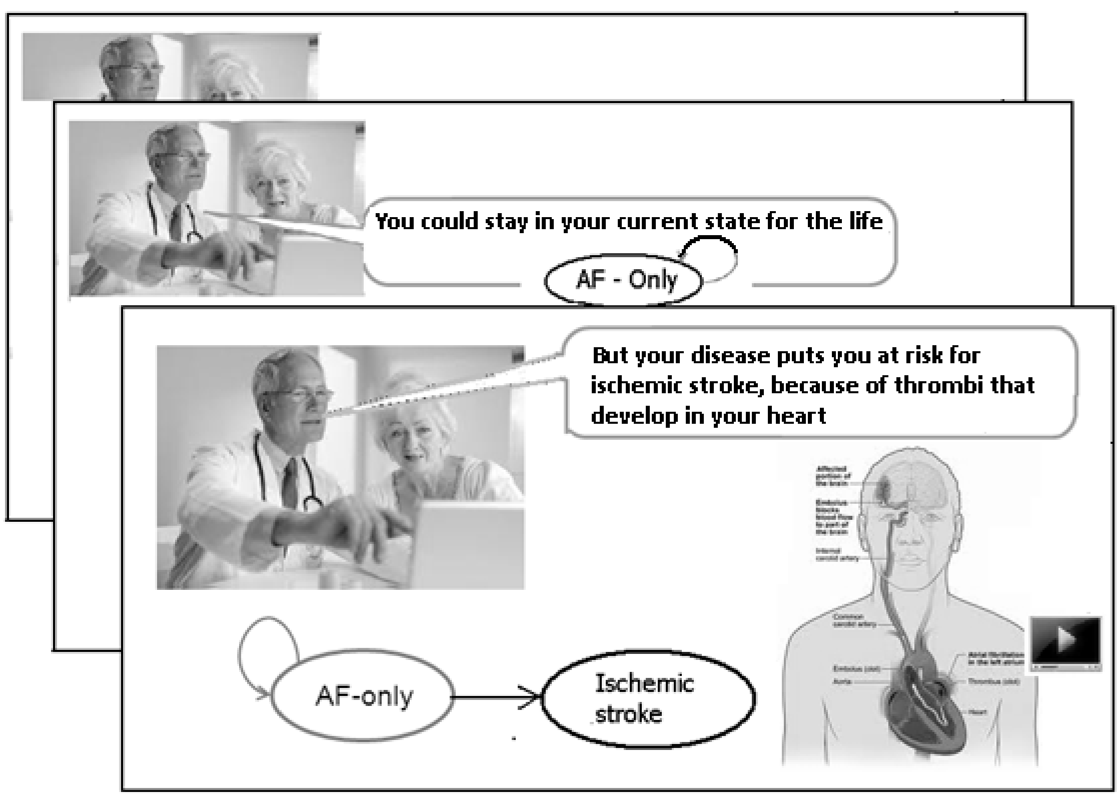

Figure 3 – Interface facilities to communicate with the patient. Phrasing, images and movies can be chosen by the physician according to the patient's characteristics.

However, it is important to recall that DTs are computational tools that lead to a probabilistic estimate of the occurrence of the disease patterns. Thus, for example, patients may be informed about the time periods they might expect to spend in a given health condition. Additionally, DTs may be used to estimate Quality-Adjusted Life Years (QALYs): this is a more sophisticated functionality sometimes requiring the collection of sensitive information. Eligibility of the patient for a QALYs estimate must be judged individually and re-assessed at follow up (as the patient's psychological conditions may change). As a matter of fact, QALYs are defined by multiplying life year periods by the so-called "utility coefficients" (UCs). These are numbers between 0 (death) and 1 (perfect health) representing the value (the "desirability") of a health state for the patient. Among several methods for eliciting UCs[10,11], the most appropriate is the "standard gamble". The patient is asked questions such as the following one:

"...you are an AF patient, so you understand what this implies for your quality of life. Imagine there exists a surgical intervention that can cure you, but that carries a 5% risk of death. Would you be willing to take this risk?"

