

Reti Bayesiane per la Gestione del Rischio Clinico in Emodialisi

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In Italia la cultura del rischio in sanità è ancora limitata, anche se il Ministero della Salute sta promuovendo lo sviluppo di solide basi per una corretta gestione dei rischi. Il nostro lavoro propone l'utilizzo di metodologie Bayesiane per identificarne e quantificarne una sottocategoria: i rischi clinici. L'approccio proposto, di natura empirica, si fonda su Reti Bayesiane (BNs) costruite per i singoli pazienti e per la struttura che li accoglie. L'approccio di risk management è completato arricchendo le BNs con nodi decisionali, affinché i medici e la governance clinica possano assumere decisioni ottimali (analisi di scenario) per il singolo profilo di rischio analizzato. La metodologia è stata applicata all'analisi del rischio clinico in pazienti nefropatici in trattamento emodialitico.

risk management, risk assessment, risk control, Bayesian Method, prior selection, Bayesian Network, updating, Bayesian decision making

Preventing adverse events is one of the crucial concerns of modern Health Care Organizations (HCOs). The Italian Healthcare Department "Ministero della Salute" (Ministero della Salute, 2004) defines an adverse event as an "unwanted damage and uneasiness due to health service's supply which provoke morbidity, mortality or a longer hospital stay; the damage and the uneasiness should not be related to the natural worsening of patient disease". The adverse events generally involve patients and are due to causes which are related to the health care process. Clinical risk (CR) is a sub-category related to the particular service supplied, i.e. the health care delivery; the focus of CR management is patient safety. The paper concentrates on the problem of managing clinical risks in the clinical context of a haemodialysis (HD) department. In particular, exploiting a theoretical analysis on the HD process presented elsewhere (Cornalba C. et al., 2005), we study the application of Bayesian methods for dealing with the risk management problem. The purpose of the research is to provide a Bayesian network (BN) model, which, focusing on patient safety, will help health care decision makers to analyse diagnostic and therapeutic practices and to prevent adverse events that influence the patients' hospitalization and mortality risk. The model will also deal with the impact of adverse events on expected costs for both the patients and the clinical department.

Risk management comprehends two main aspects: assessment and control. On its turn, clinical risk assessment involves risk analysis and risk evaluation. The former is the systematic use of available information sources to identify and to estimate CR; in particular, risk analysis includes the choice of a methodology for dealing with risks given the context (e.g. HCO, HD department, the single patient, ...). Risk evaluation is the judgement of whether a risk is acceptable (for example, through cost/benefit analysis or outcome results versus targets). Whenever a risk is not acceptable, it is necessary to take decisions in order to avoid it or to reduce its probability. This phase is defined as risk control.

Herein, we apply the previous steps to the HD treatment of patients suffering from End Stage Renal Disease (ESRD), a severe chronic condition that corresponds to the final stage of kidney failure. For our purpose, we will consider α as the adverse event occurring during dialysis sessions; a β is defined as the failure to reach a prescribed treatment goal at the end of a dialysis session; this may be due to patient's clinical problems occurring during the dialysis session or to errors of the health care providers. In particular, we have identified two clinical "damages" related to non-adherence: re-hospitalization and mortality; moreover, we have identified the expected cost as the main organizational risk. We are interested to measure the patients' hospitalization and mortality risks and to optimise the decisions on their therapeutic plans.

Hospitalization and survival are influenced by several factors and we exploit non-adherence monitoring results to extract risk profiles for patients and clinical centres. To identify CR, select risk factors and their relations we make use of nephrologist knowledge (domain expert), ESRD guidelines and international clinical studies.

Data Collection and Pre-Processing. We have implemented a data warehouse to collect monitoring and clinical data coming from a limited assistance dialysis centre ("A.O. of Vigevano", Italy). Forty-six patients have been monitored since May 2001. The data warehouse contains data monitored during each patient dialysis session (in general, about four hours three times a week), and personal data, patients history and physicians prescriptions (usually updated quarterly). Before data analysis we have performed several pre-processing steps. A 3-DM array of data (patients $\times$ variables $\times$ time) has been reorganized into a HD datamart (47×10^5).