To help understand the risk value[12], MobiGuide offers the interface shown in Figure 3, in which a corresponding portion of the smiles randomly turns to red according to the proposed risk. After the patient's reply (yes/no), the question is iterated with higher/lower risks, respectively, until reaching a value for which the patient is uncertain about accepting or not the risk, according to the so-called ping-pong strategy. Imagine this value is 2%. At this point, UC of AF is calculated as 1- risk (e.g., 1-0.02=0.98). Thus, in the model, if the patient is expected to live 10 years with AF, this will turn into 9.8 QALYs. In some cases this allows patients to realize that some options may increase life expectancy but reduce quality of life. Other utility elicitation methods are available beyond a standard gamble. Therefore, MobiGuide provides graphical interfaces also for the time trade-off method, the rating scale method, and for questionnaires that indirectly enable us to obtain the patient's UCs.

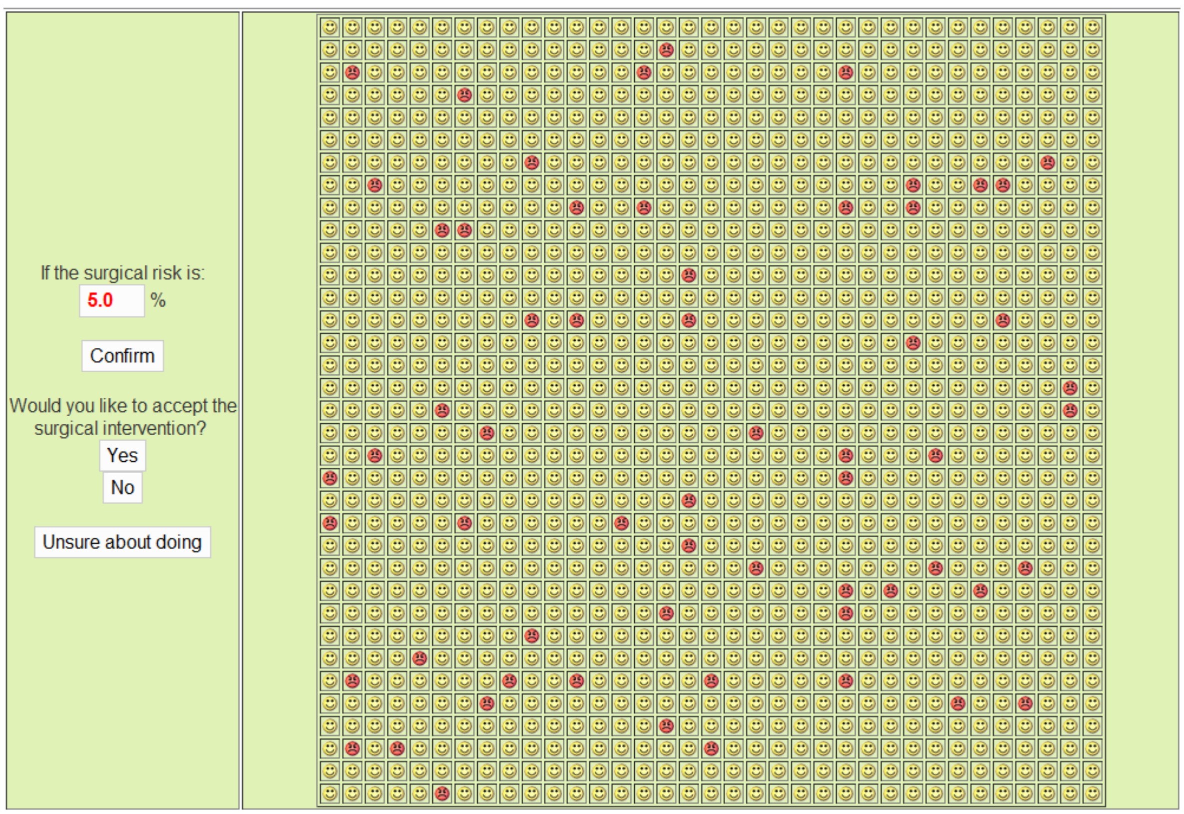

Figure 4. The standard gamble interface: red (death) and yellow (life) smiley faces provide the graphical representation of the risk (the probability of death), which is easier for patients to understand than a simple number.

Expected Values

Payoff	Warfarin	ASA	No therapy
Life Years	22 years 3 months	22 years 1 months	21 years 1 months
QALYs	15 years 12 months	15 years 10 months	15 years 0 months
Patient Costs	10154 €	3179 €	3041 €

Submit

Figure 5. The expected values of three quantitative outcomes of interest to the patient (rows), for every possible treatment choice (columns).

In addition to health-related outcomes, a DT can calculate expected out-of-pocket costs, which also are important for the patient, mainly when deciding a long-term treatment. Figure 5 shows the results that can be discussed with the patient. As is often the case, the most effective therapy is also the most expensive one, and the estimates represent additional information that might help the patient to make the choice.

In this specific case, warfarin is better than ASA and ASA is better than no therapy, as regards both the expected life and the quality of life. However, in general there could be a trade-off between years of life and their quality, representing another aspect for the patient to think about.

Eventually, although beyond the MobiGuide scope, note that, if the economic evaluation concerned a population instead of a specific patient, so that social costs or costs of the national health system were involved, the estimates shown in Figure 5 could be used to obtain incremental cost/effectiveness and cost/utility ratios, useful for policy makers to make strategic decisions.

Continuity of the communication

It is very important to ensure that communication between a patient and his/her hospital caregivers is not limited to the shared decision moment, but continues also after a therapeutic decision has been taken. To this aim, visualization of what happens in-between two control visits is useful. In particular, UCs and answers to quality of life questionnaires can change over time, and the graphs may be the basis for discussing changes that occurred in the patient’s health state. These changes could imply to reconsider the decision about treatment.

We are currently adapting the CareCRUISER[13] interface and its functionalities to accomplish these communication tasks. CareCRUISER (see Figure 6) uses different visualization techniques to represent relevant characteristics and temporal constraints of treatment plans in combination with patient data. It provides three different views to communicate specific information, (1) the logical view to visualize the logics of treatment plans, (2) a view to show the hierarchical structure of these plans, and (3) the temporal view to represent time constraints of treatment plans. The temporal view also allows for zooming and navigating along the time line. CareCRUISER supports visual and interactive means for assessing the effects of applied treatment plans on the quality of life of each patient using color-coded distance information and slopes and enables the comparison of multiple patients at the same time. Therapeutic actions are annotated by diamonds below the patients’ parameters.

CareCRUISER was designed for caregivers and we are adapting it for the patients’ perspective and demands including a view of the UCs and answers to the quality of life questionnaires.