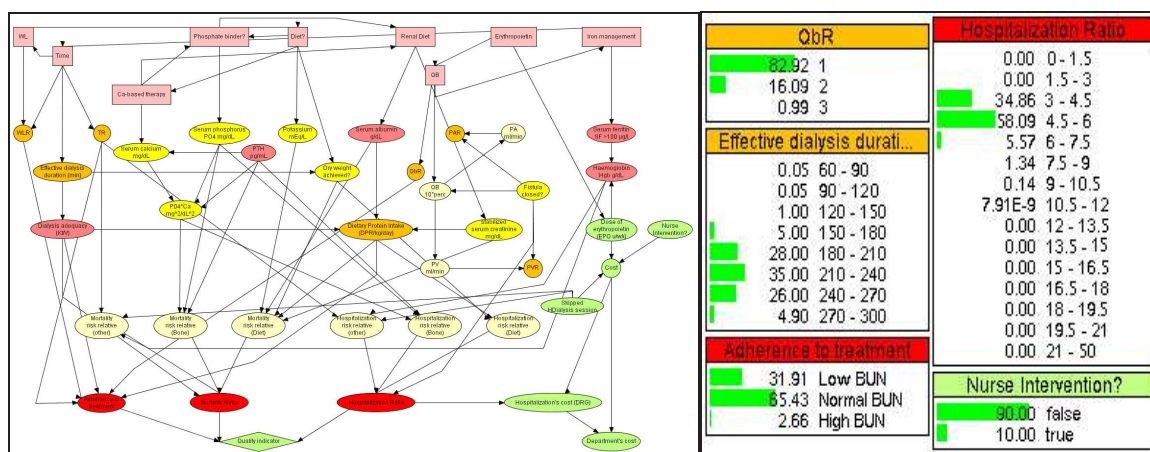
The BN variables have been discretized following a knowledge-based strategy: binning and bounding of each variable (also intervals' length and number selection) have been chosen accordingly to published ESRD clinical guidelines. Moreover, each dialysis session has been synthesized through the vector of the median values of the monitoring variables; the comparison of the median values with pre-defined clinical treatment goals has finally allowed to assess the outcome of the dialysis session, i.e. the presence of an adverse event.

Bayesian Methods. A risk is generally defined as the combination of the probability of occurrence of harm and the severity of that harm. Bayesian methods are often suggested as the proper way to make formal use of subjective information such as expert opinion (nephrologist) and organization judgments (guidelines), or prior literature studies. In our case study, we chose Bayesian Network (BN) (Jensen FV., 1996, Cornalba C. and Giudici P., 2004) to perform the

risk assessment. BNs can also be conveniently applied for decision making in the risk control phase. BNs are particularly suited for CR management. They allow to clearly express the relationships between the problem variables and to learn risk profiles from the available data. Furthermore, they may add knowledge on the dependences among risks and their causes (i.e. measures of non-adherence) and help to take the optimal decisions and interventions to minimize risks and to evaluate their economic impact.

Prior Distributions and Network Topology. A Bayesian Network model has been defined through the probabilistic relationships among the monitoring variables, and between such variables and the re-hospitalization and mortality risks. Many approaches for the selection of the priors have been suggested: herein we have applied a modification of a method called “empirical Bayes” in which maximum likelihood estimates are used to determine model parameters for a parametric prior. To form the likelihood we have relied on the literature (and in particular on the DOPPS study (Rayner HC et al., 2004)). Whenever it wasn’t possible to apply this approach, but some information was available about a certain variable, we have applied a generalization of Laplace’s “principle of insufficient reason” called the maximum entropy criterion. It makes no shape assumptions and specifies the prior distribution in an optimal way. For the prior specification see Lee and Wright (1994). Otherwise, “noninformative” distribution is selected: since the use of a uniform prior is problematic (i.e. improper prior), we choose this solution only if posterior leads to a proper distribution.

We defined some network topology constraints (Fig. 1, on left) before the learning phase, in order to express well-established medical knowledge and to limit the number of possible BN during updating.



Updating and Decision Making The BN is revised and updated with incoming data available in the data warehouse with a time window of three months. The learning algorithm is

(NPC) implemented in the Hugin package (www.hugin.com). After the learning phase, each patient’s network may reveal some new dependencies discovered in the data. The result is a therefore a different Bayesian Network for each patient, expressing the individualized risk profile; the individualized marginal (Fig. 1, on right) and conditional probability distributions complete the patient-specific risk profile assessment. Such assessment may be progressively updated as far as there are organizational changes. To take into account this aspect,

the BN has been augmented with decision nodes, representing the therapeutic decisions. This step complete risk evaluation: after risk analysis, decisions (three macro-category: diet, renal bone disease and a residual one) on risk acceptability are taken. Bayesian decision theory applies the idea of maximizing expected utility: a concave utility function (risk adverse) has been built giving a different weight to the three decision types. During the control phase the risks which are likely to occur during future dialysis sessions are calculated: scenario analysis allows highlighting the critical elements that may have impact on patient's risk; thanks to the availability of decision and utility nodes, the model assist users in testing the effect of a change in diet or treatment and in taking proper decisions. It is interesting to note that it is possible to perform the same kind of analysis on the data coming from all patients, thus highlighting the risk profile of the overall dialysis center.

The risk management process comprehends the assessment and control of adverse events. These steps stress the importance of using all the available information, even if that information came from heterogeneous sources, such as expert knowledge, literature or process specific data. Our proposed system implements such steps allowing to detect and forecast adverse events in managing HD patients. In this paper we have described the BN-based approach, which analyses the available information sources to estimate a current risk profile for patients and departments. This approach also supports the prediction of the decision effects on the expected costs and utility thus allowing choosing the optimal treatment strategy to minimize patient outcome risk. Interesting results have been obtained: a general patient and department risk profiles are obtained on the basis of prior information, and this information is then updated in the light of the data collected by a clinical monitoring system. The ultimate goal of our efforts is the improvement of patients' outcome: a consistent set of decisions about the risk assessments and their proper management allow nephrologists and decision makers (governance) to enhance resource allocation, to reduce mortality and hospitalization risks. Other research directions that we are currently investigating are related to choose robust Bayesian techniques to explore the sensitivity of the results to the assumptions and to the chosen prior distributions.

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