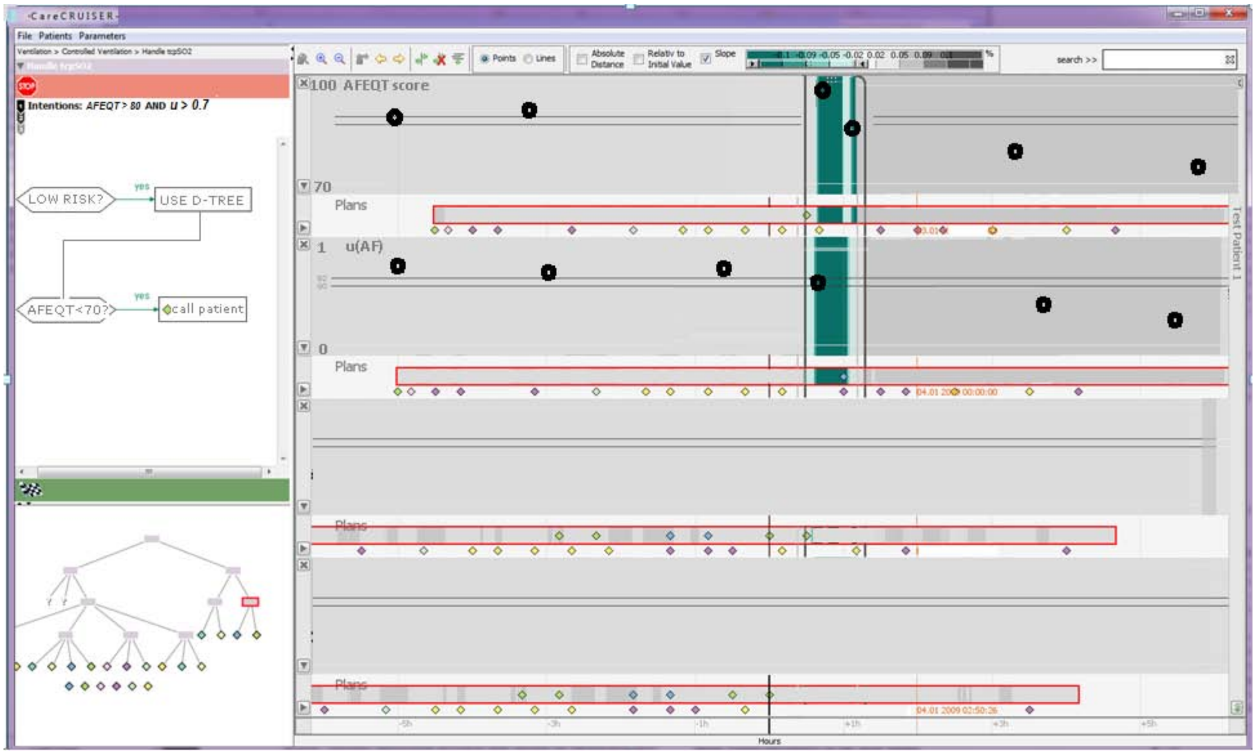

Figure 6. The CareCRUISER interface. The logical view (upper left part) communicates the logical structure of treatment plan execution by means of a flowchart-like representation. The lower left part displays a tree graph to visualize the hierarchical structure of treatment plans and sub-plans; the time-oriented view (right part) focuses on the temporal-qualities of applied treatment plans, clinical actions, and patient parameters as well as effects of applied treatment plans on the patient's condition.

Integrating shared decision making with guideline specification and runtime application

The MobiGuide architecture integrates the shared decision-making framework with an advanced automated guideline application platform. To do so, the GL specification represents each computer-interpretable guideline (CIG) in the Asbru CIG formalism[14].

During GL knowledge acquisition and specification in MobiGuide, we identify the relevant decisions that could be affected by personal context and preferences. The elicitation process examines all of the decision points in the GL and considers which of the personal context variables that are specified in MobiGuide's context and effect ontology[15] could impact decision-making, and how. Personal context variables that may affect care recommendations include among others the patient's ability to comply with treatment, the ability to maintain routine diet (which may change during travel), daily activities, time required to reach the medical center, support level (from family members or live-in help), and exercise level. Different contexts are represented as part of Asbru's *Filter Conditions*, the compulsory eligibility criteria for the overall GL, and for each sub-plan of the GL. These conditions can include, in general, complex temporal patterns (e.g., "patient has had more than three weeks of liver dysfunction", abstracted from raw-data types such as values of several enzymes), as well as demographic and other constraints, including a list of predefined contexts.

A special indication for the need to perform shared decision making is added whenever the final determination whether to use one sub-plan or the other depends on the patient's preferences. The Picard Asbru interpretation engine[16] calls at such *forking points* the shared decision making module to obtain the patient's preferences, which might be elicited qualitatively or quantitatively. The shared decision-making module returns the name of the chosen sub-plan to follow. The rest of the GL beyond the forking point is applied as usual by the Picard engine.

System validation

We have performed a technical evaluation, showing that the various components, i.e., the Picard DSS, the electronic patient record (in which the context information is stored), and the tool for shared decisions, all communicate smoothly, while being implemented in different servers and with different technologies (the detailed description of the MobiGuide overall technical architecture is out of the scope of the current paper).

In addition, we have performed a preliminary evaluation of the usability of the tool for utility elicitation. Five patients have been interviewed by a cardiologist and, while the sample size is still too small to draw conclusions, the initial results are encouraging. Only one of the patients refused to complete the full interactive dialog. The remaining four patients were happy with the approach, even though they found certain questions, in particular the time trade-off question, very hard to answer. This question is phrased in the following style:

"Our national statistics states that the life expectancy of a 57 years old man is 25 years. Assuming that we are speaking purely in statistical terms (of course you could live much longer than that), if you could choose, would you prefer to live your remaining 25 years of life with AF, or live several years less, say 20, in perfect health?"

Our feeling is that if patients are currently in a stable state with respect to their disease, they prefer to live as long as possible, even if not in perfect health. Unlike the time trade-off question, the standard gamble question seems much easier to answer, and similarly for using the rating scale. Questionnaires are also easy to fill in, since they only ask about symptoms and daily life activities. These initial impressions, if confirmed by additional evaluation, might lead to certain design decisions with respect to the preference-elicitation methods we use.

Discussion

Different authors proposed probabilistic frameworks to improve the methodology used for GL development. When developing a GL, medical experts and epidemiologists try to compile everything into rule-like recommendations. But it is difficult to combine probabilities coming from different clinical trials (different sources of knowledge) without a formal model. Sim et al.[17] proposed that randomized clinical trials (RCTs) be reported into electronic knowledge bases—trial banks—in addition to being reported in text. For this purpose, they had developed a framework for representing the methodology and the results of different clinical trials in a standard fashion. Patient preferences, however, are not a standard part of clinical-trial reports.

Lehmann's THOMAS system[18] enabled a physician who has an understanding of the general methodology, but not necessarily of any computational details, to perform a Bayesian statistical analysis of an RCT, in order to obtain assistance with a specific clinical decision. The results of a new clinical trial can update in a Bayesian manner the current probabilities of different treatment methods. The THOMAS model allows also for a very simple representation of the patient's preferences, as a "pragmatic threshold" for the difference in life expectancy between two options, below which the current (control) therapy is preferred, thus representing the morbidity/mortality tradeoff. No particular method for eliciting this threshold was supplied as part of the system.

Sanders et al.[19] have developed and implemented a model for automatically generating GLs from evidenced-based normative decision models. ALCHEMIST, a web-based system, analyzes a decision model, creates a computer-interpretable guideline (CIG) in the form of an annotated algorithm, and displays for the guideline user the optimal strategy. ALCHEMIST'S interface enables remote users to tailor the guideline by changing underlying input variables and observing the new annotated algorithm that is developed automatically. However, although the model can be automatically updated when evidence is updated, it does not explicitly include any patient preferences, nor does it attempt to elicit them explicitly.

Glasspool et al. [20] developed REACT, a decision support system for medical planning, based on logical argumentation. It helps evaluating pros and cons of every planning decision, by showing outcome measures and argumentations in favor or against possible treatments. Changes in a treatment plan may be simulated, with immediate feedback showing the updated outcomes estimate. The system has been evaluated in the breast cancer field[21]. Differently from our system, it does not explicitly address the patients' quality of life in quantitative terms.

In the MobiGuide framework, once a GL specification is completed (including an indication of all potential forking points and the decision trees relevant to these points), at run time, during a patient visit, a care provider guided by the GL-based DSS can elicit the patient's personal context and preferences (utilities) and define the patient's personal profile and personalized DT. Based on these, recommendations will be provided by the DSS for prescribing treatment (e.g., medication prescriptions) based on shared decisions for the different context states defined in the patient's personal profile. The MobiGuide system will assist the patient, mostly through his mobile phone interface, to perform measurements and take medications at specified times, based on treatment plans that are applicable for the patient's current state and context. We also intend to enable the patient to change the setting of his current state; the MobiGuide system would then activate the plans that are applicable for the new context.

Conclusions

The challenge we face in MobiGuide is to empower patients by involving them in reasoning about the therapy most appropriate for them, together with their caregivers, within a rational framework such as decision analysis. Our tools are intended to make decision analysis accessible, if not to all, at least to that portion of patients who want to make a more informed choice, that considers their personal preferences.

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References

1. Groopman, JE. Your medical mind : how to decide what is right for you New York : Penguin Press, 2011
2. Doyal, L. (2001). Informed consent: Moral necessity or illusion? Quality in Health Care 10(Supplement i):i29-i33.
3. McNeil BJ, Weichselbaum R, Pauker SG. (1978). Fallacy of the five-year survival in lung cancer. New England Journal of Medicine 299(25):1397-401.
4. McNeil BJ, Weichselbaum R, Pauker SG. (1981). Speech and survival: tradeoffs between quality and quantity of life in laryngeal cancer. New England Journal of Medicine.305(17):982-7.
5. Woolf SH, Chan ECH, Harris R, et al. Promoting informed choice: transforming health care to dispense knowledge for decision making. Ann Intern Med 2005;143(4):293-300.
6. Peleg M, Tu SW, Bury J. Ciccarese P, Fox J, Greenes RA, Hall R et al. (2003). Comparing Computer-Interpretable Guideline Models: A Case-Study Approach. J Am Med Inform Assoc, 10(1), 52-68.
7. Camm AJ, Lip GY, De Caterina R, Savelieva I, Atar D, Hohnloser SH, Hindricks G, Kirchhof P; ESC Committee for Practice Guidelines (CPG), Bax JJ, Baumgartner H, Ceconi C, Dean V, Deaton C, Fagard R, Funck-Brentano C, Hasdai D, Hoes A, Kirchhof P, Knuuti J, Kolh P, McDonagh T, Moulin C, Popescu BA, Reiner Z, Sechtem U, Sirnes PA, Tendera M, Torbicki A, Vahanian A, Windecker S; Document Reviewers, Vardas P, Al-Attar N, Alfieri O, Angelini A, Blömstrom-Lundqvist C, Colonna P, De Sutter J, Ernst S, Goette A, Gorenek B, Hatala R, Heidbüchel H, Heldal M, Kristensen SD, Kolh P, Le Heuzey JY, Mavrakis H, Mont L, Filardi PP, Ponikowski P, Prendergast B, Rutten FH, Schotten U, Van Gelder IC, Verheugt FW. 2012 focused update of the ESC Guidelines for the management of atrial fibrillation: an update of the 2010 ESC Guidelines for the management of atrial fibrillation--developed with the special contribution of the European Heart Rhythm Association. Eur Heart J. 2012 Nov;33(21):2719-47
8. Detsky AS, Naglie G, Krahn MD, Redelmeier DA, Naimark D. Primer on medical decision analysis: Part 2--Building a tree. Med Decis Making. 1997 Apr-Jun;17(2):126-35.
9. Sonnenberg FA, Beck JR. Markov models in medical decision making: a practical guide. Med Decis Making. 1993 Oct-Dec;13(4):322-38.
10. Morimoto T, Fukui T. Utilities measured by rating scale, time trade-off, and standard gamble: review and reference for health care professionals. J Epidemiol 2002;12(2):160-178
11. Prosser LA, Grosse SD, Wittenberg E. Health utility elicitation: is there still a role for direct methods? Pharmacoeconomics. 2012 Feb 1;30(2):83-6.
12. Ancker JS, Senathirajah Y, Kukafka R, Starren JB Design Features of Graphs in Health Risk Communication: A Systematic Review. J Am Med Inform Assoc. 2006, 13(6): 608–618.
13. Gschwandtner T, Aigner W, Kaiser K, Miksch S, Seyfang A. CareCruiser: Exploring and Visualizing Plans, Events, and Effects Interactively, 4th IEEE Pacific Visualization Symposium, Hongkong, pp. 43--50, 2011.
14. Shahar Y, Miksch S, Johnson PD. (1998). The Asgaard project: A task-specific framework for the application and critiquing of time-oriented clinical guidelines. Artificial Intelligence in Medicine 14 29-51.
15. Fux A, Peleg M, Soffer P."How Can Personal Context Improve Adherence to Clinical Guidelines Joint KR4HC/ProHealth Workshop, Tallinn, Estonia, September 3, 2012.

16. Shalom E, Friedman I, Shahar Y, Hatsek, A., and Lunenfeld, E. (2011). Towards a realistic clinical-guidelines application framework: Desiderata, Applications, and lessons learned. In: Lenz R, Miksch S, Peleg M, Reichert M, Riaño D and ten Teije A. (eds): Process Support and Knowledge Representation in Health Care. Revised selected papers from the Proceedings of the BPM 2012 Joint Workshop, ProHealth 2012/KR4HC 2012, Tallinn, Estonia. Lecture Notes in Artificial Intelligence 7738, Sprinter-Verlag, Berlin, Heidelberg, 2013, pp. 56-70
17. Sim I, Owens D, Lavori P, and Rennels G. Electronic Trial Banks: A Complementary Method for Reporting Randomized Trials. Medical Decision Making 2000;20:440-450.
18. Lehmann HP and Shortliffe EH. THOMAS: building Bayesian statistical expert systems to aid in clinical decision making. Computer Methods and Programs in Biomedicine 35 (4), 1991, 251–260.
19. Sanders GD, Nease RF, and Owens DK. Design and Pilot Evaluation of a System to Develop Computer-based Site-specific Practice Guidelines from Decision Models. Medical Decision Making 2000;20:145-159.
20. Glasspool DW, Fox J, Castillo FC and Monaghan VEL. Interactive Decision Support for Medical Planning. In M. Dojat, E. Keravnou and P. Barahona (Eds.): Artificial Intelligence in Medicine. Proceedings of the 9th Conference on Artificial Intelligence in Medicine in Europe, AIME 2003. Lecture Notes in Artificial Intelligence (LNAI 2780), Berlin: Springer-Verlag. 2003, 335-339.
21. Glasspool DW, Oettinger A, Braithwaite D, Fox J. Interactive decision support for risk management: a qualitative evaluation in cancer genetic counselling sessions. J Cancer Educ. 2010 Sep;25(3):312-316.